Guest editors

Andrew J. Hoffman
and Nicholas Poggioli

Contributing authors

Pratima Bansal
Kevin Brennan
Maurie J. Cohen
Paul Dewick
Cigdem Z. Gurgur
Joerg S. Hofstetter
Ju Young Lee
Alice Mascena
Rohit Nishant
Saeed Rahman
Joseph Sarkis
Patrick Schröder
Himanshu Shekhar
Natalie Slawinski
P.J. Stephenson
Thompson S.H. Teo
Judith Walls
Monika Winn

CUTTER
AN ARTHUR D. LITTLE COMMUNITY

AMPLIFY

Vol. 35, No. 5, 2022

Anticipate, Innovate, Transform

Defining Systems Change in Sustainable Business: Part II

CUTTER

AN ARTHUR D. LITTLE COMMUNITY

Founding Editor: Ed Yourdon
Publisher: Karen Fine Coburn
Group Publisher: Christine Generali
Production Manager: Linda Dias
Editors: Jennifer Flaxman, Tara K. Meads

Amplify is published monthly by Cutter Consortium, an Arthur D. Little community, 37 Broadway, Suite 1, Arlington, MA 02474-5552, USA; +1 781 648 8700; www.cutter.com.

Contents

Opening Statement

by Andrew J. Hoffman and Nicholas Poggioli, Guest Editors

This is the second of two issues of *Amplify* on what systems change means for sustainable business in the Anthropocene Age. The first issue approached the question from two directions.[1] First, it explored what systems change means by examining the mental models we bring to the challenges we face, both at the individual level and the cultural/institutional level. Second, it identified what changes market actors could and should make using political and social mechanisms.

This issue explores how to make needed changes happen by examining three systems change topics. First, how can we use the linkages between environmental and economic systems to change market structure and, consequently, how actors compete? Second, how do we redefine waste to alter how market actors impact the natural environment through producing and disposing of materials? Third, what system changes can we accomplish through innovation or by using technologies like IT, artificial intelligence (AI), and blockchain to address unsustainable practices?

In This Issue

Linking Natural & Social Systems

To tackle our first theme of linking environmental and economic systems, P.J. Stephenson and Judith Walls call for a "new biodiversity paradigm for business." They show that current corporate guidelines for engaging on biodiversity are inconsistent and confusing, leaving companies unable to manage nature-based risks, capture nature-based opportunities, and prevent disruptive climate change. To correct these inconsistencies, they identify fundamental issues that businesses and other actors must resolve in the links between market systems and the nature systems that generate biodiversity. Achieving a biodiversity paradigm for business would mean a market structure in which competition and profit are compatible with high biodiversity and biodiversity preservation. Getting there requires companies to set science-informed biodiversity targets, support standardized reporting frameworks across companies and industries, and prioritize data and technology that increases their understanding of their relationships with (and impacts on) biodiversity and nature systems.

This issue explores how to make needed changes happen by examining three systems change topics.

Next, Saeed Rahman, Natalie Slawinski, and Monika Winn examine how pioneering companies in agriculture, agri-food, and other sectors can build and leverage ecological knowledge (knowledge about the very ecosystems they rely on) to develop innovative practices that help regenerate social and natural systems. In doing so, these companies can reap benefits for their business and help turn our unsustainable agricultural systems into systems that sustain a growing human population without severely degrading or destroying ecological systems necessary for agriculture and other industries.

Emphasizing that our economic systems can only grow within the limits of the biosphere, in our next article Himanshu Shekhar suggests a framework of "aligning with macro and accomplishing in micro" for controlled and sustainable future growth. Many businesses operate on the assumption that resources like clean air, water, and predictable weather are freely provided by nature. However, the planetary boundaries framework vividly shows that natural systems are limited in their capacity to provide these natural resources and ecosystem services. The combined impact of business activity is exceeding the limits on many of these systems, threatening to diminish the supply of resources and services provided by nature. Businesses must update their assumptions about what nature provides "for free" and act to address growing scarcity

concerns, including the potential for rapid cost increases on inputs that many business models incorrectly assume will remain low. Accomplishing controlled, sustainable growth requires a change in how business people and other decision makers view the availability of resources and services assumed to be freely and limitlessly produced by nature.

Even as innovation creates value for a firm, it can destroy value within other systems.

Material or Waste?

Two articles in this issue explore how our definitions of and approaches to waste can open new possibilities in systems change**.** Joseph Sarkis, Paul Dewick, Maurie J. Cohen, Joerg S. Hofstetter, and Patrick Schröder discuss how concepts like circular economy, degrowth, and post-growth redefine which materials are considered waste and which are considered useful. Circular economy and degrowth approaches could provide stronger sustainability outcomes by rethinking what counts as waste in supply chain analyses, operations, and management. They look at supply chain subsystems that support strong sustainability outcomes, using practical examples. They show how strong sustainability can support societal and economic resilience and identify ways to overcome challenges to changing market systems.

Kevin Brennan then outlines how Lean and Six Sigma process management systems could be changed to redefine waste in ways that capture environmental impacts. These models historically seek to eliminate waste in production processes by defining it as anything that does not contribute to increasing customer value. Brennan argues that this customer-centric definition of waste should be broadened to recognize that a focus on customer value leads to practices that reduce environmental quality. Process management must redefine waste to include unsustainable waste like resource overuse, scarcity, and externalities. This approach would look beyond process automation that focuses on the economic benefits of waste reduction, encouraging managers to think of sustainability as a "cost" imposed on them, rather than an objective for process improvement. It will also be necessary to understand how to reconcile situations where customer value and environmental value require difficult tradeoffs. Doing so will require new metrics that capture environmental waste. This shift in perspective would ensure that process practitioners incorporate sustainable thinking into their improvement initiatives and make visible the true cost of unsustainable practices within process management systems.

Innovation & Technologies

The third set of articles highlights innovation and technologies as a means of systems change. Pratima Bansal, Ju Young Lee, and Alice Mascena describe how corporate innovation often produces severe, unintended social consequences. Even as innovation creates value for a firm, it can destroy value within other systems. This occurs with innovation that produces disposable products — the firm captures value from increased sales, but the waste disposal destroys environmental and social value. The authors propose that companies move away from the traditional innovation model focused on the firm to a systems innovation model focused on the firm and its products in relation to other systems. Drawing on design thinking to identify interactions and relationships between the company and other actors and systems, systems innovation would encourage companies to avoid unintended social consequences by compelling them to be intentional about their innovation's wider impacts.

Rohit Nishant and Thompson S.H. Teo discuss how to limit the negative impacts of AI adoption by using concepts from both regenerative and doughnut economics. These two approaches seek to reconstruct economic systems so they operate within the sustainable operating limits of natural systems. Pointing out that AI adoption threatens to exceed sustainable boundaries by increasing aggregate demand for energy and new materials, Nishant and Teo put forth a 3Rs framework with which AI adopters can keep the impacts of AI within sustainable boundaries. For example, regeneration techniques can be used to redefine AI waste products like heat into inputs for producing energy, increasing the energy efficiency of AI infrastructure. Rationalization would help companies explicitly consider the carbon footprints of any proposed AI adoption, a form of internalizing costs that are often imposed on social and environmental systems. The authors also encourage companies to engage with customers about the impacts of the technologies they consume, including AI-based technologies embedded in chatbots and digital games.

Finally, Cigdem Z. Gurgur describes how a blockchain-based Internet of Things (IoT) can push market systems toward sustainability. While traditional technologies like enterprise resource planning and electronic data interchange enable information sharing, blockchain offers new opportunities relevant to systems design. Blockchain connects stakeholders with multiple sources of verified information, generates a richer informational landscape for executing business processes, and enables secure transactions between untrusted actors. Trusted networks can reduce transaction costs, simplify processes, and reduce resource intensity compared to traditional transaction technologies. Gurgur explores the conditions needed to facilitate blockchain deployment in the next generation of supply chains, specifically through IoT technologies that have attractive applications for creating, monitoring, and enforcing sustainability standards.

The articles in this issue of *Amplify* revolve around the themes of redefining taken-for-granted business concepts, attending to consequences traditionally seen as outside the responsibility of companies, and broadening company engagement with actors often seen as independent from business. Explicating and incorporating links between the natural environment and economic activity redefines business activity from something that happens in relation to nature to being something that happens in nature. Process management, circular economy, doughnut economics, and system innovation demonstrate that the activities we consider important to running a company in turn influence the impacts for which we are responsible. Although technology and innovation can help mitigate or address some of these impacts, the articles in this special issue suggest that changing market and business systems toward sustainability requires reconsideration of several fundamental assumptions. Such reconsideration is necessary as we enter the age defined by unprecedented human impacts on the planet's systems.

Reference

[1]Hoffman, Andrew, and Nicholas Poggioli (eds.). "Defining Systems Change in Sustainable Business: Part I." *Amplify*, Vol. 35, No. 4, 2022.

Andrew J. Hoffman is the Holcim Professor of Sustainable Enterprise at the University of Michigan's Ross School of Business and the School for Environment and Sustainability (SEAS). He is a globally recognized thought leader in the area of sustainability, addressing environmental challenges — the science and the cultural, institutional, political, and managerial factors and influences impacting the response of corporations, governments, IGOs/NGOs, and individual executives. Dr. Hoffman has authored more than 100 articles and 18 books and has received numerous honors and awards, including the 2020 Best Teaching Award from the Academy of Management's Organizations and the Natural Environment Division and the 2019 Alfred N. and Lynn Manos Page Grand Prize for Sustainability Issues in Business Curricula. He earned a bachelor of science degree in chemical engineering from the University of Massachusetts, a master of science degree in civil and environmental engineering from the Massachusetts Institute of Technology (MIT), and a PhD in both management and civil and environmental engineering from MIT. He can be reached at ajhoff@umich.edu.

Nicholas Poggioli is a Postdoctoral Research Fellow at the University of Michigan's Erb Institute for Global Sustainable Enterprise, a partnership between the Michigan School of Business and the School for Environment and Sustainability (SEAS). His research and teaching address how business management can be both profitable and compatible with stable ecological and social systems. Dr. Poggioli soon will be joining the Appalachian State University Walker College of Business faculty as an Assistant Professor of Management. Prior to academia, he worked for private, nonprofit, and public sector organizations, including REI, the Orange County Business Council, Gulf Restoration Network, Spurlock Museum, the Peace Corps, AmeriCorps, and the US National Park Service. Dr. Poggioli earned a master's degree in urban and regional planning from the University of California–Irvine and a PhD in business administration from the University of Minnesota. He can be reached at poggioli@umich.edu.

BE THE DIFFERENCE

A New Biodiversity Paradigm for Business

by P.J. Stephenson and Judith Walls

Biodiversity is an urgent grand challenge that businesses must address to manage risks, pursue nature-based opportunities, and contribute to the fight against climate change. Business activities are integral to addressing risks and solving challenges like anthropogenic climate change and biodiversity loss.[1] Biodiversity — the diversity of life in genes, species, and ecosystems — is declining at an unprecedented rate.[2] This trend is worrying: nature provides the foundation for life on Earth and contributes between US $44 trillion and $150 trillion to the world's economy.[3]

Biodiversity is inherently linked to business operations and supply chains. When businesses fail to address biodiversity, they expose themselves to substantial operational, legal, financial, and reputational risks that accumulate to our entire economic system.[4] For example, 75% of agricultural crops, worth $2.4 trillion, rely on insect pollination, and insect populations are rapidly declining, threatening not just the industry but our food security.[5, 6]

Biodiversity is inherently linked to business operations and supply chains.

Biodiversity is also an opportunity for business. More than 60% of cancer-fighting agents have natural origins, a market worth $112 billion annually, with a human well-being value that is incalculable.[7, 8] Nature-based solutions can also address up to 30% of climate change mitigation.[9] Businesses have strong reasons to focus on biodiversity.

In the last decade, the private sector has made significant contributions to reducing greenhouse gas emissions but only limited efforts to tackle the biodiversity crisis. Considering that 96% of business leaders are not well-informed about biodiversity, it is difficult for them to know how to embed biodiversity in their sustainability governance practices and introduce necessary systems changes.[10] Business leaders need ways to find nature-positive solutions and resources to help them make informed decisions about biodiversity.

Business & Biodiversity: Fundamental Issues

Several fundamental issues need to be resolved to connect biodiversity to business, as we explore below.

Biodiversity Is Daunting for Business & Poorly Understood

Although the connection to biodiversity is evident in sectors like agriculture, fisheries, forestry, and mining, companies in other sectors may not see an immediate link, especially if they have multiple product lines with long supply chains. Food cultivation and resource extraction sectors account for 63% of the total share of pressure on biodiversity. However, when the entire supply chain is taken into account, 90% of the pressure on biodiversity is linked to food and beverage (including packaging), infrastructure and mobility, energy, and fashion.[11] The fashion industry, for example, relies on exploitation of land, plants, and fresh water to produce raw materials for fibers while creating pollution across its value chain.

These types of links can be difficult for companies to map out, especially if their supply chains are geographically dispersed. In turn, finance and insurance institutions struggle to become enablers of nature-based solutions. Part of the difficulty is that biodiversity terminology is often new and confusing to business leaders, a problem compounded by the use of varied definitions and approaches. The growing array of tools, standards, best practices, metrics, and platforms designed for business can be difficult to navigate and prioritize.

Businesses Aren't Focused on Long-Term Biodiversity-Related Risks

Positive ecosystem impacts can take many years to realize, so biodiversity solutions require long-term vision. Executive turnover and shareholder pressure to produce immediate results can make businesses myopic, leading them to favor what benefits them now over what would benefit them later.[12]

Flooding, droughts, storms, and sea-level rise make climate change risks evident; the many serious risks of biodiversity loss (transitional, physical, legal, and systemic) are less well understood.[13] So, while some companies reap the reputational benefits of investing in natural capital, most struggle to find holistic solutions, tackling biodiversity issues unilaterally or with a small circle of colleagues or consultants. This compounds the impression that biodiversity is daunting and increases the urgency for clear biodiversity decision-making tools for business.

