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# STANDARDS AS ENABLERS FOR A CIRCULAR ECONOMY

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## Abstract

A successful transition to a circular economy (CE) will require global participation, but the path to that transition will follow many unique routes depending on local situations. The transition must have rigorous technical underpinnings and well-conceived social interventions. In addition to solid technical foundations, consensus will add legitimacy to new and revised business practices thereby reducing the risk in their adoption. Standards created by voluntary consensus bodies are uniquely positioned to serve these purposes. In these bodies, stakeholders from a broad spectrum of society (industry, academia, government) come together to define solutions for unique circumstances and communicate them through published standards. Standards are developed by systematically determining the scope of the work, agreeing on terminology, and building on that foundation to create detailed specifications. Early engagement in the standards bodies can position stakeholders to be leaders in the path that lies ahead. This paper reviews several efforts to coordinate industries to facilitate the adoption of circular practices and technologies, highlights opportunities for further development, and discusses the role of consensus-based standards in these efforts. It highlights two recent international standards activities supporting the transition to a CE in the International Organization for Standardization (ISO) and ASTM International, followed by an example of a carbon savings measure designed to encourage more reuse of materials. While the initial standards efforts are underway, greater participation will be needed to complete the necessary agreements to establish a successful CE. ISO Technical Committee 323 on Circular economy is developing a set of standards including terminology, fundamental principles, metrics, product circularity data sheet definitions, and documenting business models and industrial case studies. These standards will support the UN Sustainable Development Goals and hence are applicable across many levels of economic and infrastructural development. ASTM International, in contrast, focuses on specialized technical standards to be used to operationalize changes in existing practices. The ASTM Committee E60 Sustainability produces standards for operationalizing sustainability in practice and supports the work of other committees to pursue sustainability objectives. E60 recently developed a roadmap for standards to foster a CE of manufacturing materials and is initiating new work in this area. The paper concludes with an example for incentivizing broader stakeholder participation in the transition to a CE through metrics for calculating carbon avoidance and highlights the need for standards to support the approach.

## Introduction

Facilitating the transition from a linear (take-make-use-dispose) economy to a circular one requires that we reevaluate our relationship with products, the materials and processes we use to make them, and our attitudes about them once they reach the end of their useful life. This requires that we see both the trees and the forest–i.e., take a systems-level perspective in which we zoom in on individual product life cycle stages while understanding how the materials and information flowing in and out of those stages influences the entire product life cycle. Due to its role in the transformation of materials into products and the generation of economic activity, the manufacturing sector is a major stakeholder in the transition to a circular economy (CE). In fact, the CE shows great promise for manufacturers to fulfill sustainability goals in part because they can view it through the lenses of both sustainability and economics. In terms of sustainability, a CE promotes the efficient use/reuse and equitable allocation of resources. If successfully implemented, a CE will reduce our reliance on the extraction of non-renewable resources (Nadeem et al., 2019), decrease environmental damage from resource extraction (van Loon et al., 2017), and promote manufacturing and better waste management (Halog & Anieke, 2021). From a purely economic lens, a CE for materials and products challenges us to build a hyper-efficient closed-loop economic system in which waste and products at their end-of-life are seen as a resource instead of a burden (Schmitt et al., 2021; Webster, 2016).

The transition to this more sustainable and economically attractive system of material use and product creation has already begun, but it remains a patchwork of initiatives and policies (Reslan et al., 2022; Hapuwatte et al., 2022). To solve this patchwork problem, broad coordination is needed among local and federal governments, international governing bodies, manufacturers themselves, financial institutions, and consumers. Standards are a key tool for creating this coordination. First, foundational standards create a consensus around, for example, terminology (e.g., an agreed upon definition of a CE), practice methods (e.g., establishing best practices for measuring, predicting, and reducing environmental impacts.), and reporting standards (e.g., the Greenhouse Gas Protocol). Standards also build trust among consumers to have faith that products are designed for circularity, made of post-consumer materials, and can satisfy claims of environmental quality (Flynn & Hacking, 2019). In addition, because the improvements can be difficult to implement, especially for small- and medium-sized firms, standards can decrease the barriers that organizations face when adapting and improving their practices (Escoto et al., 2022). Finally, while most standards are voluntary, meaning firms can choose to adhere to them, the fact that they are developed through consensus by a diversity of relevant stakeholders means that they are often widely implemented in practice and can be contractually relied on and used to develop and adhere to regulations (Association of Equipment Manufacturers, 2021).

