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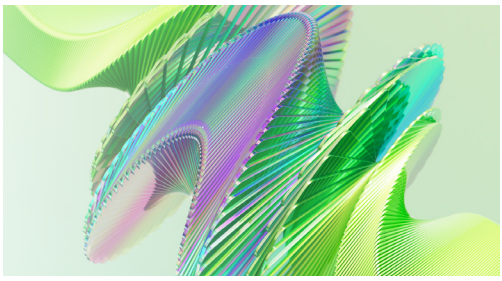
Anticipate, Innovate, Transform

Investment Opportunities for a Sustainable & Circular Economy

CONTENT



INVESTMENT OPPORTUNITIES FOR A SUSTAINABLE & CIRCULAR ECONOMY

BY PAUL DEWICK AND JOSEPH SARKIS, GUEST EDITORS

The circular economy (CE) includes a series of practices intended to close the production-consumption loop, extend product use, reduce the number of resources needed to provide the same goods and services, and regenerate and restore ecosystems. These practices can occur at the individual level, in multiple levels within organizations, between organizations, across supply chains, and over geographic regions.

Investments in CE and sustainability initiatives by various investment institutions, organizations, and governments are expected to be in trillions of US dollars, with anticipated returns across the triple bottom line of sustainability initiatives (economic, social, and environmental).[1]

In the US, the Bipartisan Infrastructure bill, which contains many sustainability and CE investments, is budgeted for US $2 trillion. The European Green Deal policy is looking to invest tens of billions of euros, likely reaching hundreds of billions on various projects, including CE initiatives. In Asia, China has invested billions of yuan in circular economy, sustainable supply chains, and decarbonization of industry, with some investments going back decades.

Private investment organizations are providing their customers with multiple environmental, social, and governance (ESG) investment opportunities as well. Organizations such as BlackRock have proposed programs and funds that will invest in companies incorporating CE practices. This investment is part of a wider vista of US sustainability investing, estimated at US $8.4 trillion in 2022.[2]

Organizations looking to invest in CE initiatives (and sustainability practices) must make capital budgeting decisions and determine both strategic and tactical investment decisions. These decisions are diverse and include operational and strategic concerns. Should they shift to closed-loop systems? Should they invest in research and new equipment for by-product usage? Should they introduce leasing (service-based) models? As they do this, companies must look beyond their stockholders to satisfy a variety of stakeholders, including consumers, supply chain partners, and communities.

There are concerns associated with these CE and sustainability investments.[3] For example, government agencies need to determine the mega-projects in which they will invest and make this investment in a socially equitable and inclusive way. Similarly, investment portfolio managers must determine which organizations are actually CE-friendly — a difficult proposition given that the definition of circular economy is a contested and polysemous term. Individual organizations must determine whether the hurdle rates and investment models to support their decisions are appropriate for the circular economy and sustainability.

IN THIS ISSUE

This issue of *Amplify* explores how businesses and public entities can manage investments in the circular economy in light of complex concerns that overlap many dimensions of social, technological, environmental, and economic systems.

We begin with a broad perspective of CE investment through a systematic literature review by Lihua Sun and Zhuowen Chen. Their review reveals six key aspects of CE investments: government, financial institutions and instruments, cooperation and collaboration, corporate governance, technology, and assessment tools. The remaining five articles further unpack these major dimensions.

In the next article, Ghulam Sorwar describes how bonds and loans, government financing, capital markets, and fintech can impart a solution for an effective circular economy. He acknowledges the need to consider complexities and says planning is a paramount objective in these activities; he then proposes coordinated local initiatives as an important way forward.

By nature, the circular economy involves multiple stakeholders. Thus, incentivizing investments in organizations with circular business models and facilitating better risk assessment for circular collaborative ventures are crucial. In their article, Ani Melkonyan-Gottschalk, Denis Daus, Lara Johannsdottir, and Daniel Goldmann introduce a framework in which physical infrastructure design, regional development strategies, and supply chain governance take place across society, industry, science, and policy. Best practices from around the world are showcased, highlighting places where society, industry, science, and policy have come together in multistakeholder partnerships to facilitate circular transformations. The authors draw attention to the role of finance and investment in the success of these initiatives.

Next, the focus shifts to a material that has caused serious environmental concerns. Plastic pollution is a very visible indicator of the negative externalities associated with linear systems of consumption and production. One obstacle to addressing plastic pollution is a lack of investment due to insufficient market incentives. In this context, Henning Wilts and Virginia Pillmann recommend plastic credits as a financing mechanism for investment in circular plastic systems. Echoing the framework of Melkonyan-Gottschalk et al., the need for collaboration between government (policy), industry, and society (consumers) is clear when it comes to promoting plastic credits. The article takes us to a developing region of the world via case studies about three Indian cities. Wilts and Pillmann discuss the conditions that can support plastic credit programs without undermining incentives for waste prevention and extended producer responsibility in India and present lessons for a variety of other contexts.

INCENTIVIZING INVESTMENTS IN ORGANIZATIONS WITH CIRCULAR BUSINESS MODELS & FACILITATING BETTER RISK ASSESSMENT FOR CIRCULAR COLLABORATIVE VENTURES ARE CRUCIAL

Scant data availability and poor data quality make it difficult for investors to choose where to invest and how to evaluate their investments. In their article, Tien-Shih Hsieh and Zhihong Wang identify new sources of data and emerging technology that can be deployed to offer a more comprehensive understanding of circular investments and performance. The authors provide insights into how waste management companies and manufacturers can use the Internet of Things and blockchain to capture real-time data. The digital tools introduced can store data in a transparent manner to support decision-making and corporate governance. The authors also consider how to interpret news and social media data using sentiment analysis and how to employ artificial intelligence to analyze large amounts of ESG data in real time to inform investment decisions.

Staying on the theme of supporting corporate governance, our final article tackles the challenges of applying traditional accounting methods to organizations with circular business models. Subhasis Ray and Ritesh Kumar Dubey say organizations face several challenges when adapting circular accounting systems, including determining the traceability of products and materials, verifying the value of products and materials, recognizing revenue, and disclosing circular performance. Ray and Dubey say companies can address accounting complexities of the circular economy through lifecycle assessment, impact accounting, movement-based accounting, and new accounting standards. These approaches help drive activities that lead to successful organizational investment in CE and sustainability initiatives.

FROM CIRCULAR ECONOMY TO CIRCULAR SOCIETY

Collectively, the articles in this issue of *Amplify* shed light on how businesses and public organizations can address CE investments. They describe how organizations can monitor and measure investments in CE initiatives (both specific facilities and the entirety of the supply chain); how managers and investors can overcome data limitations in assessing CE performance and risks; and how technology can support CE investment determination, allocation, dispersion, deployment, and monitoring.

Proactively seeking interaction across government, industry, science, and society should be seen as an enabling strategy for organizations seeking to invest and support sustainability and CE initiatives, but it requires overcoming the complexities that come with these endeavors. Making sense of the myriad of financial instruments at the disposal of government and financial institutions, coupled with knowledge of the regulatory environment and international financial-reporting standards, is part of the complexity faced by policymakers, executives, and managers.

We close by drawing attention to areas still in need of investigation, including how CE investment priorities differ across countries and regions. There are a variety of cultural and socioeconomic contexts that need to be overcome — simply identifying some of these issues is an important initial effort.

How finance can be directed toward inclusive, just, and equitable circular projects in various institutional contexts is a necessity. Although alluded to in the articles here, a more explicit evaluation beyond economic, environmental, and business decisions is needed. We need a holistic, systemic evaluation of how government, financial institutions, and industry can optimize investment synergies.

Circular projects are currently measured on how they achieve improvements in circular outcomes, but they need to move beyond doing no harm to mitigating climate change and protecting biodiversity (i.e., regenerative investment, not maintaining the status quo). Such investments should be seen as the gold standard.

As you read through the articles in this issue, consider how you and your organization can make a significant difference. The discussion will no doubt continue, and we hope a clearer image is emerging for a circular economy that can advance to a circular society with appropriate and sustainable investment.

THERE ARE A VARIETY OF CULTURAL & SOCIOECONOMIC CONTEXTS THAT NEED TO BE OVERCOME

REFERENCES

[1] Lacy, Peter, and Jakob Rutqvist. *Waste to Wealth: The Circular Economy Advantage*. Palgrave Macmillan, 2015.

[2] "2022 Report on US Sustainable Investing Trends." US Sustainable Investment Forum (SIF), accessed October 2023.

[3] Dewick, Paul, et al. "Circular Economy Finance: Clear Winner or Risky Proposition?" *Journal of Industrial Ecology*, Vol. 24, No. 6, June 2020.

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CIRCULAR ECONOMY INVESTMENT

PRACTICAL INSIGHTS FROM LITERATURE

Authors

Lihua Sun and Zhuowen Chen

Larry Fink, CEO of BlackRock — the world's largest asset manager — emphasizes the significance of investing in the circular economy (CE). Such investments not only address pressing environmental challenges, such as climate change, resource scarcity, and biodiversity loss, they can also foster higher economic growth and deliver favorable financial returns.[1]

In recent years, the CE field has attracted increasing investment interest from a variety of actors. One notable example is the EU, which is proactively implementing several funding schemes to facilitate the transition to a CE.[2] The European Investment Bank contributed €3.4 billion (about US $3.7 billion) between 2018 and 2022 to support 118 CE projects across several sectors.[3] The world-leading photochemical etching company, Precision Micro, invested £5 million (about US $6.3 million) in reconfiguring its processes to significantly improve its material recovery and reuse rates.[4]

Although the importance of CE investments is undeniable, the overall size and level of investment remain relatively low.[5] To effectively expand the scale of CE investments, it is imperative to embrace diverse perspectives and implement a wide array of new practices.

For this article, we conducted a systematic literature review of studies of CE investments. We performed a thorough literature search in the Web of Science and Scopus databases, using keywords relevant to CE investments. From the initial pool of research papers, we carefully screened 38 articles based on their content's relevance. The primary goal was to identify practical CE investment insights from the perspective of various stakeholders. We completed both a manual and automated content analysis of the studies. The automated content analysis of our research used chatbots, employing both ChatPDF and TianGong GPT tools concurrently. This dual approach produced a comprehensive literature analysis.

ALTHOUGH THE IMPORTANCE OF CE INVESTMENTS IS UNDENIABLE, THE OVERALL SIZE & LEVEL OF INVESTMENT REMAIN RELATIVELY LOW

Our analysis yielded insights on several key aspects of CE investments (summarized in Figure 1). Six topics of practical interest arise from the literature, including concerns and roles related to: (1) government, (2) financial institutions, (3) cooperation, (4) corporate governance, (5) technology, and (6) assessment tools. There are interrelationships among these topics, but we will focus on each separately.

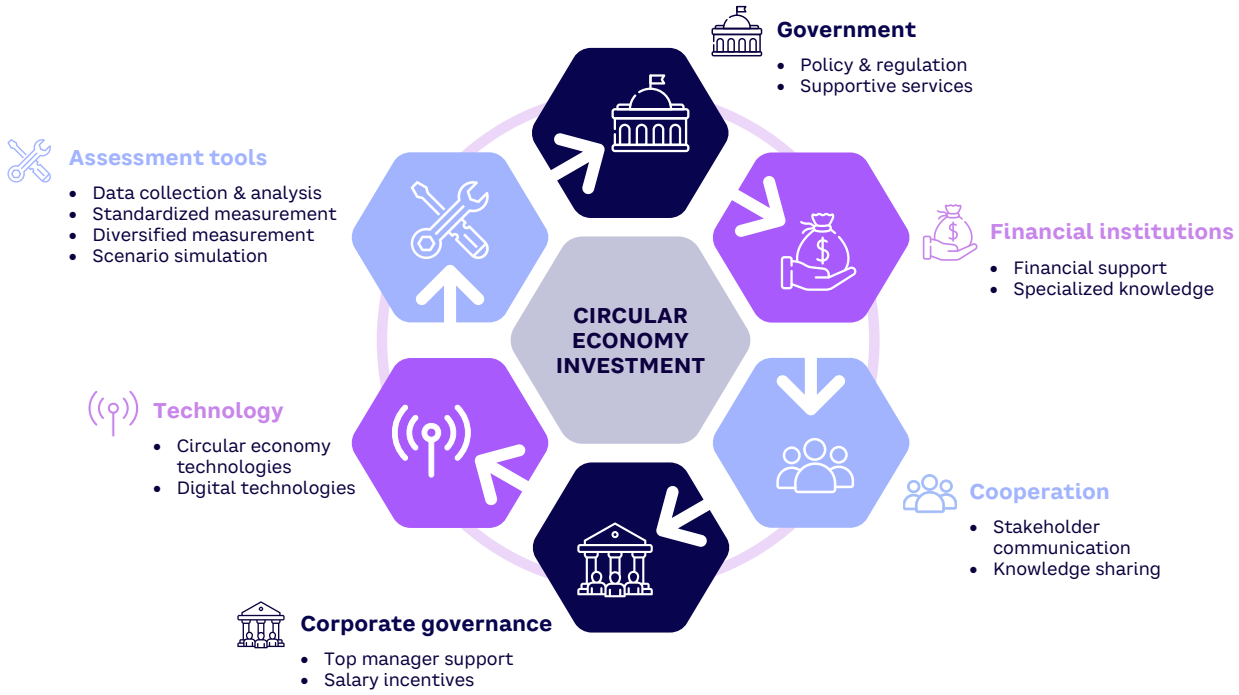

Figure 1. CE investment topics of practical significance

GOVERNMENT

Governments play a crucial role in promoting investment within the CE field, including developing policies and strengthening regulations/guidance. CE projects often involve substantial capital investments, requiring governments to formulate fiscal policies and provide funding to support them.