Businesses Don't View Biodiversity as an Interdependent System

Businesses typically interact with biodiversity on a piecemeal basis and are rarely charged with governing entire ecosystems. A corporation usually sources from a relatively small portion of land with the purpose of maximizing the utility of that space. Furthermore, economic models tend to assume natural resources are replaceable — if a tree is used as a raw material, it can be replaced. But this approach overlooks the adverse effects of replacing old trees with young ones, the interactions with the rest of the ecosystem, and the incompatibility of replacing one species with another (or natural capital with other sources of capital).[14]

Figure 1 shows the Mitigation Hierarchy, a tool to help companies limit their negative impacts on biodiversity by considering four actions in setting no-net-loss or net-gain targets.[15] Although the first two steps in the hierarchy encourage the avoidance or minimization of negative biodiversity impacts through appropriate site selection or operational planning, the other two perpetuate the idea that biodiversity can either be restored or its destruction offset by restoring elsewhere.

In reality, the restore and offset steps are complex, expensive, and difficult to measure and achieve. Environmental impact assessments (EIAs) promote the idea that business pressures on nature can be easily predicted and replaced, but EIAs often fall short of adequately addressing biodiversity impacts.[16]

Biodiversity Measures for Business Are Inadequate

Numerous biodiversity-related indicators have been developed for corporations, many striving to find a single metric — an animal or plant equivalent of carbon dioxide units (see Table 1). These indicator frameworks

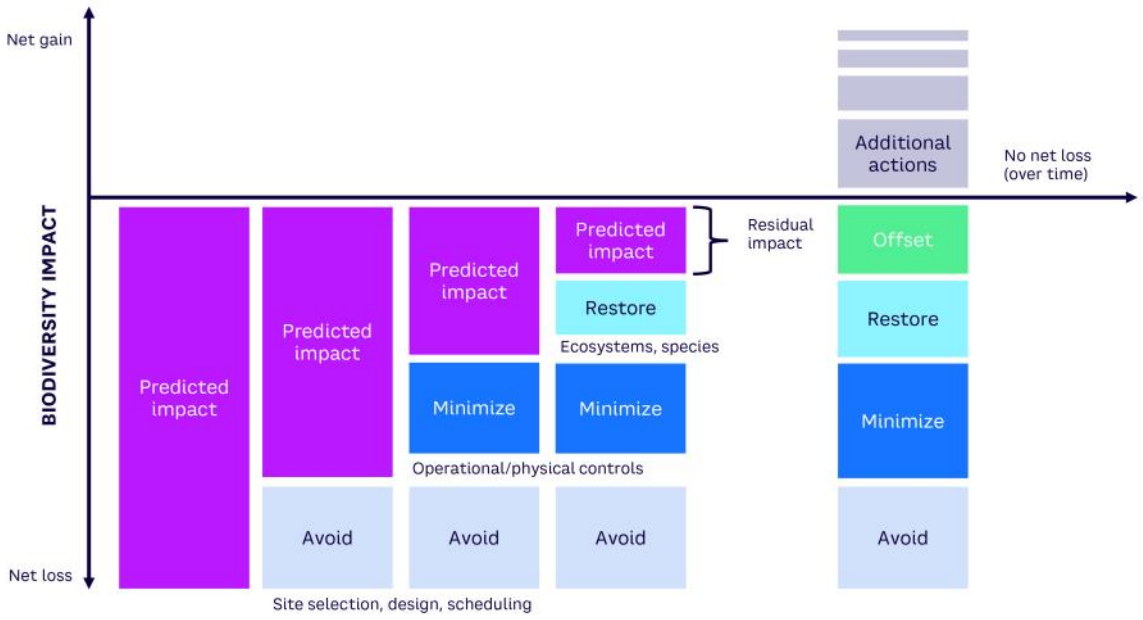

Figure 1. The Mitigation Hierarchy (adapted from Mitchell)

INDICATORS/FRAMEWORKS	LEADS (SECTORS)
Cross-sectoral	
Biodiversity Estimated Impact Value	LIFE Institute
Biodiversity Footprint Calculator	Plans Up et al.
Biodiversity Impact Metric	Cambridge Institute for Sustainable Leadership (CISL), Cambridge University
Biodiversity Indicators for Site-Based Impacts	United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC)
Biodiversity Net Gain Calculator	Arcadis
Bioscope	Platform BEE, Dutch government, et al.
CDSB Framework for Biodiversity-Related Disclosures	Climate Disclosure Standards Board
Earth Dividend	Earth Capital
ENCORE (Exploring Natural Capital Opportunities, Risks, and Exposure)	Natural Capital Finance Alliance
Global Biodiversity Score	CDC Biodiversité
Global Reporting Initiative	Global Sustainability Standards Board
GloBio	PBL Netherlands Environmental Assessment Agency
Healthy Ecosystem Metric Framework	CISL, Cambridge University
Product Biodiversity Footprint	I CARE
Species Threat Abatement and Restoration Metric	IUCN, Newcastle University, Biodiversity Consultancy et al.
Sector-specific	
Agrobiodiversity Index	Bioversity International (agriculture/food)
Biodiversity Ecosystem Services Index	Swiss Re Institute (insurance industry)
Biodiversity Footprint Approach	ASN Bank (finance sector)
Biodiversity Indicator and Reporting System	IUCN (cement and aggregates)
Biodiversity indicators for companies	UNEP-WCMC (extractives)

Table 1. Examples of biodiversity indicators and monitoring and disclosure frameworks developed specifically for business

are generally rigorous, replicable, and consistent, but none of them cover all business applications in all biomes. Most are still under development, and many use one blunt metric (e.g., mean species abundance) that does not reflect the complex differences between ecosystems and species.[17]

More importantly, the indicators developed for businesses are different from those used by governments, environmental nongovernmental organizations (NGOs), and conservation experts. This reflects a difference in framing goals:

- The draft goals, targets, and indicators of the Post-2020 Global Biodiversity Framework of the Convention on Biological Diversity (CBD) focus on species and habitats in terrestrial, marine, and freshwater ecosystems.

- The draft Taskforce on Nature-Related Financial Disclosures (TNFD) framework focuses on a confusing mix of realms (land, freshwater, ocean atmosphere), biomes, environmental assets, and ecosystem services.
- The Science Based Targets Network (SBTN) guidance for business separates biodiversity from other aspects of nature (climate, freshwater, land, and ocean).

Since climate change and biodiversity loss are inherently linked and self-reinforcing, it is a false dichotomy to treat them separately. If the private sector continues to treat biodiversity planning and monitoring differently from public and civil society sectors, understanding will be hindered, and opportunities for cross-sectoral lessons learned and data sharing will be significantly reduced.

Business indicators for biodiversity mostly rely on secondary data and modeling rather than direct measurement, using assumptions that may not be accurate.

Biodiversity Data Is Not Accessed or Used

Accurate, reliable, timely data is essential for corporate biodiversity governance. Nevertheless, companies face challenges accessing existing data or collecting new data, especially geo-referenced data that links activities to specific sites, supply chains, species, and habitats. This may be the reason only 3%-12% of European and US companies report anything on biodiversity.[18] Even when companies do report, the information is often not specific, measurable, or time-bound, making it difficult to determine business impacts.[19]

Business indicators for biodiversity mostly rely on secondary data and modeling rather than direct measurement, using assumptions that may not be accurate. Companies do not know how to collect their own data or where to source existing data. Thus, there is an urgent need to develop biodiversity decision-making tools to help companies access the biodiversity data and methods needed for successful monitoring and governance.

Signs of Change: Shifting Toward a New Paradigm

In spite of the ongoing challenges, there are signs of a paradigm shift in the corporate sector.

Businesses Are More Engaged & Working with Others to Address Biodiversity

Businesses are more engaged with, and integrated into, global biodiversity processes than they were a decade ago.[20] There was a *Business and Biodiversity Forum* at the 2018 *CBD Conference of the Parties*, and the CBD's draft Post-2020 "Target 15" specifically commits businesses to increase positive impacts. The trend for increased business engagement is also reflected in biodiversity monitoring and reporting. Disclosure to the CDP (previously the Carbon Disclosure Project) on the topics of water and forestry increased dramatically from 2010 to 2020 (see Figure 2). (Note: About half of the disclosures are not made public. In 2021, water and forest disclosure represented 25% and 7% of total disclosures, respectively. By comparison, more than 99% of companies disclosed on climate change.[21])

These trends indicate an ongoing transformation, although the impact is varied. For example, although a third of companies disclose on forests, commodity-related deforestation continues.[22] The gap between disclosure and positive impact is commonly referred to as greenwashing. However, relationships between the private sector and civil society have improved, with many partnerships and initiatives helping companies become more accountable to rigorous, meaningful biodiversity targets (see Table 2). Many companies are also making unilateral commitments to enhance sustainability. Between 2001 and 2016, 66 companies from around the world made no-net-loss or net-positive impact commitments, with half of the companies specifying their biodiversity goals.[23]

Small Steps & Legislation Encourage Businesses to Act on Biodiversity

Reservations about biodiversity and complicated action options persist, but some recent guidelines encourage companies to begin with small steps, planning change for one specific raw material, process, or product rather than all company activities.[24] Companies can also break

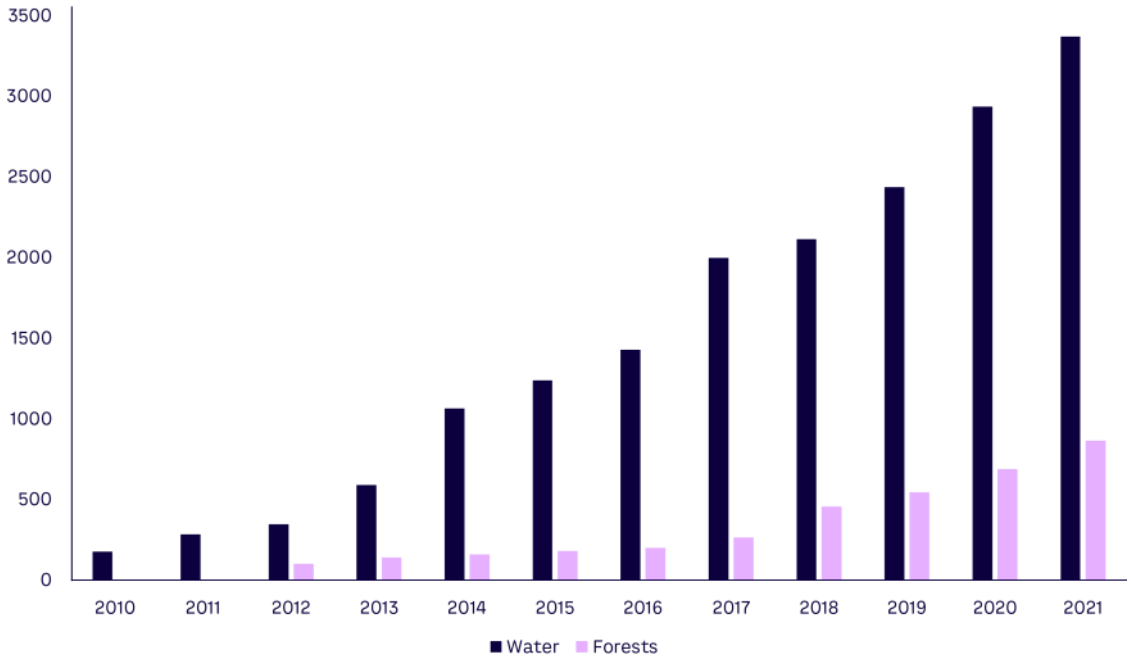

Figure 2. The number of companies disclosing information on water and forest biodiversity to the CDP from 2010 to 2021

down activities into more manageable units and define and monitor biodiversity goals at a level of granularity relevant to their operations (e.g., product line, raw material, supplier, type of operation, asset type, asset location).

Stakeholder engagement is key and, given that biodiversity is not the core business of most companies, working with external experts (e.g., international organizations, NGOs, academic institutions, consultants) will remain important.

In Europe, legislative frameworks are shifting toward more non-financial disclosures, as demonstrated by the EU's Non-Financial Reporting Directive and the proposed Corporate Sustainability Reporting Directive. In parallel, the Platform for Sustainable Finance (including private sector representatives) is developing details on which company operations can be considered sustainable as part of a new green taxonomy.

An International Sustainability Standards Board is being set up to work with investor-focused initiatives such as the Climate Disclosure Standards Board and the TNFD. This combination of growing interest and engagement and increasing policy and legislation incentives will facilitate a significant upsurge in corporate biodiversity commitments in coming years, with Europe as a key hub.

Biodiversity Guidelines & Tools for Business Are Being Improved & Harmonized

New guidelines, tools, and standards are being developed to help businesses navigate biodiversity, some taking lessons from conservation science and practice, applying them to the business context[25] and removing the divergence between sectoral approaches.

Companies, international organizations, NGOs, and consultancies are starting to collaborate and develop linkages and synergies on biodiversity, coalescing around the concept of nature positive and moving toward improving biodiversity and the biomes it's found in by 2030 (see Figure 3).[26] The faster we can harmonize business biodiversity guidelines and build and test decision-making tools in business settings, the sooner we can ramp up business interaction with biodiversity governance and deliver impact.

