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Report

# Measuring circularity: a critical analysis of some relevant indicators

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# 01 Introduction

The concept of Circular Economy has become of great importance in the last decade, and this trend is likely to strengthen in the EU in the years to come. In fact, the European recovery strategy from the Covid-19 sanitary emergency is based on the EU Green Deal, which is in turn deeply connected to the New Circular Economy Action Plan adopted by the Commission in March 2020. Timmermans, the Executive Vice-president for the Green Deal, stated that "*to achieve climate-neutrality by 2050, to preserve our natural environment, and to strengthen our economic competitiveness, requires a fully circular economy*"[1]. In order to achieve this goal, it becomes an absolute necessity to measure circularity at different levels: geographical areas, such as cities and regions, as well as narrower entities such as economic sectors, companies and even at the product-level. A "metric system" for circularity would allow describing the current situation, evaluating possible future achievements and hence directing policy interventions towards regions or sectors more in need.

This report's aim is to shed light on this issue, providing a critical review of some of the existing indicators measuring the circular economy. This will not be a comprehensive review: many papers, such as Saidani et al. (2019), have already filled in the gap in the literature by providing original taxonomies for the classification of the circular economy indicators. In what follows, we will instead analyse some of the most relevant and more recently introduced indicators, sometimes reporting the formulas needed for their computation, in order for the interested reader to get a broad picture of how these indicators are constructed, of their main advantages and shortcomings. Future research will provide a new synthetic indicator, or at least a small set of measures, based on the existing literature; it will be more synthetic, comprehensive and directly employable by policymakers, company representative, as well as academics.

The report proceeds as follows. Section two introduces the topic by defining what we mean by "circular economy" and by motivating the need for introducing a consistent set of indicators aimed at its measurement. Section three describes what different indicators for circularity should be measuring, stressing the different relevant dimensions to be taken into account as well as the potential difficulties met when providing a synthesis. Section four reviews some existing indicators for circularity according to their unit of interest (country-level or company-level): it describes the indicators proposed by either international institutions, think-tank or some large companies, which started in the last decade to implement internal metrics for circularity as well as to

1 https://ec.europa.eu/growth/content/new-circular-economy-action-plan-shows-way-climate-neutral-competitive-economy-empowered_en

communicate to the public the underlying methods for their construction. Moreover, section four includes a discussion on the indicators classified and proposed by the scientific community. Section five concludes.

# 02 The Circular Economy and its measurement

The economic system we live in is mostly linear: products get designed, made and/or assembled, employed in the value chain towards the production of final goods in case they are intermediate products, and finally they are consumed by final users, who then produce waste related to the product itself or at least to its packaging. We usually refer to the previous as to the "life" of products, from their birth to their death/disposal, and this is why we call our economic system *"linear"*. Such a product's life has an impact on the environment in all its different stages and to different degrees depending on the specific good that we are considering. Until some decades ago, however, we were not worrying too much about the possible negative impacts of such a paradigm on the environment. Creating goods -ultimately, from raw materials- and eventually disposing of them represents a problem when natural resources, defined as what we have before the "birth" of the product, and available space, defined as what we need after its usage or "death", are limited, as they are in a finite planet like ours. This problem is expected to become much more compelling in the very close future, considering that the world population is increasing and, at the same time, the quantity of raw materials used by every new human being has been increasing itself in the last decades (CEN and Enea, 2020).

For this reason, the scientific and the institutional community started referring to a new concept of development, more sustainable, mostly based on the Reduce-Reuse-Recycle paradigm: a circular economic system. The latter should be, at least in part, self-regenerating: the extraction of natural resources should be limited, thanks to the design of products and because of new technologies for recycling that create second-end materials; products themselves should be designed for being re-used, instead of being disposed of; eventually, the need itself for new products should be limited. The Ellen Mc Arthur foundation defines the Circular Economy as *"a global economic model that aims to decouple economic growth and development from the consumption of finite resources"*[2]: this suggests that we should abandon the idea of linearity we are used to, together with the concepts of "virgin" materials and "waste", towards a global re-thinking of our economic system.

The concept of circular economy has been refined and discussed in the recent literature. Banaite (2016) provides a detailed history of the concept of circular economy. He describes its relationship with the broader paradigm of sustainable development and points to some shortcomings that could lead to misevaluations of the level of circularity of the economic

2 https://www.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail#:~:text=A%20circular%20economy%20is%20a,the%20consumption%20of%20finite%20resources.

system. Pearce and Turner (1991) introduced the concept of circular economy in their description of the four main economic functions of the environment: it provides human beings with a basin of resources for the economy, a waste bin for residual flows, a life-support system as well as utility from its beauty itself. Andersen (2006) stressed that recycling and reducing waste are important but not sufficient to achieve circularity, if not accompanied by a reduction of the dependence from raw materials. Ghisellini et al (2016) go one step further and state that a more circular economy should not be a better waste-management system and that the 3R (Reduce-Reuse-Recycle) represent only a small part in the construction of a sustainable future, defined as the situation in which forthcoming generations will be able to achieve the same welfare as current generation.

The data speak for itself: from 1970 to 2017, world population doubled (from 3.7 to 7.5 billion), while material consumption increased by four times (from 26.6 to 109 Gt) (Circle Economy Amsterdam, 2020). Only 9.6% of all materials used in 2017 came from recycling; the remaining 90.4% of all inputs used were extracted from the soil (minerals, metals, fossil fuels) or derived from human intervention in the ecosystems (biomasses). This huge dependence from virgin materials needs to be stopped.

For this reason, the circular economy has become one of the focal points of the EU Green Deal. The New Circular Economy Action Plan was proposed in early March 2020, five years after the first action plan on Circular Economy launched by the EU. The pillars of the plan are the following[3]:

- **Make sustainable products the norm in the EU:** ensure that products placed on the EU market are designed to last longer, are easier to reuse, repair and recycle, and incorporate as much as possible recycled material instead of primary raw material;
- **Empower consumers:** consumers will have access to reliable information on issues such as the reparability and durability of products to help them make environmentally sustainable choices. Consumers will benefit from a true "Right to Repair";
- **Focus on the sectors that use the most resources and where the potential for circularity is high.** The Commission will launch concrete actions on:
  - electronics and ICT
  - batteries and vehicles
  - packaging
  - plastics
  - textiles
  - construction and buildings
  -food
- **Ensure less waste.** The focus will be on avoiding +waste altogether and transforming it into high-quality secondary resources

3 https://ec.europa.eu/commission/presscorner/detail/en/ip_20_420



# 03 What should a Circular Economy indicator communicate?

Circularity is a very complex topic both to identify and to be measured. It deals with all parts of the production process and of the value chain, and it often touches intangible measures and business practices. In very general terms, we believe that measuring circularity should communicate how far away we are from a linear economic paradigm, which uses virgin resources without making up for this employment and produces waste that will pollute our planets for many centuries to come, and how close we are to a fully sustainable zero-waste and zero-pollution system. Given the multi-faceted nature of circularity though, which comprehends the design of products, their disposal afterlife, the length of the product's life itself, it becomes very difficult to move from the above "distance" definition to an employable synthetic measure on how good we are in making the economy circular, by "closing" and "narrowing" the loop at the same time.