For instance, the government of Alberta, Canada, announced a CAD $58 million (about US $42 million) fund for a series of public and private CE projects. A significant portion of this funding, up to CAD $10 million, has been invested in the region's plant protein processing emission reductions and water sustainability project, exemplifying one of the many forward-thinking CE projects the government has undertaken.[6]

Measures including tax breaks, subsidies, and special funding programs can reduce the cost pressure and risk associated with CE investments. This support can attract more investors. Because CE investments typically involve multiple stakeholders and operate within a complex market environment, clear and fair regulation is imperative. Governments should ensure CE program compliance, improve transparency requirements, and maintain market order and fairness.

For example, in November 2021, the Capital Markets Board of Turkey issued a guideline for green bonds and green lease certificates. The guide includes a list of projects related to the transition to a circular economy, including wastewater management, product eco-involvement, and pollution prevention and control. The guide's release is meant to boost investor confidence in transparency and external validation while promoting diverse investment opportunities in sustainable development projects.[7]

Governments also can help investors build expertise and capabilities. Knowledge, technology, and tools related to the field of CE investments (some of which are discussed later) can be extremely beneficial. Governments can increase publicity and education efforts to enhance public awareness about CE, stimulating demand for investments in this domain. For instance, since 2019, Valladolid, Spain, has been organizing a "Circular Weekends" network to facilitate communication between various companies and other organizations to work together on CE projects.[8]

By supporting R&D and CE technology implementation, governments can drive technological innovation, leading to more innovative products and services in the CE investment market, which can attract more investors.

Governments also should establish more harmonized indicators and standards for assessing the alignment of investments with CE objectives.[9] For example, the Metrics Working Group of the Australian Circular Economy Hub introduced principles for CE metrics across Australia's states and territories, businesses, and communities. These principles emphasize metrics based on a sound conceptual framework, encompassing the entire lifecycle and all aspects of CE and consistency with accepted data standards.[10] These metrics can inform community or private investment.

FINANCIAL INSTITUTIONS

Institutional investors can offer financial support and expertise to propel CE growth. Asset management firms, mutual funds, university endowments, and pension funds can allocate substantial financing in favor of projects and businesses aligned with CE principles.

For instance, the Impact Bridge fund, which supports Spanish businesses engaged in CE investments, has launched a €150 million impact fund (about US $157 million). Notably, this initiative garnered support from institutional investors, including the European Investment Fund (€30 million), MicroBank (€10 million), and pension funds.[11] These investors become key drivers in facilitating the transition from traditional linear investment approaches[12] to more sustainable full-circular investment models.[13]

Institutional investors attract private capital for the CE space. Private capital, in addition to providing essential financial support, fosters dynamism within CE investments. Its flexibility, commitment to transparency, support for innovation, and expertise in specific industries make it particularly valuable to small businesses and early-stage companies that are driving CE.[14]

Private capital can unlock a plethora of CE investment opportunities and support diversity in investment. For example, the Circulate Capital Ocean Fund I-B operates as a private equity investment vehicle, directing a substantial sum of US $50 million toward addressing the pressing issue of plastic waste in the regions of Southeast Asia and South Asia.[15]

CORPORATE GOVERNANCE FACTORS PLAY STRATEGIC ROLES IN CE INVESTMENT & SUSTAINABLE DEVELOPMENT

COOPERATION

Communication and knowledge sharing among stakeholders (government, enterprises, third parties, and research institutions) contribute to effective resourcing for CE. Effectively integrating various stakeholder resources, expertise, and technologies contributes to improving market-demand evaluation, identifying CE investment opportunities, promoting technological innovations, and ensuring risk mitigation.

For instance, the EU launched the Circular Economy Finance Support Platform in 2017. It gathers and presents good practices in the CE domain from various types of business to guide aspiring participants in CE investments.[16] Another notable case is the Inter-American Development Bank, which invested US $4 million and collaborated with Circulate Capital to address the pressing issue of waste plastic in the oceans of Latin America and the Caribbean.[17] Each group involved multiple stakeholders — a transdisciplinary effort.

CORPORATE GOVERNANCE

Corporate governance factors play strategic roles in CE investment and sustainable development. Corporate executives significantly influence the strategy and magnitude of investments. According to a recent survey, about 70% of supply chain leaders plan to invest in the CE.[18] This is an admirable number but implies that executive knowledge and support are necessary. The top management team (as in most strategic situations and decisions that filter down to operational actions) is integral for corporate development and top-down CE strategies.

Governance requires developing policies and procedures that standardize circularity understanding, performance measures, and practices across the organization. Salary incentives tied to CE or sustainable performance can play a positive role in promoting the shift to investment in the CE field. The issues can be complex to manage, and the Organisation for Economic Co-operation and Development (OECD) has published a useful checklist for governance for the circular economy for organizations.[19]

TECHNOLOGY

CE investments are influenced by a variety of emergent technologies. Staying informed and being proactive about aligning investment strategies with evolving trends help organizations capitalize on the transformative potential of these technologies, fostering a more efficient and impactful CE.[20]

CE technology innovations encompass a wide range of sectors, including materials production, waste management, reuse, recycling, resource conservation, and energy efficiency.[21] The current limited level of circularity presents promising opportunities for new technologies to contribute significantly to achieving circularity. CE investments should prioritize these forward-looking solutions to push the boundaries of CE technologies. This approach encourages the exploration of emerging solutions and disruptive innovations, potentially generating long-term benefits for investors.[22]

Investing in digital and artificial intelligence (AI) technologies is of particular importance. These technologies enable real-time monitoring and data exchange, leading to heightened resource efficiency and reduced waste;[23] they also can help monitor returns on CE investments. Data analysis can provide a deeper understanding of market demand, enabling more intelligent and precise

CE investments. Investment risks can be mitigated with these technologies and can facilitate well-informed CE decision-making. Embracing and leveraging digital and AI tools propel CE toward greater efficiency and sustainability, making it a win-win proposition for businesses and the environment.

ASSESSMENT TOOLS

CE investment challenges can be mitigated through more objective and comprehensive tools for assessing CE investments.[24] These tools help investors optimize resource allocation, quantify potential impacts, and assess CE investment feasibility. Big data and data-driven analysis can provide decision support for investors.

CE investments often involve new technologies, new business models, and uncertain market environments. Assessment tools can support risk assessment and management, reducing investment risks to support the likelihood of successful CE investments. The following assessment tool types show promise:

- **Data collection and analysis tools.** Comprehensive, reliable data sources can support more informed CE investment decisions.[25] Data must include resource inputs, waste production, emissions, energy consumption, economic returns, and social impacts. Data analysis tools can organize, process, calculate, and analyze data to support CE investment decisions. For example, European banking group Intesa Sanpaolo is considering CE's de-risking effect and integrating and adjusting its risk assessment tools, methodologies, and credit-rating models to consider CE.[26]
- **Standardized measurement tools.** These tools can enable seamless comparisons between CE projects across diverse regions and industries.[27] They also can foster resource allocation. Standardized metrics serve as a common language, facilitating effective communication and cooperation among stakeholders, including investors, governments, and nongovernmental organizations. These measurements can drive continuous improvement, incentivize best practices, and combat greenwashing practices.
- **Diversified measurement tools.** These tools encompass lifecycle assessments, environmental and social impact evaluations, technology-specific assessments, and comprehensive cost-benefit analysis.[28] Lifecycle assessments provide a holistic understanding of projects from inception to end of life, while environmental and social impact evaluations gauge their ecological and societal consequences.
- **Technology-specific assessments.** These ensure the viability of circular solutions, and comprehensive cost-benefit analyses help decision makers assess risks and potential benefits from both short- and long-term perspectives. For example, the Cradle to Cradle closed-loop lifecycle approach helped Switzerland's Forster Rohner Textiles make investment decisions that included a product called "Climatex" that eventually represented a third of Rohner's revenues.[29]
- **Scenario-simulation tools.** Given the multitude of factors influencing CE investments, such as technological advancements, policy changes, market fluctuations, and internal organizational adjustments, the investment landscape can be complex. Scenario modeling involves constructing potential scenarios for various futures, helping investors assess feasibility and benefits under varying circumstances.[30] These investment-planning tools help CE investors anticipate risks, prepare responses, and iterate and refine planning. They also incent business model innovation, ultimately fostering more informed decision-making. Embracing scenario-simulation tools empowers CE investors to navigate uncertainties with confidence and chart a course toward successful, sustainable investments.

CONCLUSION

Exploring future directions in the field of CE investments requires new insights and actions. Both internal and external organizational practices play a role in CE investments. External practices include government policies, regulations, financial incentives, and support from financial institutions. Internal factors include organizational governance and managerial behavior.

Embracing and leveraging emerging technologies, including those specifically designed for CE activities and data analytics, and other innovative tools for assessing and measuring CE performance, can be indispensable in fostering CE investments. Last but not least, effective communication, cooperation, and knowledge sharing among diverse stakeholders are vital in driving CE investments forward and creating a collective impact.

REFERENCES

[1] "The World's Largest Investor Embraces the Circular Economy: BlackRock." Ellen MacArthur Foundation, 23 September 2021.

[2] "Financing the Circular Economy." EU, accessed October 2023.

[3] "Circular Economy Overview 2023." European Investment Bank (EIB), May 2023.

[4] "Investments into Circular Economy Reached New High in 2022." Resource Media, 15 May 2023.

[5] Schröder, Patrick, and Jan Raes. "Financing an Inclusive Circular Economy: De-Risking Investments for Circular Business Models and the SDGs." Chatham House, the Royal Institute of International Affairs, July 2021.

[6] "Alberta Announces $58 Million for Circular Economy Projects Worth $528 Million in Public and Private Investment." Emissions Reduction Alberta, 13 February 2023.

[7] Yalçin, Döne, and Arcan Kemahli. "Turkey's CMB to Issue More Green Bonds and Green Lease Certificates." CMS, 22 December 2021.

[8] "Ten Cities Leading Their Way in Circular Economy — European Hub." The Circular Collective, 19 August 2021.

[9] Dewick, Paul, et al. "Circular Economy Finance: Clear Winner or Risky Proposition?" *Journal of Industrial Ecology*, Vol. 24, No. 6, June 2020.

[10] "Principles of Circular Economy Metrics." Australian Circular Economy Hub, 8 September 2022.

[11] "InvestEU: Impact Bridge Launches €150 Million Impact Fund with the Support of the European Investment Fund and MicroBank." European Commission, 15 June 2023.

[12] "Financial Sector Presents Roadmap to Circular Economy." De Nederlandsche Bank, 7 February 2022.

[13] Dewick et al. (see 9).

[14] "Why Consider a Circular Economy?" JPMorgan Chase & Co, accessed October 2023.

[15] "Circulate Capital Ocean Fund I-B." International Finance Corporation (IFC), accessed October 2023.

[16] EU (see 2).

[17] "IDB Lab Partners with Circulate Capital to Combat Ocean-Bound Plastics." Inter-American Development Bank (IDB), 25 October 2021.

[18] "Gartner Survey Shows 70% of Supply Chain Leaders Plan to Invest in the Circular Economy." Press release, Gartner, 26 February 2020.

[19] "The Circular Economy in Cities and Regions." Organisation for Economic Co-operation and Development (OECD), accessed October 2023.

[20] Ibrahim, Abubakar. "Experts Say Nigeria's Economy Needs National Policy, Technological Transfer to Scale Up Investment." *Business Day*, 17 November 2022.

[21] Lu, Shirley, and George Serafeim. "How AI Will Accelerate the Circular Economy." *Harvard Business Review*, 12 June 2023.

[22] Resource Media (see 4).

[23] "The Circular Economy as a De-Risking Strategy and Driver of Superior Risk-Adjusted Returns." Ellen MacArthur Foundation/Bocconi University, July 2021.

[24] "Banks Opening Up for Circular Business." Innovation in Textiles, 5 June 2023.

[25] "Financing the Circular Economy." Ellen MacArthur Foundation, accessed October 2023.

[26] Ellen MacArthur Foundation/Bocconi University (see 23).

[27] "Closing the Loop: Responsible Investment and the Circular Economy." Principles for Responsible Investment (PRI), 4 October 2022.