Opportunities Are Emerging for Enhanced Data Availability & Sharing

Conservationists have learned that strong planning is a prerequisite of successful biodiversity monitoring. Business can learn from this experience to develop indicators set against goals and objectives to provide meaningful management information.[27] Data can be

Program/Lead Developers	Goal
Guidelines	
Business & Biodiversity Offsets Programme Roadmap for Planning for Biodiversity Forest Trends, Wildlife Conservation Society	To develop goals around biodiversity net gain and the broader mitigation hierarchy
Biodiversity Targets and Finance UN Environment Programme, UNEP Finance Initiative and Global Canopy	To help finance companies identify suitable goals
Cross-Sector Guide for Implementing Mitigation Hierarchy Biodiversity Consultancy	To plan in the context of the mitigation hierarchy
IUCN Guidelines for Planning and Monitoring Corporate Biodiversity Performance	To develop a corporate biodiversity strategic plan with goals, objectives, and core linked indicators of performance
Natural Capital Protocol Capitals Coalition	To conduct natural capital assessments as part of biodiversity planning
Science-Based Targets for Nature Initial Guidance for Business Science-Based Targets Network	To set targets on nature (biodiversity, climate, freshwater, land and ocean)
What Does Nature Positive Mean for Business? Practitioner Guide World Business Council for Sustainable Development	To navigate actions, tools, and other resources across different value chains and guide business to credibly contribute to nature-positive outcomes
Tools	
Aligning Biodiversity Measures for Business collaboration UNEP-WCMC et al.	To improve clarity and build consensus on how businesses and financial institutions can measure and report on performance
Biological Diversity Protocol Biodiversity Disclosure Project, hosted by Endangered Wildlife Trust	To identify, measure, manage, and report on biodiversity impacts
ENCORE tool (Exploring Natural Capital Opportunities, Risks, and Exposure) Natural Capital Finance Alliance	To assess environmental risks (for financial institutions such as banks, investors, and insurance firms)
The Equator Principles The Equator Principles Association	To determine, assess, and manage environmental and social risk
TNFD Nature-Related Risk & Opportunity Management and Disclosure Framework Task Force on Nature-Related Financial Disclosures	To understand risks, dependencies, and impacts on nature to support reporting, metrics, and data needs
Standards	
IUCN Global Standard for Nature-Based Solutions IUCN	To design and verify nature-based solutions to yield the desired human wellbeing and biodiversity outcomes
Performance Standards on Biodiversity Conservation and Sustainable Management of Living Natural Resources International Finance Corporation	To avoid or mitigate threats to biodiversity arising from operations as well as sustainably manage renewable natural resources

Table 2. Summary of the main cross-sectoral and finance sector guidelines, tools, and standards developed or under development to help businesses address biodiversity

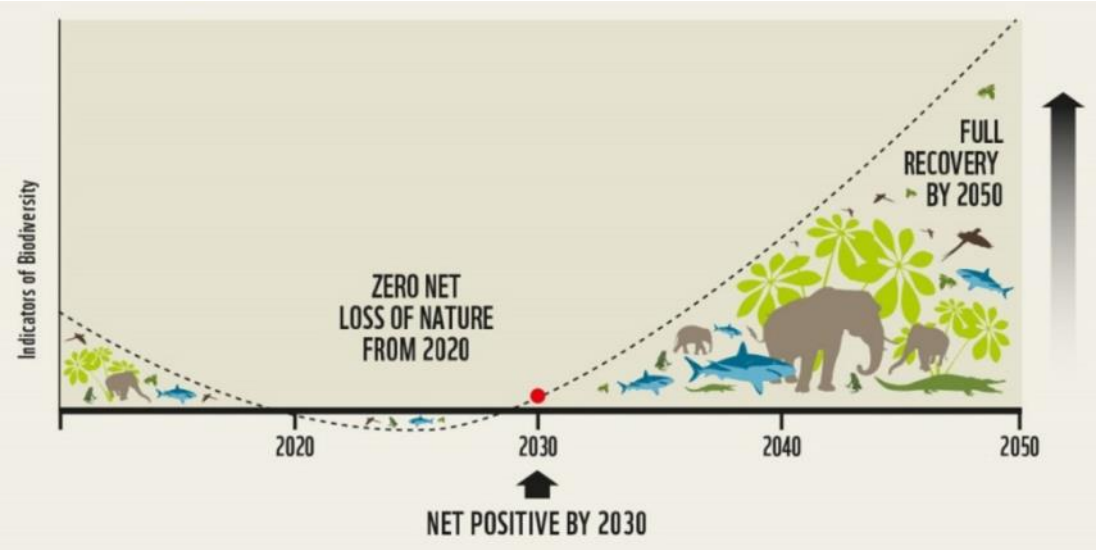

Figure 3. A graphical representation of a global goal for nature positive (source: Locke et al.)

aggregated from local to global levels and presented in formats that facilitate decision making (dashboards, graphs, maps), using terminology understood by business.

This is best achieved by using a set of common key performance indicators (KPIs) across a company's scope of influence, preferably harmonized with indicators used by conservationists. Large, global biodiversity data sets and guidance on how companies can monitor biodiversity are increasingly accessible.[28, 29] For example, satellite-based remote sensing data is readily available to measure land use, and ground-based and water-based sensors (from camera traps to acoustic recording devices) are improving the ease of monitoring species and habitats, as are environmental DNA analyses.

There is also global growth in national policies for private sector biodiversity monitoring.[30] Making biodiversity data open access, and therefore shareable, will be key. For instance, many companies are collecting biodiversity data when they conduct EIAs. Making that data freely available will make it possible to build a global picture, assess cumulative impacts, and allow more efficient use of data for decision making.[31]

How Businesses Can Shape a Future Centered on Biodiversity

To drive systemic change and embed the economic sector into ecological systems, a new corporate biodiversity paradigm is needed, with the same scope and scale we recently witnessed for climate change governance. We believe several trends are needed to support this process:

- **Science-informed biodiversity goals and targets for business are critical to successful action**. Goals must be based on scientific data and set in collaboration with other sectors, government agencies, and NGOs. More companies should make public commitments on biodiversity, based on risk assessments across space (location) and time (long-term horizons). Corporate goals must be harmonized with CBD's Post-2020 Global Biodiversity Framework and UN Sustainable Development Goals.

- **Companies need to move toward a nature-positive agenda linking biodiversity and climate change**. No-net-loss is becoming a concept of the past as the corporate sector steps up to join governments and civil society in going beyond avoidance and mitigation to proactively protect and restore species and natural habitats. As such, committing to a nature-positive agenda may even represent a rethink of what defines ethical business practice. Business investment in nature-based solutions must become more prominent, especially through solutions tackling both climate and biodiversity, like the restoration of mangrove forests, which can conserve species while sequestering four times more carbon than rainforests.[32]

- **Reporting frameworks must be improved.** These frameworks should be harmonized and standardized to avoid confusion within and between companies

and better link monitoring to goals and targets, enhancing data and lesson sharing. The most successful indicators will likely be those based on conservation science and practice and include not only measures of responses and pressures, but also impacts on the state of biodiversity.

- **Companies must leverage new forms of data and technology**. The increased use of remote sensing combined with artificial intelligence can help companies move away from inaccurate modeling with out-of-date secondary data toward near-real-time collection of primary data. Financial institutions and data organizations must increasingly embed spatial data to connect company assets and sites to biodiversity indicators.

If we are to witness such transformative change, companies must adopt a long-term, embedded perspective of nature rather than focusing on short-term financial growth metrics. Many investors and stakeholders (including banks and insurance companies) are increasingly aware of the potential downsides of businesses that fail to address climate change and biodiversity. Companies will find it easier to raise capital and insure assets if they consider their overall, long-term impact on nature — a genuine win-win for business and the planet.

References

[1]Quinney, Marie. "New Report Shows Why Fighting Climate Change and Nature Loss Must Be Interlinked." World Economic Forum, 21 June 2021.

[2]"Global Assessment Report on Biodiversity and Ecosystem Services." IPBES, 2019.

[3]"Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy." World Economic Forum, 19 January 2020.

[4]Winn, Monika, and Stefano Pogutz. "Business, Ecosystems, and Biodiversity: New Horizons for Management Research." *Organization & Environment*, Vol. 26, No. 2, 1 June 2013.

[5]"Why Bees Matter: The Importance of Bees and Other Pollinators for Food and Agriculture." Food and Agriculture Organization (FAO) of the United Nations (UN), 20 May 2018.

[6]Wagner, David, et al. "Insect Decline in the Anthropocene: Death By a Thousand Cuts." *Proceedings of the National Academy of Sciences (PNAS)*, Vol. 118, No. 2, 11 January 2021.

[7]Demain, Arnold, and Preeti Vaishnav. "Natural Products for Cancer Chemotherapy." *Microbial Biotechnology*, Vol. 4, No. 6, 18 November 2010.

[8]Mikulic, Matej. "Size of the Cancer Drug Market Worldwide in 2019 and 2030." Statista, 17 November 2021.

[9]Griscom, Bronson, et al. "Natural Climate Solutions." *Proceedings of the National Academy of Sciences (PNAS)*, Vol. 114, No. 44, 16 October 2017.

[10]"When It Comes to Biodiversity, Businesses Are at a Loss." Quantis, 14 September 2021.

[11]Kurth, Torsten, et al. "The Biodiversity Crisis Is a Business Crisis." Boston Consulting Group, March 2021.

[12]Kim, Anna, Pratima Bansal, and Helen Haugh. "No Time Like the Present: How a Time Perspective Can Foster Sustainable Development." *Academy of Management*, Vol. 66, No. 2, 18 April 2019.

[13]"Nature is Too Big to Fail. Biodiversity: The Next Frontier in Financial Risk Management." PricewaterhouseCoopers (PwC)/ World Wildlife Fund (WWF), January 2020.

[14]Cohen, François, Cameron J. Hepburn, and Alexander Teytelboym. "Is Natural Capital Really Substitutable?" *Annual Review of Environment and Resources*, Vol. 44, October 2019.

[15]Ekstrom, Jon, et al. "A Cross-Sector Guide for Implementing the Mitigation Hierarchy." Cross Sector Biodiversity Initiative and The Biodiversity Consultancy, 2015. (The Mitigation Hierarchy was first introduced in: Mitchell, Robin. "Mitigation in Environmental Assessment – Furthering Best Practice." *Environmental Assessment*, Vol. 5, No. 4, 1997.)

[16]Ritter, Camila, et al. "Environmental Impact Assessments in Brazilian Amazonia: Challenges and Prospects to Assess Biodiversity." *Biological Conservation*, Vol. 206, February 2017.

[17]Lammerant, Johan, et al. "Assessment of Biodiversity Measurement Approaches for Businesses and Financial Institutions. Update Report 3." European Commission, December 2019.

[18]Carvajal, Mariela, Muhammad Nadeem, and Rashid Zaman. "Biodiversity Disclosure, Sustainable Development and Environmental Initiatives: Does Board Gender Diversity Matter?" *Business Strategy and the Environment*, Vol. 31, No. 3, March 2022.

[19]Addison, Prue F.E., Joseph W. Bull, and E.J. Milner-Gulland. "Using Conservation Science to Advance Corporate Biodiversity Accountability." *Conservation Biology*, Vol. 33, No. 2, April 2019.

[20]Tidd, Olivia. "Why Biodiversity Is Moving to Top of Mind for Investors." Lazard Asset Management, February 2022.

[21]CDP website, 2022.

[22]"The Collective Effort to End Deforestation: A Pathway for Companies to Raise Their Ambition." CDP, 2020.

[23]de Silva, Gayan Charitha, et al. "The Evolution of Corporate No Net Loss and Net Positive Impact Biodiversity Commitments: Understanding Appetite and Addressing Challenges." *Business Strategy and the Environment*, Vol. 28, No. 7, November 2019.

[24]Stephenson, P.J., and Giulia Carbone. "Guidelines for Planning and Monitoring Corporate Biodiversity Performance." IUCN, 2021.

[25]Addison, Prue F.E., et al. "Bringing Sustainability to Life: A Framework to Guide Biodiversity Indicator Development for Business Performance Management." *Business Strategy and the Environment*, Vol. 29, No. 8, December 2020.

[26]Locke, Harvey, et al. "A Nature-Positive World: The Global Goal for Nature." Nature Positive, 2020.

[27]Stephenson, P.J. "The Holy Grail of Biodiversity Conservation Management: Monitoring Impact in Projects and Project Portfolios." *Perspectives in Ecology and Conservation,* Vol. 17, No. 4, December 2019.

[28]Stephenson, P.J., and Carrie Stengel. "An Inventory of Biodiversity Data Sources for Conservation Monitoring." *PLoS ONE*, Vol. 15, No. 2, 2 December 2020.

[29]Cousins, Neil, and Simon J. Pittman. "Guidance for Defining Ecologically Appropriate Scales of Analysis for Marine Biodiversity in Relation to IFC Performance Standard 6." Bluedot Associates, 2021.

[30]zu Ermgassen, Sophus, et al. "The Role of 'No Net Loss' Policies in Conserving Biodiversity Threatened by the Global Infrastructure Boom. " *One Earth*, Vol. 1, No. 3, 22 November 2019.

[31]Stephenson, P.J. "A Review of Biodiversity Data Needs and Monitoring Protocols for the Offshore Wind Energy Sector in the Baltic Sea and North Sea." Renewables Grid Initiative, October 2021.

[32]Sanderman, Jonathan, et al. "A Global Map of Mangrove Forest Soil Carbon at 30 m Spatial Resolution." *Environmental Research Letters*, Vol. 13, No. 5, 30 April 2018.

P.J. Stephenson is Research Project Manager at the University of Lausanne, Switzerland; Chair of the IUCN SSC Species Monitoring Specialist Group; and an independent conservation and sustainability consultant. Since 2017, he has focused much of his work and research on tackling business sustainability issues. Dr. Stephenson has worked in biodiversity conservation for Scottish Natural Heritage in the Cairngorms, WWF in the Democratic Republic of Congo and Tanzania, and Conservation International in Côte d'Ivoire. He also managed WWF programs for elephants, great apes, and rhinos across Africa. Dr. Stephenson served as WWF International's Director of Conservation Strategy & Performance, where he drove results-based management across the global network; Senior Advisor, Monitoring, at the International Union for Conservation of Nature; and Senior Research Fellow at ETH Zürich. He is coauthor of the "IUCN Guidelines on Planning and Monitoring Corporate Biodiversity Performance" and has worked with companies such as Alcoa, Boskalis, Earthly, Enel, Jan de Nul, and Nespresso. Dr. Stephenson's current research is funded by the Swiss Network for International Studies. He earned a PhD in zoology from the University of Aberdeen. He can be reached at stephensonpj@gmail.com.

Judith Walls is Full Professor and Chair of Sustainability Management at the Institute for Economy and the Environment, University of St.Gallen, Switzerland. Prior to academia, she worked in investor relations as Head of Research, Consulting and Business Development for Technimetrics (later Thomson Reuters) in Europe and Asia-Pacific. Dr. Walls also spent many years working with conservation organizations regarding the human-wildlife conflict and how best to manage this through entrepreneurial solutions in locations like Namibia, Botswana, and Mongolia. Her research focuses on the nexus of corporate governance and environmental sustainability. Dr. Walls's work has examined the role of CEOs, top management teams, boards of directors, shareholders, and stakeholders in driving corporate transformation for sustainability. She has a special interest in the topic of biodiversity and land use and the (emotional) dynamics of contested industries, such as mining and trophy hunting. Dr. Walls has been awarded and published in top-tier academic journals. She earned a master's of science degree in wildlife, biodiversity, and ecosystem health from the University of Edinburgh, Scotland; a PhD in management from Rensselaer Polytechnic Institute; and has pursued a post-doctoral research fellowship at the Erb Institute for Global Sustainable Enterprise, University of Michigan. She can be reached at judith.walls@unisg.ch.