Standards may be key to coordinating stakeholders in the transition to a CE, but identifying the standards that are needed and determining the best way to create them is a daunting task. A successful CE will require three categories of overlapping standards: 1) shared goals, 2) management standards, and 3) measurement standards (Figure 1) (Escoto et al., 2022; Reslan et al., 2022). Shared goals involve initiatives that direct broad standards efforts, like the UN's Sustainable Development Goals and Sustainability Accounting Standards Board (SASB) guidance, which incorporates metrics for 77 different industries. Management standards specify how organizations should manage themselves and their supply chains, for instance, to reduce negative impacts on the environment and human health and safety; the International Organization for Standardization (ISO) gathers representatives from different countries to create international standards that help bring consistency and quality to management practices worldwide. Finally, the measurement category involves standards for material quality/performance, communicating technical specifications, testing, and process improvements; ASTM International contributes heavily to this area.


Figure 1 Types of standards needed to transition to a circular economy (CE).

Along with broad standards initiatives, circular business models are needed to transition to a CE (Agrawal et al., 2019; Hopkinson et al., 2018; Romero & Rossi, 2017). Companies are increasingly making ESG (environmental, social, governance) commitments in response to consumer and shareholder demands, regulations, and planning for longevity. However, the types and scopes of commitments being made need to be balanced across a circular system that extends beyond the efforts and interests of individual organizations. Mechanisms are needed to incentivize companies to make their own operations more circular, and in doing so strengthen the larger value chains. For instance, large organizations are seeking means to account for the impacts of their supply chains in addition to their own individual contributions. From there, they are reporting these impacts, reduction goals, and progress towards those goals through reporting standards (e.g., SASB; the Global Reporting Initiative). These industries and their consumers, shareholders, and governments are increasingly desiring metrics for measuring progress towards these goals that are traceable and transparent.

This paper reviews three initiatives–two standards efforts and one metric-based approach to incentivize firms– to coordinate manufacturers to operationalize circularity and further the transition to a CE. The first is ISO Technical Committee (TC) 323 on Circular economy, a technical committee established in 2018 to work on management standards. The second is ASTM International's Committee E60 on Sustainability, which is creating operational measurement standards to support the transition to a CE. Finally, we describe a research effort to calculate carbon avoidance to measure the impacts of material reuse. We show how metrics such as the carbon avoidance measurement can be used to incentivize participation in a CE and the need for standards and policies to exploit this type of measurement.

## Standards and Measures for the Transition

### ISO TC 323 and its Working Groups

ISO is a global federation of national standardization bodies from 167 member countries. Its primary objective is to facilitate the development of standards to ensure the quality, safety, and efficiency of products and services. ISO standards are agreements developed through consensus with the participating ISO member countries and thus help maintain current and enable new trade links and fair practices between nations.

Over the years the ISO has developed a suite of management standards for supporting manufacturing practices. Several ISO standards are frequently deployed to address sustainable manufacturing goals, such as improving production quality (ISO 9000 series), quantifying environmental impacts (ISO 14000 series), and optimizing the performance of energy systems (ISO 50001 and ISO 20140 series) (Escoto et al., 2022; Brundage et al., 2018). The concept of CE builds on these goals of sustainable manufacturing while extending the scope from the internal operations of a business to support the integration of materials back into the economy at the end of their initial use.

Implementing a CE requires a systems-level perspective which enables materials to retain the most value in reentering the system (i.e. the economy) after their initial use. Realizing that the current ISO suite of standards lack a dedicated set of standards on CE and its implementation, ISO Technical Committee (TC) 323 on Circular economy was established in 2018. The scope of ISO TC 323 extends beyond the manufacturing sector. Currently numerous organizations around the world have implemented sustainability practices independent of any standardized framework, thus limiting the overall benefit across product and/or system value chains. The ISO TC 323 standards aim to provide a global vision to organizations (public and private) and countries (developed and developing) across the world to collectively and systematically transition towards a CE model.