[28] Geng, Yong, et al. "Measuring China's Circular Economy." *Science*, Vol. 339, No. 6127, March 2013.

[29] Larson, Andrea, and Jeff York. "Rohner Textiles: Cradle-to-Cradle Innovation and Sustainability." Darden Case No. UVA-ENT-0085, Darden Business Publishing, 21 October 2008.

[30] Yu, Xianyu, et al. "Exploring the Investment Strategy of Power Enterprises Under the Nationwide Carbon Emissions Trading Mechanism: A Scenario-Based System Dynamics Approach." *Energy Policy*, Vol. 140, May 2020.

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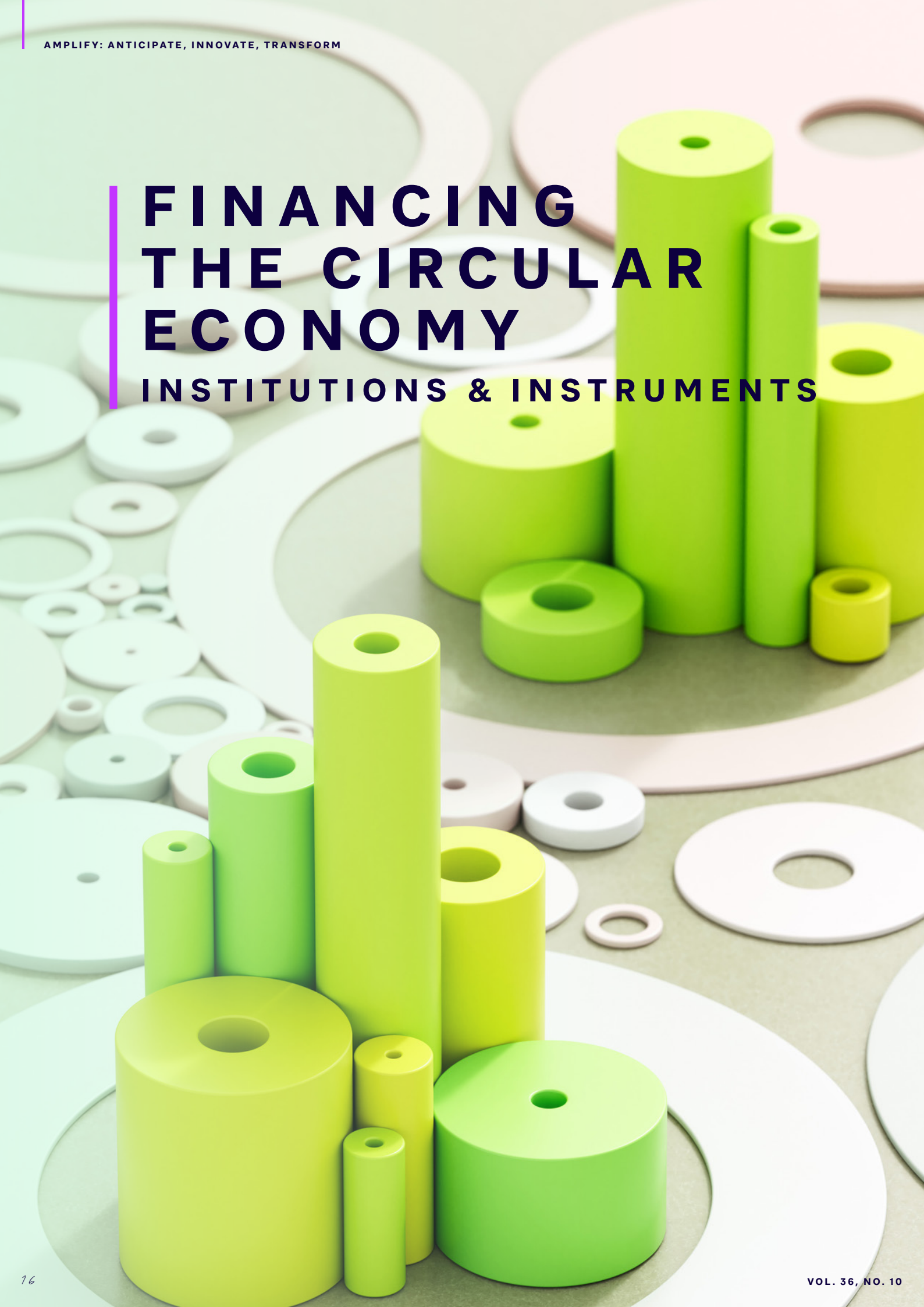
FINANCING THE CIRCULAR ECONOMY

INSTITUTIONS & INSTRUMENTS



Author

Ghulam Sorwar

The circular economy (CE) was a natural state to our ancestors, and dramatic climate change events and their impact on our society are bringing it back into vogue.[1] Today's CE models aim to promote sustainable growth while maximizing material reuse and minimizing waste. However, the transition to a circular economy poses significant challenges, including how we will finance it.

This article highlights new ideas and initiatives financial institutions are using to tackle climate challenge and discusses how these actions impact their approach to the circular economy. It examines how existing and new financial instruments are being used by financial institutions and governments to tackle the climate challenge and create the circular economy. The article looks at this from several perspectives, including financial corporate markets (e.g., the bond market) and the role of governments. It concludes by examining how modern finance can be manipulated based on climate change and circularity and how financial resources can be diverted to activities to give the impression of contributing to the circular economy — when the money is doing anything but that.

FINANCIAL INSTRUMENTS

Below are descriptions of financial instruments and how they're being used to create the circular economy.

BOND & LOAN INSTRUMENTS

Bonds are fixed-income securities that are, essentially, IOUs issued by borrowers such as central banks and corporate institutions. A bond investor lends money to the bond issuer in return for periodic interest payments known as "coupon payments" and the return of the bond's face value (known as the "principal") when it matures. *Green bonds* are an adaptation of traditional bonds that are issued to fund sustainable and CE-related projects.[2] The proceeds from green bonds can be used to finance projects specifically related to the conditions under which the bonds are offered. For example, in 2020, Daimler and Volkswagen each issued a €2 billion green bond (about US $2.1 billion) to support their transition to electric vehicles.[3]

Sustainability-linked bonds are a second adaptation of traditional bonds. Unlike green bonds, in which the investment return is fixed at the issuance of the bond, returns on sustainability-linked bonds are determined by the financial performance of the firm subject to its sustainability criteria. If a firm meets and exceeds its sustainability criteria, it may pay less for borrowing.

TODAY'S CE MODELS AIM TO PROMOTE SUSTAINABLE GROWTH WHILE MAXIMIZING MATERIAL REUSE AND MINIMIZING WASTE

Green loans are a third adaptation. Similar to bonds, they are created between two institutions with a specific project in mind, rather than a range of projects.

NATIONAL & LOCAL GOVERNMENT FINANCING

Government financing can take place either at a regional or national level. In addition to issuing bonds, government financing can involve:

- **Grants and subsidies**. Both local and national governments can offer financial incentives, grants, and other subsidies to encourage CE projects such as the development of recycling infrastructure.
- **Regional bonds.** These are issued by regional councils and are focused on the needs of the region as it works to maintain sustainability features.
- **New financial institutions.** Regional banks and credit-lending agencies create new entities that cater to the funding needs of the circular economy, often with the local government underwriting the loans.
- **Tax incentives.** Government tax incentives act as a spur to local and regional sustainable development through public-private partnerships that would not have been possible otherwise.
- **Long-term financing.** These loans have advantageous terms for households working to make their property energy efficient through insulation, renewable energy, and recycling.

CAPITAL MARKETS

Capital markets have been very active in creating new financial products that (at least in theory) make significant contributions to the circular economy by incorporating environmental, social, and governance (ESG) criteria as part of the product design. These innovations have resulted in significant amounts of financial capital flowing into CE ventures. Some common products are:

- **Exchange-traded funds (ETFs).** These are similar to individual stocks and thus can be traded in a similar manner.[4] ETFs can incorporate various categories of assets such as stocks, bonds, commodities, and index funds.
- **Index funds.** These are mutual funds that mimic the performance of market indices (e.g., FTSE 100 or S&P 500). Rather than relying on management to pick individual stocks, index funds track a chosen index based on the chosen risk level of an investor. Index funds aim to provide broad exposure to the capital markets at low cost while reducing extreme investment risk. Several ETFs and index funds incorporating ESG criteria as part of their brief have been set up, including BlackRock's iShares and Vanguard's FTSE Social Index Funds.
- **Mutual funds.** These are investment instruments that gather finances from many parties to invest in a diversified portfolio of assets, including stocks, bonds, commodities, derivatives, and other securities.[5] A number of institutions have issued ESG-oriented mutual funds, including Vanguard, BlackRock, and UBS. Each of these funds has benefited from interest in sustainability. Unfortunately, it is not yet clear whether the ESG-based mutual funds perform better than traditional mutual funds. However, given the long period traditional mutual funds have been in existence, ESG-based mutual funds may yet promote sustainable development while providing a healthy return to investors.

- **Real estate investment trusts (REITs).** These let individuals invest in income-generating real estate without having to buy, manage, or finance it directly. REITs have taken an active approach in adapting to the circular economy and sustainability. Examples include green building initiatives in which new environmental practices are introduced to reduce a building's carbon footprint; properties that incorporate renewable energy sources such as solar and wind; community and social responsible projects in which community development programs align with sustainable and CE principles; and programs that require tenants and owners to work together to decrease water consumption and optimize waste management practices. For example, Hannon Armstrong Sustainable Infrastructure Capital is known for incorporating circularity and sustainability into its REITs.
- **Green certificates.** These contribute to sustainability and the circular economy in several ways, including Renewable Energy Certificates (RECs, mainly in the US) and Guarantee of Origin (GoO) certificates (mainly in Europe).
- **Carbon credits.** These are similar to green certificates and include certified emission reductions (CERs) under the Clean Development Mechanism (CDM). The CDM defined in the Kyoto Protocol incorporates company projects involved in CERs, including renewable energy and energy efficiency. For example, the Katingan Mentaya Project in Kalimantan, Indonesia, encourages local farmers to abstain from clearing virgin forest by helping them sell carbon credits from their land.

FINTECH

Decentralized finance using blockchain technology is revolutionizing the financial world and creating new ways to finance economic activities.[6] Blockchain's key strength is that information within it cannot be changed, reducing fraud risk. The technology's data transparency and lowered risk means individuals and institutions can inexpensively set up and manage platforms that let them exchange (and advertise) products or services, leading to an overall demand for new goods. Platforms can be further expanded to include the use of smart contracts that interact with each other based on preset rules. For example, a payment and/or additional reward could be made if a particular product is recycled, without any human intervention.

Existing fintech platforms that focus on crowdfunding could be used to finance new setups focused on the circular economy. This can be done in various ways, including peer-to-peer lending, in which investors can directly connect to borrowers through the issuance of bonds or new types of financial instruments. Peer-to-peer lending's strength lies in its ability to democratize the investment process and make it more efficient — there is no financial intermediary such as a bank to charge fees. The drawback of this approach is that, in certain circumstances, it can lead to mis-selling of financial instruments.

ESG-themed robo-advisors focus on providing investment advice based on ESG criteria. This helps investors incorporate traditional metrics for financial performance while including sustainability and the circular economy in their investment plans. Robo-advisors are inexpensive to run because they do not require human input and are likely to be impartial, so they are a creative alternative to hiring expensive fund managers.

Since fintechs are in the digital space, they can easily leverage advanced analytics. Examples include using big data to understand complex patterns to help firms optimize their recycling, creating digital token assets that enable the ownership of fractional items, and automatic compliance with rules and regulations. This rich data set could make it easier to explore alternative patterns and payments; in an ideal situation, machine learning would be used to develop innovative new financial instruments geared toward the needs of specific projects in the circular economy. By integrating fintech into the circular economy, businesses and customers can enhance recent developments in digital technology to speed up the green economy.

KEY CHALLENGES

The most obvious challenge to developing circular finance is greenwashing, which is particularly acute in financial instruments. For example, green bonds could be issued with the intent of investing the proceeds in environmentally friendly products, but some of the proceeds could be invested in projects that are not environmentally friendly. Similarly, ETFs could be issued with an emphasis on investing in companies with green credentials, but the portfolio might end up including companies involved in environmentally harmful activities.

The ESG criteria that investors use to assess company performance also creates challenges. There is no universally accepted definition of what constitutes a financial instrument that would satisfy all ESG criteria. Thus, two financial instruments meeting ESG criteria could come onto the market with very different environmental outcomes.

It's not clear whether ESG is the right way to develop finance for the circular economy. Indeed, one might argue that ESG benefits capital markets rather than investors, since the institutions offering these products not only charge a hefty product fee compared to traditional products, they also tend to create less robust financial products in which higher risks are transferred to the investors. Seen from this perspective, these products might be a distraction that delays the creation of the circular economy and could be the ultimate form of greenwashing.

THE WAY FORWARD

The complexity of ESG definitions, along with a lack of international agreements, numerous accounting standards, and regional differences in how financial institutions and capital markets are regulated, make it impossible to develop an all-encompassing financial mechanism to fund the circular economy.