FARM TO STABLE

How Ecological Knowledge Can Catalyze System-Level Change: Lessons from Agriculture & Beyond

by Saeed Rahman, Natalie Slawinski, and Monika Winn

Climate change and biodiversity loss have prompted businesses in a range of industries — from agri-food and agriculture to clothing, pharmaceuticals, forestry, fisheries, mining, tourism, and energy — to seek a more holistic understanding of their interdependence with ecosystems.

Firms rely on ecosystems for natural resources that are critical to their business, yet their business practices often deplete those very ecosystems and cause them to degenerate.

Ecosystems degenerate when their natural structure and processes are changed to the extent they are unable to fully recover from stresses (regardless of whether the changes were from human activities or large-scale natural disasters). In contrast, a regenerative ecosystem can bounce back from the stresses caused by seasonal floods, higher temperatures, or wildfires so that they can go back to their highest-functioning states.

Business practices involving the widespread use of chemicals, increased pollution and waste accumulation, or inefficient use of non-renewable natural resources can severely degrade ecosystems, threatening the survival of species that depend on them. Once an ecosystem reaches degenerative thresholds, it becomes unstable and may break down.

Armed with an increased awareness of the risks of ignoring this interdependence, many firms are not just rethinking their practices, but going further. By learning from the very ecosystems they rely on, they build ecological knowledge, allowing them to develop sustainable practices that contribute to the regeneration, rather than the degeneration (and associated risks), of social and natural systems.[1]

An industry that illustrates the complex interdependence between business, society, and nature especially well is industrial agriculture. With the world's population projected to hit 10 billion by 2050, the demand for food worldwide is expected to rise by 56%, making us increasingly reliant on industrial agriculture.[2]

Unfortunately, the current chemical-based industrial agriculture system is already pushing far beyond the world's environmental limits. The system primarily promotes monoculture cropping: the growing of the same commodity crops year after year. Monocropping, as it is often called, degenerates soil ecosystems by burning soil carbon instead of storing it and by degrading nutrients and biological activity in the soil.[3]

In addition to monocropping, industrial agriculture relies on synthetic pesticides, insecticides, and fertilizers. It is the largest source of water and air pollution, a major contributor to soil erosion, the biggest drain on fresh water, a leading cause of biodiversity loss — and it's responsible for a *third* of global greenhouse gas emissions.[4]

Many companies continue to contribute to this fundamentally unsustainable system, often because they are embedded in socioeconomic system structures that make it difficult to change. Yet a growing number of innovative firms are engaged in creating ecological knowledge that allows them to build growing practices that restore and regenerate ecosystems. In doing so, these pioneers experience significant benefits from better understanding how ecosystems efficiently provide the natural resources they depend on. The resulting regenerative approaches are a dramatic departure from current industrial agricultural practices. In fact, if their take-up is nurtured effectively across supply chains, they have the potential to transform our food systems to become sustainable.

General Mills, one of the largest food producers in the US, offers a powerful example of such work. The company developed a partnership with farmers, suppliers, the University of Minnesota, and Xerces Society (a major pollinator and wildlife conservation nonprofit) to implement large-scale habitat restoration projects with the goal of conserving biodiversity and securing the long-term supply of its critical raw materials.[5]

California-based Bonterra Organic Vineyards is another good example. A leading producer of wines made from organically grown grapes, Bonterra regularly collaborates with a network of like-minded farms, local beekeepers, other wineries, environmental nonprofits, agricultural research organizations, and other supply chain partners to exchange knowledge and information about organic growing practices. These practices include using cover crops, integrating wildlife, composting soil, and reducing the company's water footprint. The goal is to create a flourishing natural ecosystem, stronger plants, and greater yields, thus promoting both sustainability and organizational efficiency.[6]

What Is Ecological Knowledge?

As the General Mills and Bonterra examples illustrate, businesses are increasingly deepening their ecological knowledge. They are doing so by expanding place-based and geographically specific understandings, learnings, practices, and beliefs about the inter-relationships and mutual interdependencies between living beings (including humans) and their (nonhuman) environment.[7] Ecological knowledge is derived from systematic, long-term observations of natural phenomena and the relationships among species, ecological processes, and ecosystem functions.

Current sources and keepers of such knowledge range from scientific groups to diverse communities of natural resource users, including networks of professionals that generate knowledge through many years of observation and direct interaction with the natural environment.[8] Examples include local communities, indigenous groups, and other users of natural resources that can offer substantial knowledge about ecosystems and ecosystem dynamics. Such knowledge ranges from understanding an individual species or species ecology to knowledge about the larger ecosystem of which they are part.[9]

Hunters, for example, develop knowledge about a specific ecosystem from their near-daily observations of the area covered, including one species preying on another species, fluctuations in populations of these predators, and other changes in ecology and the behavior of specific animals. Fishermen/women create experience-based knowledge about marine ecosystems, including fish behavior, specific fishing locations, local marine stocks, and how these things change over time.

Farmers can similarly develop a deep understanding of local ecological conditions, including agricultural production systems, species traits, watershed services, and traditional soil management measures. The agro-ecological knowledge held by farmers includes climatic conditions relevant to crop production, natural enemies of crops and pesticide alternatives, bird species and conservation, plant types and their insecticidal/medicinal properties, and seed varieties that have adapted to soil and weather patterns.[10] Other types of ecological knowledge include traditional cropping practices, weather characteristics, irrigation practices, crop rotation, and the behavior of drought-resistant species and varieties.[11]

Businesses both large and small are also becoming important sources and keepers of ecological knowledge, often through partnerships. One example is Sea Cider Farm & Ciderhouse on Vancouver Island in Canada. Sea Cider turned to ecological knowledge about pollination, soil health, water usage, and invasive species to improve the company's overall sustainability performance. Ivy invades forest ecosystems, and another invasive plant, gorse, is destroying coastal sand ecosystems on Vancouver Island. Sea Cider partnered with the Nature Conservancy of Canada (Canada's largest national land conservation organization) and leading biologists and environmental studies researchers from Vancouver Island's University of Victoria to strengthen its knowledge about invasive species and the island's unique ecology. The company is using the resulting knowledge to manage invasive species in its apple orchard.

How Businesses Acquire & Use Ecological Knowledge

Transforming a firm's in-depth understanding of its embeddedness in (and interdependence with) nature into organizational knowledge can enhance the firm's performance and reduce its negative impact on nature.[12]

Companies in a variety of industries increasingly use their knowledge about ecosystem dynamics to strengthen their capacity to improve their relationships with nature and contribute to ecologically and socially sound development.

Below, we examine how two companies in very different industries discovered important knowledge about the complex relationships between their

organizations and the ecosystems they rely on. This, in turn, enabled them to source critical raw materials for their businesses.

Barilla

Barilla, the world's largest user of durum wheat semolina, implemented a sustainable agriculture project between 2010 and 2014 to bring systemic changes to the cultivation of durum wheat. At the time, durum wheat was responsible for more than 80% of the ecological footprint of pasta, including very high water consumption and reduced land biodiversity.

The project's main goal was to generate knowledge about complex agriculture systems to help achieve a consistent supply of high-quality wheat while preserving soil and ecosystem functions, thus reducing the negative ecological impact of pasta.

A cross-functional team of Barilla managers from global supply chain, R&D, and others formed a multi-stakeholder partnership with Horta, an organization with expertise in scientific research and technological innovation; Life Cycle Engineering, an Italian consulting firm with expertise in lifecycle assessment and eco-design; and — importantly —with farmers, farmer organizations, and local authorities from the northern, central, and southern parts of Italy.

In the first phase, an in-field experiment applied new ecological knowledge about crop rotation and generated many surprising results: CO2 emissions went down by nearly 50%, and soil productivity, final yield, and product quality improved dramatically, increasing farmers' profitability.

In the next phase, the ecological knowledge this multi-stakeholder partnership generated was codified into a "Handbook for Sustainable Cultivation of Durum Wheat" to provide farmers with practical suggestions on crop rotation, soil preparation, the choice and amount of seeds, controlling weeds, disease protection, and more. Using this knowledge, Barilla's partner Horta built the interactive Web tool granoduro.net to provide practical decision support to farmers on weed and pest management, water balance, crop lifecycles, and environmental impacts.[13]

The effort led Barilla to launch "Barilla Sustainable Farming" in 2013, a project that now promotes sustainable agriculture practices to more than 10,000 farms around the world.

IKEA

For IKEA, cotton is an essential raw material. In the early 2000s, health risks to farmers, soil erosion, and water scarcity made the harmful environmental and social impacts of conventional cotton production an urgent issue for the company. The firm ventured far upstream into its cotton supply chain to work with farmers, farmer organizations, and local nongovernmental organizations to understand how cotton is cultivated and processed in places like Pakistan and India.

The resulting knowledge helped the company initiate sustainable cotton-farming practices that not only reduced the negative environmental impacts of cotton production, but also lowered the cost of production and improved the quality of raw materials.[14]

IKEA then formed the Better Cotton Initiative (BCI), a multi-stakeholder partnership with Adidas, Gap, H&M, International Federation of Agricultural Producers, International Finance Corporation, World Wildlife Fund, and several local development organizations. The projects initiated by BCI have helped more than 1 million farmers in 20 countries to significantly reduce the use of pesticides, water, and fertilizers in cotton production while increasing soil health and biodiversity. The organization has also helped improve socioeconomic conditions in farming communities. BCI's 600 members now source and supply sustainable cotton at all stages of the textile supply chain.

These two stories illustrate how a new breed of business organizations is pushing beyond traditional boundaries by explicitly incorporating their understanding of nature into their strategies.[15]

They also demonstrate that a large-scale, system-level change toward more ecologically sustainable production systems is an evolutionary process, one that requires organizations to access as many sources of ecological knowledge as possible.

How Ecological Knowledge Can Contribute to Positive Systems Change

Over the last four decades, we've observed a growing movement toward sustainable agriculture, with a focus on creating food production systems that do not degrade the natural resource base, thus ensuring the ability of future generations to produce and flourish.

The examples above show how innovative businesses are adopting the principle of regeneration: creating and strengthening the capacity of nature, organizations, and communities such that each can support the other in mutually beneficial ways.

Project Drawdown, a nonprofit led by climate activist and entrepreneur Paul Hawken, compiles the world's leading information resources on science-based climate solutions. It ranks regenerative agriculture systems as a critical opportunity for humanity to achieve climate health while ensuring financial well-being for farmers.

Given the current destructive impact of agriculture on nature (and with that, the long-term detrimental effects on human society as a whole), the question arises whether this movement can be the start of a large-scale transformation of current food production and farming systems.

In theory, a widespread systems change in the sector is possible if it can invent food production systems that work with nature, lower unsustainable use of water and other nonrenewable natural resources, regenerate healthy soil by restoring its carbon and nutrient content, and ultimately enhance biodiversity and natural habitat in farming areas.

The efforts of pioneering firms and other organizations discussed earlier suggest that a drastic shift toward regeneration could indeed help achieve such a system-level transformation in the agriculture sector.[16]

Core to the discovery, implementation, and promotion of the lessons learned about regenerative practices are strong partnerships between businesses, including farmers, researchers, environmental nonprofits, investors, and other community stakeholders. Such deliberate collaboration helps companies scale up regenerative food production systems and adopt regeneration-oriented sustainability principles.

For example, General Mills partnered with Nature Conservancy, Soil Health Institute, Soil Health Partnership, and National Wheat Foundation to support research into achieving widespread adoption of regenerative soil health practices.[17]

Equally inspiring, since 2017, Patagonia has worked with Rodale Institute (which pioneered the organic food movement in the US), Dr. Bronner's soaps, Wild Farm Alliance, National Science Foundation, and Nature's Path (a leading producer of certified organic foods) to form the Regenerative Organic Alliance to promote practices and standards that align with the principles of regenerative agriculture.

Businesses like General Mills and Patagonia do not only adopt the principle of regeneration based on ecological knowledge to embed sustainability throughout their own organizations; they promote its understanding and adoption through powerful networks of other social actors.

Joining the many parties engaging in and pushing for change are governing bodies. Many municipal, regional, and higher-level government entities are taking a proactive approach to building knowledge about and using the principles of regenerative agriculture.

In 2021, the University of Missouri with support from the Missouri Department of Conservation launched the Center for Regenerative Agriculture, the first of its kind in the Midwest. In collaboration with the local government, local farmers, farm and conservation organization representatives, and local agribusiness, the center develops innovative tools and regenerative farming methods that can lead to more resilient local food systems.

Regeneration Canada, a nonprofit organization founded in 2017, is working closely with governments, farmers, scientists, agronomists, businesses, indigenous communities, and citizens to create awareness of how soil regeneration can support a healthy food system.

The Regenerative Agriculture and Agritech Network launched by the Government of British Columbia (BC) offers a useful support system for local farmers to help them learn about, adopt, and expand regenerative farming practices. With this initiative, the BC government hopes to build a more resilient provincial food system to better respond to long-term, climate-related challenges.[18]

All these developments suggest that regenerative agriculture is much more than a buzzword. We must also note the changing role of consumers. Consumers are starting to pay attention to the fact that foods produced using regenerative principles can help with environmental challenges, including climate change.

The phenomenon has become part of the larger consumer conversation and is beginning to shape consumer choices. Some argue that regenerative agriculture has the potential to produce the next generation of foods that are beyond organic.[19]

Momentum is growing thanks to recent popular documentaries such as *Kiss the Ground* and *The Biggest Little Farm* and widespread coverage of issues like local food security, food safety, global supply chain complexities, and the United Nations Sustainable Development Goals.

Many large investors, yet another vital party in prompting change, have recently taken special interest in promoting regenerative agriculture. For example, US-based investment fund Farmland LP, a certified B Corporation, invests in converting monocropping-focused industrial agricultural land into organic farmland using regenerative farming practices. The company manages more than US $175 million in assets and more than 15,000 acres of sustainable farmland in Northern California, Oregon, and Washington.

Clearly, more businesses need to adopt the principles of regeneration to generate large-scale system change. This requires recognizing the power of ecological knowledge to: (1) fundamentally strengthen an organization's capacity to manage its relationships with nature more sustainably in the long term; and (2) provide a profitable business model in the short term.