The first step to be made is to identify the unit of interest for the analysis. As Banaite (2016) summarises, an indicator is good when it is appropriate for measuring the variable of interest in the specific context of interest, also called "*level of implementation*". Measuring the level of circularity of a metropolitan area, for instance, requires considering multiple aspects that are not present when considering a business. When talking about circularity, three levels of implementation can be considered: the micro, the meso and the macro level. The micro-level is the one of the single firm (or consumer), which have specific characteristics and should be judging its achievements in circularity matters with respect to its particular sector and situation. The meso-level is the one of companies linked geographically and/or by their specific businesses, constituting the potential for an "industrial symbiosis". The macro-level is achieved by zooming out and focusing on a specific geographical area (a city, a region, ultimately a country) mostly in its connection to broader geographical areas (Vercalsteren, 2018).

As it will become clear in the following sections, measuring circularity is particularly challenging because it involves the synthesis of multiple aspects in a singular indicator. None of the three levels of implementation presented above is exempt from this intrinsic difficulty, hard to overcome. In what follows, we will critically review some of the most used and relevant indicators, referring to different levels of the implementation. The aim of this paper is not providing a comprehensive review of all indicators available at this time: many studies such as Saidani et al. (2019) and Avdiushchenko and Zajac (2019) have already provided useful classifications, proposed original taxonomies and sometimes even user-friendly software capable of identifying the best indicator among the plethora of the available ones. This shows the main shortcoming of this field: having many units of measurements, even guiding interested users in the choice of the most suitable one, can prevent stakeholders from meaningful discussions, as everyone speaks a different language. Different points of view do not converge into one over the same issue, and everything becomes relative to the chosen perspective; exactly the opposite of what a metric, unique and replicable by definition, should do.

In what follows, we stress the main advantages and the main shortcomings of the indicators analysed. We believe that this constitutes a useful exercise and it is the first necessary step towards identifying the best indicators among the ones already in place, with the ultimate goal of proposing a new indicator that could build on them.



# 04 Review of the existing indicators

The following section reviews some of the most relevant existing indicators, classified according to the unit of interest: country-level or company-level indicators.

## 4.1- Country-level indicators

**EUROSTAT Circular Economy indicators**

The EEA published a report in April 2020 titled "*Resource efficiency and the circular economy in Europe 2019 – even more from less*" that summarises different policies, targets achieved as well as different indicators at the state and the regional level available in the Member States. The report starts by reviewing the different data that the EU Member States are required to submit to the Eurostat, and that can be useful for assessing their overall (macro) level of circularity. For instance, per Regulation (EU) No 691/2011 on European environmental economic accounts, Member States are required to report economy-wide Material Flow Analysis (MFAs) data within a common framework and submit these to Eurostat. MFAs is an environmental engineering method that deals with the systems approach and mass balance (Fisher-Kowalski, 1998), whose output is the analysis of material and energy flows in industrial processes. Furthermore, the EEA report underlines that EU Member States are also subject to Regulation (EC) No 2150/2002 on waste statistics, defining an accounting framework for the production of relevant figures on generation, recovery and disposal of waste. This shows that regulations in terms of data collection and administration with respect to relevant aspects of the circular economy do exist in the EU, via the Eurostat channel. Eurostat also directly manages a set of indicators that are explicitly referring to the circular economy at the macro-level (Member State level or EU27 average), which are reported in Table 1.

The EEA report also reviews different indicators, still at the macro level, proposed by the different Member States. Among them, the French set of indicators deserves to be mentioned, as it is quite comprehensive, dealing with multiple aspects of circularity, even though compact (10 indicators in total). The topics covered are the following: domestic material consumption per person; resource productivity; the number of ecolabel holders; the number of industrial symbiosis projects; car-sharing; food waste; household spending on product repairs and maintenance; quantities of waste sent to landfill; use of recycled raw materials in production processes. The first four indicators refer to sustainable production, the second four to sustainable consumption and the last two to waste management. The Italian Ministry of Environment together with the Ministry of the Economic Development stressed

4 https://www.minambiente.it/sites/default/files/archivio_immagini/economia_circolare_ed_uso_efficiente_delle_risorse_-_indicatori_per_la_misurazione_della_circolartita_-_bozza_maggio_2018.pdf

the need for constructing specific indicators for measuring the circular economy in 2018[4], listing the set of available measures that could be synthesised in one. The Ministry website has not been updated since then.

The Eurostat website presents the following list of Circular Economy indicators for all EU countries as well as for the EU27 average, divided into four categories: production and consumption, waste management, secondary raw materials and competitiveness and innovation. The first three families of indicators are common metrics of circular economy advancement and mostly deal with end-of-life (waste, recycling) in production and consumption, trade in recyclable materials and importance of recycled materials in the production process. The fourth family of indicators analyses the circular economy from a different but very meaningful perspective: circular economy as a self-standing economic sector, whose importance in terms of gross investment, employment a value-added is analysed. We believe that these latter indicators are particularly meaningful and allow useful comparisons across countries.

The point of view of the fourth set of indicators is not the process towards a more circular production, which can be declined differently in the different industries and in different countries, but a direct measure of the average importance (in terms of GDP) that enhancing circularity implies in every country. Circularity impacts on investments and employment levels, and those economic outcomes can be used in cross-country analysis to estimate the importance of circularity. EU economies, in fact, do exhibit variability in their degree of economic development. It would be interesting, by means of a simple correlation analysis or via a univariate regression analysis, to see what is the relationship between environmental policy, measured for example by the EPS index provided by the OECD (Botta and Kozluk, 2014) and investment in circularity. A positive coefficient would provide initial support for the Porter Hypothesis (Porter and Van Der Linde, 1995).

Table 1 - EUROSTAT CIRCULAR ECONOMY INDICATORS

| | |
|---|---|
| **Production and consumption** | |
| EU self-sufficiency for raw materials (percentage) | Green public procurement |
| Waste generation | Generation of municipal waste per capita<br>Generation of waste excluding major mineral wastes per GDP unit<br>Generation of waste excluding major mineral wastes per domestic material consumption (percentage)<br>Food waste (million tonnes) |
| **Waste Management** | |
| Recycling rates | Recycling rate of municipal waste (percentage)<br>Recycling rate of all waste excluding major mineral waste (percentage)<br>Recycling / recovery for specific waste streams<br>Recycling rate of overall packaging (percentage)<br>Recycling rate of plastic packaging (percentage)<br>Recycling rate of wooden packaging (percentage)<br>Recycling rate of e-waste (percentage)<br>Recycling of bio-waste (kg per capita)<br>Recovery rate of construction and demolition waste (percentage) |
| **Secondary raw materials** | |
| Contribution of recycled materials to raw materials demand | End-of-life recycling input rates (EOL-RIR) (percentage)<br>Circular material use rate (percentage) |
| Trade in recyclable raw materials (tonne) | Imports from non-EU countries<br>Exports to non-EU countries<br>Intra EU trade |
| **Competitiveness and innovation** | |
| Private investment, jobs and gross value added related to circular economy sectors | Persons employed (percentage of total employment)<br>Value-added at factor cost (percentage of gross domestic product (GDP) at current prices)<br>Number of patents related to recycling and secondary raw materials |

A unique summary measure on the level of circularity has not been provided yet. The existing indicators could be collapsed in a unique one by constructing a weighted average or via principal component analysis, as in the study proposed by wbcsd and KMPG (2020) reviewed below, in the section devoted to think-tank indicators.

