JUST2CE

A Just Transition to Circular Economy

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CHAPTER 14

Critical analysis of Assessment methods for CE understanding and monitoring

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Abstract

The Circular Economy (CE) concept is nowadays very common in scientific literature and in public discourses. It has become a prominent point addressed by politicians of every coalition and by corporate representatives, and even a keyword in advertising. However, there is no univocal definition of the CE concept, let alone a shared assessment method. Different national and international organizations, academics, and other stakeholders have proposed different assessment frameworks and related indicators for CE monitoring. In this chapter, a critical analysis of some of the proposed CE assessment and monitoring attempts is conducted, discussing indicators and perspectives adopted in CE monitoring.

Keywords: circular economy indicators; assessment methods; circular economy definition; multi-criteria assessment

Circular Economy assessment is based on the definition of circular economy adopted, which is still unclear. As a consequence, current CE indicators are mainly approaching CE from a technocratic perspective, while they should include other aspects like wellbeing and equity.

14.1 Introduction

The Circular Economy (CE) concept has gained a strong momentum in the last decades, both in the scientific community and in many other sectors of society, as governments, non-governmental organization (NGOs) and businesses (Lazarevic and Valve, 2017). The number of scientific works on CE has been growing significatively. The Scopus citation database reports 508 documents on CE in the timeframe 2000-2010, while the number dramatically increases to 24'891 documents in the timeframe 2011-2023 (19'114 results only within 2020 and 2023). Of the total 25'399 scientific works published from 2000 to July 2023, almost half (47%) identifies as subject areas Environmental science, Engineering and Energy, 8% identifies as subject area Social Sciences, 7% identifies Business, Management and Accounting. From the analysis of the subject areas, it is clear how the CE matter is approached in a strong technocratic perspective, as it is acknowledged mostly as a technological/material issue, thus calling for mostly material/technological approaches (Greene et al., 2024; Purvis et al., 2023).
As an example, this perspective is recognized within the perhaps most famous and most widespread definition of CE, from the Ellen MacArthur Foundation (EMF), acknowledging the CE as a restorative industrial economy framework, minimizing waste and resource use. It is intuitive that indicators and methods developed and in

development for CE assessment and monitoring will be influenced by the definition of CE and by the perspective adopted.

Since a general consensus about what a CE is, what it should do and represent and how it should be achieved is lacking, assessment methods and metrics tend to focus on different aspects and to emphasize different features. In this chapter, some of the most prominent definitions of CE will be reported and analysed, as well as some CE indicators and metrics, in order to understand the general, common perspective towards the CE topic, and its feasibility in addressing the issues faced nowadays by human societies.

14.2 – Circular Economy definitions

Different stakeholders, as worldwide NGOs, national and international policy makers, academics, and industry have provided some sort of definition or outlining of the CE concept. Some significant efforts in CE definition by different sources, representative of noteworthy efforts from governments, NGOs, academia and international institutions, are:

- The term "circular economy" is a generic term for the reducing, reusing and recycling activities conducted in the process of production, circulation and consumption. […] The state shall work out industrial policies in accordance with the requirements for the development of a circular economy (People's Republic of China, 2008).
- The circular economy refers to an industrial economy that is restorative by intention; aims to rely on renewable energy; minimises, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design. […] It involves a careful management of materials flows, which, in the circular economy, are of two types as described by McDonough and Braungart: biological nutrients, designed to re-enter the biosphere safely and build natural capital, and technical nutrients, which are designed to circulate at high quality without entering the biosphere. (Ellen MacArthur Foundation, 2012).
- In a circular economy the value of products and materials is maintained for as long as possible; waste and resource use are minimised, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value (European Commission, 2015).
- The circular economy is an economic system where waste is designed out, everything is used at its highest possible value for as long as possible and natural systems are regenerated. The concept of circularity closely mimics nature, where there is no waste: all materials have value and are used to sustain life in a myriad of ways. If we effectively deploy these strategies, we will ultimately require fewer materials to provide for similar societal needs (Circle Economy, 2008).
- Circular Economy is an economic system that targets zero waste and pollution throughout materials lifecycles, from environment extraction to industrial transformation, and to final consumers, applying to all involved ecosystems. Upon its lifetime end, materials return to either an industrial process or, in case of a treated organic residual, safely back to the environment as in a natural regenerating cycle. It operates creating value at the macro, meso and micro levels and exploits to the fullest the sustainability nested concept. Used energy sources are clean and renewable. Resources use and consumption are efficient. Government agencies and responsible consumers play an active role ensuring correct system long-term operation (Nobre and Tavares, 2021)