The time is right for innovative tools, metrics, frameworks, and models that can convince businesses, governments, investors, and practitioners that systemic change is both needed and possible. For agriculture in particular, regenerating and revitalizing the entire ecosystem of the farm (from soil biodiversity and organic matters to plants and other species) can and needs to contribute to mitigating climate change effects, strengthening biodiversity, and ensuring a satisfactory livelihood for farmers.[20]

By reintroducing crop-rotation practices, restoring natural pollinators, improving irrigation techniques, and/or reintroducing some traditional crop varieties, organizations can profitably strengthen ecosystems and ensure the well-being of the planet's entire social-ecological system.

Conclusion

From giants like Nestlé and General Mills to family-owned operations like Nature's Path, businesses are going beyond typical routines, structures, processes, and markets to embed new knowledge about their business-nature interface into their strategies and management processes. Global multinational companies like Unilever increasingly acknowledge that a healthy natural ecosystem with the ability to regenerate is essential for the resilience of both their business's supply chain and long-term sustainability.

This approach challenges established ways of doing business and requires new and radical thinking, but embedding ecological knowledge throughout an organization can create deeply innovative and economically successful business models while strengthening biodiversity and restoring/regenerating ecosystems.

After years of incremental efforts in response to environmental regulations and stakeholder pressure, this is both surprising and encouraging. Further strengthening of this emerging movement may well promise more fundamental system shifts toward truly sustainable business practices.

In this article, we have shown that businesses can boost knowledge creation by entering into wider partnerships and alliances with suppliers, research institutions, and scientific communities and by developing dynamic relationships with governments, customers, investors, and local communities.[21]

Notably, such partnerships help businesses (and all network members) develop a more sophisticated understanding of interdependent social, economic, and ecological systems. They also allow firms to significantly shift their strategic approach and outcomes, going beyond business as usual to learn new ways of doing things.

Once organizations across a variety of industries better understand their deep interdependence and interactions with social and ecological systems and apply the resulting knowledge to their business practices and strategies, we're likely to see positive, system-level changes on local, regional, national, and even global levels. The agri-food industry provides an excellent example of how ecological knowledge can contribute to the systems-level change that will be required to thrive within our ecological limits and ultimately to sustain the 10 billion people projected to be living on our planet by 2050.

References

[1]Hawken, Paul. *Regeneration: Ending the Climate Crisis in One Generation*. Penguin Books, 2021.

[2]Ranganathan, Janet, et al. "How to Sustainably Feed 10 Billion People by 2050, in 21 Charts." World Resources Institute, 5 December 2018.

[3]Thorpe, Devin. "How Investing in Regenerative Agriculture Can Help Stem Climate Change Profitably." *Forbes*, 12 December 2018.

[4]Mbow, Cheikh, et al. "Chapter 5: Food Security." In *Special Report on Climate Change and Land*, The Intergovernmental Panel on Climate Change (IPCC), 28 March 2022.

[5]Garcia, Tonya. "Honey Nut Cheerios to Dedicate 3,300 Acres of Land to Bee Habitats by 2020." *Fox Business*, 26 April 2016.

[6]Sheppard, Laurel. "Bonterra Digs In, Reduces Carbon with Regenerative Farming." TriplePundit, 15 August 2019.

[7]Olsson, Per, Carl Folke, and Fikret Berkes. "Adaptive Comanagement for Building Resilience in Social–Ecological Systems." *Environmental Management*, Vol. 34, June 2004.

[8]Whiteman, Gail, and William H. Cooper. "Ecological Embeddedness." *Academy of Management Journal*, Vol. 43, No. 6, 2000.

[9]Olsson, Per, and Carl Folke. "Local Ecological Knowledge and Institutional Dynamics for Ecosystem Management: A Study of Lake Racken Watershed, Sweden." *Ecosystems*, Vol. 4, 2001.

[10]Silva-Andrade, Horasa Lima, et al. "Do Farmers Using Conventional and Non-Conventional Systems of Agriculture Have Different Perceptions of the Diversity of Wild Birds? Implications for Conservation." *PLoS ONE*, Vol. 11, No. 5, 2016.

[11]Gómez-Baggethun, Erik, et al. "Traditional Ecological Knowledge and Community Resilience to Environmental Extremes: A Case Study in Doñana, SW Spain." *Global Environmental Change*, Vol. 22, No. 3, August 2012.

[12]Pogutz, Stefano, and Monika I. Winn. "Cultivating Ecological Knowledge for Corporate Sustainability: Barilla's Innovative Approach to Sustainable Farming." *Business Strategy and the Environment*, Vol. 25, No. 6, September 2016.

[13]Ruini, Luca Fernando, et al. "Increasing the Sustainability of Pasta Production Through a Life Cycle Assessment Approach." IFIP International Conference on Advances in Production Management Systems, September 2013.

[14]Pogutz, Stefano. "IKEA and the Better Cotton Initiative." Oikos, 2014.

[15]van Hille, Iteke, et al. "Strategizing Nature in Cross-Sector Partnerships: Can Plantation Revitalization Enable Living Wages?" *Organization & Environment*, Vol. 34, No. 2, 2021.

[16]Rahman, Saeed, Stefano Pogutz, and Monika Winn. "Inventing Regenerative Sustainability: Theoretically, Empirically, Practicall." *Proceedings of the International Association for Business and Society*, Vol. 31, 2020.

[17]Anzilotti, Eillie. "General Mills Has a Plan to Regenerate 1 Million Acres of Farmland." *Fast Company*, 4 March 2019.

[18]Arnason, Robert. "British Columbia Forms Regenerative Ag Network." OrganicBiz, 13 August 2021.

[19]Blair, Jennifer. "Regenerative Agriculture Is Becoming the Next Big Thing for Consumers." Manitoba Co-operator, 9 April 2021.

[20]Hahn, Tobias, and Maja Tampe. "Strategies for Regenerative Business." *Strategic Organization*, Vol. 19, No. 3, December 2021.

[21]Lundvall, Bengt-Ake. "From The Economics of Knowledge to The Learning Economy." In *The Learning Economy and The Economics of Hope*, edited by Padmashree Gehl Sampath and Rajneesh Narula. Anthem Press, 2016.

Saeed Rahman is Assistant Professor of Strategy at the School of Business, University of the Fraser Valley, Canada. His research interests include ecological knowledge, regenerative business, regenerative agriculture, social-ecological systems perspective, and systems resilience. Dr. Rahman's research investigates whether and how new knowledge about organization-nature interdependencies allows a business to effectively adapt to threats from ecosystem degradation, including climate change or loss of biodiversity, and not further reduce broader ecosystem resilience. His research on ecological knowledge focuses on exploring how agriculture and agri-food businesses can successfully develop sustainable strategies based on critical knowledge about the business-nature interface and traditional/indigenous and scientific knowledge on agricultural practices and ecosystem dynamics. Dr. Rahman received a Social Sciences and Humanities Research Council Doctoral Fellowship and was awarded a Graduate Fellowship from the Pacific Institute for Climate Solutions. Prior to academia, in a career spanning more than 10 years, he worked in the development sector with various organizations, including KPMG, Deloitte Touche Tohmatsu Ltd., and World Bank, and in the corporate sector for the multinational company Reckitt Benckiser UK Ltd. Dr. Rahman earned a PhD in strategy, organization theory, and sustainability from the Peter B. Gustavson School of Business, University of Victoria, Canada. He can be reached at saeed.rahman@ufv.ca.

Natalie Slawinski is Professor of Sustainability and Strategy and Director of the Centre for Social and Sustainable Innovation at the Peter B. Gustavson School of Business, University of Victoria, Canada. Her research focuses on understanding sustainability, temporality, and paradoxes in organizations. Dr. Slawinski's most recent research examines these themes in the context of the social enterprise. She has been published in Organization Science, Strategic Management Journal, *and* Organization Studies. *Dr. Slawinski serves as Advisor to the Centre for Social Enterprise, Memorial University, and is a Research Fellow at the Judge Business School Centre for Social Innovation, University of Cambridge. She is also a member of the editorial review board of* Organization & Environment. *Dr. Slawinski earned a PhD from Ivey Business School, University of Western Ontario, Canada. She can be reached at nslawinski@uvic.ca.*

Monika Winn, Professor Emerita, served as Professor of Sustainability and Strategy, Francis G. Winspear Scholar, and cofounder and Director of the Centre for Social and Sustainable Innovation at the Peter B. Gustavson School of Business, University of Victoria, Canada, until July 2020. She is a pioneering scholar in the area of business sustainability and has won many awards. Her leadership helped sustainability and social responsibility become integral parts of the culture and values at Gustavson. Dr. Winn's research focuses on organizational and institutional change related to sustainability. She has been published in Academy of Management Review, Organization Studies, Business & Society, Journal of Business Venturing, British Journal of Management, *among others. She has actively collaborated with colleagues in several international research networks spanning Europe, North America, and Australia. Dr. Winn earned a PhD from the University of California, Irvine. She can be reached at miwinn@uvic.ca.*

SHIFTING FOCUS

Sustainable Growth Pathway: Aligning with Macro, Accomplishing in Micro

by Himanshu Shekhar

For a long time, businesses assumed they'd be able to operate within a stable society under a stable global climate with predicable weather and free natural resources like clean air, water, and soil. Today's changing climate challenges those assumptions.

Humanity is overconsuming Earth's resources and transgressing important planetary boundaries.[1] As businesses extract and consume resources to produce goods and services, they cross lines that could lead to runaway climate change and biogeochemical-cycle disruption to the point of threatening our existence.

To ensure Earth's survival, businesses must shift their focus from assumption of abundance to assumption of limits within interconnected systems. This shift does not necessarily mean no growth — businesses can reorient their processes to work within a new, more interconnected, limited-resource system. Such reorientation could provide growth opportunities in solutions that limit resource consumption such as circular economy, alternative materials and processes, ecosystem services, natural resource management, and so forth.

Immediate action is needed. Some forward-thinking companies have made commitments to lower their carbon emissions, but too many are waiting and watching, considering incremental actions and looking for direction from other players.[2]

There are two reasons for this half-baked approach. First, businesses are under pressure from society to better manage their resource consumption. Some sectors are expected to go further, exceeding regulatory mandates and reporting on their actions to improve the environment. Second, businesses are seeing climate-related issues such as extreme weather events and supply chain disruptions impact their performance.

Addressing these two problems simultaneously is difficult. This article looks at the climate change phenomenon and its impacts on survival and growth from a pro-climate decision-maker's perspective. We suggest a framework designed to help companies achieve growth and adapt to the evolving business environment while addressing climate change issues.

4 Lenses

Businesses are being forced to respond simultaneously to climate change at the macro (external) level and the micro (internal) level. At the macro level, we have global discourse, including international treaties like the 2015 Paris Agreement. The macro level also includes changes to the overall business environment as the effects of climate change become more apparent. In the near future, businesses not acting on climate are likely to face legitimacy issues and competitive challenges. Businesses can address these concerns with operational efficiencies and transparent disclosures, by investing in and adopting climate-friendly technologies and processes, and by developing and offering green products.

The micro level revolves around a business's location, supply chain, natural resources, practices, and processes. Companies may experience process disruptions, issues stemming from extreme weather events, resource conflicts with the local community, and the need to implement macro-level targets. Possible actions include adapting to future climate changes, building more resilient supply chains, creating local solutions, solving communities' climate-related problems, and helping to prevent the local ecosystem from collapsing.

There are four main lenses through which businesses should view their macro and micro climate-related goals: climate science, climate governance, business stakeholders, and community stakeholders (see Figure 1).

1. Climate Science

Climate science provides our current understanding of climate change and its potential impact on our existential resource assumptions. It's also our basis for

Figure 1. How the four lenses play out in macro and micro environments

acting to minimize such changes. Planetary boundaries identify global natural resource cycles and their limits, but a complete understanding of those limits and their interdependence is still developing.[3] The climate change phenomenon is complex and interdependent on other physical and biological systems. The current science has good models for predicting global-scale climate-related phenomena (macro), but local projections (micro) must be further developed if we are to generate effective local area interventions.[4]

2. Climate Governance

Climate governance provides a way to better understand limited resource allocation and management among various stakeholders. At a macro level, climate governance targets businesses to reduce their impact on resources and cut emissions. International agreements and national governments' regulatory and institutional regimes set guidelines for business operations to limit externalities. Since the challenge is global and interdependent, international agreements are critical to overarching governance and response. At a national level, governments must balance the needs of their economy with the collective good.

The 2015 Paris Agreement was a testament to the potential for global action to be converted into national goals. Climate activists and nongovernmental organizations (NGOs) also push governments to regulate businesses strictly. These regulations may evolve to become mandatory with greater inputs from climate science, adversely impacting noncompliant companies.

At the local level, regulation implementation and natural resources constraints become very important.[5] In some cases, natural resource conflicts within the community impact business sustainability and require better local governance.

3. Business Stakeholders

A firm's operations, resource requirements, associated emissions, and available technologies to reduce climate impact are a product of its industry and location. At a macro level, the role of a company's industry peers in driving emission reduction is critical. Customers who demand greener products are also key.

Suppliers and neighboring businesses comprise the firm's micro environment. They understand the local impact and share the local responsibility. Supply chain partners are crucial in making businesses more resilient to climate impact, as we saw when automakers had to stop manufacturing certain models during the pandemic due to a shortage of chips and other electronic parts.

4. Community Stakeholders

These stakeholders care about, or are impacted by, the natural environment; they may or may not be transactionally related to the business. They ask questions about the business's impact on climate change and planetary boundaries and (sometimes) on themselves. At a micro level, these stakeholders are concerned with the area's shared natural resources and any local customs that help sustain them.

Constraints on Actions

Climate change presents novel business risks, and multiple factors may constrain business actions, including:

- **Interdependencies.** The biggest challenge businesses face in taking climate action is the interdependencies between systems. When solutions benefit some while harming overall, they are referred to as maladaptations.[6] For example, air-conditioning to cool a building increases the temperature and emissions in the surrounding area. Similarly, some solutions reduce the impact on one planetary boundary while increasing others. For example, efforts to reduce carbon emissions through rapid forestation in arid regions may alter the land-use pattern. The interdependencies of Earth's climate necessitate clear scientific understanding and thoughtful solutions. Often, system complexities prevent us from taking long-term steps because the ripple effects from interdependencies were not initially apparent.
- **Currently available technologies.** Technologies that address climate change are still evolving, and many are costly to implement. Some, like renewable energy and electric mobility, may become more efficient as they mature. Immediate investment by businesses in these technologies may lock in investments and lead to lower efficiency compared to future technologies.
- **Limits to resources.** Clearly, businesses do not have unlimited amounts of capital or managerial time and climate-related initiatives must compete with others for those resources.