### EU Raw Material Initiative

One of the aspects in making the economy more circular is the reduction of its dependence from virgin materials, non-renewable in the short run. The starting point for measuring the hoped-for decrease over time in resource employment is a reliable metric on their presence in the initial rings of the value chain. The EU Raw Material Scoreboard fills this gap by providing policymakers with quantitative data on raw materials.

The EU Raw Material Scoreboard was introduced explicitly for monitoring progress towards a circular economy by the European Innovation Partnership (EIP) on Raw Materials. The latter was launched in 2012 by the European Commission. It is constituted by industry representatives, public services representatives, scientists and NGOs members. The EIP focuses on non-energy raw materials, mainly metals and minerals, in order to provide a platform aimed at enhancing the innovation process (and, dealing with raw materials, those innovations will have important effects on circularity). The EU Raw Material scoreboard is published every two years since 2016. The last edition refers to 2018 and overall shows an expansion of circular economy sectors. The critical points deriving from the analysis of the quantitative data, on which EU policymakers should particularly be aware, are the following[5]. First, the EU depends on the rest of the world, as it mostly imports raw materials: this makes the European economy particularly vulnerable to price fluctuations, and supply disruption happens. Valuable raw materials are often wasted because recycling technologies are not yet available or widespread, and because the waste management system lacks optimisation.

### EU Eco-Innovation Indicators

The EU introduced specific indicators as well as a dashboard aimed at illustrating eco-innovation performance across the EU Member States. There are sixteen indicators, grouped in five dimensions: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency and socio-economic outcomes. The resource efficiency outcome indicators are particularly relevant with respect to the circular economy, in particular the ones on material, water and energy productivity. These metrics are likely to be highly correlated with country-level indicators on the circular economy and could be taken into account when assessing a country's circularity level. Moreover, the Eco-Innovation Index (summarizing all the sixteen indicators available) allows a comparison of each country to the EU average and provides a

5 https://ec.europa.eu/growth/content/raw-materials-scoreboard-2018_en

broader picture of the environmental situation of each EU member state. This could be useful for considering the improvements in terms of circularity in relative terms with respect to the overall level of green innovation.

**EU Resource Efficiency Scoreboard**
The indicators in the EU Resource Efficiency scoreboard measure the level of resource efficiency of the EU Member states and of the EU overall in terms of sustainable employment of resources: "*Resource efficiency means using the Earth's limited resources in a sustainable manner while minimising impacts on the environment. It allows us to create more with less and to deliver greater value with less input*"[6]. The data are collected from the Eurostat database as well as sourced from the repositories of the EEA. Table 2 reports a list of the available indicators, updated at an annual frequency.

Table 2 – EU Resource Efficiency Scoreboard

| **Lead indicator** | **Resource productivity** |
|---|---|
| **Dashboard indicators** | |
| **Materials** | Domestic material consumption per capita |
| **Land** | Productivity of artificial land |
| | Built-up areas |
| **Water** | Water exploitation index |
| | Water productivity |
| **Carbon** | Green gas emissions per capita |
| | Energy productivity |
| | Energy dependence |
| | Share of renewable energy in gross final energy consumption |
| **Thematic indicators** | |
| ***Transforming the economy*** | |
| **Turning waste into a resource** | Generation of waste excluding major mineral wastes |
| | Landfill rate of waste excluding major mineral wastes |
| | Recycling rate of municipal waste |
| | Recycling rate of e-waste |
| **Supporting research and innovation** | Eco-innovation index |
| **Getting the prices right** | Environmental tax revenues |
| | Energy taxes by paying sector |
| ***Nature and ecosystems*** | |
| **Biodiversity** | Common bird index |
| | Area under organic farming |
| | Landscape fragmentation |
| **Safeguarding clean air** | Urban population exposure to air pollution by particulate matter |
| | Urban population exposed to PM10 concentrations exceeding the daily limit value (50 μg/$m^3$ on more than 35 days in a year) |
| **Land and soils** | Estimated soil erosion by water - area affected by severe erosion rate |
| | Gross nutrient balance on agricultural land |
| ***Key areas*** | |
| **Addressing food** | Daily calorie supply per capita by source |
| **Improving buildings** | Final energy consumption in households |
| | Final energy consumption in households - share of selected fuels |
| **Ensuring efficient mobility** | Average carbon dioxide emissions per km from new passenger cars |
| | Pollutant emissions from transport |
| | Modal split of passenger transport - passenger cars |
| | Modal split of freight transport - by road |

6 https://ec.europa.eu/environment/resource_efficiency/

Once again, the length of this list shows the absence of a unique indicator summarising, at least per thematic area, the content of the scores reported above. Unless one needs to compare very specific sub-indicators, such as the "estimated soil erosion by water", a unique index number taking into account multiple aspects of the impacts of human activity on nature and ecosystem would be useful. Some indicators such as the "daily calorie supply per capita by source" and "urban population exposure to air pollution by particulate matter", which are with no doubt related to economic development and rising concerns towards pollution, seem however a little forcedly listed among the above indicators on resource efficiency.

The lead indicator, *resource productivity*, is the ratio between GDP and Domestic Material Consumption (DMC), measuring the amount of materials used by the economy. DMC sums up imports of raw materials to their domestic extraction, net of exports. This measure indicates how much value added (GDP) is produced by an economy per unit of material used independently from its source; this is particularly relevant in economies such as the EU ones, which are overall net importers of virgin materials from the rest of the world. This measure, however, lacks an important dimension: it refers to the consumption perspective only. A country could be importing final goods that are very material intensive, still the indicator would not be affected by this. In fact, this measure reports the resource efficiency level achieved by the production that takes place in a country. In case that country substitutes domestic production to the import of final goods that are material-intensive, i.e. in case the country is "offshoring" the production of those goods, a low level of this indicator could give a false impression that the country is resource-efficient, while its consumption patterns show the opposite.

**The Circular Economy Scoreboard by ENEL and The European House - Ambrosetti**
Enel, together with The European House-Ambrosetti, proposed a circular economy scoreboard for assessing the level of circularity of different EU countries (Circular Europe, 2020). The focus of the indicator is macroeconomic, and the score is built using a multi-level approach that is centred on the four following pillars:

- **sustainable inputs:** measuring the share of renewable energy and of recyclable, recycled and biodegradable materials to manufacture goods and provide value in consecutive lifecycles
- **end-of-life:** describing ways of recovering end-of-life value of asset, products and materials through reuse, remanufacturing and recycling.
- **extension of useful life:** reflecting the

capability of increasing the duration of the useful life, with respect to usual end-of-life of a product or its components
- **increase of the intensity of use,** measuring the increase of the benefit obtainable with each unit of input (material and energy) used deriving from a higher intensity of use (e.g. sharing goods)

The twenty-three key performance indicators reported in Table 3 are evaluated for EU each country over a 5-year period. The assessment of circularity is then made on ten indicators (in bold) chosen among the available ones using principal component analysis. Countries are then ranked according to the overall circularity level that they reach.

The results for 2018, the most recent year of the analysis, indicate strong variability among the EU members about their performance in circularity. Ireland, Luxemburg and Belgium are the best performing countries overall. Italy, in the fourth decile of the distribution, is considered a well-performing country as well; in particular, it exhibits high results in terms of the "end-of-life" indicators whereas the performance is quite poor in terms of "increase the intensity of use" indicators. The worst performing countries overall with respect to circularity are Greece, Bulgaria, Cyprus and Romania.