The previous list is far to be considered complete, as scholars have identified hundreds of definitions of CE (Kirchherr et al., 2023), acknowledging it as a tool mainly aimed at economic growth (Kirchherr et al., 2017), or alternatively focused on environmental conditions (Helander et al., 2019), while social aspects seem to be underestimated. In the same perspective, most of the scientific literature couple the CE concept with waste management related principles, like the 9R framework (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover), the Waste Hierarchy principle, upcycling, production of clean and renewable energy and resource efficiency (Nobre and Tavares, 2021).

Of course, the approach to CE definition also influences the approach to CE assessment. However, even though the mentioned definitions are from relevant and diverse bodies, the attention towards a social perspective of the CE transition remains limited or even absent. This translates in the lack of significant efforts for quantitative and/or qualitative evaluations of social features within a just CE transition.

14.3 Circular Economy assessment in a worldwide transition

Most of the proposers of the different mentioned CE definitions, also suggest some kind of metrics and indicators for the assessment of CE.

The EMF proposes a Material Circularity Indicator (MCI), aiming at defining the degree of circularity of materials involved in production processes (Ellen MacArthur Foundation, 2015). The MCI (**Figure 14.1**) accounts for flows of virgin resources, of reused or recycled resources, and of waste generated, calculating a value between 0 (least circularity) and 1 (most circularity), also accounting for the durability of products. The EMF also provides a set of businesses-oriented indicators, trough the Circulytics project, organized as 2 categories i): Enablers and ii): Outcomes, and 11 themes (Strategy and planning; Innovation; People and skills, Operations, External engagement; Products and materials; Services; Plant, property, and equipment assets; Water; Energy; Finance), for supporting the assessment of the levels of circularity within interested businesses (Ellen MacArthur Foundation, 2022).

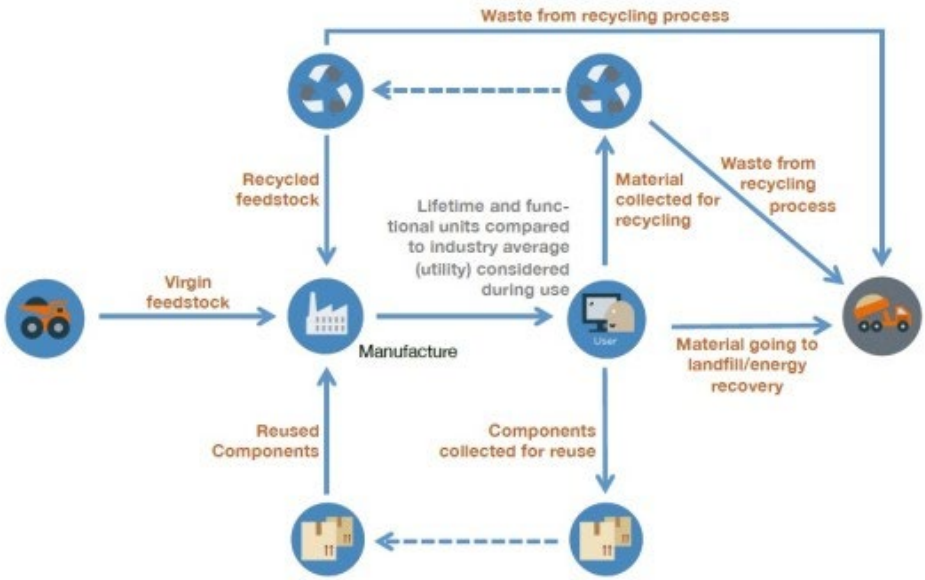

Figure 14.1The Material Circularity Indicator (Ellen MacArthur Foundation, 2015)