To succeed, the circular economy must be truly global. Given the wide variety of financial institutions and financial institutions subject to different legal jurisdictions and definitions of what constitutes "green," it is unlikely a single taxonomy can be developed.

Therefore, a local approach involving public-private collaboration is worth considering. For example, local or central governments could issue bonds that pay above a certain threshold when certain environmental criteria are met or exceeded. Governments could also consider funding any large infrastructure project that meets environmental criteria at advantageous terms.

Public-private partnerships in which both parties contribute equity at a predetermined ratio to form companies that tackle a particular sustainable issue (e.g., solar farms, wind farms, recycling plants) are another possibility. The drawback of this approach is that companies may receive funding based on strong environmental criteria and then either do the bare minimum or not do anything at all.

Escalating complexity has been a continuous theme in the drive to develop finance models to fund the circular economy. This can lead to products that cost more, contain hidden or excessive financial risk, and/or result in investors being swindled.

One major step forward would be an international agreement on what to charge for greenhouse gas emissions that could be used for both green certificates and carbon credits. This would eliminate the need to develop complex financial instruments that meet stringent ESG criteria and are based on complex, overlapping rules. Unfortunately, the political will for this does not presently exist at a global level.

Given what is at stake (the financial resources required and the financial costs that will be incurred if the climate challenge is not met quickly), it's clear that the response so far has been anemic and uncoordinated. We may quickly return to a point of no return — and if that happens, the current financial global infrastructure may ultimately collapse and with it a sustainable future.

REFERENCES

1 Barros, Murillo Vetroni, et al. "Circular Economy as a Driver to Sustainable Businesses." *Cleaner Environmental Systems*, Vol. 2, June 2021.

2 Bhutta, Umair Saeed, et al. "Green Bonds for Sustainable Development: Review of Literature on Development and Impact of Green Bonds." *Technological Forecasting and Social Change*, Vol. 175, February 2022.

[3] Rocha, Priscila Azevedo, and Paul Cohen. "VW Follows Daimler with Green-Bond Cost Savings in Debut Deal." Bloomberg, 16 September 2020.

[4] Rompotis, Gerasimos G. "The ESG ETFs in the UK." *Journal of Asset Management*, Vol. 23, January 2022.

[5] Petridis, Konstantinos, et al. "Measuring the Efficiency of Mutual Funds: Does ESG Controversies Score Affect the Mutual Fund Performance During the COVID-19 Pandemic?" *Operational Research*, Vol. 23, No. 54, August 2023.

[6] Siddik, Abu Bakkar, Li Yong, and Md Nafizur Rahman. "The Role of Fintech in Circular Economy Practices to Improve Sustainability Performance: A Two-Staged SEM-ANN Approach." *Environmental Science and Pollution Research*, Vol. 30, February 2023.

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A COLLABORATION FRAMEWORK FOR REGIONAL CIRCULAR ECONOMY TRANSFORMATION

Authors

Ani Melkonyan-Gottschalk, Denis Daus,
Lara Johannsdottir, and Daniel Goldmann

Climate change, rapid urbanization, resource overconsumption, and shifts in demand patterns profoundly influence economic systems. Economic insecurity, made worse by the pandemic and geopolitical instabilities, will also cause changes in regional development strategies, production and consumption systems, value and supply chain management, and raw material extraction.

Despite progress in materials and resources efficiency, the past few decades have seen a continued rise in material intensity.[1] Resource extraction is projected to increase by 119% from 2022 to 2050 (from 90 to 184 billion tons per annum), and greenhouse gas emissions (GHG) are expected to increase by 41%.[2]

Higher-income nations are responsible for 74% of global resource extraction.[3] To combat this situation, the European Commission in 2020 adopted a Circular Economy Action Plan (CEAP) to support achievement of the United Nations Sustainable Development Goals (UN SDGs).[4] Part of the European Green Deal, CEAP seeks to reduce the EU's consumption footprint and subsequently halve the EU's circular material use rate, while boosting economic growth.[5]

The plan includes circular economy (CE) strategies to transform regional economic systems by implementing advanced digital technologies, societal changes, and behavioral changes, as well adoption of CE practices and laws in public-private partnerships (PPPs). CEAP focuses on sectors that depend on infrastructure, use the most resources, and have the greatest circularity potential, including steel and aluminum production, construction and building, textiles, batteries and vehicles, food systems, logistics and packaging, and information/electronics/communications. Understanding varying investment priorities across countries and regions and their implications for organizations and their supply chains is needed for circular transformation.

Efficient circular transformation strategies can be developed and implemented through improved cooperation among science, industry, government, civil society, and the natural environment, known as the "Quintuple Helix."[6] Better instruments for making sound industrial and political decisions within complex and dynamic socioeconomic systems must be developed.

Circular transformation strategies included in the EU Green Deal are based on the assessment of low carbon-growth potential: carbon-pricing systems, green technology policies, infrastructure development, and the removal of barriers to behavioral change. Carbon pricing can be achieved via governmental instruments and political frameworks, but behavioral change can be reached only by empowering local authorities and communities, grassroots organizations, industrial leaders, and civil society.

EFFICIENT CIRCULAR TRANSFORMATION STRATEGIES CAN BE DEVELOPED & IMPLEMENTED THROUGH IMPROVED COOPERATION

Collaborative strategies for industries to accelerate transitions toward net-zero carbon are discussed in theory. However, there is still a gap between theory and practical implementation of collaborative CE approaches.

A wide span of costs for resource-efficiency measures and varying levels of return makes CE investment difficult. This situation highlights the need for: (1) financial and regulatory incentives for circular business models and (2) risk assessment for collaborative strategies. Despite the risks associated with developing and implementing collaborative strategies for transforming circular regions, PPPs with innovative funding mechanisms play a critical role in designing, implementing, and advancing circular regions. These collaborations facilitate knowledge sharing, resource mobilization, innovative co-funding mechanisms, and coordinated stakeholder action, enabling the development of holistic, effective CE-enabled environments.

MULTI-STAKEHOLDER FRAMEWORK FOR COLLABORATIVE CE TRANSFORMATION

This article introduces a collaboration framework for CE transformation that identifies key tangible (soft) and intangible (hard) factors that can be vertically and horizontally integrated. Horizontal integration occurs across the design of physical and digital infrastructure, regional development strategies, and supply chain governance. Vertical integration occurs across policy, science, industry, and society, each interacting with the natural environment (see Figure 1).

In other words, for circular regional transformation, the three horizontal aspects must be designed and implemented in a collaborative way; take place across society, industry, science, and policy; and be embedded in the natural environment.

The framework integrates soft (environmental awareness, education) and hard (data analytics, infrastructure) factors, both of which must cover both social and technical aspects of CE transformation. Sustainability assessment and decision support systems should only be developed after this collaborative framework is built (later in the article, we outline the steps necessary for a region to holistically transition toward circularity).

Tables A and B at the end of this article show best-practice examples in a variety of sectors (electronics, construction, food services, textile industry, and transportation) based on the CE collaborative framework. Each case describes initiatives that align with CE principles, such as designing for durability and reuse, closing resource loops, prioritizing renewable resources, facilitating sharing platforms, and processing waste for reentry into industry.

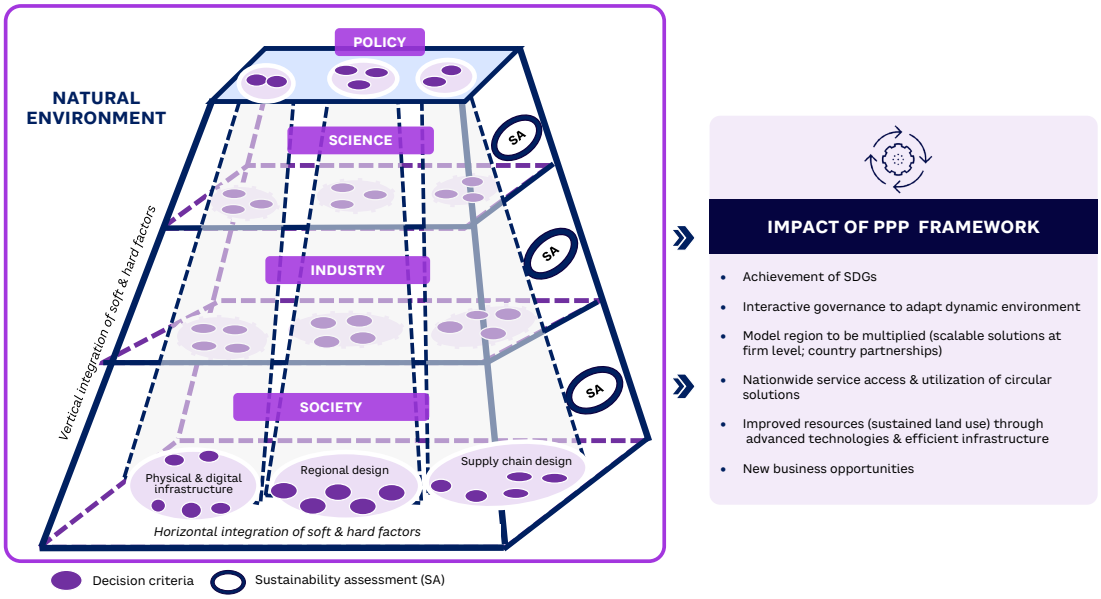

Figure 1. Multi-stakeholder framework for collaborative CE transformation

Tables A and B also outline real-world examples of organizations and communities implementing actions to transition away from linear take-make-waste models toward more sustainable and circular resource management. Their actions are classified into the three categories: (1) physical and digital infrastructure, (2) regional design, and (3) supply chain design.

One of the best examples of circular region transformation is the territorial cluster of Southeast Lower Saxony. It was the first German region accepted in the Circular Cities and Regions Initiative (CCRI) of the EU in September 2022 because it created an almost-complete industrial chain — from raw materials to the fabrication of high-tech products.[7]

Businesses, trade organizations, public corporations, politicians, nongovernmental organizations, and members of civil society came together to develop a region for "circular production and use." This includes a professional network of citizens playing a key role in the cascaded use of products, giving them a second life after the first one and before final recycling.

COLLABORATIVE ACTION PLAN FOR CIRCULAR TRANSFORMATION

Figure 2 shows actions to be taken collaboratively for a holistic circular transformation, combining various aspects of physical and digital infrastructure with regional and supply chain design. It shows a shared vision in which diverse stakeholders make investment decisions while ensuring transparency, accountability, and monitoring the implementation of an effective circular transition.

Implementing CE practices almost always requires collaboration among various stakeholders along the value chain. Sharing knowledge and innovation improves business processes, products, and services and has the potential to open new markets and revenue streams and create new partnerships.

However, there are several challenges that can arise during the transition:

- Ensuring that all stakeholders share a common vision for the circular transition and commit to it can be difficult, especially when interests and priorities vary.

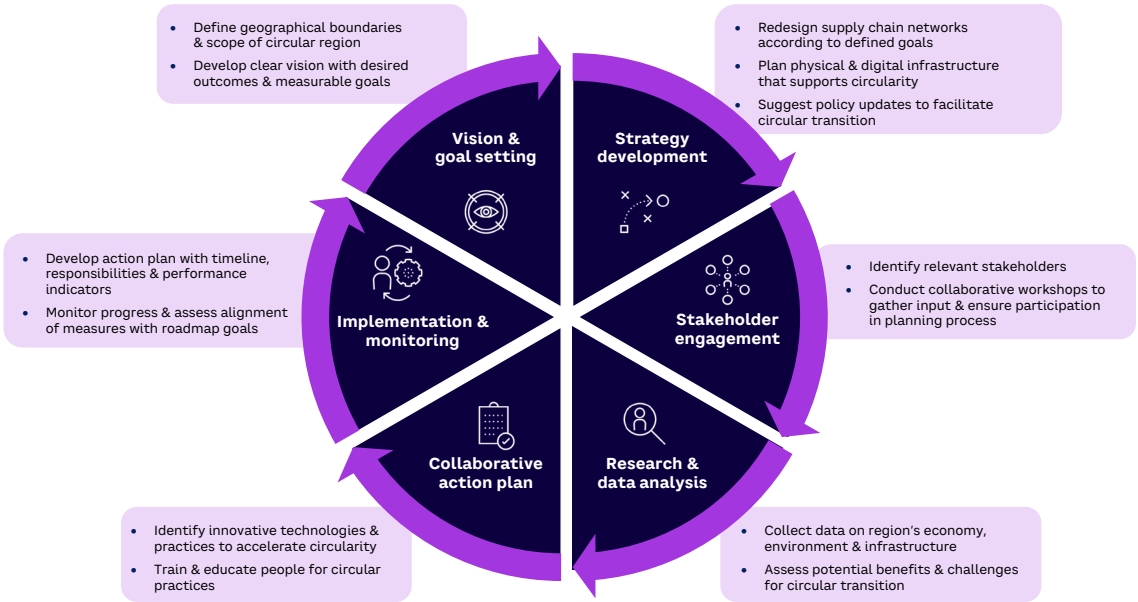

Figure 2. Collaborative steps to attain regional circularity

- The pricing system differs between public and private sectors, as well as across various industries.
- When policymakers are not on board, policies and regulations may hinder the adoption of circular practices. Even if political support is given, funding and resources may be limited, requiring careful prioritization and innovative financing mechanisms.
- Integrating new technologies and practices into existing systems and industries can be a complicated, costly endeavor. The complexities and myriad trade-offs during the transition make establishing accurate, consistent metrics for circularity and tracking the transition progress a complex procedure.
- Convincing the broader society of the benefits and necessity of a circular economy may require extensive public-awareness campaigns and/or streamlined education.