Recognizing that the CE needs to be implemented collectively by different regions and countries around the world, at this stage the ISO TC 323 standards are being drafted as foundational standards as opposed to operational standards as they may be implemented to support a broad range of circumstances. Each working group (WG) in TC 323 remains cognizant of the diverse challenges developing and developed countries face in terms of transitioning to a new economic paradigm such as a CE. This awareness is particularly important given the highly inter-interconnected nature of global supply chains. Thus, the ISO TC 323 aims to promote harmonization and interoperability to enable a CE across the world.

Under ISO procedures, technical committees (TCs) produce standards as is illustrated in Figure 2. Each country can contribute to the development of the standard but only receives a single vote in the final approval process. ISO TC 323 comprises the five working groups (WGs) as shown in Table 1 each producing an initial standard as indicated. The WGs produce committee draft (CD) standards documents. In the US, these five WGs are mirrored in the ANSI-appointed technical advisory group, i.e., the US TAG. The US TAG for ISO 323 is coordinated by ASTM's E60 Sustainability Committee. The TAG appoints US experts to the ISO WG, develops US consensus for contributing to the development of the new standards, submits ballot comments, and casts the US vote on the draft standards documents.

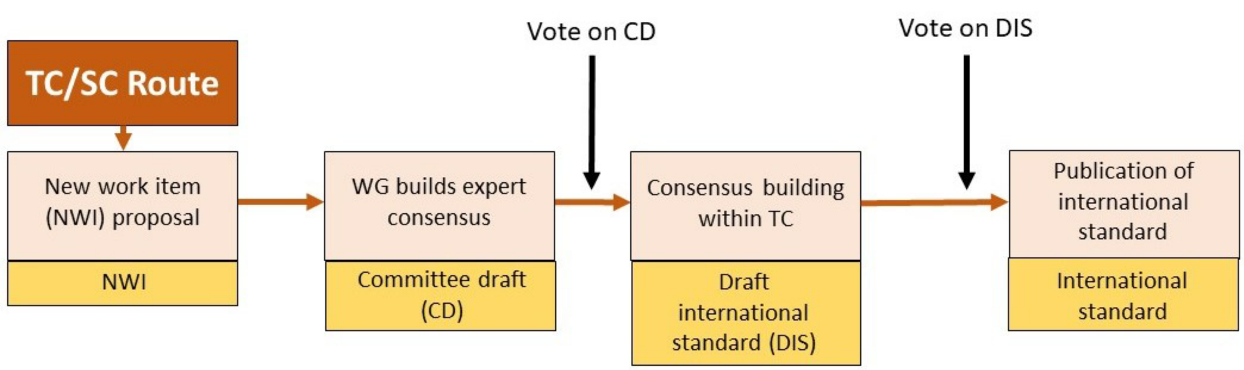


Figure 2: The stages of development for an ISO standard, including each step in the process and deliverables that emerge from each step (adapted from ISO, n.d.).

Table 1: An overview of standards development across ISO TC 323's five working groups.

| Working Group | Standard | Scope |
|---|---|---|
| 1 | ISO/ DIS 59004 Circular Economy - Terminology, Principles and Guidance for implementation | Identify CE-related terms and develop technically sound definitions. |
| 2 | ISO/DIS 59010 Circular Economy – Guidance on the transition of business models and value networks | Collate business case studies that are implementing circular economy by identifying a framework for organizations to develop circular business models. |
| 3 | ISO/DIS 59020 Circular Economy - Measuring and assessing circularity | Identify metrics to measure and quantify circular economy (value-based, LCA-based, etc.) and work to harmonize the most relevant metrics. |
| 4 | ISO/DTR 59031 Circular economy – Performance-based approach – Analysis of case studies<br>ISO/DTR 59032.2 Circular Economy – Review of business model implementation | Collate data on developing a performance-based approach for circular economy (Economy of Functionality and Cooperation) via the identification of relevant definitions and concepts that will help analyze and evaluate case studies from a triple-bottom line perspective. |
| 5 | ISO/WD 59040.2 Circular Economy - Product circularity data sheet (PCDS) | Develop a PCDS, a standardized document that enables the digital exchange of data related to circularity characteristics of products across supply chains to facilitate data related to circularity characteristics to support standardization and transparency. |