Similarly, the Circle Economy Foundation proposes a measure of the global level of circularity as the ratio of end-of-life materials cycled back into the global economy, in so doing reducing the need for primary resources. This metric is equal to 7.2% in 2023, in decline compared to values from 2018 (9.1%) and 2020 (8.6%) (Circle Economy, 2023). The metric is calculated through the accounting of the resource needs in different societal departments (Housing; Communication; Mobility; Healthcare; Services; Consumables; Nutrition). Through selected actions in a roadmap, they foresee a possible increase of the circularity metric to reach 17% by 2050, also mitigating greenhouse gas (GHG) emissions.

The EU proposed, in January 2018, a monitoring framework for CE, revised in 2023 (Eurostat, 2023). The EU framework includes 5 thematic areas: i) production and consumption, ii) waste management, iii) secondary raw materials, iv) competitiveness and innovation, v) global sustainability and resilience. Each thematic area includes several indicators, such as material footprint, resource productivity, consumption footprint, greenhouse gas emissions from production activities and material dependency. The monitoring framework is based on the circular economy priorities in the context of the European Green Deal, highlighting, for instance, that the number of EU-registered patents on recycling and secondary raw materials increased by 14% between 2000 and 2019; that in 2021 there were 4.3 million jobs in the economic sectors relevant to the circular economy, an increase of 11% compared with 2015. Moreover, EU GHG emissions from production activities decreased by around 25% between 2008 and 2021. However, the EU monitoring framework is deficient in indicators related to the social dimension, to the circular business models and industrial symbiosis, and to the water use, energy use and emissions, thus somehow disregarding the main elements of CE (Feiferytė-Skirienė and Stasiškienė, 2021).

From an academic/scientific perspective, many studies focus on CE from the micro (e.g., products, companies, consumers) and the macro (e.g., cities, regions, nations) levels, while the meso level (e.g., supply chains, industrial parks) is quite underexplored, even if the importance of the meso level is highly recognized (Kulakovskaya et al., 2022). In general, the importance of CE measurements is acknowledged as an important aspect to allow or to facilitate the transition to a CE framework. It is argued that CE metrics should focus beyond the common linear economy, and the infinite growth-related parameters, and should rather include other aspects, such as wellbeing and cooperation, in a multi-perspective framework (Santagata et al., 2020). The strong connection between CE and the concept of sustainability and sustainable development allows the use of several indicators for the assessment of CE implementations (Pauliuk, 2018).

The CE assessment is mainly performed by means of quantitative approaches, as the LCA and the MFA, thus adopting some or all their indicators as feasible CE metrics. These are consequently mostly related to greenhouse gases emissions, resource use, recovery and reuse of materials, use of renewable energy, emissions of toxic substances, and to other bio-physical or economical indices. In these approaches very often, socio-economic and wellbeing features are disregarded, although some methods encompassing these characteristics also exist, as for example the S-LCA method, providing information about the social effects associated with the life cycle of a product (despite still under significant development), the LCC method, accounting for all funds expended in support of an item from its conception and fabrication until the end of its useful economic life, and the Emergy Accounting (EMA), a thermodynamics-based and systems-oriented method evaluating processes from an environmental perspective and accounting for stock and flows based on their quality, embedding socioeconomic insights within the inclusion of flows of labor and services (namely, undirect labor). Also, the local/non-local dichotomy, as

considered by the EMA method, could represent a protection factor taking into account the needs of local communities as part of the complex system to be acknowledged within a just transition.