A WAY FORWARD

This article discusses the important role that stakeholders from policy, science, industry, and society play in collaborative circular transformations, either as beneficiaries or through direct contributions, active support, and engagement. The success of these initiatives relies on collaboration with a diverse range of financing sources, including impact investors, traditional investors, public funding, banks, and venture capitalists. Note that impact investing fosters measurable, positive social and environmental outcomes alongside traditional financial returns.

Securing financial support from various channels is essential for successful sustainability projects. Government agencies provide guidelines and funding opportunities while creating regulatory conditions for businesses and communities, and businesses cooperate with governments to ensure alignment with regional and national sustainability policies. Both established companies and start-ups are needed for implementing and scaling CE projects, providing technical solutions, manufacturing knowledge, and specialized expertise in areas like electronics, textiles, urban mobility, construction, packaging, and agriculture.

The interdisciplinary nature of CE initiatives calls for partnerships with various areas of expertise. Because of their engagement in R&D, research institutions and universities contribute the scientific foundation of these solutions, fostering technological advancements and environmental assessments. They also provide educational support, which is crucial for CE projects. The societal dimension of CE projects (e.g., providing feedback and participating in data collection) is another key dimension, since citizens are often the beneficiaries of CE initiatives.

Our action plan outlines the necessary steps for a region to holistically transition toward circularity, overcoming challenges while reaping social, environmental, and economic benefits.

REFERENCES

[1] Rockström, Johan, and Mattias Klum. *Big World, Small Planet: Abundance Within Planetary Boundaries*. Yale University Press, 2015.

[2] Geng, Yong, Joseph Sarkis, and Raimund Bleischwitz. "How to Globalize the Circular Economy." *Nature*, Vol. 565, January 2019.

[3] "High-Income Countries Are Responsible for 74 Percent of Excess Resource Use Causing Ecological Breakdown." The London School of Economics and Political Science, 6 April 2022.

[4] "Sustainable Development Goals." United Nations (UN), accessed October 2023.

[5] "Circular Economy Action Plan." European Commission, accessed October 2023.

[6] Carayannis, Elias G., Thorsten D. Barth, and David F.J. Campbell. "The Quintuple Helix Innovation Model: Global Warming as a Challenge and Driver for Innovation." *Journal of Innovation and Entrepreneurship*, Vol. 1, No. 2, August 2012.

[7] "Circular Cities and Regions Initiative: Supporting Europe's Circular Economy at Local and Regional Level." European Commission, accessed October 2023.

PROJECT	GOALS & AIMS	PHYSICAL & DIGITAL INFRASTRUCTURE	REGIONAL DESIGN	SUPPLY CHAIN DESIGN
Fairphone (The Netherlands)	• Production of sustainable/ethical smartphones • Increase of environmental sustainability (addressing product lifecycles, recycling rate of minerals & metals) • Increase of social responsibility by addressing working conditions	• Investments in local development & infrastructure	• Provision of living-wage bonus for factory workers from region	• Sourcing of fair trade gold & conflict-free minerals • Design of modular & replaceable components • Easy disassembly & refurbishment • Reuse & recycle when refurbishment costs exceed phone value • Take-back scheme with partnering reuse & recycling company
Reflow pilot project (Berlin, Germany)	• Implementation of digital & organizational platform to optimize use of wastewater heat • Reduction of CO2 emissions • Increase in energy efficiency • Use full potential of wastewater heat from underground water pipes • Settle Berlin as European pioneer city for data-driven usage & recycling of wastewater heat	• Bundling data in Web app that serves as intelligent radar • Creation of wastewater heat database that reflects its potential to citizens, public institutions & companies	• Developing a neighborhood urban production hub	• Mapping of wastewater heat data & potential for productive activities • Creating sustainable business model across supply chain
CE incentives (Finland)	• Eliminate linear incentives & incent CE • Reduction of food waste • Decrease lifecycle emissions from food services via circular procurement • Provide vegetarian meals	• Coordinate city's food-service areas	• Engage with stakeholders for long-term change in region • Early childhood education	• Monitoring & lifecycle assessment of emissions across supply chain • Track drivers of GHG emissions from production to waste • Implement mitigation measures across supply network
Circular business innovations (India)	• Support circular & resource-efficient business innovations in textile sector • Reduce water consumption & air pollution • Establish better working conditions	• Establish facilities for water recycling, rainwater harvesting & energy conservation • Effluent treatment to purify water used in textile production	• Establish eco-friendly textile production park to boost regional development • Set up health & safety protocols	• Water reuse, conservation & filtration to transition water supply
Sharing & exchange platforms (Seoul, South Korea)	• Facilitate second-hand markets, sharing & exchange platforms in mobility services • Installation of 2,000 car-sharing stations across city	• Execution of highest fiber optic broadband penetration & fastest Internet in the world • Install free WiFi services in all outdoor spaces • Enable highest smartphone penetration rate in the world at more than 67% • Operate one of the best subway systems, wired for high-speed Internet	• Regionally shared services among public transportation, bikes & scooters & individuals without cars	• Design & implement seamless transportation network

Table A. Best practices for CE initiatives (cases have been selected based on multi-stakeholder participation from policy, science, industry, and society)

PROJECT	GOALS & AIMS	PHYSICAL & DIGITAL INFRASTRUCTURE	REGIONAL DESIGN	SUPPLY CHAIN DESIGN
Separation & recovery at RAG administration building (Essen, Germany)	• Establish circular engineering in construction & building sector • Improve indoor air quality • Separate & reuse building components • Use of regenerative energy sources	• Apply green walls, dust-binding carpet, Cradle-to-Cradle-certified parquet flooring • Implement material passport, pergolas equipped with photovoltaic modules • Installment of charging stations for electric cars & e-bikes • Setup of multifunctional green roof & retention area for rainwater	• Develop circularly built city quarter	• Apply take-back system • Design & implement closed-loop water cycle
Biological & technical loops (Cup Zero, UK)	• Design biological or technical loops • Reduce waste-stream pollution & impact on nature • Operate returnable packaging service for beverages & food brands • Reduce single-use plastic packaging	• Use proven technological solutions to track individual cups & reward users for being in system	• Recover material & feed back into regional economy	• Offer tailored end-to-end service
Waste & resource input minimization (Infarm, Germany)	• Reduce waste & minimize resource input in food system • Reduce carbon emissions for transportation • Reduce water, fertilizer & space usage	• Develop hyper-local production of herbs & leafy greens in smart, modular "farms" • Establish remote-control & monitor farm on cloud-based platform	• Sell just-harvested produce	• Modular production close to consumers to shorten supply chain
Bioregion Vestland (Norway)	• Promote polycentric governance • Create innovative products & services that phase out fossil-based plastic • Integrate corporate social responsibility within bioregion	• Research & design facilities for use in experimentation & pilot production	• Use design-driven R&D, focusing on geography of natural ecosystem • Establish collaboration & coordination between different institutional actors at various scales	• Focus on biological loops in value chains that are also circular, sustainable & profitable for local economy
Renewable resources (Chamwino, Tanzania)	• Prioritize renewable resources • Improve well-being of local communities by providing 7,000 households with clean water • Improve food security	• Establish solar-powered water supply • Renovate water tank • Install innovative irrigation scheme	• Implement water-supply network-extension project to reach more households in Makang'wa & neighboring villages	
Organic production from market waste (Quelimane, Mozambique)	• Process waste & ensure reentry into industry at highest value • Increase city resilience through secure food-production systems • Develop micro to small-medium scale entrepreneurs • Improve soil fertility • Increase yields	• Establish composting facility to process increased food waste from 11 urban food markets	• Support food production in small fields owned by family households using organic fertilizers • Train community associations to be involved in compost-making process	• Develop distribution system of compost to 140 neighboring gardens to produce vegetables & food crops for growing population • Compost is brought back to the soil, increasing production while conserving soil
The Recycling Partnership (US)	• Advance CE by building better recycling system • Transform underperforming recycling programs	• Install lidded recycling carts • Invest in sorting equipment & process improvements	• Develop "Feet on the Street" anti-contamination program influencing residential recycling behavior	• Improve aluminum recycling • Develop coalitions for recycling: material, film & flexibilities, polyethylene terephthalate (PET) plastic & polypropylene to advance CE for packaging across value chain

Table B. Best practices for CE initiatives (cases have been selected based on multi-stakeholder participation from policy, science, industry, and society)

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Ani Melkonyan-Gottschalk is Executive Director of the Centre for Logistics and Traffic at the University of Duisburg-Essen, Germany. She has been involved in research and teaching for over 15 years in the areas of sustainable economies and frameworks for transitioning toward both sustainable and smart governance. Prof. Dr. Melkonyan-Gottschalk's expertise spans various domains, including sustainable and circular economies, smart and sustainable urban regions, sustainable supply chain management, the interconnectedness between resource and food systems, mobility and logistics systems, digital and innovative business ecosystems, and sustainable and inclusive governance models. She leads international, trans-disciplinary research groups overseeing projects such as "Innovative Logistics for Sustainable Lifestyles," "Competence Network of Industrial and Rural Interlinkages," and "Innovative Citrus By-Products Supply Chain in the Mediterranean Area." These initiatives entail conducting comprehensive sustainability assessments across the entirety of modern services, both in stationary and online commerce while simultaneously exploring innovative business models related to sharing and circular economies. Through projects such as "Economic Assessment of Environmental Impact" funded by NASA, "Climate Mitigation and Adaptation Strategies" for the cities of Duisburg and Essen, "Essen — Green Capital City of Europe, 2017," and the Mercator Foundation–funded project "NEMO — New Emscher Mobility," Prof. Dr. Melkonyan-Gottschalk actively collaborates with local governmental authorities and industrial partners to develop collaborative decision support systems aimed at facilitating sustainable transition strategies. She has been published in more than 30 scientific publications and four monographs. Prof. Dr. Melkonyan-Gottschalk earned a bachelor's degree in economics and a master's degree in mathematical modeling from Yerevan State University, Armenia, and a PhD in environmental sciences from the University of Duisburg-Essen. She can be reached at ani.melkonyan-gottschalk@uni-due.de.

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FINANCING CIRCULAR PLASTICS SYSTEMS

Authors

Henning Wilts and Virginia Pillmann

Plastic dominates modern life. It offers extraordinary properties that ease industrial and everyday processes like packaging and transporting products, which helps reduce food waste. However, through mismanagement of plastics and plastic waste, plastic pollution is having negative effects on the environment, human health, and social justice.

Most of these negative impacts can be addressed by proper waste management infrastructures and the use of high-quality recycling technologies. The key challenges are not technical; they stem from a lack of investment due to insufficient market incentives, especially in emerging and developing countries.

This article focuses on the concept of plastic credits as a new financing mechanism for investment in circular plastic systems. Plastic credits are "a transferable unit representing a specific quantity of plastic pollution removed from the environment and/or put into the circular economy (i.e., collected and/or recycled) in excess of what would have happened in the absence of the credit-generating activity."[1]

Plastic credit programs are getting a lot of attention and offer significant opportunities for financing circular plastic systems. However, uncoordinated and unregulated plastic credit programs carry risk, especially around incentives for waste prevention and the introduction of extended producer responsibility (EPR) systems — both are cornerstones in achieving sustainable plastic use.

This article discusses the conditions necessary to ensure that plastic credit programs lead to more circular systems (especially for plastic packaging) and do not undermine incentives for EPR systems, especially waste prevention. Our ideas are based on our empirical investigation of plastic credit systems in India.

BACKGROUND: IDEA & CONCEPT OF PLASTIC CREDITS

Plastic credit programs originate from climate change mitigation. Companies can offset their greenhouse gas emissions by buying carbon credits based on implementing certified measures that reduce CO2 emissions, such as industrial emission-reduction projects or reforestation.[2] Many believe that carbon credits (with an estimated global market size of US $979 billion in 2022[3]) lead to efficient climate protection because CO2 emissions should be reduced in places where mitigation costs are low. Often, this means emerging countries rather than countries that have already picked the "low-hanging fruit." The argument for plastic credits is not as straightforward because specific environmental impacts depend on local circumstances. Nevertheless, they can make sense from an economic point of view.[4]

Because plastic credits promise a source of funding for underfinanced waste management in many parts of the world, several plastic credits programs have emerged over the last year, including a commercial one from rePurpose Global and nongovernmental organization–based programs from Zero Plastic Oceans and BVRio. They highlight the potential of such systems to increase collection and recovery/recycling of plastic waste in countries without sufficient waste management infrastructure while creating socioeconomic benefits by improving income opportunities for waste workers.