Potential Assistance

Businesses are vital to countering climate change, so policy makers and other stakeholders must provide assistance to proactive businesses if they expect this to happen without shrinking the economy. Examples of assistance include:

- **Legitimacy.** The acceptance of a company or industry's standard business practices and operating procedures by its employees, stakeholders, and the general public is known as a social license to operate.[7] Businesses can earn (or continue) this license by engaging in problems like climate change. At the macro level, this legitimacy can help businesses gain access to resources and capital. At the micro level, it helps businesses earn support from key stakeholders such as employees and the community.
- **Implementation support.** Climate change science can be challenging to understand and integrate into business operations and processes. Organizations such as CDP, Greenhouse Gas (GHG) Protocol, Global Reporting Initiative (GRI), Ceres, and the We Mean Business Coalition can help bridge this gap with initiatives like Science Based Targets.[8] They can also help businesses with initiatives such as climate-related disclosures, target framing, and campaigns to spread awareness.
- **Market mechanisms.** Governments and regulators promote market-based mechanisms (like carbon trade) that enable proactive firms to invest in cutting-edge technologies and increase revenues.
- **Traditional knowledge.** Communities generally have proven mechanisms to manage local natural resources that science may not have explored. These initiatives help explain the local environment and can be an asset in designing micro-level interventions, helping both the community and its businesses. For example, in India, a watershed development program run by ITC (a conglomerate that began as Imperial Tobacco Company) mobilizes farmers to form water user groups aimed at capturing water for irrigation and improved soil fertility. By making farms less dependent on the yearly monsoon, farmers can grow more than one crop per year.
- **Risk management.** Climate change causes changes in resource availability, which can increase risk. Manufacturers and companies that develop natural resources are usually the hardest hit, but service-based companies can be impacted by extreme events like floods and pandemics. There's also a risk of climate activists targeting businesses and interrupting business routines. Identifying the potential for these risks can help businesses better manage them.

Aligning with Macro

There are many opportunities for businesses to align with the macro environment. Let's look at the opportunities for each lens (see Figure 2):

- **Embrace climate science.** Science suggests ways for businesses to reduce resource consumption. For

Figure 2. Aligning with the macro environment

example, science-based targets provide industry-specific pathways to reducing impact. Companies should embrace the best-available science and implement available solutions, but they should be ready to switch to better solutions if the opportunity arises. Business leaders should also understand the dependencies and potential opportunities from climate science and new technologies. They should avoid investing in business segments that the new climate-sensitive system may challenge.

- **Follow climate governance.** Governments commit to national goals regarding climate change and resources. Businesses can and should align to these to the extent possible, including following international institutions' measurement and tracking parameters. They should also consider leveraging existing assistance in the form of generic green technologies, monitoring and reporting systems, market mechanisms, and capital supported by government and nongovernment entities. For example, companies in the RE100 alliance commit to using 100% renewable energy in their operations.[9]

- **Work with business stakeholders.** In this business environment, all parties benefit when companies work with industry peers to create common standards and practices. Groups such as the Cement Sustainability Initiative, which traverses national boundaries, can help industries create and roll out measures to help businesses adapt to new climate scenarios.[10] Similarly, businesses can work with consumers to create products and services that are environmentally benign yet provide equivalent or improved satisfaction to customers.

- **Communicate with community stakeholders.** NGOs and other interested parties track the extent to which businesses are fulfilling their commitments to the environment. Businesses can align themselves through frequent communication and transparent disclosures using institutionally determined standards.

Aligning with the macro environment provides a view of the changing system that incorporates limits, shows emerging business opportunities, and supports the resources necessary for future growth.

Accomplishing in Micro

There are a number of challenges for business in the micro climate change scenario, yet this is where critical progress toward adapting to climate change must occur. Large multinationals may have distinct requirements for each branch, factory, supply chain, and/or raw material site. The idiosyncratic nature of micro factors makes it essential for companies to conduct careful assessments and use their limited resources wisely.[11] Let's look at how each lens relates to climate-related actions at the micro level (see Figure 3):

- **Support climate science.** Regional and local climate models are still evolving, but businesses need solid local connections for success. Companies can start by investing in local climate science, seeking to better understand the local environment and its natural resource flows. They can also invest in research to develop supply chain contingencies to mitigate climate change issues.

- **Get involved with climate governance.** At the micro level, climate governance is about getting all stakeholders on board. Companies can use scientific research and local resource governance understanding to design local frameworks aligned to the macro level but beneficial to the local environment.

Figure 3. Accomplishing in the micro environment

- **Collaborate with business stakeholders.** Local climate impacts are (and will continue to be) based more on geography than business relations. Companies should talk with neighboring businesses about pooling resources and with supply chain partners about reducing resource/product vulnerabilities.
- **Engage with community stakeholders.** Businesses share local resources like clean water and air with their communities, so engagement in these areas is the most critical tool at the micro level. The local community's traditional knowledge should be used to better understand resource interdependencies and externalities. Businesses should respect local requirements and involve the community in accomplishing climate resilience for both the community and its businesses.

Accomplishing in the micro environment makes firms more resilient in the face of climate change while safeguarding growth.

Conclusion

Climate action is imperative. The current business focus is on carbon emissions, and energy sector greening is the first step. But our increased encroachment on planetary boundaries calls for a new system: a deeper understanding of the climate-stability assumption and efforts to grow within limits. The "aligning with macro and accomplishing in micro" framework is one way to approach the challenge.

References

[1]Steffen, Will, et al. "Sustainability. Planetary Boundaries: Guiding Human Development on a Changing Planet." *Science*, Vol. 347, No. 6223, 13 February 2015.

[2]DeMendonca, Taryn, and Yan Zhou. "When Companies Improve the Sustainability of the Natural Environment: A Study of Large US Companies." *Business Strategy and the Environment*, Vol. 29, No. 3, March 2020.

[3]Steffen et al. (see 1).

[4]Clift, Roland, et al. "The Challenges of Applying Planetary Boundaries as a Basis for Strategic Decision-Making in Companies with Global Supply Chains." *Sustainability*, Vol. 9, No. 2, 15 February 2017.

[5]Goswami, Subhojit. "How Is Coke-Pepsi Boycott in Tamil Nadu Linked to Concern Over Groundwater Depletion?" Down to Earth, 3 March 2017.

[6]"Maladaptation." Wikipedia, accessed May 2022.

[7]Demuijnck, Geert, and Björn Fasterling. "The Social License to Operate." *Journal of Business Ethics*, Vol. 136, No. 15, January 2016.

[8]Science Based Targets website, 2022.

[9]RE100 Climate Group website, 2022.

[10]"Cement Sustainability Initiative." World Business Council for Sustainable Development (WBCSD), 2022.

[11]Williams, Amanda, Gail Whiteman, and Steve Kennedy. "Cross-Scale Systemic Resilience: Implications for Organization Studies." *Business & Society*, Vol. 60, No. 1, 1 January 2021.

Himanshu Shekhar is a PhD candidate at Indian Institute of Management Bangalore, India. His research interests focus on understanding corporate decision making on sustainability and climate change. Prior to academia, Mr. Shekhar spent about 10 years working in software, sustainable finance, carbon management, and public policy. Over the years, he has developed corporate strategies on renewable energy, energy efficiency, sustainability, and climate change, collaborating extensively with internal and external stakeholders and providing consultancy to the government on infrastructure development, renewable energy financing, risk guarantee facilities, and climate finance in developing national-level schemes and frameworks. Mr. Shekhar has written multiple white papers on climate-related business, such as renewable energy, electric mobility, and water infrastructure on policy and financing. He earned an MBA in finance and strategy from XLRI Jamshedpur, India. He can be reached at Himanshu.shekhar19@iimb.ac.in.

AN OPEN INVITATION

Coordinating Circular & Degrowth Systems for Strong Sustainability

by Joseph Sarkis, Paul Dewick, Maurie J. Cohen, Joerg S. Hofstetter, and Patrick Schröder

The pandemic threw into stark relief how quickly the world and its systems can change. What was once considered impossible — the shutdown of economic systems for the benefit of society as a whole — became possible. Governments, communities, businesses, and almost every other institution paused for an extended period. As systems have slowed, some of them (like supply chains) have become less resilient or been completely disrupted. In the midst of this chaos, we are learning a lot about transitions to sustainability.

As members of Future Earth's Systems of Sustainable Consumption and Production Knowledge-Action Network (SSCP KAN), we conduct research that creates knowledge and catalyzes actions to support resilient, sustainable systems. The academic community at large has been debating the issues and contexts of sustainable consumption and production for a number of decades. The recent public health crisis elevated this discourse to a new level.

Critics have raised credible questions about whether the circular economy can result in strong sustainability.

A working group within SSCP KAN has been studying (and unabashedly championing) the circular economy. In "The Circular Economy — A New Sustainability Paradigm?" Geissdoerfer et al. define the circular economy as a "regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops." The authors argue that a circular economy can be achieved through "long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling."[1]

The idea of the circular economy has been around for decades. Although a single definition has been elusive and assessment frameworks remain fuzzy, in the last five years, policy makers, industrial managers, and financiers have ramped up their interest and support for it.[2] Proponents point to its potential to address several of the grand challenges facing society: contributing to the United Nations (UN) Sustainable Development Goals (SDGs), mitigating climate change, and reinvigorating our economic systems after the pandemic.

Critics have raised credible questions about whether the circular economy can result in strong sustainability, defined as a deep change resulting in "continuance in the long term," where no future resource or social system is threatened by today's actions.[3] Another perspective to consider is that weak sustainability allows for the diminishment of natural systems if human systems benefit, while strong sustainability does not allow such a transfer.[4]

Some argue that degrowth and post-growth are more closely aligned to strong sustainability (degrowth is a drastic reduction in consumption and production as a way to improve human well-being). Many degrowth scholars argue that the circular economy is a way of depoliticizing growth such that it happens in an unsustainable fashion. They worry that organizations can use the language of circular economy without substantially changing their practices — in essence, greenwashing.[5]

In an earlier commentary, we argued that pitting circular economy against degrowth creates a false dichotomy.[6] A recent editorial in *Nature* agrees with our assessment.[7] In this article, we discuss how the two perspectives can be brought together, identifying the infimals (subsystems) that contribute to both supremals (the circular economy and degrowth) in the context of strong sustainability.

Specifically, we draw attention to infimals such as dematerialization, de-obsolescence, and product-service systems (PSS). Patterns, structures, and mental models associated with these systems require us to consider

their implications on humanity's well-being and other broad measures of social progress.

Circular Economy

Given this publication's audience of information systems experts, we provide a series of industry examples that show the power of a circular economy system, and its shortcomings, from a sustainability perspective.

The evolution of the circular economy has been closely aligned with the sustainability of information systems (IS) or green information technology (IT). The IS and IT communities are necessary and integral players.[8, 9] Advances in digitalization and circular economy are increasingly interconnected.

One of the most basic infimals of circularity is recycling. Materials from end-of-life of IT hardware can be acquired from disassembled computer hardware. Plastics, metals, and glass are part of every computer and computer infrastructure. A subsystem connecting actors on both the consumption and production sides is required to collect, deconstruct, store, and distribute these materials to realize the benefits.

Currently, this subsystem needs fresh inputs. Although recycling is at the forefront of most people's minds when the concept of circular economy is raised, such procedures are actually close to the bottom of the circular hierarchy (see Figure 1). In some cases, recyclability can impose greater environmental impacts than using virgin materials. A social phenomenon called "wishcycling" (the well-intentioned belief that a product or material is recyclable when it is not) can also create problems.

As a rule of thumb, infimals of repurposing (using discarded parts in a new product with a different function) and remanufacturing (using discarded parts in a new product with the same function) offer higher levels of circularity, use fewer natural resources, retain more of the value and function of the original product, and impose less environmental pressure than recycling.[10]

Reusing and repairing typically promise even higher environmental gains, but even these subsystems can flatter to deceive. For example, reusing can do more harm than good, keeping inefficient products in circulation (e.g., cathode ray televisions and monitors) while their new, more efficient replacements add to the number of total products in use.

There is also a social response called the "rebound effect" within a putative circular economy system, where organizations and individuals increase the use of services or products because there is less inhibition and guilt. This creates a challenge for eco-efficiency-based solutions that lack supporting behavioral systems.

This is why subsystems based on rethinking and redesigning are needed. PSS (also known as servicization or servicizing) is a prime example. In IT, cloud computing is an important PSS. Software that was previously sold as a product with a package, manuals, and disks now resides on interorganizational networks. Software and data storage have become services rather

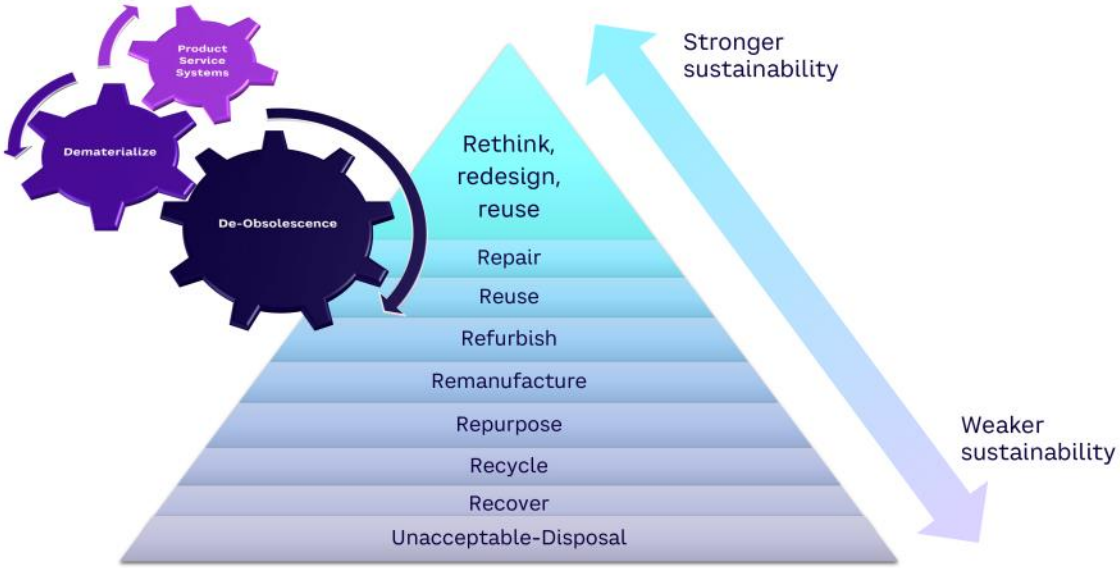

Figure 1. Circular economy and some of its subsystems along a sustainability spectrum

than products. This example also represents dematerialization or ephemeralization in the IT industry as less material is being used, reducing resources at various stages of production and distribution. However, managing some aspects of production and service delivery may require additional resources and materials. For example, the network hardware, energy usage, and data warehousing storage facilities could cause even greater resource usage.