Within grey literature (namely, non-academic publications), a significant number of different software tools encompassing multiple scopes and aims can be found. Several of these tools and software applications are business and material/product oriented, with an environmental perspective. Of these, the wider part tends to include one of more life cycle-related indicator (e.g., carbon footprint, resource depletion, waste recovery, etc.) (Muñoz et al., 2023). These tools also tend to mainly disregard the socio-economic aspects of CE, reflecting the largely technocratic approach of current CE definitions.

14.4 Limits and future perspectives for CE measurements

However, it is argued that these interpretations of CE raise questions regarding the validity of the assumptions embedded within the CE concept and within the never abandoned idea of infinite growth (Giampietro and Funtowicz, 2020). If, as claimed by several definitions of CE, human societies have to mimic the network of material and energy exchanges happening in the natural ecosystems, the need for a thorough anticipation by governments and science is needed, meaning an improved ability of foreseeing and anticipating the possible problems and challenges ahead. Relying only on 'invisible hand' and human ingenuity as a way to solve problem is an idea heavily tied to outdated 'more of the same' approaches typical of market-based mechanisms of the linear oriented economy frameworks, not acknowledging the new social and bio-physical constraints that are still brought up in the CE discourses and narratives, but are then guiltily and incredibly lost when indices for CE measurements are proposed.

Thus, CE measurements and indicators should go further than the indices and methods usually implemented within linear economy models (**Table 14.1**), such as GDP, revenues and market prices, among others, but should widen to include other aspects, including wellbeing, stability, equity and environmental integrity, and other networking/collaboration-oriented aspects (Oliveira et al., 2021).

Table 14.1 Features of linear and circular economy (Oliveira et al., 2021)

Linear Economy	**Circular Economy**
Business based	Network based
Stand-alone activities	Collaborative, nexus oriented
Mono–criteria (value based on maximum income	Multi–criteria (value based on selected characteristics)
Design and planning for unlimited growth	Resources are limited
Conservative (more–of–the–same approach)	Regenerative (saving resource generation patterns), flexible about pursued results
Concentration (getting more, spending less)	Redistributive (fair resource allocation)

Human societies are to be intended and acknowledged as complex systems, and as such, they follow oscillating pattern of growth and degrowth phases based on the availability of resources (Odum and Odum, 2001). The so-called pulsing paradigm (**Figure 14.2**) follows four main stages: (i) Growth: abundant resources, increases in population, structure, and assets; low-efficiency and high-competition; (ii) Climax and Transition: maximum size

depending on available resources; efficiency increase; collaborative patterns; information storage; (iii) Descent: less resources available, decrease in population and assets, increase in recycling patterns; (iv) Low Energy Restoration: no-growth, consumption smaller than accumulation, and storage of resources for a new cycle ahead. Policies and assessment methods should therefore accordingly adapt to the current situation, as well as indicators. Western societies may be on the verge of a descent (and complex) phase, and this situation needs to be correctly acknowledged.