**Table 3 - The Key Performance Indicators of Circular Economy Scoreboard**

| | Performance Indicator | Unit of measurement | Source |
|---|---|---|---|
| *Sustainable inputs* | **Circular material use rate** | **%** | **Eurostat** |
| | **Resource productivity** | **Euro per tonne of material consumption** | **Eurostat** |
| | **Share of total organic area in total utilised agricultural area** | **%** | **Eurostat** |
| | Water productivity | €/m$^3$ of water | EEA |
| | Energy intensity | TOE per thousand Euros | Eurostat |
| | **Share of energy from RES** | **% final energy consumption** | **Eurostat** |
| | Final energy consumption by RES in transport | % final energy consumption | Eurostat |
| | Final energy consumption by electricity in manufacturing sector | % final energy consumption | Eurostat |
| | Final energy consumption by electricity by households | % final energy consumption | Eurostat |
| *End-of-life* | Packaging waste recycled | % | Eurostat |
| | Total generation of waste per GDP unit | kg per million Euros | Eurostat |
| | **Industrial waste treated by recycling** | **% on total industrial waste generated** | **Eurostat** |
| | **Municipal waste treated by recycling** | **% on total municipal waste generated** | **Eurostat** |
| | Patents related to recycling and secondary raw material per employees in Circular Economy sectors | patent per employees | Eurostat |
| | Sewage sludge treated and disposed in agriculture or as compost | % of sewage sludge produced | Eurostat |
| *Extension of useful life* | End-of-life vehicles recovered and reused | % of end of vehicles scrapped | Eurostat |
| | **Load factor** | **tonne-km / vehicle-km** | **Eurostat** |
| | **Value added of retail sale of second-hand goods** | **Euro per capita** | **Eurostat** |
| | Employment in repair and reuse sectors | % of total employment | Eurostat |
| *Increase of the intensity of use* | **Individuals using any website or app to arrange an accommodation from another individual** | **%** | **Eurostat** |
| | **Individuals using dedicated websites or apps to arrange a transport service from another individual** | **%** | **Eurostat** |
| | Collective transport on total passenger transport | % of total inland passenger-km | Eurostat |
| | Individuals using the internet | % of individuals aged 16 to 74 in the last 12 months | Eurostat |



The summary indicator obtained is used as an explanatory variable in a regression analysis aimed at establishing a relationship between economic and social outcomes and the overall circularity level. The study finds that the more circular the economy is, the better a country's economic and social performances are (measured by GDP, employment, investment, labour productivity, etc.). One worry is that the results could be biased: in fact, investments in more circular businesses can be due to the need of complying with stricter environmental regulations (see Porter at al. (1995)) that are more likely to be in place (or to be correctly implemented) in richer countries or in general in countries that exhibit a higher "rule of law" indicator. This would be suggested by the Environmental Kuznets Curve (see Dinda (2004) for a recent survey): countries at different stages of economic development would exhibit different levels of pollution, the relationship between pollution and development being inversely u-shaped. Moreover, the relationship between higher circularity and better economic performance could suffer from an omitted variable bias, because institutions that matter for economic development are probably the same that matter for environmental awareness. Reverse causality could also be in place. Identification calls for an appropriate instrumental variable in this setup, but the econometric model estimated is not yet available on the websites of the proposing institutions. The latter is to be considered, in general, the possible difficulty that a researcher could meet when estimating the effect of circularity on the economy.

## 4.2- Company-level indicators

This section provides a review of the most relevant and recent indicators aimed at measuring the level of circularity in companies.

**Ellen Mc Arthur Foundation (EMA)**

The Ellen MacArthur Foundation, under the Circularity Indicators Project, has developed different indicators aimed at measuring circularity. The set of metrics proposed by the foundation include indicators at the product and at the company level, as well as a tool at the product level. These indicators have multiple purposes (EMA, 2015). In fact, they can be used for evaluating the circularity of new products in the process of being designed. They could be useful for internal reporting purposes, in order to make communication easier among different branches of the same company or between the company and its stakeholders. Moreover, they could be used as internal standards by the buying divisions, when the company purchases products from the market.

**Cyrculitics (EMA)**

The EMA foundation proposed Cyrculitics in 2020 and advertises it as the "*most comprehensive circularity measurement tool for companies*". This tool is aimed at measuring the entire circularity level of a company, supporting decision making towards business choices aimed at enhancing circularity and provides transparency to investors and stakeholders.

The method is based on an automated scoring process. Companies are asked to answer to specific questions on their business that can be classified in *themes* (each one in Italic) according to the following scheme:

**ENABLERS**

- *strategy and planning* on the circular economy (i.e. whether circular economy is central to the CEO agenda, whether the circular targets proposed are measurable, whether a circular economy implementation plan exists)
- *innovation on the circular economy* (i.e. whether innovative processes are undertaken following circular economy principles)
- *people and skills* (i.e. on the existence of training on the circular economy)
- *operations* (i.e. whether processes are meant to be circular)
- *external engagement* (directed towards costumers, suppliers, policymakers)

**OUTCOMES**

- *services* (i.e. the revenues deriving from circular services)
- *products and materials* (i.e. the mass if inflows and outflows, classified depending on the source and on the potential outcome)
- *water* (i.e. water demand and its reduction targets)
- *energy* (i.e. electricity demand and its sources)
- *finance* (i.e. investment on the circular economy)

Each quantitative answer is represented by a number between zero and one hundred by construction, whereas each qualitative answer is given a “score” in the same range. The resulting score for each one of the above themes is constructed as a weighted average the answers. The weights are reported in the questionnaire, so every company knows what is considered more important in the construction of the theme indicator. Theme indicators are then averaged out, again using a weighting scheme, in which weights are are a function of the type of company, the material mass used, the position played in the value chain. The final score represents a unitary metric at the company level, summarized by a letter (from A to E).

This approach is quite simple and intuitive. The transition of qualitative answers to a numerical score would require some additional explanation, in order to exclude that indicators derive from a subjective perspective. Moreover, the fact that the weighting scheme is reported in the questionnaire increases the incentives for company’s representatives to answering in order to maximize the company’s specific score.

**Material Circularity Indicator (EMA)**

The *Material Circularity Indicator* (MCI) measures the level of circularity of a single product. It is represented by a score from zero to one, where one indicates the highest level of circularity, and is constructed using the answers to the following questions (EMA, 2015):

- **Input** in the production process:
  - How much input is coming from virgin and recycled materials and reused components?
- **Utility** during use phase:
  - How long and intensely can the product be used compared to an average industry product of a similar type? This accounts for increased durability of products, but also repair/ maintenance and shared consumption business models
- **Destination** after use:
  - How much material goes into landfill?
  - How much energy can be recovered?
  - How much is collected for recycling?
  - What components are collected for reuse?
- Efficiency of **recycling**:
  - How efficient are the recycling processes used to produce recycled input and to recycle material after use?