Organizations such as WWF[5] and the Circulate Initiative[6] have emphasized fundamental risks linked to plastic credit systems. Without clear definitions and standards, plastic credits could be used for greenwashing without any relevant positive impacts. Without sufficient transparency, governance-control mechanisms, and independent external verification of collected plastic waste, treatment processes, and treatment outcomes, fraud is also a risk. Companies voluntarily using plastic credits to offset their environmental impacts are not committed to long-term collection/recovery infrastructures, so there is also a risk that plastic credits can be misused by short-term activities or even one-off events.

PLASTIC CREDITS IN RURAL INDIA

India suffers badly from environmental pollution but has great potential for improvement. Plastic waste pollution is prevalent in India's rural regions, and a lack of financial support often hinders the collection and (environmentally friendly) end-of-life plastic processing.

In recognition of this, India´s 2016 plastic waste management rules have expanded to include rural areas, with responsibility for implementation handed to local administrations, also known as "gram panchayats."[7] Little improvement has been reported so far, mainly due to a lack of dedicated investments. To support these ambitions, the 2016 Plastic Waste Management Rules introduced an EPR program by the Ministry of Environment, Forest and Climate Change.[8]

Multiple amendments have been made to the regulations (in 2018, 2021, and 2022) but have thus far been unsuccessful in funneling sufficient finances toward waste management improvements. With the EPR implementation facing both short- and mid-term obstacles, particularly in rural areas, plastic credits may be the solution to improve traceability, accountability, and compliance while developing the necessary financial mechanisms.

PROJECT OVERVIEW

A project called "Plastic Credits — Financing the Transition to the Global Circular Economy" aims to finance the implementation and improvement of a waste management structure in India's rural regions, with pilot programs in Goa, Maharashtra, and Kerala. Insights into this project were gained through a site visit in September 2022 that allowed us to deepen our understanding of activities on ground by asking direct questions about existing waste-collection systems. In Goa, 25 kilotons of multilayer plastics (MLP) are generated per year; only 11% is collected. In Maharashtra, a value of 13 kilotons of MLP generation was estimated; so far, none has been collected.[9]

In rural India, informal waste pickers play a key role. For example, in Goa, informal waste pickers know the formal collection schedule and collect high-value materials and plastics in advance. The value of the collected plastic arriving at the materials-recovery facility is lower, but the financing structure via the municipality ensures this isn't an issue for the local facility, and it gives collectors an incentive to ensure more accurate waste sorting.

At the end of the project-implementation phase, 379 workers in Kerala, 109 in Maharashtra, and 23 in Goa were involved in collection, preprocessing, and separation activities. Since women are employed almost exclusively for waste segregation, this results in a social benefit as well.

While discussions about an EPR program as a financing instrument of waste management activities are taking shape, the interrelation of such a framework with plastic credits remains unclear. India amended its EPR regulation in July 2022, mandating recycling and reusing of a certain percentage of plastic produced by manufacturers, importers, and brand owners.

During our site visit, city officials told us about the challenges they face in implementing EPR, saying there are issues with motivating companies to register under EPR and difficulties finding companies that purchase and recycle plastic under the EPR program.

PLASTIC CREDITS SHOULD NOT UNDERMINE EPR

The links between plastic credit programs and EPR programs for packaging must be considered. EPR stresses the need for companies to take responsibility for end-of-life costs related to the packaging (and other products) they put on the market.[10] This may include incentives around recyclability of products, use of recycled materials, and awareness-raising activities for needed waste-prevention solutions.[11]

There is ample evidence that EPR systems contribute to reducing packaging waste in the environment and enable financing of reliable waste management structures to ensure that waste is collected, sorted, and treated.[12] Therefore, it's important to ensure plastic credit programs don't undermine or contradict current or future EPR systems. This can be done by avoiding:

- **Companies that buy plastic credits lobbying against the introduction of EPR systems as part of a country's policy that would lead to mandatory fee-based payments (or physical obligations to collect and recycle their waste).** EPR systems for packaging are more expensive for the obliged companies and, if mandatory, they cannot decide to pay less or not pay at all.
- **Cherry-picking of profitable types of waste as well as lowball pricing based on nonpayment for labor and lack of safety and health standards.**[13] Plastic credit systems, when coexisting in the same area, to some extent also compete for paying clients, which means they compete over price; this can lead to cherry-picking waste and/or lower worker-safety standards.

> **THERE ARE ISSUES WITH MOTIVATING COMPANIES TO REGISTER UNDER EPR & DIFFICULTIES FINDING COMPANIES THAT PURCHASE & RECYCLE PLASTIC UNDER THE EPR PROGRAM**

CRUCIAL REQUIREMENTS

Policymakers, companies, and consumers should work together to ensure plastic credit systems don't conflict with the development of EPR systems or waste prevention. Experiences with carbon credits have shown the need for the following three items to be addressed by plastic credit systems before being purchased by private companies or public institutions:

1. **Plastic credits should always be a last resort; prevention should be the priority.** Plastic credits should only be sold to organizations that can prove they explored all available waste-prevention options. Companies communicating the amounts of plastic waste offset by plastic credits should always indicate the total amounts of plastic packaging put on the market, so the public can directly compare the negative and positive impacts of the company in question.
2. **Plastic credit programs should commit to investing a share of their income into long-lasting infrastructures (as opposed to one-off cleanups) that can also benefit EPR programs.** The longevity of these commitments should be publicly communicated.
3. **Plastic credit systems should be a first step in the establishment of comprehensive EPR systems.** Companies should reach out to all relevant stakeholders regarding data management and contractual arrangements, pursue credible monitoring of their activities, and actively participate in the development of harmonized criteria.

OUTLOOK

In March 2022, the United Nations Environment Assembly (UNEP) adopted a historic resolution to develop an international legally binding instrument on plastic pollution.[14] The need for innovative financing solutions was highlighted by many stakeholders, especially regarding countries or regions in which EPR systems have not yet been established. Plastic credits could play an important role here, but a transparent, credible governance system ensuring the quality criteria outlined above would be needed.

Further research is necessary to determine exactly how plastic credit programs can influence the quality of collection systems, the incentives for companies buying plastic credits to invest in waste prevention, and the coordination with EPR systems.

REFERENCES

[1] "Guidelines for Corporate Plastic Stewardship." 3R Initiative/Earth Action (EA)/South Pole/Quantis, February 2021.

[2] This understanding is based on: "WWF Position: Plastic Crediting and Plastic Neutrality." WWF, January 2021. Nevertheless, it's important to note that legal definitions are lacking, and the field of plastic credits is evolving quickly.

[3] Daedal Research. "Global Carbon Credit Market: Analysis by Traded Value, Traded Volume, Segment, Project Category, Region, Size and Trends with Impact of COVID-19 and Forecast Up to 2028." Research and Markets, April 2023.

[4] "Plastic Credits — Friend or Foe?" ValuCred, July 2021.

[5] WWF (see 2).

[6] "A Sea of Plastics Claims and Credits: Steering Stakeholders Towards Impact." The Circulate Initiative, January 2021.

[7] "Notification: G.S.R 320(E)." Central Pollution Control Board (CPCB), India Ministry of Environment, Forest and Climate Change, 18 March 2016.

[8] Proff, Silvia, et al. "Plastic Credits — Financing the Transition to the Global Circular Economy: Final Assessment Report on the Pilot Regions Goa, Maharashtra, and Kerala." rePurpose/Wuppertal Institut, November 2022.

[9] Proff et al. (see 8).

[10] "Resources EPR Toolbox." Prevent Waste Alliance, accessed October 2023.

[11] "Extended Producer Responsibility: Guidance for Efficient Waste Management." Organisation for Economic Co-operation and Development (OECD), September 2016.

[12] "Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options." Organisation for Economic Co-operation and Development (OECD), 22 February 2022.

[13] "Guidelines on Best Practices for Credit Systems Related to the Circular Economy." Circular Credits Mechanism/BVRio/Circular Action Hub, September 2021.

[14] "Intergovernmental Negotiating Committee on Plastic Pollution." United Nations Environment Programme (UNEP), accessed October 2023.

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ADOPTING MODERN TECHNOLOGY TO EVALUATE CIRCULAR ECONOMY INVESTMENTS

Authors

Tien-Shih Hsieh and Zhihong Wang

The circular economy (CE) aims to minimize waste, maximize the use of resources, and promote sustainability. It is designed as an alternative to the traditional economy, which follows a "take-make-dispose" pattern in which resources are extracted and products are manufactured, used, and then discarded as waste.[1,2] The CE goal is to reduce the environmental impact of economic activities, including resource depletion and pollution, while creating economic value and promoting social well-being.

Investing in the circular economy involves financial support of businesses and projects that embrace sustainable practices and aim to reduce waste while maximizing resource efficiency. Unfortunately, a lack of data availability and poor data quality make it difficult for investors to: (1) choose where to invest and (2) evaluate the performance of their investments. Reliable, comprehensive data on resource use, waste generation, and CE practices is limited and is often inconsistently reported by companies, making it challenging to accurately quantify investment effects.

Traditional data sources (e.g., waste/recycling data and energy-consumption data) are frequently criticized for biases, incompleteness, and inconsistency because they tend to be self-reported and lack standardization.[3,4] Integrating multiple data sources and adopting a systemic analytics approach can provide a more comprehensive understanding of the circular economy and sustainability performance.

This article identifies modernized data sources that enable big data analytics to help investors better evaluate their CE investments.

IOT & SENSOR DATA

The Internet of Things (IoT) and sensor data play a pivotal role in the transition from linear economies (make, use, dispose) to circular models. IoT connects everyday objects and devices to the Internet, allowing them to collect and exchange data without human intervention. IoT and sensor data are important in the modern CE[5] because they enable automated, efficient, comprehensive data processing and evaluation, which allow businesses to optimize their usage, leading to reduced waste and lower costs.

> **INVESTING IN THE CIRCULAR ECONOMY INVOLVES FINANCIAL SUPPORT OF BUSINESSES & PROJECTS THAT EMBRACE SUSTAINABLE PRACTICES**

However, it's important for a business to identify the problem it aims to solve using IoT and sensor data. For example, a waste management company might want to use that data to track its waste-collection operations and maximize its efficiency. After selecting the appropriate sensors and choosing a data storage location (on a local server or in the cloud), the system would provide real-time data on resource utilization, equipment performance, and environmental conditions, allowing for immediate response to inefficiencies or issues.

The waste management company might install trash bin sensors throughout its system to monitor waste-collection levels in real time to save money on fuel costs, maintenance, and labor by reducing unnecessary trips. Over time, the collected data could be analyzed to identify waste-generation trends and patterns. This information could inform future waste-reduction initiatives, increasing ROI. Although the up-front costs for such a system would be high, there's an excellent chance the company would save money in the long run.

In summary, IoT and sensor data equip internal business investors (e.g., corporate managers) with real-time insights into their performance and help outside investors make more efficient decisions.

BLOCKCHAIN & TRANSPARENCY DATA

Blockchain can play a significant role in advancing CE practices by enhancing traceability, transparency, and trust in supply chains and product lifecycles. In a blockchain-based supply chain, when a product is made, a unique digital identity with an embedded RFID (radio-frequency identification) or NFC (near-field communication) chip is created for each product. As the product moves through the supply chain, each transaction or handoff is recorded, creating an unchangeable history.

In this way, every product or material in the circular economy can be tracked from its origin to end of life, ensuring transparency and verifying the authenticity and sustainability of the product.[6] Storing lifecycle data on a blockchain results in an immutable record of the entire supply chain, from raw material extraction to production, distribution, and disposal. This allows investors to trace the journey of products and materials, ensuring they meet sustainability and circularity standards.

Using blockchain data to evaluate the performance of CE initiatives involves leveraging various technologies to gather, track, and analyze relevant data that provides insights into sustainability and circularity.[7] However, deploying a blockchain network or platform that supports a decentralized and transparent system that tracks products or goods from their origin to the end consumers can be a complex task. For example, network nodes need to be placed strategically in various locations within a supply chain.

Blockchain data can be used with IoT devices to provide effective data sources.[8-10] For example, a waste management company could install IoT sensors to track waste and store data on the blockchain, recording and verifying recycling processes to ensure waste materials are properly handled and disposed of or recycled in an eco-friendly manner. Similarly, a manufacturer could use IoT sensor devices to track energy consumption and carbon emissions during the production process and store data on the blockchain to provide transparent and verifiable reporting.