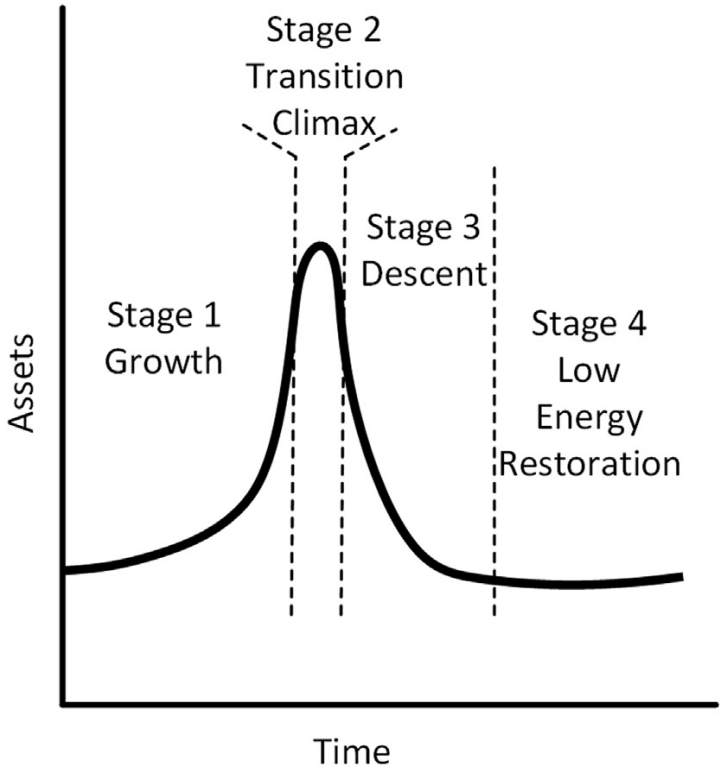

Figure 14.2 The pulsing paradigm (After Odum and Odum, 2001)

To overcome the reductionist approach of current linear economy-oriented indicators still applied to the CE framework, novel indicators are much needed, able to include the environmental dimension (conservation of natural capital, decrease of pollution, environmental protection, etc.), together with the social dimension (quality of food and education, jobs, participatory strategies, etc.), giving attention to the different kind of impacts of the alternative options within the surrounding environmental and socio-economic constraints (Santagata et al., 2020). This could be performed by the implementation and the integration of different methods, in a multi-perspective approach. This way, a holistic point of view becomes achievable, gaining a systemic understanding of problems and solutions.

14.5 LEAF: an effort for LCA and Emergy integration

Within the scientific literature, some efforts in the integration of complementary assessment methods can be found. Method integration could represent a feasible way for CE assessment by allowing a deeper multi-criteria analysis of case studies, scenarios, future plannings and implementations. In particular, several scholars investigated the potential for integration of the LCA and EMA methods, exploiting at the same time the similar way they are performed (i.e., by compiling analogous inventories of input and output energy and material flows) and the opposite perspectives adopted (the downstream, product oriented LCA point of view, and the upstream, ecosystem oriented EMA approach) (Ingwersen, 2011; Marvuglia et al., 2013; Raugei et al., 2014). A recent approach provided an LCA/EMA integration procedure, applying the two opposite perspectives to deliver a much deeper comprehension of the assessed systems. The procedure, called LEAF (LCA & EMA Applied Framework), shown in **Figure 14.3**, consists of i) an Ex-Ante LCA, identifying the hotspots within the investigated case study; ii) a number of EMA scenarios, modelled around the selected hotspots, to evaluate the performances of proposed solutions; iii) Ex-Post LCAs of each EMA scenario, to assess to what extent each proposed solution has addressed and maybe removed the hotspots identified by the Ex-Ante LCA. This way, both the environmental effects and the general sustainability and performances of different solutions are explored, starting from the most significant constraints identified (Santagata et al., 2020).