This indicator considers the effects of a good’s production on the environment in terms of its “linear” life, accounting for the materials used, the length of its life span and ultimately its recyclability. This methodology is similar to the Life-Cycle Assessment (LCA) one in that it focuses on a product’s life, but it is more specific than the LCA because it focuses only on the materials, their origin and their future after a product’s usage. Indeed, the main shortcoming of this indicator is its mostly exclusive focus on technical cycles and materials from non-renewable sources. For this reason, often it is complemented with additional indicators: the “*complementary risk indicators*”, referring to material scarcity or toxicity and indicating the need of moving towards a more circular technology, and the “*complementary impact indicators*”, related to energy and water usage and indicating the benefits of circular models.

The mathematical formulation of the MCI clarifies its meaning, and therefore it is useful to go through some of the formulas used to construct this indicator. Proceeding backwards with respect to the detailed description that we can find in (EMC, 2015), ultimately the MCI is defined as

$$MCI = \max(MCI^*, 0)$$
$$\text{where } MCI^* = 1 - LFI \times F(X)$$

In the latter formula, LFI is called Linear Flow Index of the product and F is some function of the utility X. The Linear Flow index measures the proportion of the materials that flow linearly in the product and takes a value between 1 (totally linear) and 0 (totally circular). It is computed as a non-linear combination of the amount of virgin materials used in the product and of the different types of waste that the product generates at the end of its life. It corresponds to the proportion of virgin material employed that ends up in unrecoverable waste, representing the more direct and dramatic impact of the product on the environment. The utility X accounts for both the time length of the product’s use phase and for its intensity of use, both in relative terms with respect to industry’s averages of those two components. The function F is chosen *ad hoc*: increasing the utility of a good, by using it longer or at a higher intensity, should affect the MCI as much as reducing virgin materials and waste in a given time period. In other words, increasing the utility should have an impact proportional to decreasing the linearity of the flow and improving its circularity. This requires a function such as

$$F(X) = \alpha / X$$

It can be proven that setting $\alpha = 0.9$ ensures that MCI = 0.1 for a fully linear product whose utility equals the industry average.

Given the definition of the indicator, the circularity of a product may increase because

- less virgin material is employed to start with
- less virgin material ends up being completely wasted
- the product's lifetime increases
- the intensity of use increases

Looking back at the definition of MCI*, one could wonder whether it could lead to a negative number. Indeed, if products are responsible for almost linear flows (LFI = 1) and deliver a utility level worse than the industry average (X < 1), then the index could result in a number smaller than zero. In order to avoid such a scenario, this is the reason why ultimately the MCI has been defined as

$$MCI = \max(MCI^*, 0)$$

The latter formula shows immediately one of the main shortcomings of the indicator. In fact, should two products exhibit a high level of "linearity" (as opposed to "circularity"), one would not be able to compare them: their MCIs would end up being both zeros. The Ellen MacArthur Foundation documentation states that *"…as it is not anticipated that this methodology would normally be used for these kinds of product, there should not be any problems with this approach"*. In our opinion, however, this statement might not be true, and this could represent an intrinsic problem to this indicator. Having a meaningful metric system means allowing for a comparison of objects consistent along the spectrum of the metric itself. Therefore, if the indicator is limited between 0 and 1, one expects the difference in circularity between two very linear products, scoring respectively 0 and 0.2, to be the same in magnitude as the difference between two very circular products, scoring respectively 0.8 and 1. This ends up not being true as the MCI is truncated, i.e. a product with an MCI equal to 0 could indeed have an MCI* equal to -0.01 or -0.1, h. Hence, the difference in circularity with a product scoring 0.2 could be very different indeed.

Another shortcoming of the indicator is that a very detailed "*bill of materials*" needs to be considered for computing it, i.e. all materials used in the assembly of the product need to be enumerated. On top of being a costly exercise for the company, this creates incentives for misreporting. Moreover, such an indicator deals with circularity in a mere "material" sense and cannot be considered complete. At the company-level, the MCI is a weighted average of the MCIs of the single products. In order to simplify the calculations, usually, a single MCI is computed for every family of similar products, and then these figures are aggregated at the firm-level.

**wbcsd**

The World Business Council for Sustainable Development (wbcsd) is a non-profit organisation dealing with sustainable development issues since 1992. It is formed by the CEOs of 200 important companies, many of which are multinationals, such as Nestlé, 3M, Danone and DuPont. Its main purpose is creating a synergy among the participating companies and share knowledge in order to accelerate the transition towards sustainable development. With particular regards to the circular economy, the goal of the organization organisation is creating, both within and across different businesses, engagement so that new solutions towards a more sustainable economic paradigm could be achieved.

The focus of the organisation is increasing resource efficiency, for instance via a proposed ten-fold increase in the eco-efficiency of materials, in order to reach the target of a zero-waste world by 2050. "Factor10" is indeed the name of the Circular Economy project that brings members together in order to re-design the production process: to be less dependent from virgin materials and to impact less on the planet via a strong waste reduction. For facilitating the project, some circular metrics were proposed by wbcsd in collaboration with KPMG (2020): it is a set of 21 Circular Transition Indicators (CTISs) in order to help member companies as well as non-members answering to the following questions (wbcsd and KPMG, 2020):

- How circular is my business?
- How do we set targets for improvement?
- How do we monitor improvements resulting from our circular activities?

As for the vast majority of indicators on the circular economy, the CTI metrics are based on material flows accounting, combined with additional indicators on resource efficiency, resource efficacy and value value-added by the circular business. In general, terms, the CTI indicators are in line with the Ellen MacArthur Foundation pillars on designing out waste and pollution, keep products and materials in use and regenerate natural systems. The objective of these indicators is helping companies in their transition towards a more circular economy. In order to make the procedure user-friendly, an online tool has been implemented in order to support users in calculating their measures of circularity, according to the following principles: simplicity, consistency, completeness, flexibility, complementarity and neutrality.

The indicators can be classified into three families:

1) Close the loop:
   - % of circular inflow, assessing the total circularity of inflowing materials
   - % of circular outflow, assessing the total circularity of outflowing materials
   - % of water circularity, still to be defined and proposed by the working group responsible for the CTIs
   - % of renewable energy over total energy used in the production process
2) Optimise the loop:
   - % critical material over the total mass of linear inflows
   - % recovery type, indicating how materials can be reused (recycled, repaired, refurbished)
3) Value the loop:
   - circular material productivity: linking the material flow indicators with conventional financial firm-level metrics

The choice of the indicators on a company's part should follow the following logical scheme:

1. SCOPE: Determine the boundaries
2. SELECT: Select the indicators
3. COLLECT: Identify sources and collect data
4. CALCULATE: Perform the calculations
5. ANALYSE: Interpret results
6. PRIORITISE: Identify Opportunities
7. APPLY: Plan and act

Step one (Scope) starts from a definition of the intent of the circularity assessment. In particular, the company needs to understand why circularity is important for its business, what the relevant issues are, who the audience of the assessment is and what could drive optimal value for all stakeholders from the material stream assessment. One example is reported: if the company needs to assess its level of circularity in front of the CFO, probably it would use the "*circular material productivity*" indicator.

The "*circular material productivity*" is probably the most interesting and innovative indicator, although very simple, proposed in this study. It is said to link firm performance to material usage: in fact, it is computed as the ratio between revenues and the total mass of linear inflows, indicating basically revenues *per kg* of materials used. This ratio increases if revenues increase, holding constant the materials used in the production process; and it also increases and/or in case the mass of materials employed decrease, but nonetheless revenues do not turn out to be negatively impacted. According to the study, a company is considered to become more successful in decoupling financial growth from linear resource dependence in case the indicator rises over time.