To ensure real-time tracking and reporting, IoT sensors should be integrated across a supply chain to enable automated data input. For example, for perishable fruits planted on a farm and transported to supermarkets, farmers could install temperature sensors and GPS tracking devices in the fruit containers to monitor the freshness of the product across the supply chain. By leveraging blockchain data in this manner, organizations can assess the performance of their CE initiatives to drive accountability, transparency, and innovation in their sustainability efforts.

In summary, blockchain provides an unchangeable, transparent record of products and resources in the circular economy that can strengthen trust and facilitate real-time sustainability assessments for internal business investors.

NEWS & SOCIAL MEDIA SENTIMENT DATA

Modern natural language processing (NLP) uses algorithms to analyze large amounts of natural language data.[11,12] Sentiment analysis is a subfield of NLP that aims to discern the mood or sentiment behind text.

NLP can help users analyze news and social media sentiment to gain insights into public perception, potential risks, and opportunities related to CE investments.[13,14] For example, positive sentiment trends can highlight investment opportunities in companies or sectors that are well received by the public for their CE efforts. Highly positive sentiment can indicate lower reputational risk; negative sentiment may signal reputational or regulatory risks.

To use this data source, investors must first identify and subscribe to reputable news outlets and social media platforms that frequently discuss CE topics. Platforms like X (formerly Twitter), Facebook, Bloomberg, and Reddit provide APIs so users can scrape the Web to collect relevant data points from news articles, blogs, and other online publications.

Many times, freshly scraped sentiment data contains irrelevant information due to language nuances. In fact, data cleaning and text processing of text-based sentiment data can be complex. Some investors purchase structured data from providers like Brandwatch to save time on data cleaning and standardizing.

> **BLOCKCHAIN PROVIDES AN UNCHANGEABLE, TRANSPARENT RECORD OF PRODUCTS & RESOURCES IN THE CIRCULAR ECONOMY THAT CAN STRENGTHEN TRUST**

The next step is determining how to implement the sentiment analysis. For this stage, investors need NLP tools that can process and analyze large volumes of news articles, blogs, social media posts, and comments. Python code libraries NLTK (Natural Language Toolkit) and TextBlob are often used for sentiment data analysis, and deep learning frameworks like TensorFlow and PyTorch are popular tools for building neural network–based sentiment models. Platforms like Hugging Face Transformers provide pretrained models that can help users more easily perform sentiment analysis.

It's important for investors to understand that sentiment analysis results must be carefully interpreted in the context of the domain or industry they are analyzing. For example, the word "degradation" is often interpreted as something that has deteriorated or become worse. However, in biodegradable products or materials, degradation is a desired feature, indicating the material can break down naturally without causing long-term environmental harm.

In summary, news and social media sentiment data provide both internal and external CE investors with clear views of public opinions and the latest sustainability trends in evaluating the sustainability performance of a business.

AI-DRIVEN SOLUTION: TRUVALUE LABS

Truvalue Labs is one of the first companies to use artificial intelligence (AI) and NLP to provide investors with a more robust perspective on environmental, social, and governance (ESG) performance. The company's platform uses AI to aggregate and process data from news articles, social media, regulatory findings, and nongovernmental organization reports to give investors near-real-time insights into a company's ESG activities.

Company-reported data can be framed in a way that highlights the positive and downplays the negative. Truvalue Labs's emphasis on external data sources offers investors a less biased view of a company's engagement with the CE principle.

In addition to company-specific data, Truvalue Labs analyzes ESG trends by sector and region. Users can tailor their results on specific aspects of the circular economy, including waste reduction, product longevity, or sustainable sourcing. This gives investors a broader understanding of specific sectors or regions, helps them analyze multiple companies or sectors simultaneously, and lets them tailor their analysis to focus on the ESG issues, sectors, or regions that align with their priorities.

In summary, Truvalue Labs uses AI to analyze large amounts of ESG data in real time, offering both internal and external investors timely insights into companies' sustainability practices, risks, and opportunities and facilitating informed investment decisions.

CONCLUSION

Advanced tools and data-driven methodologies not only enhance transparency and precision, they also capture real-time dynamics, helping both internal and external investors make more informed decisions. In a world transitioning from linear to circular models, leveraging technology is key to measuring sustainability impacts and ensuring responsible resource utilization.

REFERENCES

[1] Stahel, Walter R. "The Circular Economy." *Nature*, Vol. 531, March 2016.

[2] Geissdoerfer, Martin, et al. "The Circular Economy — A New Sustainability Paradigm?" *Journal of Cleaner Production*, Vol. 143, February 2017.

[3] Chatterji, Aaron K., et al. "Do Ratings of Firms Converge? Implications for Managers, Investors and Strategy Researchers." *Strategic Management Journal*, Vol. 37, No. 8, June 2015.

[4] Berg, Florian, Julian F. Kölbel, and Roberto Rigobon. "Aggregate Confusion: The Divergence of ESG Ratings." *Review of Finance*, Vol. 26, No. 6, November 2022.

[5] Gubbi, Jayavardhana, et al. "Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions." *Future Generation Computer Systems*, Vol. 29, No. 7, September 2013.

[6] Lim, Ming K., Witold Bahr, and Stephen C.H. Leung. "RFID in the Warehouse: A Literature Analysis (1995–2010) of Its Applications, Benefits, Challenges and Future Trends." *International Journal of Production Economics*, Vol. 145, No. 1, September 2013.

[7] Saberi, Sara, et al. "Blockchain Technology and Its Relationships to Sustainable Supply Chain Management." *International Journal of Production Research*, Vol. 57, No. 7, 2019.

[8] Christidis, Konstantinos, and Michael Devetsikiotis. "Blockchains and Smart Contracts for the Internet of Things." *IEEE Access*, Vol. 4, May 2016.

[9] Panarello, Alfonso, et al. "Blockchain and IoT Integration: A Systematic Survey." *Sensors*, Vol. 18, No. 8, August 2018.

[10] Wang, Xu, et al. "Survey on Blockchain for Internet of Things." *Computer Communications*, Vol. 136, February 2019.

[11] Coleman, John. *Introducing Speech and Language Processing*. Cambridge University Press, 2005.

[12] Mishne, Gilad, and Maarten de Rijke. "Language Model Mixtures for Contextual Ad Placement in Personal Blogs." In *Advances in Natural Language Processing, Proceedings of the 5th International Conference* (FinTAL). Springer, 2006.

[13] Bollen, Johan, Huina Mao, and Xiaojun Zeng. "Twitter Mood Predicts the Stock Market." *Journal of Computational Science*, Vol. 2, No. 1, March 2011.

[14] Tetlock, Paul C. "Giving Content to Investor Sentiment: The Role of Media in the Stock Market." *The Journal of Finance*, Vol. 62, No. 3, May 2007.

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BENDING THE LINEAR ECONOMY TO CIRCULAR

ACCOUNTING COMPLEXITIES & CONCERNS

Authors

Subhasis Ray and Ritesh Kumar Dubey

Mass production and mass consumption are critical to the linear economy. However, they have led to mass wastage and pollution and are testing the limits of ecological systems and planetary boundaries. This is the primary reason that responsible consumption and production is one of the United Nations 17 Sustainable Development Goals (UN SDGs).

The buzz around the circular economy (CE) is not new, but the pandemic and climate change have led to more serious discussions and activities. Companies like Apple have been at the forefront of recycling and reuse, using robots like "Daisy" for recycling old iPhones and trade-in programs for a variety of products. Clothing company Patagonia promotes repair and reuse for its customers through its "Worn-Wear" program. Home furnishing and goods store IKEA has committed to using more recycled and renewable materials in its products and now runs a store selling only used products. Unilever, Coca-Cola, Nike, and many more have set ambitious goals for supporting the circular economy and have pledged increased use of recycled products in their products or packaging.

The entrepreneurial ecosystem around the circular economy has also taken giant strides. Start-ups like Grover (Germany), Back Market (France), Everphone (Germany), Danggeun Market (South Korea),Swappie (Finland), Cashify (India), refurbed (Austria), Rheaply (US), Upway (France), Attero (India), Neeman (India), Cartlow (UAE), Reebelo (Singapore), FloorFound (US), Refurbi (Colombia), Again (UK), Recycle Jar (Bangladesh), Cyrkl (Czech Republic), Fjong (Norway), Ecovia (India), GiveAway (Belarus), Bekia (Egypt), Repurpose (the Netherlands), recircular (Spain), and Flip.ro (Romania) provide examples of an emerging CE-based enterprise ecosystem.[1]

Given their large carbon footprints, innovation ability, and market share, large companies should be leading from the front and communicating their progress (see Table 1). Apple is, once again, a good example with its "Environment|Mother Nature" video featuring CEO Tim Cook and actress Octavia Spencer (playing Mother Nature).[2]

Another organization at the vanguard in communicating circular performance to a variety of audiences is health and nutrition company DSM (established in 1902 by the Dutch Government as Dutch State Mines). It has been committed to circularity for many years, and in 2017 set a goal to become a fully circular company by 2030. It releases a yearly circularity report for the public, institutional investors, and shareholders and reports on its circular performance through its website, social media channels, and marketing materials. It also participates in industry events and conferences to disseminate its learnings and experiences about its circularity journey. In 2022, DSM was named the "Circular Economy Company of the Year" by Circular Economy Club (CEC); World Economic Forum and the Ellen MacArthur Foundation (EMF) have also recognized the company for its leadership.

> **THE ENTREPRENEURIAL ECOSYSTEM AROUND THE CIRCULAR ECONOMY HAS TAKEN GIANT STRIDES**

	AUDIENCE	CHANNELS	KEY FEATURES
DSM	Institutional investors, shareholders, general public	Website, social media, marketing materials, investor days, earnings calls, circularity report	Comprehensive, transparent, engaging communication
Nike	Institutional investors, shareholders, general public	Website, social media, marketing materials, sustainability report	Focus on key circular performance metrics and case studies
Unilever	Institutional investors, shareholders, general public	Website, social media, marketing materials, sustainability report	Focus on circularity goals and progress
Tetra Pak	Institutional investors, shareholders, general public, customers	Website, social media, marketing materials, sustainability report, customer case studies	Focus on circularity solutions and impact
Apple	Institutional investors, shareholders, general public, customers	Website, social media, marketing materials, sustainability report, product launch events	Comprehensive, transparent, engaging communication

Table 1. Communicating circularity performance

Too often, circularity and sustainability reports lack substantive financial information, and this frequently leads to charges of greenwashing. The reason lies in the complexities of financing and accounting in relation to circular business models. The CE transition will require not only new financing models, but also a novel approach to accounting practices for CE products and services.

ACCOUNTING COMPLEXITIES IN A CIRCULAR ECONOMY

The business models prevalent in the circular economy are not well suited to traditional accounting methods because tracking the flow of products and value addition to account for costs and pricing is a complex process. Table 2 shows the advantage that large corporations have in dealing with the complexities of circularity: they have a structure in place and the resources to tweak existing structures. However, multinationals must overcome the inherent rigidness of their existing organizational structure, which tends to resist change.

Patagonia, an American outdoor recreation clothing retailer operating in more than 10 countries, has been at the forefront of circularity and sustainability since its inception in 1973. Its commitment to circularity can be seen on its website, where it tells the public it believes "being carbon-neutral is not enough" and in its iconic 2011 ad campaign "Don't Buy This Jacket," which urged customers to practice circularity and sustainability.

According to Patagonia, it is moving toward 100% recycled or organic materials and has a repair service and take-back program for all its products. After 50 years of operation, Patagonia aims to become carbon-neutral by 2025, demonstrating the role that resource constraints can play in a corporate sustainability and circularity mission.

In contrast, Unilever, an almost 100-year-old company, announced its focus on circularity in 2014 and plans to become net-positive by 2030. As stated in its "Sustainable Living Plan," Unilever has reduced the waste impact per customer by 34% since 2010 for its products and has achieved around 96% reduction in total waste per ton since 2008 for its manufacturing concerns and uses 52% reusable plastic in its packaging.[3] Despite the large scale and late commitment, Unilever aims to achieve its commitment within 15 years. Clearly, large multinationals can leverage their organizational structure and resources to advance toward a more circular business model at a faster pace.

ACCOUNTING ISSUE	LARGE MULTINATIONAL	START-UP
Complexity of business operations	High	Low
Number of countries & currencies	High	Low
Accounting standards	Multiple	One
Availability of qualified accounting staff	High	Low
Resources for accounting software	High	Low

Table 2. Accounting complexities of large multinationals vs. start-ups

Another complexity stems from the lifecycle of a product/material in a circular economy, which may involve multiple companies and jurisdictions (see Figure 1).