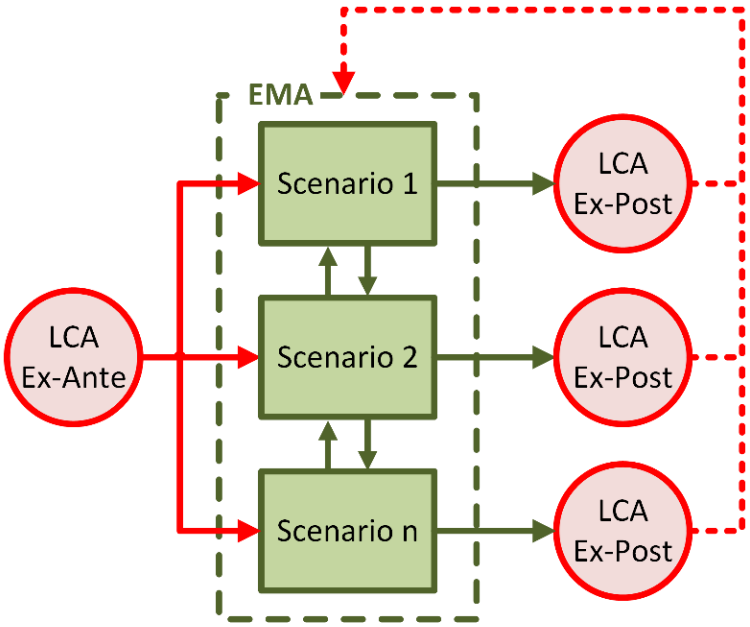

Figure 14.3 The LEAF Procedure (Santagata et al., 2020)

A multi-criteria, multi-perspective approach like the example discussed above would present the advantages of acknowledging and analysing CE features as complex systems, requiring holistic ways of study and assessment, delivering solutions capable of encompassing the so much advocated "circular aspects" needed to facilitate an equal, just and sustainable transition. The LEAF procedure seems to be capable of capturing environmental features together with socio-economic ones, the latter involved by the EMA method. Thus, the LEAF procedure represents a still improvable efforts for building new methods and indices.

14.6 Conclusions

The transition to a Circular Economy, and the implementation of CE strategies, must be capable of distancing from a reductionist, technocratic approach and have to be acknowledged as a complex system, requiring complex approaches taking into account local features and local stakeholders. Most of the current CE definitions and, consequently, indicators still fail in acknowledging that CE should not be just a technocratic matter intended to support and reinforce the old linear infinite growth delusion. Thus, the opportunity of using the need for new assessment frameworks for a new paradigm by international bodies and government should represent a chance for developing new metrics going further the simple idea of economic growth that are capable of including wellbeing, equity, environmental integrity and economic stability, in so doing ensuring, or at least facilitating, the concept of *'just transition'* that would be fair and feasible for all.

References

Circle Economy, 2023. The circularity gap report 2023. Amsterdam.

Circle Economy, 2008. What is the circular economy? [WWW Document]. URL https://www.circle-economy.com/circular-economy/what-is-the-circular-economy (accessed 7.28.23).

Ellen MacArthur Foundation, 2022. Circulytics. Weighting and scoring approach.

Ellen MacArthur Foundation, 2015. Circularity Indicators. An approach to measuring circularity.

Ellen MacArthur Foundation, 2012. Towards the Circular Economy Vol. 1 - An economic and business rationale for an accelerated transition.

European Commission, 2015. Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Closing the loop - An EU action plan for the Circular Economy. European Commission, Brussels, Belgium.

Eurostat, 2023. Improved circular economy monitoring framework now live - Products Eurostat News - Eurostat [WWW Document]. URL https://ec.europa.eu/eurostat/web/products-eurostat-news/w/wdn-20230515-1 (accessed 9.7.23).

Feiferytė-Skirienė, A., Stasiškienė, Ž., 2021. Seeking Circularity: Circular Urban Metabolism in the Context of Industrial Symbiosis. Sustainability 2021, Vol. 13, Page 9094 13, 9094. https://doi.org/10.3390/SU13169094

Giampietro, M., Funtowicz, S.O., 2020. From elite folk science to the policy legend of the circular economy. Environ Sci Policy 109, 64–72. https://doi.org/10.1016/j.envsci.2020.04.012

Greene, M., Hobson, K., Jaeger-Erben, M., 2024. Bringing the circular economy home – Insights from socio-technical perspectives on everyday consumption. Cleaner and Responsible Consumption 12, 100157. https://doi.org/10.1016/J.CLRC.2023.100157

Helander, H., Petit-Boix, A., Leipold, S., Bringezu, S., 2019. How to monitor environmental pressures of a circular economy: An assessment of indicators. J Ind Ecol 23, 1278–1291. https://doi.org/10.1111/JIEC.12924