Another IT infimal is planned de-obsolescence: transformation in the design, manufacture, and returns of materials and products to extend the life of the product; for example, modular design for computers and supporting systems (modular design may mean simply updating various aspects of computers as innovations are introduced). Many times, the innovations are incremental and consist of either engineered or manufactured parts that can quickly be adapted.

Consideration of the challenges of current circular solutions brings us to another supremal of the sustainability discourse: the degrowth economy.

Degrowth Economy

Degrowth economists argue that we should focus on using drastically fewer resources and consuming less through new political-economic paradigms to achieve strong sustainability and improve human well-being.[11]

In a 1968 speech at the University of Kansas about the inadequacies of gross national product (GNP), Robert F. Kennedy once argued that it measured "everything, in short, except that which makes life worthwhile."[12] The degrowth school of thought has substantially extended this perspective, contributed to the era of ferment involving alternative measures of progress competing to replace GNP (now called GDP, or gross domestic product), and institutionalized a new socioeconomic system to support a range of new measures.

A good example is the Beyond GDP project,[13] which has engaged global statisticians through the United Nations Statistical Commission. The institutionalization of a single Beyond GDP metric (or a dashboard approach of additional metrics to complement GDP) is seen as a way to lessen the dominance of customary economic growth concepts and rebalance political and economic systems toward social and environmental goals.[14]

There are several very practical infimals shared by the degrowth supremal and the circular economy supremal. For example, dematerialization contributes by requiring less material use to achieve similar levels of utility from products and services. Options exist to rethink and redesign products where less material is required or where certain problematic materials are replaced with less environmentally damaging alternatives. Including dematerialization in design and applying systems thinking has long been seen as a way of reducing the input of energy and materials, in some cases, by a factor of four or even a factor of 100.[15] Dematerialization on this scale is aligned with the demands of degrowth, but there remains significant room for improvement.

Durability is another example. Some industries have made strides on product durability, but the electronic products industry is lagging. A 2021 study funded by the EU analyzed opportunities for more durable smartphones, pointing to the need to design products with more resilience to environmental stresses and improper use, better batteries, and future-proofing in terms of user needs (e.g., software/firmware updates and enhanced memory/storage capacity).[16]

Dematerialization, material substitution, and durability are examples of the more practical infimals supporting degrowth. These interventions can be coupled with the circular economy infimals of de-obsolescence and PSS to support strong sustainability goals.

Similar to the circular economy repair infimal, the democratization of technology supports degrowth. For example, products designed for repair can result in less consumption by extending the life. Community-run repair cafes are springing up in cities and towns to support this endeavor, especially for electrical products, which are often beyond the technical capabilities of end users to service.[17, 18] The recently proposed US Fair Repair Act of 2022 and other pending bills to codify a right to repair support both higher degrees of circularity and degrowth transitions.

Bridging the Divide for Strong Sustainability

Production- and consumption-related infimals help change organizational and individual behavior around circular economy and degrowth systems. Eco-efficiency strategies for organizations include initiatives related to goods and services provisioning.[19] Sustainable supply chain management includes eco-efficiency activities that

can function within a circular system, ranging from end-of-pipe capture solutions to cleaner production activities. Designing for the environment is another opportunity to "green" products at early stages.

The consumption side also has links to the circular economy and degrowth. These activities could be defined as sufficiency strategies; they include expenditure mix and realization of quality of life.[20] These activities shift consumption from material to immaterial (dematerialized or PSS infimals) without causing undue societal disruption or unjust social results.

The final element of a sufficiency strategy is to try to improve well-being with the same or lessened per unit expenditure. For example, the advent of streamed movies means we can see the latest films without traveling to a theater; although the social experience may be lost, other gains can occur.[21]

Bundling services can also change behavior and enhance well-being without conventional economic growth. For example, in Switzerland, travelers can buy the mobility option that best suits their needs. Mobility services are integrated into a digital platform and a user app, providing door-to-door transport and offering individualized trip-planning and payment options. Users can buy a single ticket or a monthly subscription.[22] Note that the underlying regional partnership requires support from consumers, platform developers, service providers, communities, and regulators and that these types of innovations require new technologies, enhanced integration, and behavior change.

The roster of infimals is changing and growing, giving rise to significant challenges for managers and organizations. But there is an argument for potentially positive consequences in the long run, one of which is resilience.

Circular Economy + Degrowth = Strong Sustainability → Resilience

The pandemic showed us the need to build sustainability and resilience into our systems. Stories about electronic equipment such as ventilators needing local parts were widely circulated at the height of the pandemic. Indeed, we saw that circular economy practices resulted in greater resilience by strengthening localization of sourcing and building agility.[23] However, we must realize that resilience may also depend on redundancy and having reliable and multiple circular sources.

For a time, economic growth was less of a concern as resilience assumed greater importance. Shifting away from growthism and focusing on sufficiency was elemental to building an enhanced capacity for resilience.

Resilience is, of course, a critical feature of strong sustainability. As we became less arrogant and insistent about economic growth, the pandemic experience showed us how resilience can be built into our responses to sustainability crises like climate change.[24]

We now turn to identifying actions that can help us address these challenges.

Overcoming Challenges

Both circular economy and degrowth can help us overcome challenges through coordination at the supremal and infimal levels. Instead of a growth spiral (where a circular economy results in unsustainable growth), we must coordinate both to be part of a degrowth spiral. The technology-organization-environment framework can help determined enablers assist in resolving tensions.

General-purpose technologies can make processing more efficient and enable resource sharing in PSSs. Integrated, multi-stakeholder technologies such as the Internet of Things, blockchain technology, artificial intelligence, and global positioning systems are examples of information technologies that can move production-consumption systems toward strong sustainability. The same is true for biotechnologies and self-repairing nano technologies that can contribute to the development of new materials consistent with the objectives of dematerialization and de-obsolescence.

Opportunities for organizational innovation include new methods for contractual relationships. For example, leasing rather than owning is a way to maintain product- and material-stewardship control.[25] Similar innovations will be needed to support product and material recovery in order to encourage circular and degrowth design and production and create value from use optimization.

There is a business case for using circularity and degrowth simultaneously. For example, Bosch Power Tools produces high-quality, durable work equipment.

It is able to build for de-obsolescence by upgrading its power drills using remanufacturing principles. This uses less virgin material while allowing the company to effectively compete against poorer-quality, lower-priced alternatives.

Managing in this circular environment with degrowth is not a trivial decision, and each business case will vary based on products, ability to process materials, and access to end-of-life products.[26]

Governments must design innovative policies that change the rules of the game and create markets that favor organizations and end users embracing circularity and degrowth and letting them showcase their successes in public forums. Equity is (or should be) a concern for policy makers. No one should be left behind as these systems initiatives are applied—a key element in the EU's circularity-friendly Green Deal initiative.

This transition will require alternative skills and jobs. New work models will be needed, not only for circular economy and degrowth systems, but for work environments such as Industry 4.0 to support closer alignment with the principles of strong sustainability.

Transdisciplinary Opportunities

We must create opportunities for organizations and individuals to work across sectors and disciplines — a transdisciplinary effort. For example, industrial, governmental, academic, and nongovernmental organizations (NGOs) have jointly tried to develop a roadmap for the circularity of electronics through the Circular Electronics Partnership (CEP).[27] CEP involves multiple stakeholders and provides a series of action items designed to catalyze and nurture the necessary changes. The roadmap provides an overall vision for a circular economy as well as specific strategic steps and practices.

Researchers are increasingly focused on the concept of co-creation, which emphasizes close, long-term relationships between academics and industrial and societal stakeholders. Co-creation recognizes that scholarship is only one input into complex processes of adaptation. At the same time, industrial solutions singularly oriented around profits can cause serious unforeseen consequences to broader society. Collaborative efforts between scholars and non-academic stakeholders can increase legitimacy, ownership, and accountability for both the problem and the solution.[28]

Both our circular economy working group and SSPC KAN actively encourage transdisciplinary co-creation and co-action.[29] We are writing this article to encourage members of the broader community to join us. We recognize that industry, government, and local communities must join with scholars, think tanks, and NGOs to lead this effort. Consider this an open invitation for readers to join us in understanding, building, implementing, and maintaining strong, sustainable systems.

References

[1]Geissdoerfer, Martin, et al. "The Circular Economy — A New Sustainability Paradigm?" *Journal of Cleaner Production,* Vol. 143, No. 1, February 2017.

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

[3]For the debates between "weak" and "strong" sustainable consumption, see: Lorek, Sylvia, and Doris Fuchs. "Strong Sustainable Consumption Governance: Precondition for a Degrowth Path?" *Journal of Cleaner Production,* Vol. 38, January 2013.

[4]Solow, R.M. "Intergenerational Equity and Exhaustible Resources." *The Review of Economic Studies,* Vol. 41, 1974.

[5]Valenzuela, Francisco, and Steffen Böhm. "Against Wasted Politics: A Critique of the Circular Economy." *Ephemera: Theory & Politics in Organization,* Vol. 17, No. 1, 2017.

[6]Schröder, Patrick, et al. "Degrowth Within — Aligning Circular Economy and Strong Sustainability Narratives." *Resources, Conservation & Recycling,* Vol. 146, July 2019.

[7]"Are There Limits to Economic Growth? It's Time to Call Time on a 50-year Argument." *Nature,* 16 March 2022.

[8]Sarkis, Joseph, and Hanmin Zhu. "Information Technology and Systems in China's Circular Economy." *Journal of Systems and Information Technology,* Vol. 10, No. 3, November 2008.

[9]Sarkis, Joseph, Chulmo Koo, and Richard T. Watson. "Green Information Systems & Technologies — This Generation and Beyond: Introduction to the Special Issue." *Information Systems Frontiers,* Vol. 15, October 2013.

[10]Potting, José, et al. "Circular Economy: Measuring Innovation in the Product Chain." PBL Netherlands Environmental Assessment Agency, January 2017.

[11]Kallis, Giorgos, et al. "Research on Degrowth." *Annual Review of Environment and Resources*, Vol. 43, October 2018.

[12]Kennedy, Robert F. "Remarks at the University of Kansas, March 18, 1968." John F. Kennedy Presidential Library and Museum, accessed May 2022.

[13]"Beyond GDP: Making Nature Count in the Shift to Sustainability." United Nations Environment Programme (UNEP), accessed May 2022.

[14]van den Bergh, Jeroen C.J.M. "A Procedure for Globally Institutionalizing a 'Beyond-GDP' Metric." *Ecological Economics,* Vol. 192, February 2022.

[15]Hawken, Paul, Hunter Lovins, and Amory Lovins. *Natural Capitalism: Creating the Next Industrial Revolution*. Little, Brown & Company, 1999.

[16]Cordella, Mauro, et al. "Durability of Smartphones: A Technical Analysis of Reliability and Repairability Aspects." *Journal of Cleaner Production*, Vol. 286, March 2021.

[17]van der Velden, Maja. "'Fixing the World One Thing at a Time': Community Repair and a Sustainable Circular Economy." *Journal of Cleaner Production*, Vol. 304, July 2021.

[18]Moalem, Rikke Marie, and Mette Alberg Mosgaard. "A Critical Review of the Role of Repair Cafés in a Sustainable Circular Transition." *Sustainability*, Vol. 13, No. 22, November 2021.

[19]Tukker, Arnold, et al. "The Impacts of Household Consumption and Options for Change." *Journal of Industrial Ecology*, Vol. 14, No. 1, January/February 2010.

[20]Bocken, Nancy M.P., and Samuel W. Short. "Towards a Sufficiency-Driven Business Model: Experiences and Opportunities." *Environmental Innovation and Societal Transitions*, Vol. 18, March 2016.

[21]Jungall-Michelsson, Jessica, and Pasi Heikkurinen. "Sufficiency: A Systematic Literature Review." *Ecological Economics*, Vol. 195, May 2022.

[22]Jittrapirom, Peraphan, et al. "Mobility as a Service: A Critical Review of Definitions, Assessments of Schemes, and Key Challenges." *Urban Planning*, Vol. 2, No. 2, June 2017.

[23]Nandi, Santosh, et al. "Redesigning Supply Chains Using Blockchain-Enabled Circular Economy and COVID-19 Experiences." *Sustainable Production and Consumption*, Vol. 27, July 2021.

[24]Sarkis, Joseph, et al. "Overcoming the Arrogance of Ignorance: Supply-Chain Lessons from COVID-19 for Climate Shocks." *One Earth*, Vol. 3, No. 1, July 2020.

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

[26]Atusu, Atalay, Céline Dumas, and Luk N. Van Wassenhove. "The Circular Business Model." *Harvard Business Review*, July–August 2021.

[27]"Circular Electronics Roadmap: An Industry Strategy Towards Circularity." Circular Electronics Partnership (CEP), accessed May 2022.

[28]Mauser, Wolfram, et al. "Transdisciplinary Global Change Research: The Co-Creation of Knowledge for Sustainability." *Current Opinion in Environmental Sustainability*, Vol. 5, No. 3-4, September 2013.

[29]Hofstetter, Joerg S., et al. "From Sustainable Global Value Chains to Circular Economy — Different Silos, Different Perspectives, but Many Opportunities to Build Bridges." *Circular Economy and Sustainability*, Vol. 1, March 2021.