Over the last few years, WG 1 has reached consensus on establishing common terminology and an understanding of CE principles based on a rigorous consensus process. The ISO 59004 has passed through the working group and is now at the Draft International Standard (DIS) stage; from there it will proceed to final balloting, in which the standard is evaluated for technical robustness and prepared for publication(Figure 2). Since its initiation, experts participating in the WG 1 have debated extensively in the context of CE principles, fine tuning definitions and understanding the notion of material recovery and formulating guidance for resource management actions (ISO/ DIS 59004). The WG has deemed this document technically complete as indicated by approval of the committee draft (CD) document and final publication of ISO 59004 is expected in 2024. WG 2 focused on developing a compendium of CE use cases with the aim of creating a framework that helps businesses adopt CE practices. The WG 2 standard, 59010, is also approved and is at the DIS stage. WG 3 has developed DIS 59020 that identifies a set of metrics to assist in quantifying and measuring a CE. At this point the metrics identified are mostly restricted to physical material flows, emissions, and water. Given the uncertainty around data associated with computing sustainability metrics, this harmonization for both data and methodologies is needed. While most of the definitions in ISO 59010 are informative some are normative, meaning that they will be required to be in conformance with the standard. WG 4 produces draft technical reports (DTR 59031 and DTR 59032) that focus on understanding specific case studies. Finally, WG 5 is undertaking the development of a Product Circularity Data Sheet (PCDS), 59040. The document from WG 4 and WG 5 have not yet gained committee approval and are at the working draft stage.

## ASTM Committee E60

ASTM International is another international standards body that creates consensus-based technical standards to support many of the goods that society relies on. Its Committee E60 on Sustainability addresses sustainability goals and is beginning to include the transition to a CE. While the ISO TC 323 working groups are developing standards that lay the foundation for a CE generally (through principles, definitions, business guidelines, and product datasheets), ASTM seeks to integrate circularity and sustainability into existing engineering, manufacturing, and sector-specific practices. E60 technical subcommittees cover a variety of sectors, including building and construction (E60.01), healthcare sustainability (E60.42), and manufacturing (E60.13). As such, E60 has the expertise to drive refined sector-specific CE standards either within the committee or by supporting other committees. Whereas ISO TC 323 specifies best practices for transitioning to a CE through macro-level management, ASTM E60 contributes the operational expertise to, for example, principle and performance standards (Figure 1). E60's technical expertise on sustainability and CE supports other ASTM committees and, as mentioned earlier, formulates U.S. positions for ISO 323 via the ISO TAG. E60 members collaborate with and participate directly in other committees across ASTM to support coordination across the sustainability efforts of these groups (e.g., Committee D20 on Plastics; Committee E54 on Homeland Security Applications).

In April 2022, ASTM E60 hosted a workshop to identify drivers and barriers that manufacturers are experiencing when implementing circularity into their business practices. Information was gathered from a pre-workshop survey (N=260), speaker presentations, and roundtable discussions among participants and speakers from across the manufacturing sector. The two major takeaways from this effort were a list of six categories of standards needs (Table 2) and a proposed roadmap to fill those needs. One category of standards addresses foundational needs, such as consensus around terminology and reporting towards circularity goals. The other categories identify needs from a systems perspective, to transition through the entire product life cycle (from cradle to cradle as opposed to cradle to grave). The categories include support for addressing system-wide needs, front-end design, manufacturing production, back-end recovery, and recycling. While recycling can be viewed as a back-end recovery process, its critical role in transitioning generated enough interest and momentum among the survey respondents and workshop participants to create its own category. In the US, participation in moving towards circularity is being driven by both government and corporations responding to consumer demands. For example, part one of the EPA's National Recycling Strategy explicitly strives for a CE (US Environmental Protection Agency, 2021). An example from the corporate side is the US Plastics Pact, which is an agreement among large plastics value chain participants to use circularity principles to reduce, redesign, and more responsibly source plastic packaging (US Plastics Pact, 2021). Standards can support these efforts by improving collection infrastructure and strengthening the market for sorting and recycling technologies making them more accessible, especially to small- and medium-sized recyclers.