Ingwersen, W.W., 2011. Emergy as a life cycle impact assessment indicator. A goldmining case study. J Ind Ecol 15, 550–567. https://doi.org/10.1111/j.1530-9290.2011.00333.x

Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. Resour Conserv Recycl 127, 221–232. https://doi.org/10.1016/J.RESCONREC.2017.09.005

Kirchherr, J., Yang, N.H.N., Schulze-Spüntrup, F., Heerink, M.J., Hartley, K., 2023. Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions. Resour Conserv Recycl 194, 107001. https://doi.org/10.1016/J.RESCONREC.2023.107001

Kulakovskaya, A., Knoeri, · C, Radke, · F, Blum, · N U, 2022. Measuring the Economic Impacts of a Circular Economy: an Evaluation of Indicators. Circular Economy and Sustainability 2022 3:2 3, 657–692. https://doi.org/10.1007/S43615-022-00190-W

Lazarevic, D., Valve, H., 2017. Narrating expectations for the circular economy: Towards a common and contested European transition. Energy Res Soc Sci 31, 60–69. https://doi.org/10.1016/J.ERSS.2017.05.006

Marvuglia, A., Benetto, E., Rios, G., Rugani, B., 2013. SCALE: Software for CALculating Emergy based on life cycle inventories. Ecol Modell 248, 80–91. https://doi.org/10.1016/J.ECOLMODEL.2012.09.013

Muñoz, S., Hosseini, M.R., Crawford, R.H., 2023. Exploring the environmental assessment of circular economy in the construction industry: A scoping review. Sustain Prod Consum 42, 196–210. https://doi.org/10.1016/J.SPC.2023.09.022

Nobre, G.C., Tavares, E., 2021. The quest for a circular economy final definition: A scientific perspective. J Clean Prod 314, 127973. https://doi.org/10.1016/J.JCLEPRO.2021.127973

Odum, H.T., Odum, E.C., 2001. A prosperous way down : principles and policies. University Press of Colorado.

Oliveira, M., Miguel, M., van Langen, S.K., Ncube, A., Zucaro, A., Fiorentino, G., Passaro, R., Santagata, R., Coleman, N., Lowe, B.H., Ulgiati, S., Genovese, A., 2021. Circular Economy and the Transition to a Sustainable Society: Integrated Assessment Methods for a New Paradigm. Circular Economy and Sustainability 1–15. https://doi.org/10.1007/s43615-021-00019-y

Pauliuk, S., 2018. Critical appraisal of the circular economy standard BS 8001:2017 and a dashboard of quantitative system indicators for its implementation in organizations. Resour Conserv Recycl 129, 81–92. https://doi.org/10.1016/J.RESCONREC.2017.10.019

People's Republic of China, 2008. Circular Economy Promotion Law of the People's Republic of China. Standing Committee of the 11th National People's Congress of the People's Republic of China, Beijing, China.

Purvis, B., Celebi, D., Pansera, M., 2023. A framework for a responsible circular economy. J Clean Prod 400, 136679. https://doi.org/10.1016/J.JCLEPRO.2023.136679

Raugei, M., Rugani, B., Benetto, E., Ingwersen, W.W., 2014. Integrating emergy into LCA: Potential added value and lingering obstacles. Ecol Modell 271, 4–9. https://doi.org/10.1016/j.ecolmodel.2012.11.025

Santagata, Remo, Zucaro, A., Fiorentino, G., Lucagnano, E., Ulgiati, S., 2020. Developing a procedure for the integration of Life Cycle Assessment and Emergy Accounting approaches. The Amalfi paper case study. Ecol Indic 117, 106676. https://doi.org/10.1016/J.ECOLIND.2020.106676

Santagata, R, Zucaro, A., Viglia, S., Ripa, M., Tian, X., Ulgiati, S., 2020. Assessing the sustainability of urban eco-systems through Emergy-based circular economy indicators. Ecol Indic 109. https://doi.org/10.1016/j.ecolind.2019.105859

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