This indicator has the main advantage of being relatively easy to compute and interpret: it provides a simple measure of firm characteristic as a function of materials used. Several comments can be made on this indicator. First of all, considering its evolution over time for a single business or business-line does make perfect sense, as computing its change washes out all the sector-specific and firm-specific characteristics that are supposed to be constant over time. When the metric is used for comparing different business lines, instead, set aside different companies altogether, its interpretation becomes much more difficult. First, revenues depend on prices: some sectors and some firms could exhibit a higher indicator just because they sell relatively more expensive products. Moreover, different sectors and different firms within a sector have different needs for the mass of materials to be employed in the production process: comparing the indicator for different companies needs caution, as a firm could perform better from a circular perspective only because it produces goods requiring fewer materials to start with. For this reason, we believe that this indicator should be interpreted in comparison with sector-specific or product-specific averages. Moreover, the name "productivity" could be misleading: both sales and the total mass of materials are a function of output. Hence, the indicator should, in principle, at least be independent from firm's size for single-product firms. As soon as the company is multi-product, though, the output of each product would enter the numerator and the denominator at the same time (algebraically, it will not be possible to cancel them out): different product quantities will act as weights both at the numerator and at the denominator. Consider a company that makes some products that are highly-dependent on virgin materials, but do not account much when compared with overall output, i.e. the fraction of that product sold over total output is low: those product lines will have a negligible importance in the computation of the indicator. This makes total sense as the metric proposed reports an overall company "average". From a circularity-enhancing perspective, however, it would be useful to compute this indicator also separately for each product, as well as providing a variance measure. This would allow a better understanding of how progresses towards circularity are undertaken in different departments and would help identify the



specific product lines that suffer more in terms of circularity and should be devoted more attention by the central sustainability management.

**ENEL**

Enel, being an energy company, stressed the importance of considering two dimensions for measuring circularity: physical quantities (such as the share of renewable inputs and all scores on material utilisation) and use indicators (such as load factors). Focusing only on the physical dimension, in fact, would imply considering similar products that instead differ a lot in terms of their life span. Within physical indicators, Enel stresses the importance of considering material flows separated from energy flows. The link between energy and circular economy is very strong, and policy makers should take it into consideration (D'Amato et al. (2020)): by increasing the level of circularity in any production process, in fact, we save energy in the production process; by making energy production more circular, we increase our distance from the linear paradigm of our economy. Energy deserves to be considered in the circular economy indicator, but a strategy is needed in order to make this special input comparable to the tangible ones, and Enel provides one.

Instead of considering a set of indicators, respectively for material, energy and use, Enel proposed a unique metric for measuring the circularity of its business, which can be applied to other companies as well. CirculAbility© (born in 2016 and registered in 2018) is the name of the methodology proposed. The main advantage of this method is the inclusion of all pillars of circular economy, from inputs to end-of-life. The latter has been taken into special consideration: what matters is not what can be recycled, but instead what can be *re-introduced* in the production cycle. Another strength of the model is the integration between *energy* and *materials*, allowing to consider a unique metric instead of two separate measure that could potentially misrepresent the circularity level of the business.

The overall Circularity Index (CI) proposed by Enel is based on three assumptions, which can be rephrased as follows:

1) some formulas are used in order to create a meaningful index, even if not linked to physical considerations about materials;
2) energy is taken into account after its conversion in materials (i.e. in a mass, measured in kg), in particular considering how much material would be needed for producing a certain energy quantity;
3) the final indicator will be a pure number (i.e. no unit of measurement attached) because it is computed as a ratio

Given the above assumptions, the indicator proposed by Enel is a non-linear combination of two separate indicators: CF (Circular Flow) and CU ("Circularity in Use").

CF (Circular Flow) is computed considering circular inputs and outputs of material and energy according to the following formula

$$CF = \frac{2 - \left(\frac{V}{TI} + \frac{W}{TO}\right)}{2}$$

where V is non-sustainable inputs, TI is total inputs, W is non-sustainable waste, and TO is the total waste. If all inputs and all output were sustainable, CF would take the value of 1. If instead, they were all non-sustainable, the index would take value 0.

CU represents the "circularity in the use approach". It is computed as follows:

$$CU = \frac{Lex}{Lbau} \times \frac{Ush}{Ubau} \times \frac{Usap}{Ubau}$$

where the letter L represents Life (in years), U the time of use (as a % of total time), the notation "BAU" stands for "Business As Usual" (i.e. without interventions for increasing circularity by means of prolonging a product's life), SH is related to sharing products and SAP to "service as a product". In other words, the indicator measures the useful life of each product by taking into account how much it lasts more with respect to comparable objects (first factor), how much time it can be used in a sharing mode (second factor) and the possibility of it being sold as a service and not as a product stricto sensu (last factor). In this way, a product's useful life gets to be expanded not only when the good truly lasts more, but also by the possibility of multi-user usage (i.e. sharing) and by the fact that goods that are sold as services can be re-sold multiple times.

The final indicator, called Circularity Index (CI), is computed according to the following formula:

$$CI = CF + \frac{(1 - CF)(CU - 1)}{2CU}$$

The CF itself represents the first part. In the second term, the non-circular flow (1-CF) is multiplied by a number called "use factor" (the fraction (CU-1)/2CU)), which basically weighs that the contribution of non-circular materials and energy by how much the product is used. Therefore, the higher the use, the higher the CI, because the non-circular inputs and outputs are related to a more long-lasting product. Since CF is a number between 0 and 1 and the "use factor" is between 0 and 0.5, the CI turns out to be bounded between 0 and 1 as well: products that are more circular get a score of 1 and less circular products a lower score ("fully linear" products would score 0). If CF is 1, CI is 1 as well (totally circular product); if CF is 0, meaning that inputs and outputs are not sustainable, CI corresponds to the use factor and hence is between 0 and 0.5. The non-circularity of inputs and outputs is considered for the computation of the index, and the higher this component, the lower the index itself. Usage enters the picture only mediated by the non-circular component above (1-CF), which gets to be "discounted" according to usage itself: the weight of linear materials is lower, the higher the "use factor" of a product. To sum up, low circular products that are not at all long-lasting get a CI as low as zero. Fully non-circular products that happen to have a very long life span turn out to have a CI of 0.5. Non-circular products (from a material perspective) can get at most an index of 0.5. Fully circular products get a CI of 1 (extreme case, not realistic).

This indicator can prove to be very useful. Virgin materials, energy and waste all enter the indicator. The length of a product's life, computed taking into account sharing, also contributes to the indicator, but only in lowering the "negative" impact of linear inputs and outputs on the circularity index. This makes sense, as a totally circular product (CF equal to 1) will still get the maximum CI possible (1). One could wonder whether it makes sense that totally circular products -from a material perspective- with a very long life score 1 as well as those products that are fully circular but not long long-lasting. This can be the result of a deliberate choice, if materials are more important than products' life span. At the same time, the process towards a more circular economy has just started, hence it is very unlikely to find products whose CF is indeed 1.

