Circular economy for a sustainable planet: Quantifying the effects of circularity

Research Objectives
Dr Simone Bastianoni and the Ecodynamics group employ data-driven approaches to underpin key strategies that will help us move to a circular economy.

Detail
Bio
Dr Simone Bastianoni is full professor of environmental chemistry and provost for sustainability at the University of Siena. He has 30 years’ experience in investigating sustainability indicators, adopting a holistic view, including eMergy, eXergy, ecological footprint, life cycle assessment (LCA), and greenhouse gases balance. Bastianoni is President of the Siena Alliance for Carbon Neutrality.

Collaborators
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References


Personal response prompt
Your research offers great hope for the very important aspect of measurement when implementing circular economy; what are the next steps for you?

The next most important step is to operationalise the theoretical framework introduced with this work. The idea is to apply the proposed approach to support decision-makers in planning strategical actions in their territories. A further step is to operationalise it with application at the meso-scale within planned or existing industrial symbioses.
Circular economy for a sustainable planet

Managing our planet’s resources carefully is becoming an emergency. A committed focus on environmental management and sustainability is urgent, as is our pressing obligation to address climate change. Dr Simone Bastianoni from the University of Siena, Italy, along with his colleagues, is working to improve data-driven approaches to underpin key decisions and strategies for moving to a circular economy (CE). Building on the strengths of life cycle assessment (LCA) methodology, they provide a widely applicable holistic approach to measuring circularity.

It has been estimated that, should current lifestyles and population growth continue, we face a very startling statistic for the year 2050: almost three planet Earths would be required to sustain us. This is a stark reminder that Earth’s resources are finite. It is now widely understood that bodies at all levels must work to reduce the generation of waste and the use of resources, while minimising environmental impacts.

A CIRCULAR APPROACH

The concept of circular economy (CE) has existed for some decades and is being begun to be adopted globally. CE is designed to reverse the ‘take, make, dispose’ approach that the linear economy pursued widely for centuries. Ideally, CE should pursue a more just and fair behaviour through better and optimised management of resources (reducing the use of raw materials and waste generation) by reusing, refurbishing, and recycling. This approach also follows the concept of sustainable equity – the proper balance between intergenerational equity (between the present and future generations) and intragenerational equity (between different people of the present generation). Better management of our resources can also lead to a reduction in pollution and emissions.

Circularity is designed to be effective at the micro-scale (eg, products), meso-scale (eg, organisations or companies), and at the macro-scale (eg, nations or regions). Implementation of CE involves rethinking processes, business models, designs, policies, and strategies on all levels. Led by Dr Simone Bastianoni, the Ecodynamics research group at the University of Siena, Italy, is employing data-driven approaches to underpin key decisions and strategies that will help us move to a CE.

MEASURING THE EFFECTS OF CIRCULAR STRATEGIES

Although no unique definition of CE exists, organisations, regions, and nations are beginning to align on various approaches to reach the common goal of curbing environmental impacts. It is essential to measure and monitor progress, and to quantify the environmental negative impacts as well as benefits. Circularity indicators are commonly used in a monitoring framework. The indicators for circularity assessment used until now are lacking in several ways. The existing approaches are usually confined to a specific sector or even a single product. They are typically applied to micro-scale systems, and don’t address the environmental impacts of the changes being studied in a holistic way.

It is necessary for studies to incorporate a whole-system approach, whereby a full system is modelled to include the integration of all key sub-systems. It is crucial to understand the interdependencies of the sub-systems (ie, single firms) in terms of helping design more circular processes and solutions. Further, there is a need to add a temporal dimension whereby both existing and proposed systems can be assessed and monitored.

A HOLISTIC APPROACH

Bastianoni and colleagues set out to address existing limitations and advance current models. He explains, “Our approach is not bound to a specific sector; it allows to capture the environmental impacts, and it is sensitive to the temporal dimension.” The researchers have adopted indicators from the ISO-defined life cycle assessment (LCA) methodology, acknowledged to be an effective tool when examining environmental impacts for all stages of the life cycle.

The model specifies environmental impact categories of interest, such as climate change, ozone layer depletion, acidification potential, or eutrophication. Measuring the impacts for each category and comparing it with a hypothetical fully linear system yields the circularity indicators for each category. These indicators provide quantitative insight with respect to the individual impact categories considered, and allow circularity assessment for a system as a whole. Different types of circularity implementation can be modelled and compared, which will help with planning and design for optimum circularity.

Determining indicators for the different impact categories allows for trade-offs to be analysed; it could be that a particular category is identified as producing a negative impact, although this could generate significant gains across other categories.

QUANTIFYING CIRCULARITY EFFECTS OVER TIME

The model can be extended for a dynamic perspective to measure impacts when a system has been operational for some time, after circularity initiatives have been implemented. The hypothetical fully linear system is again used as a benchmark, and a simple subtraction technique can be used to differentiate between circularity gains and any other time-dependent improvements due to, for example, technological efficiencies.

Bastianoni summarises, “This approach provides a tool to inform managers and policy-makers for planning circularity actions and monitor their effectiveness while also capturing the temporal dimension.”

REAL OPPORTUNITIES

The LCA-based approach can be applied at the micro- or macro-scale, to any sector or product. Consider the province of Siena, Italy. It is host to a macro-level system of agricultural activity, geothermal energy production, and a range of other sectors including transport. These are linear systems with no circularity.

To remodel this region to a more circular economy, a bio refinery could be introduced which uses residues (otherwise disposed) from cereal production and takes residual geothermal energy to produce fuel as second-generation biofuel to support other sectors. As the whole system now incorporates circularity between its three
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sub-systems, the outputs remain the same but with reduced external inputs and waste. Considering greenhouse gas emissions impact alone, it is estimated that a required investment of 5,000 CO₂-equivalent tons (plant construction, etc) would yield a net reduction of some 15,000.

The research team also suggests circularity gains in a meso-scale local system where three companies operate linearly – producing vehicle engines, manhole covers, and bricks. Some investments could encourage reuse and repurpose residual materials to reduce waste and expensive disposal, and thus generate a level of circularity.

For example, the metallic scraps from engine production could be used at the foundry for the manhole covers, and the inert sand used in the manhole cover moulds could be re-used in the production of bricks. This symbiosis would generate additional steps involving energy and materials, and the measurement framework proposed is ideally suited to identify net gains as well as possible criticalities.

QUANTIFIABLE PROGRESS
The holistic LCA-based approach put forward by the Ecodynamics group can predict and monitor circularity in any sector for meso- and macro-scale systems. Using the indicators derived from their models, it is possible to examine the effects of proposed circularity changes within a system.

The researchers suggest this constitutes a significant step forward in terms of using LCA, rather than an improvement of the methodology itself, they describe the approach as an effective application of LCA strengths for circularity measurement. This may prove instrumental in driving important policy and strategy decisions as communities, regions, and nations make their contributions towards a sustainable development.