Table 2: Categories of standards needed for manufacturers to transition to a circular economy, as identified from a 2022 survey and workshop hosted by ASTM International.

| Category | Focus Areas |
|---|---|
| Foundational Circular Economy Standards | • Definitions/terminology<br>• Corporate Benchmarking & Reporting<br>• Life Cycle Assessment & Inventories |
| System Support Standards | • Systems Thinking<br>• Traceability & Digital Records<br>• Labeling |
| Front-End Design Standards | • Design for Circularity (general)<br>• Design for Material Circularity<br>• Product Design for Recovery |
| Manufacturing Production Standards | • Supply Chain<br>• Process Improvements<br>• Secondary Materials Marketplace |
| Back-End Recovery Standards | • General<br>• Use, Reuse, & Repurpose<br>• Repair<br>• Refurbish & Remanufacture |
| Recycling Standards | • Collection for Recycling<br>• Sorting<br>• Recycling<br>• Recycled Content |

ISO 323 will address some of the identified standards and ASTM Committee E60 is well positioned to address others. The roadmap from the CE workshop proposes a strategy for the committee and ASTM more broadly to move forward. Because ASTM standards development relies on volunteers, its members decide which standards are developed and when. This roadmap recommends that standards development efforts be paired with a) education and training to build the expertise needed to deploy the standards into practice as the CE transition progresses and b) research to validate approaches and enable technological, infrastructural, economic, and social progress towards new standards. The new standards themselves may begin as guidelines, then progress to best practices addressing testing and certification as experience and case studies increase.

As an outcome of the workshop, ASTM E60.13 introduced a new work item (NWI) titled *A Guide to Principles for Circular Product Design*. This NWI introduces a list of generalized design principles to apply during product design to support reintroduction of products and/or their constituent materials into the CE. These principles are created to address operationalizing CE concepts in increments to support the maturation of the CE. A goal for the work is to provide guidance for manufacturers to engage in the transition toward the CE with fewer barriers to entry and for other stakeholders, such as recyclers, to rely on consistent practices across a variety of products. This NWI also serves as a means for coordinating CE standards across ASTM and within different and specific sectors.

The NWI is structured around a primary set of general circular design principles and will feature sector-specific appendices. The appendices have unique drafting teams that include members outside of E60.13. These drafting teams work to create complementary sector-specific principles and guidelines. The NWI guidelines are defined as recommendations to operationalize circular design principles.

Overall, the *Principles of Circular Product Design* NWI encompasses all tenants of E60 by introducing a generalized CE standard that also addresses sector-specificity and enlists members from outside of ASTM E60. Once published, the *Principles of Circular Product Design* could form the basis for a certification program for circularity factors like water consumption and waste generation. Best practices and certifications are important as they improve trustworthiness among consumers and other stakeholders, ensure regulatory compliance, support the development of markets, and incentivize the use of standardized metrics (European Commission, n.d.; Tassey, 2000).

## Metrics as Incentivization

### Introduction to carbon accounting

Greenhouse gas emissions (GHG) are a common metric for the environmental impacts of products, processes, and corporations. The metrics and activities to reduce emissions are frequently called "carbon" metrics or "carbon" reduction activities because the GHG emissions are typically measured as *carbon dioxide equivalent* ($CO_2e$). Regulations on corporate GHG emissions are getting stricter. Certain regions (e.g., California, European Union) have even implemented carbon taxes and *cap-and-trade* programs (World Bank, 2022). Many corporations have also set their own voluntary carbon reduction goals, including *net-zero* targets, spurring the growth of voluntary carbon offset credits. Such practices have heightened the industry's interest in carbon reduction activities and methods to evaluate the carbon emissions of their actions. Given the interest and value of "carbon-related" metrics, we are exploring the potential of carbon metrics to incentivize material recovery practices in manufacturing, and therefore, facilitate the broader CE.