**Enel X**

Enel X belongs to the Enel group, and its aim is providing services linked to energy transformation at the home, city and industrial level with a particular focus on sustainable development. Enel X created in 2019 an applied method for measuring the circularity level of its solutions based on the CirculAbility© theorical framework according to the following five pillars[7]:

1) Commitment by suppliers to comply with the **principles of the Circular Economy** during production
2) The presence of **reusable elements** which facilitate the circular consumption model, increasing the life cycle of the product
3) Dissemination of best practices to boost the **efficiency of use of resources**
4) Product **end of life management** using innovative and sustainable methods that encourage the reuse of materials
5) Supporting the development of **environmental awareness** by involving suppliers in virtuous mechanisms

These five dimensions are considered together with the five circularity business models:

- sustainability of resources
- product as a service
- sharing platforms
- product life cycle extension
- recovery and recycling)

Enel X then calculates the Circular Economy Score of its solutions, ranging from zero to a hundred, which informs its clients on the level of circularity embedded in its products and services.

Moreover, one of the services offered by the company itself is computing a Circularity Score for businesses and for cities, both obtained by considering multiple dimensions (such as energy use, design of products, waste, inputs) and aimed at boosting the existing circularity level by adapting ad-hoc solutions.

**Philips**

Philips sustainability department represents an outlier in this review. In fact, Philips believes that using circular economy indicators, such as the percentage of recycled materials in the products, *"may pose the risk that circularity becomes an end in itself"*, when *"zero or even positive environmental impact should be the ultimate goal"*[8]. In fact, they claim that some industrial processes aimed at enhancing circularity can be themselves very polluting, even resulting in a total negative impact on the environment. According to Philips, this means that CE indicators can be used only together with measures of the overall environmental impact of circular economy business practices, using a Life Cycle Assessment (LCA) methodology.

This does not mean that this company does not believe in the importance of becoming more circular. In fact, in its website its states the

7 https://www.enelx.com/it/en/circular-economy/indicators
8 https://www.innovationservices.philips.com/news/measuring-circularity-putting-cart-horse/

following circular economy targets for 2025:
- generate 25% of sales from circular products, services and solutions;
- close the loop by offering a trade-in on all professional medical equipment, and taking care of responsible repurposing
- embed circular practices at Philips sites and send zero waste to landfill

Philips represents a company that wants to become more circular without being bounded by a specific indicator. This is a possible strategy to be considered as well, especially because it is accompanied by a broader commitment towards reducing the impact of the specific business on the environment. At the same time, though, not binding the company to a specific metric makes it impossible to judge the progresses specifically directed towards circularity, both over time and in comparison to competitors and partners.

Philips is a member of the Platform for Accelerating the Circular Economy (PACE)[9], which was launched in 2017 by the World Economic Forum as a platform for public and private sectors leaders in order to move forward in the process towards a more circular economy. This platform counts 80 public, private, international and civil society executive leaders and, since early 2019, the PACE Secretariat has been hosted by the World Resources Institute in The Hague with continued leadership and collaboration of the Forum. Moreover, given the nature of its products, Philips is also a member of StEP (Solving the E-waste Problem)[10] aimed at incentivising recyclability of electrical equipment. This topic has become of central importance for the future EU policy, and electronics are listed as the first product family to be considered in the New Circular Economy Action Plan[11].

### 4.3 - Scientific Literature

Avdiushchenko and Zajac (2019) stress the need for proposing a regional level indicator for circularity at the EU level. In this study, the authors start by pointing out the temporal delay between the developments of CE indicators in the EU in comparison with other parts of the world. In China, for instance, the National Development and Reform Commission proposed an indicator for measuring CE a the macro-level and one at the meso-level back in 2007. The first EU indicators were proposed in 2015 and the ten indicators composing the CE monitoring framework were released by the European Commission in December 2017, with the purpose of monitoring production, consumption, waste management, secondary raw materials and innovation. Alongside these specific indicators, the authors enumerate the European Scoreboards more related to CE monitoring, in particular the following ones: 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. This system for policy evaluation, according to Avdiushchenko and Zajac (2019), suffers from the same problems as the Sustainable Development Strategy (SDS) of the EU back in 2015: the multiplicity of indicators makes it difficult to evaluate the overall level of circularity achieved. While it is true that multiple dimensions need to be taken into account, especially for such a new paradigm that involves all phases of a product's life (design, production, usage, disposal), it becomes hard to compare different countries or regions when they are compared according to many dimensions.

This difficulty is once again reiterated by the fact that the authors end up proposing a set of twelve indicators for assessing CE at the regional level, each one for the following area:
- economic prosperity economy taking into account financial aspects of environmental actions
- zero-waste economy;
- innovative economy;
- energy-efficient and renewable energy-based economy;
- low carbon economy;
- smart economy;
- spatially effective economy;
- bio-economy;
- service/performance economy;
- collaborative/sharing economy;
- resource and material-efficient economy;
- socially-oriented economy

Saidani et al. (2019) propose a taxonomy of circular economy indicators: they perform a systematic literature review, from both the academic literature and the "grey" literature, and identify fifty-five indicators. These indicators are then partitioned in ten categories, according to different dimensions such as the levels of implementation, the performance, the degree of application. This analysis is accompanied by the creation of a database together with an Excel query designed to help users finding out the indicator that best suits their needs. The aim of the paper is basically helping the interested reader, who is likely to be a company representative interested in showing the level of circularity of her business, by proposing different dimensions along which the indicators can be classified, and then guiding her through the choice of the best indicator for her needs. The authors compiled such an extensive list of indicators by web-searching academic databases and non-academic sources (for instance, via Google searches). Table 4 reports a list of the indicators available in their database.

**Table 4 – Indicators from Saidani et al. (2019)**

| Acronyms | C-Indicators | Sources (authors and year) |
|---|---|---|
| ACT | Assessing Circular Trade-offs (ACT) | Circle Economy and PGGM, 2014 |
| BCI | Building Circularity Indicators (BCI) | Verberne, 2016 |
| C2C | Material Reutilization Part (C2C) | C2C, 2014 |
| CA | Circle Assessment (CA) | Circle Economy and PGGM, 2014 |
| CAT | Circularity Assessment Tool (CAT) | PGGM, 2015 |
| CBT | Circular Benefits Tool (CBT) | Advancing Sustainability LLP, 2013 |
| CC | Circularity Calculator (CC) | ResCoM, 2017 |
| CECAC | Circular Economy Company Assessment Criteria (CECAC) | VBDO, 2015 |
| CEI | Circular Economy Index (CEI) | Di Maio and Rem, 2015 |
| CEII | Circular Economy Indicators for India (CEII) | Talwar, 2017 |
| CEIP | Circular Economy Indicator Prototype (CEIP) | Cayzer et al. 2017 |
| CEMF | Circular Economy Monitoring Framework (CEMF) | European Commission, 2017 |