The accounting complexities associated with the circular economy stem from:

- **Supply chain complexity.** The circular economy often involves complex supply chains with multiple stakeholders, including suppliers, manufacturers, distributors, and consumers. Tracking and accounting for the movement of materials, products, and by-products across the supply chain can be complicated, requiring robust systems to capture data on material flows, product lifecycles, and environmental impacts at various stages. Reverse logistics and closed-loop product systems involve the flow of products and materials back through the supply chain from the customer to the manufacturer (or another party) for reuse, recycling, or disposal, a process that's difficult to manage and creates accounting challenges. Similarly, it's hard to account for the value of returned products and materials. Returned products may be damaged or defective, which can reduce their value, and the value of recycled materials often fluctuates based on market conditions. Steps include:
  - *Traceability of products/materials.* Companies must be able to track the flow of products and materials throughout their lifecycles to accurately assess their environmental impact. This movement of discarded products and materials is often long and may be circuitous, making it challenging to track. This leads to difficulties in assessing the economic value of a product or material through various flow points. For example, valuation of a metal scrap from a discarded car might be based on its intrinsic value (the type and condition of the metal) or its extrinsic value (its recycling or upcycling potential).

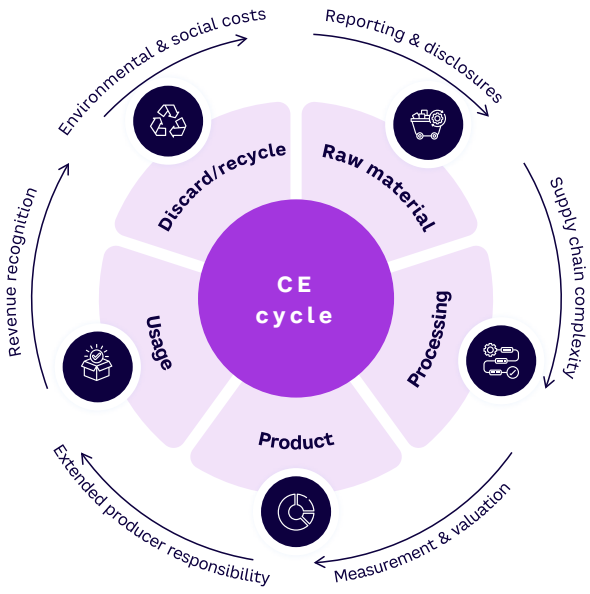

Figure 1. The complex linkage of the CE cycle

- **Measurement and valuation.** Accounting systems inculcate linear business models in which inputs transform into outputs. In the circular economy, the focus is on creating inputs out of outputs. Accounting for the value of reused or recycled materials, refurbished products, or extended product lifecycles is challenging. Determining appropriate dynamic valuation methods and accurately measuring the economic benefits of circular activities require careful consideration. For example, old furniture may have a low valuation (and price) in a linear economy. In a circular economy, old furniture may be highly valued as a way to reduce the need to cut down trees. Considerations include:
  - *Valuing products/materials.* Products and materials used in the circular economy often have different values than those in the linear economy. For example, a product designed for easy disassembly and recycling may have a lower value than one designed for disposal after use. The problem of price discovery/value is even more complex, as the value is subjective and is often at the potential buyer's sole discretion.

- **Extended producer responsibility (EPR).** In many jurisdictions, EPR regulations require producers to take responsibility for managing the entire lifecycle of their products, including their collection, recycling, or disposal. EPR models often involve financial obligations and reporting requirements. Accounting for the costs associated with product take-back, recycling infrastructure, and related liabilities requires careful consideration to comply with regulatory requirements.
- **Revenue recognition.** In the circular economy, revenue generation may occur through various models, such as product leasing, remanufacturing, subscription services, or product-as-a-service arrangements. Companies like Phillips and Michelin have used such models for lighting, health equipment, and tires. These models may require different approaches to revenue recognition compared to traditional sales-based models. Accounting for revenue recognition in such scenarios can be complex, especially when the revenue generation extends over a long period. For example, it's difficult to determine the valuation of repaired/refurbished products because the material and functional values (e.g., strength or safety) of the product undergo changes.
- **Environmental and social costs.** The circular economy addresses environmental and social challenges by reducing resource consumption and minimizing waste. Accounting for environmental and social costs like carbon emissions, water usage, or social impact requires appropriate measurement and reporting frameworks. Identifying relevant indicators and developing appropriate methodologies to assess and account for these costs are challenging. Companies need to be able to report on their environmental impact to comply with regulations and meet the expectations of stakeholders, but the environmental impact of the circular economy is often difficult to quantify. For example, multiple reuse of a conveyor belt may create new environmental challenges as the product undergoes changes in its material properties and may have different waste streams and pollution impacts.
- **Reporting and disclosures.** As the circular economy gains prominence, stakeholders such as investors, customers, and regulators are increasingly interested in the sustainability performance of organizations. Companies may face the challenge of developing meaningful metrics, reporting frameworks, and disclosures that accurately communicate their CE initiatives and outcomes. Emerging reporting standards and frameworks such as the Global Reporting Initiative and the Sustainability Accounting Standards Board (SASB) are still not able to capture the different cycles of the circular economy.

Addressing accounting complexities in the circular economy requires organizations to adapt their accounting systems, develop appropriate measurement methodologies, enhance data-collection processes, and ensure compliance with relevant regulations and reporting standards. It may also involve collaboration with other stakeholders to establish common accounting principles and frameworks specific to CE activities.

Despite these challenges, there are several benefits to accounting for the circular economy. By tracking the flow of products and materials, companies can identify opportunities to reduce waste and pollution. Additionally, by valuing products and materials differently, companies can create new markets for recycled and upcycled materials and products. Finally, by reporting on their environmental impact, companies can build trust with stakeholders and promote the transition to a more sustainable economy.

ADDRESSING ACCOUNTING COMPLEXITIES

Here are some tools and mechanisms that can help address the accounting complexities of the circular economy:

- **Lifecycle assessment (LCA).** LCA can be used to assess the environmental impact (through emissions) of products throughout their lifecycles. This information can be used to identify emission hotspots in the value chain, helping managers decide on alternative materials/products/processes and act on their product design, manufacturing, and disposal. For example, Adidas is adopting waterless, bio-based dyes for its t-shirts that will reduce both water consumption and emissions from post-use waste.
- **Impact accounting.** If one can track the flow of products and materials, the associated impact on various stakeholders (employees, customers, environment) can also be measured and accounted for. The objective is to have a positive, sustainability-driven impact rather than a finance-driven one. Traditional accounting methods should complement the approach, and optimization may also be sought on financial resources.
- **Movement-based accounting.** The value proposition driven by tracking the flow of materials and products may allow for a better assessment of the impact on the organization and other stakeholders. This also enables organizations to assess the value addition at each flow junction and properly account for it. The value derived in movement-based accounting often depends on physical and social dimensions of the product/material, such as perceived usefulness, condition, or location. For example, a bicycle may be perceived as a poor man's mode of commuting in a rural area but as an elite health item in cities. The value of the bicycle thus depends on its social-acceptance dimension and where it is located, and the bicycle's condition, usage, and usefulness may alter its valuation. Its valuation may also change within a company's supply chain and in the CE cycle of reuse and recycle.
- **Sustainability accounting.** When we talk about the circular economy, the nature of businesses can differ widely, and the focus can differ from the 3R framework (reduce, reuse, and recycle)[4] to the 9R framework (refuse, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover energy).[5] Clearly, a one-size-fits-all approach in a circular economy will not work. Instead, we need a novel accounting approach that creates a system to monitor and manage resource transfer across the value chain. There is a further need to develop a full range of dynamic metrics to assess the size of impact and circularity and integrate socioeconomic and environmental loops to measure value and impact for both sustainability and finances (see Figure 2).

Academic research suggests the possibility of a new accounting standard that can capture the essence of a circular economy and account for it financially.[6,7] Accounting standards bodies like SASB are developing new standards that are better suited to the circular economy, and the concept of value reporting is taking center stage in today's business environment.

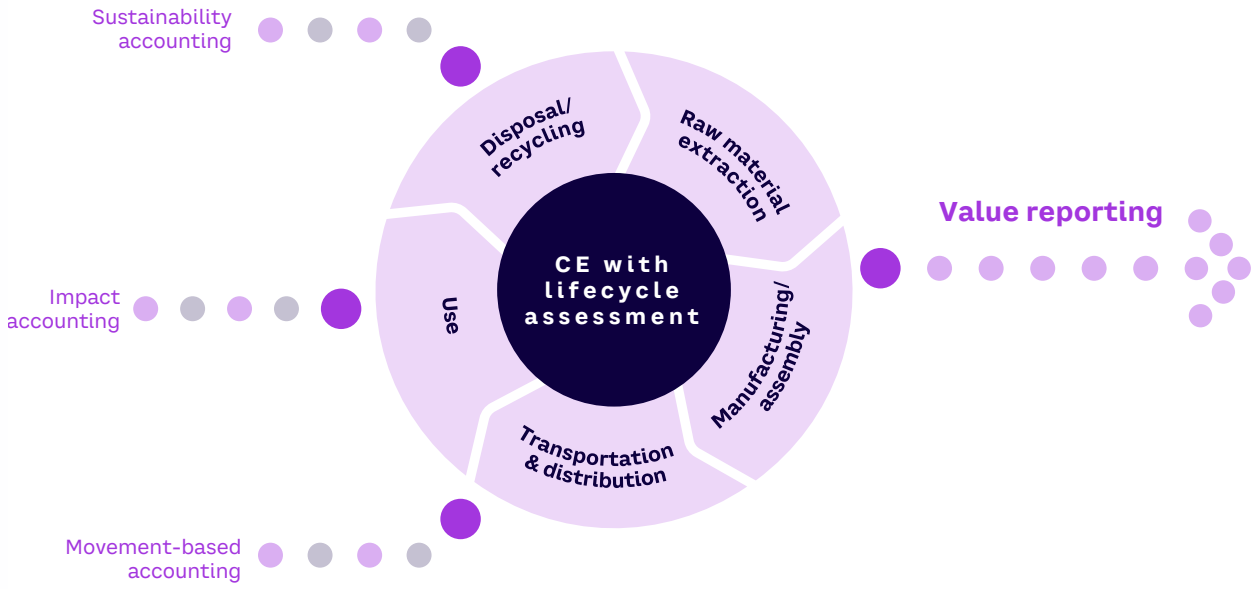

Figure 2. Developing new accounting standards and frameworks

Emerging indicators for circularity, such as those developed by EMF and the World Business Council for Sustainable Development (WBCSD), can also support new accounting standards. First, they can help identify and measure the circularity of an organization's activities. This information can be used to develop accounting standards that accurately reflect the circularity of an organization's financial performance. Second, they can raise awareness of the importance of circularity and the need for new accounting standards. This should encourage accounting standards-setters to develop new standards that support the transition to a circular economy. Third, they can be used to develop pilot accounting standards that can be tested and refined before being widely adopted.

EMF's Circulytics platform and WBCSD's Circular Transition Indicators provide measurable frameworks for identifying CE activities. Indicators such as the percentage of materials that are recycled or reused, the percentage of energy that is renewable, the amount of waste that is generated, the percentage of revenue generated from circular products and services, and the percentage of materials that are sourced from recycled or renewable sources can help in measuring financial materiality of CE items and, thus, developing a more inclusive accounting framework for companies engaging in CE activities.

New standards and accounting approaches will help companies promote transparency and sustainability and help them become more responsible and responsive to all stakeholders. Emerging technologies such as blockchain, machine learning, artificial intelligence, robotic process automation, Industry 4.0, 5G, big data analytics, and natural language processing will contribute to a comprehensive framework that can track the flow of products and materials, value them appropriately, and report on their environmental impact.

CEC, World Economic Forum, EMF, SASB, and other agencies focused on CE must create a platform designed to create awareness among organizations, regulatory bodies, and other stakeholders about the need for CE indicators and metrics in future accounting standards.

Traditional accounting methods and tools may not be able to capture the evolution of the CE model, hindering the achievement of SDGs and the transition to net zero. Businesses need standards and indicators that can be used globally but are flexible enough to work across developing economies, industry sectors, and product categories. Accounting policies and practices must evolve to help us build a more sustainable future, and all stakeholders, no matter how large or small, have a vital role to play.

REFERENCES

1 "Top 10 Waste Reuse Startups." Recycling Startups, 29 September 2023.

2 "Environment|Mother Nature." Apple, accessed October 2023.

3 "Unilever Sustainable Living Plan 2010 to 2020: Summary of 10 Years' Progress." Unilever, March 2021.

4 Prieto-Sandoval, Vanessa, Carmen Jaca, and Marta Ormazabal. "Towards a Consensus on the Circular Economy." *Journal of Cleaner Production*, Vol. 179, April 2018.

5 Van Buren, Nicole, et al. "Towards a Circular Economy: The Role of Dutch Logistics Industries and Governments." *Sustainability*, Vol. 8, No. 7, July 2016.

6 Mayer, Andreas, et al. "Measuring Progress Towards a Circular Economy: A Monitoring Framework for Economy-Wide Material Loop Closing in the EU28." *Journal of Industrial Ecology*, Vol. 23, No. 1, September 2018.

7 Jacobi, Nikolai, et al. "Providing an Economy-Wide Monitoring Framework for the Circular Economy in Austria: Status Quo and Challenges." *Resources, Conservation and Recycling*, Vol. 137, October 2018.

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