### Material recovery activities and carbon accounting

The demand for extraction of *virgin* material from the environment (i.e., *primary* material) and the landfilling or incineration of material at the end-of-use (EoU) can be minimized through effective implementation of CE activities such as *reuse*, *remanufacture*, and *recycle* (Ellen MacArthur Foundation, 2013; Hapuwatte & Jawahir, 2021; Kirchherr et al., 2017). Recovery activities are typically less resource intensive than the production of virgin materials and brand-new products due to fewer processing steps; the former therefore has the potential to curtail environmental impacts including carbon emissions (Hapuwatte & Jawahir, 2021; Yang et al., 2022). Furthermore, if these activities lead to *reduction*- or *avoidance*-based *carbon offsets*, those bring additional benefits for the stakeholders involved (World Bank, 2022).

A secondary materials marketplace (SMM) is where a manufacturer can list their excess or discarded materials, so that other companies can obtain the recoverable materials. SMMs facilitate the interaction between businesses avoiding (or reducing) material wastage and the need for primary materials production. Therefore, SMMs can be a significant component in manufacturing-related carbon emissions reduction. Yet, our work with one of the SMMs operating in multiple regions of the United States has identified that SMMs are largely underutilized. A recent ASTM workshop conducted on CE (Schumacher et al., 2023) also established the lack of standards and incentives as part of the reasons for overall paucity in recovery practices in the US industry.

If the carbon reduction or avoidance of SMM activities may be quantified and attributed, businesses' interest in carbon accounting can stimulate the use of SMMs. Furthermore, that ability to quantitatively realize the carbon benefits of recovery activities can drive the decisions to design products and processes which better employ material recovery activities, including utilization of SMMs, forming positive reinforcements.

## Available guidelines and their limitations

In terms of quantifying the carbon credits and offsets of specific projects and activities, guidance and standards are available in the form of literature such as GHG Protocol (WBCSD & WRI, 2005) and Clean Development Mechanism (CDM) methodologies (UNFCC, 2021). Many carbon regulations and voluntary marketplaces also use the GHG Protocol as their basis. While the guidelines such as GHG Protocol are extremely useful to identify and verify the activities that may claim carbon offset credits, the allocation of those credits between the stakeholders is left to the discretion of users of these guidelines (UNFCC, 2021; WBCSD & WRI, 2005). This can be especially challenging in SMMs and other such materials recovery activities as those involve multiple stakeholders. For example, SMM transactions involve at least two stakeholders—a *seller* and a *buyer*. An *equitable allocation* of avoided emissions and/or potential carbon offsets can incentivize each stakeholder's participation and also avert any *double counting errors* (WBCSD & WRI, 2004) of the carbon avoidance. We are working with industry representatives to develop a framework for accounting and allocating the carbon reductions and voluntary offset credits related to SMM activities.

## A potential solution based on allocation approaches of LCA

The life cycle analysis (LCA) literature provides *allocation approaches* (Ekvall et al., 2020; Schrijvers et al., 2016) for material recovery applications and have potential to be a basis for voluntary carbon offsets allocation. Ekvall et al. (2020) describe a good allocation approach as one that is equitable as well as can incentivize reduction of environmental impacts–including carbon emissions. Schrijvers et al., (2016) and (EC-JRC, 2010) discuss allocation approaches in detail and their potential to incentivize material recovery. For example, the *End-of-life recycling approach* can be applied when the recovered secondary material has a higher demand than the supply. In this approach, the product system providing the recovered material is allocated the benefits (i.e., avoidance of producing virgin material) of recycling. Therefore, in principle, it motivates the producers of (easily) recoverable material. If the recovered secondary material has a lower demand (e.g., a by-product that is typically considered a "waste"), then the *Cut-off allocation approach* can be applied. Here the environmental burden of primary material extraction is fully allocated to the first product system which produced the material (i.e., the user of recovered material receives the recovered material without any environmental burden related to extraction). This approach motivates the use of recovered secondary materials. LCA literature also includes other approaches such as *Market-price-based substitution approach* which allocates a higher percentage of avoidance credits producer if the market price of secondary material is closer to the price of virgin material it substituted (Schrijvers et al., 2016).