9 https://pacecircular.org/
10 https://www.step-initiative.org/
11 https://ec.europa.eu/commission/presscorner/detail/en/ip_20_420

| | | |
|---|---|---|
| CEPI | Circular Economy Performance Indicator (CEPI) | Huysman et al. 2017 |
| CET | Circular Economy Toolkit (CET) | Evans and Bocken, 2013 |
| CETUS | Circular Economy Toolbox US (CETUS) | US Chamber Foundation, 2017 |
| CEV | Circular Economic Value (CEV) | Fogarassy et al. 2017 |
| CI | Circularity Index (CI) | Cullen, 2017 |
| CIPEU | Circular Impacts Project EU (CIPEU) | European Commission, 2016 |
| CIRC | Circularity Material Cycles (CIRC) | Pauliuk et al. 2017 |
| CLC | Closed Loop Calculator (CLC) | Kingfisher, 2014 |
| CP | Circular Pathfinder (CP) | ResCoM, 2017 |
| CPI | Circularity Potential Indicator (CPI) | Saidani et al. 2017 |
| DEA | Super-efficiency Data Envelopment Analysis Model (DEA) | Wu et al. 2014 |
| ECEDC | Evaluation of CE Development in Cities (ECEDC) | Li et al. 2010 |
| EISCE | Evaluation Indicator System of Circular Economy (EISCE) | Zhou et al. 2013 |
| EMCEE | Indicators for Material input for CE in Europe (IMCEE) | EEA, 2016 |
| EoL-RRs | End-of-Life Recycling Rates (EoL-RRs) | Graedel et al. 2011 |
| EPICE | Environmental Protection Indicators (EPICE) in a context of CE | Su et al. 2013 |
| ERCE | Evaluation of Regional Circular Economy (ERCE) | Chun-Rong and Jun, 2011 |
| EVR | Eco-efficient Value Ratio (EVR) | Scheepens et al. 2016 |
| EWMFA | Economy-Wide Material Flow Analysis (EWMFA) | Haas et al. 2015 |
| FCIM | Five Category Index Method (FCIM) | Li and Su, 2012 |
| HLCAM | Hybrid LCA Model (HLCAM) | Genovese et al. 2017 |
| ICCEE | Indicators for Consumption for CE in Europe (ICCEE) | EEA, 2016 |
| ICT | Circularity Indicator Project (ICT) | Viktoria Swedish ICT, 2015 |
| IECEE | Indicators for Eco-design for CE in Europe (IECEE) | EEA, 2016 |
| IECF | Indicators of Economic Circularity in France (IECF) | Magnier, 2017 |
| IEDCE | Integrative Evaluation on the Development of CE (IEDCE) | Qing et al. 2011 |
| IOBS | Input-Output Balance Sheet (IOBS) | Marco Capellini, 2017 |
| IPCEE | Indicators for Production for CE in Europe (IPCEE) | EEA, 2016 |
| IPCEIS | Industrial Park Circular Economy Indicator System (IPCEIS) | Geng et al. 2012 |
| MCI | Material Circularity Indicator (MCI) | EMF, 2015 |
| MRCCEI | Measuring Regional CE–Eco-Innovation (MRCEEI) | Smol et al. 2017 |
| NCEIS | National Circular Economy Indicator System (NCEIS) | Geng et al. 2012 |
| PCM | Product-Level Circularity Metric (PCM) | Linder et al. 2017 |
| RCEDI | Regional Circular Economy Development Index (RCEDI) | Guo-Gand and Jing, 2011 |
| RDI | Resource Duration Indicator (RDI) | Franklin-Johnson et al. 2014 |
| RES | EU Resource Efficiency Scoreboard (RES) | Eurostat, 2015 |
| RIs | Recycling Indices (RIs) for the CE | Van Schaik and Reuter, 2016 |
| RP | Resource Productivity (RP) | Wen and Meng, 2015 |
| RPI | Reuse Potential Indicator (RPI) | Park and Chertow, 2014 |
| RRs | Recycling Rates (RRs) | Haupt et al. 2016 |
| SCI | Sustainable Circular Index (SCI) | Azevedo et al. 2017 |
| VRE | Value-based Resource Efficiency (VRE) | Di Maio et al. 2017 |
| ZWI | Zero Waste index (ZWI) | Zaman and Lehmann, 2013 |

This long list stresses, once again, the shortcoming arising when very many indicators are available: different businesses could end up choosing only those indicators that enhance their circularity level. As long as "circularity" per se is not defined according to a unique and unanimous criterion, there are incentives on stressing the dimensions more relevant to a specific company, which could at the same time be very deficient according to other standpoints. To sum up, reading this paper confirms the importance of constructing a unique indicator (or a limited set of them); first of all, in order not to get lost in the plethora of available measures; secondly, because such a big set of measures makes it clear that firms could choose the one that makes them look more circular.

Among the indicators considered by Saidani et al. (2019), some are particularly interesting and deserve a brief description. Cayzer et al. (2017) propose an indicator for measuring a product's performance along circularity dimensions. They test a prototype questionnaire whose responses are synthesised in a product-level indicator for circularity and test it in the chemical processing industry. The authors claim that their method is easy and simple but, as it is usually true with all indicators, a single metric for assessing a complex process can lead to mis-calculations and mis-interpretations. Verberne (2016) proposes an indicator for measuring circularity in buildings that takes into account technical, functional and perception dimensions. Lindner et al. (2017) review product-level indicators for circularity and propose a metric that corresponds to the share of aggregate recirculated economic value on total product value. The value-based resource efficiency indicator was developed by Di Maio et al. (2017) measures circularity as "*the percentage of the value of stressed resources incorporated in a service or product that is returned after its end-of-life*".

Other indicators proposed by the academic community are relevant even though not included in the list above. Mayer et al. (2019) propose a biophysical assessment of the level of circularity reached in the EU using a mass-balanced approach and linking official statistics on waste to the resources utilised in the production processes. Basically, they incorporate recycling and downcycling and account for waste in an MFA model. Camacho-Otero and Ordoñez (2017) define a framework for evaluating circularity in different businesses instead.

# 05 Conclusions

In this report, we reviewed some of the existing indicators for measuring circular economy at the macro level and at the company level. Those indicators come from the effort of think tanks, the scientific community, companies and institutions for providing a metric in order to assess the existing level of circularity of a system. This is needed for measuring progress towards a more circular economy. Recent contributions, such as the one by Enel and The European House – Ambrosetti, call for a "*clear definition*" and "*homogeneous and exhaustive metrics*" for measuring the circular economy.

Each indicator reviewed in this report is different and provides a different point of view on the issue. We believe that, at the macro level, the indicators proposed by Enel and The European House – Ambrosetti represent a good starting point aimed at reducing the complexity due to the existence of too many metrics. Moreover, the synthesis has been done with a statistically sound technique such as the principal component analysis. One should never forget, though, that aggregating multiple indicators in one corresponds to a loss in the information set firstly available. Moreover, additional problem arise if the indicators considered exhibit different degrees of correlation among them: the ones that are less correlated would end up being less represented in the synthesis than the group of indicators that comove more strongly (see JRC (2008) for the details).

There is the need to move one step forward and provide a unique indicator, or set of them, choosing among the existing ones or implementing a new measure. One possibility could be taking into account the distance between an ideal perfectly circular paradigm and the status quo. How far is a business from an ideal production process that does not impact the stock of virgin materials and does not produce non-recyclable disposables? Such a metric, defined as a distance (vectorial if taking into account more dimensions) could provide some interesting insight on the level of circularity of different business and would allow to compare different sectors. To this aim, we should build on what has been proposed so far and especially promote the diffusion of material and processes' accounting across businesses, cities and countries. This should be done together with campaigns aimed at increasing the awareness of consumers, in order to enhance responsible behaviors towards environmental issues in all segments of our society.



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