Once the total carbon offset is calculated according to a guideline such as the GHG Protocol, taking a similar approach in principle to LCA allocations, the carbon offset can be allocated between the stakeholders considering the demand for the secondary material. If a specific secondary material has a lower market value, a higher portion of the offset could be credited to the user of the recovered material creating an incentive to utilize the recovered material. Similarly, for higher-valued secondary materials, more offset can be credited to the producer of the recovered material. A detailed discussion of a framework for such allocation is discussed in an upcoming publication (Hapuwatte et al., 2023). Ultimately, these allocations must be set using contractual agreements between stakeholders of the carbon avoidance activities.

## Need for application-specific standards

Building consensus-based standards within specific industries will help establish frameworks to base the carbon-related agreements between stakeholders. Forming material- or industry-specific standards streamline such stakeholder agreements and help more manufacturers utilize material recovery activities–including through SMMs.

Given the complexities in value chains and carbon offset calculations, the following are a few crucial ways material and industry-specific standards can facilitate this process, by providing guidance on

- defining scope: identify the types of activities and stakeholders that need to be considered in carbon offsets calculations
- selecting the "baseline scenarios" and evaluating the "additionality tests" and other qualifications for carbon offsets (described in WBCSD & WRI (2005))
- specifying industry-specific *common* practices as market conditions and recovery practices change over time
- allocation practices for the transfer of material ownership between multiple stakeholders within the recovery value chain (e.g., intermediaries between the supply and consumption of the recovered material)
- estimating and accounting of GHG emissions for special industry practices (e.g., backhauling)

Since many of these considerations are application-specific, any general framework developed must be further adapted to the specific sector or application. That requires contribution from stakeholders of all levels of each sector. Such standards will provide consistency and transparency in the system leading to more credibility to society and engagement of stakeholders.

## Conclusions & Recommendations

A CE is a promising path to move toward a more sustainable economic system. The world's environmental crises–including climate, biodiversity, pollution, and finite natural resources–require both immediate solutions and more fundamental systemic changes, which the CE approach attempts. A circular approach to resource use is largely viewed as a strong basis for better managing our worldwide resources to reduce environmental harm and reverse the course towards future environmental degradation. Standards are foundational to this transition across nations and economic sectors. Standards for a CE will help

- design more durable and efficient products and services for the future
- assess the life cycle impacts of products before they are produced
- assure that future materials derived from non-virgin sources retain the characteristics needed to support the integrity of new products
- address the source of waste and pollution problems streamlining materials back into the economy
- provide verifiable baselines for evaluating future improvements to manufacturing processes
- rapidly deploy new technologies and scale up their use
- enable automation of global systems for recovery and traceability of goods and materials
- create transparency and accountability across organizations and industrial practices through accurate and comparable metrics
- effectively plan for the reintroduction of materials into the economy
- efficiently handle waste through automation in collection, sorting, and recovery practices
- motivate stakeholders to participate in new socio-economic systems increasing synergies

The standards needs to transition to a CE are great. The standards development process is a means by which stakeholders come together to align their different points-of-view towards common solutions. Standards setting can be a slow process as different stakeholders must come to common understandings not only of terminology but also agree on the principles by which they are willing and able to move forward. Standards setting is also a living process. Standards change over time with more experience and greater needs. If we as a society are to complete this transition to a CE, the time to start this process is now. We can lay the foundations for more rigorous standards in the future while setting the course on which those conversations will be built.

As new technologies and solutions are developed through fundamental research, the goal- and management-level standardization efforts can effectively guide and interface new approaches, technologies and methods. The measurement-level standards provide a means to introduce new technologies and transparency to evaluate their effectiveness. Standards can also establish a basis for incentivizing participation in CE activities as discussed in the example provided above. Therefore, standards will be key to the adoption and widespread deployment of a CE. The creation of standards requires participation across a range of stakeholders to work towards solutions that meet the common good.

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