Joseph Sarkis is Professor of Management in Worcester Polytechnic Institute's Business School, where he teaches and researches in the areas of environmental sustainability and business, green supply chain management, circular economy, and technology management. He has published more than 500 articles across a variety of outlets. Dr. Sarkis is an international program coordinator for the Greening of Industry Network and cochairs Future Earth's Systems of Sustainable Consumption and Production Knowledge-Action Network (SSCP KAN) working group on the circular economy. He serves as Editor-in-Chief of IEEE Engineering Management Review*; Associate Editor for* Resources, Conservation, and Recycling*; Co-Editor of the* Greening of Industry Networks Studies *book series; and is an editorial board member of* Circular Economy and Sustainability*. Dr. Sarkis earned an MBA and PhD in management sciences, both from the State University of New York at Buffalo. He can be reached at jsarkis@wpi.edu.*

Paul Dewick is Professor of Sustainability and Innovation at Keele University's Keele Business School, UK. His research explores the role of innovation in systems of sustainable consumption and production. Previously, Dr. Dewick's work examined eco-innovation in the food and "built environment" sectors; more recently, he has explored the factors facilitating and hindering the circular economy and the sustainability implications of innovations stimulated by crises. Dr. Dewick is an Honorary Senior Research Fellow at Manchester Institute of Innovation Research, elected member of the steering committee of Future Earth's SSCP KAN, cochairs SSCP KAN's working group on the circular economy, and is an editorial board member of Circular Economy and Sustainability. He earned a PhD in economics from University of Manchester, UK. He can be reached at p.dewick@keele.ac.uk.

Maurie J. Cohen is Professor of Sustainability Studies; Program Director of Science, Technology, and Society; and Chair of the Department of Humanities and Social Sciences at the New Jersey Institute of Technology. He is Associate Faculty member with the Rutgers/NJIT Urban Systems Program and Associate Fellow at the Tellus Institute. Dr. Cohen serves as Editor of Sustainability: Science, Practice, and Policy*; Associate Editor of* Environmental Innovation and Sustainability Transitions*; and is cofounder of Future Earth's SSCP KAN. He is author or co-editor of* The Future of Consumer Society, Social Change and the Coming of Post-Consumer Society, Putting Sustainability into Practice, Innovations in Sustainable Consumption, *and* Exploring Sustainable Consumption*. He earned a PhD in regional science from the University of Pennsylvania. He can be reached at mcohen@njit.edu.*

Joerg S. Hofstetter is Associate Professor in Supply Chain Management at KEDGE Business School, France, and head of KEDGE's Sustainable Supply Chain Lab. With more than 20 years' experience, he is an academic expert in circular economy, corporate sustainability, global value chains, and multinational multi-tier supply chains. Dr. Hofstetter is President of the International Forum on Sustainable Value Chains; lecturer at the University of St.Gallen, Switzerland; and Fellow of the Center for Organization Research & Design at Arizona State University. He cochairs Future Earth's SSCP KAN working group on the circular economy and is editorial board member of Circular Economy and Sustainability*. Dr. Hofstetter earned a master of science degree from the University of Stuttgart, Germany, and a PhD from University of St.Gallen, Switzerland. He can be reached at joerg.hofstetter@kedgebs.com.*

Patrick Schröder is a Senior Research Fellow at Chatham House, an independent policy institute. He focuses on the intersection of research, international development cooperation, and policy in the circular economy. Previously, Dr. Schröder was Research Fellow at the University of Sussex, UK, where he conducted research and taught on the circular economy in developing country contexts and the United Nations (UN) Sustainable Development Goals. He earned a master's degree in international relations and a PhD in environmental studies, both from Victoria University of Wellington, New Zealand. He can be reached at PSchroeder@chathamhouse.org.

WASTE NO MORE

Can Lean Practices Save the Planet?

by Kevin Brennan

Business cases for process improvement efforts focus on economic benefits for change, assessing whether work should be performed on the basis of improved revenue or reduced costs. However, as the costs of global heating add up, we are learning that this mindset is shortsighted. Enterprises need to stop seeing sustainability as a cost imposed on them rather than an objective for process improvement.

Unfortunately, our existing process improvement methods aren't designed for this. In this article, we discuss how to redefine waste from an environmental perspective. Even Lean approaches, which focus on "waste," define waste solely on the basis of a customer's willingness to pay for a product. Although conventional Lean and Six Sigma approaches can add value here, as the removal of unnecessary steps in processes and unwanted variation will almost certainly result in reduced use of resources, that is at best a happy side effect and not the goal.

Enterprises need to stop seeing sustainability as a cost imposed on them rather than an objective for process improvement.

If we want sustainability to be deeply integrated into the concept of waste, we will need to extend the concept to incorporate unsustainable waste, including overuse of resources, consumption of scarce materials, and externalities. We must also understand how to reconcile situations where customer value and environmental value require difficult tradeoffs and establish metrics that can be used effectively to assess environmental waste. The objective of these methods should be to ensure that process practitioners incorporate sustainable thinking into their improvement initiatives and that the true cost of unsustainable practices becomes visible.

The Limitations of Current Methods

It's well known that Lean, as a process improvement and management system, originated in Toyota in the years following World War II. As Lean changed over time to accommodate knowledge work and software development, the focus has been on eliminating *muda,* or waste. This is generally defined as any activity the customer would not pay for (i.e., any activity that does not add customer value to the final product or service). Lean classically recognizes seven forms of waste, although some practitioners have expanded this list. Lean perceives that some *muda* activities must be performed but should be minimized to the greatest possible extent. Lean acknowledges two other forms of waste. One of those forms, *muri* (overburdening), seems like a natural fit for sustainability concerns, as unsustainable processes overburden our natural environment — but Lean has almost no tools to assess and eliminate it.

What about other common improvement methods? Six Sigma, developed by Motorola, focuses on delivering a consistent, high-quality product or service through eliminating variation (outcomes that diverge significantly from the expected standard). Six Sigma involves identifying cases that fall outside an acceptable range, analyzing them to determine the causes of variation, and the implementing countermeasures. From the Six Sigma perspective, variations that fall below the acceptable standard of decision should be eliminated or mitigated, while performance above that standard may provide clues as to how to establish a higher level of quality.

A third approach to process improvement, not quite as well known as the others, is Eli Goldratt's Theory of Constraints (TOC).[1] TOC focuses on maximizing the potential output of a system. It posits that there is one step in any process that limits the amount of work that can be done, analogous to the "weakest link." This is called the "constraint" or "bottleneck." Goldratt argued that any improvement on any step other than the constraint will not result in increased throughput, as work must always pass through the bottleneck.

TOC focuses on identifying the constraint, improving work at the constraint, and redesigning the rest of the process to maximize the constraint's capacity. The nature of the constraint may shift over time, and it is possible for it to be something outside your process, such as input availability or market demand.

Each of these approaches comes from a distinct perspective on what will improve a process, so they have often been combined. Other tools aimed at building more efficient, customer-focused processes have also entered the practitioner toolkit, including service design and process mining. All these methods can be used to make processes more efficient and reduce the overburden on the environment, but none are designed for it.

Reframing Value for Sustainability

At a high level, it appears simple to reorient these methods to focus on a more sustainable approach. In Lean, we could perhaps define waste from the perspective of sustainability. In Six Sigma, we could examine processes to monitor the use of unsustainable materials or chemicals, aiming to move the standard to a lower level. In TOC, we could look at the environment itself as a constraint. However, there are significant problems when we try to apply these simplistic redefinitions in the context of real process improvement work.

Lean defines "value" around the needs and wants of the customer and "waste" as any activity that does not contribute to meeting them. It's relatively easy to envision scenarios where making a process more sustainable runs up against this objective. For example, someone purchasing a house might view an environmental assessment as wasteful, since it adds to the cost without increasing their enjoyment. In fact, most environmental issues (as they concern the commons, rather than individual property) are at risk of falling prey to these types of concerns.

One might say this view is overly simplistic. After all, people are increasingly concerned about global heating and the related effects on climate and weather, and this increased awareness *will* affect customer perception of value, reducing the risk that environmentally sound decisions will be considered waste. However, this is not the same thing as designing a process to be sustainable! Even if sustainability is considered to provide customer value, there will be many cases where it isn't viewed as adding *enough* customer value to justify significant investment in it.

In addition, applying Lean principles to a process often results in improvements to the sustainability of that process as a side effect. The removal or improvement of a process step will often reduce the required resources for that step, by necessity. This aspect of Lean is not coincidental; it reflects the original purpose of Lean methods at Toyota.

Lean defines "value" around the needs and wants of the customer and "waste" as any activity that does not contribute to meeting them.

Since Toyota had to operate under supply constraints and had limited opportunity to seek outside investment, it sought ways to increase the quantity and variety of its automotive products without compromising quality or requiring investment. Lean was developed as a solution to this quandary, as removing unnecessary process steps freed up people and equipment to be used elsewhere.

If we look at the seven wastes, we find that a number of them have obvious connections to sustainability. *Transportation* from site to site generally involves fossil fuel–burning vehicles, and *overproduction* involves excess consumption of resources. *Overprocessing* likely involves the consumption of excess resources. *Defects* require increased consumption during rework, and *inventory* of raw materials could be tied back to overuse of resources.

Although this *can* make a process more sustainable, it doesn't necessarily have that effect. The main point remains: customer value and sustainability aren't the same thing, and as long as Lean practitioners are focused exclusively on the former, the latter remains a lower priority. And after all, *muda* is a useful concept. It has informed a vast number of process improvement efforts around the world and is well understood by practitioners. Attempting to redefine it, or add even more forms of waste to it, is fighting against decades of practice and training. It makes little sense to change the existing understanding of *muda* when we have alternatives.

Muda comes with well-understood tools to tackle it, and its elimination has obvious and immediate positive effects. The same is true of *mura* (the waste of variability), which comes with tools like *hejunka* and takt time, as well as some borrowed from Six Sigma.

To date, *muri* has been seen as an injunction to management more than as a practice with tools of its own. However, it is a natural fit for encompassing sustainability issues. *Muri* is the direct overburdening of the people, equipment, or systems used by a given process. It's not much of a stretch to expand it to encompass the overburdening of systems the process sits within — including the environment.

The associated cost of a value stream should be considered when evaluating sustainability because overly high costs can lead to the failure of a product or enterprise.

Muri

An unsustainable process is unsustainable precisely because it places more stress on the environment than it can ultimately bear, whether that's from resource overconsumption or byproduct dumping. In contrast, a sustainable process can continue indefinitely; it is designed so the resources it uses are recycled or replenished.

If we want to incorporate sustainability into process improvement, we must develop a toolkit and integrate it with existing Lean processes and methods, such that they work together to produce the results we're seeking.

Importantly, many practitioners believe *muri* is the true root cause of many other forms of waste. If we follow that line of logic, we should find a great deal of opportunity for improvement by actively controlling it.

The Wastes of Muri

By examining various definitions of sustainability, we see that there are also seven wastes of *muri*: expediency, contamination, hazards, offloading, exhaustion, squandering, and overloading. This list may evolve over time, but it serves as a good start for people looking to make processes and products more sustainable.

Strictly speaking, the associated cost of a value stream should be considered when evaluating sustainability because overly high costs can lead to the failure of a product or enterprise. Although a category for "expense" could certainly be added, there is little risk the cost of a process will be overlooked! One thing to keep in mind, however: a process step may include more than one waste of *muri*. Practitioners may also find it useful to review other literature on sustainable value stream mapping.[2]

Let's take a closer look at the seven wastes of *muri* and their relation to processes and sustainability:

1. **Expediency** comes as a result of short-term thinking and can be the root cause of many other wastes. Pursuing expedient solutions results in short-term "fixes" that break down over time and/or mask the real costs of a decision. Expediency reduces or eliminates careful consideration of the long-term sustainability of a product or process. Expediency results in processes that include many workarounds or short-term fixes. *Expedient processes should be carefully evaluated and redesigned so they can work acceptably in the long term.*

2. **Contamination** occurs when toxic substances are created or released into the environment. This includes pollution, construction use, and use of products with toxic chemicals without a process in place to recapture/safely reuse the substance or neutralize its effects. *Processes that cause contamination should be redesigned, and past contamination should be cleaned up.*

3. **Hazards** are any element of a product or process that puts personal safety at risk, whether directly or indirectly. The hazard may apply to operators involved in the work, customers, or external stakeholders. The waste of hazard means the process cannot be performed as it is without the possibility of injury or death. *Processes or equipment that create hazards should either be redesigned to ensure safety or have countermeasures put in place to minimize the risk.*

4. **Offloading** occurs when the costs or effort required to make a process sustainable are placed on

another. This can occur because the process does not include steps to replace renewable resources (such as cutting down a forest without replanting) or when attempts are made to balance the costs of an unsustainable process by purchasing tax credits or offsets. Offloading also occurs when a problem is left for future generations to clean up and resolve. *Processes that offload problems onto others should be redesigned so the problem does not occur, or a countermeasure should be put in place that forces the organization to clean up the resource.*

5. **Exhaustion** occurs when a nonrenewable resource is used as part of a process or product. Whether the resource is plentiful or scarce, there is a limited supply of it, and each execution of the process uses some of that finite supply. Ultimately, a process that exhausts a resource cannot be sustainable. *Exhaustion can be addressed by redesigning the product such that the resource is not required or by taking steps to recover the used resources through recycling*.

6. **Squandering** is the use of a resource beyond the minimum needed to perform the process or to produce an equivalent good. This can include overuse of materials and energy. It is critical to consider squandering in the context of equivalent goods. Processes like cryptocurrency mining and trading are similar in use to other financial instruments, but they require immense and increasing use of computing resources and power. *Processes that squander resources should be redesigned to substantially reduce resource usage or be replaced with processes or products that put lower demands on the environment.*

7. **Overloading** is the waste that occurs when something is pushed beyond its capacity on a regular basis. This includes staff overwork, excessive use of a machine beyond its maintenance cycles or tolerances, and drawing renewable resources from an ecosystem to the point where it declines or collapses. Overloading introduces risk into the process because the overloaded resource may suddenly break or become unable to sustain the demands placed on it. *If a resource is overloaded, the process must be redesigned with the understanding that the resource is a constraint (TOC may be helpful here) and the load on the resource managed to be below the level where it is at risk.*

Conclusion

Recent scientific research has made it clear that the global ecosystem is at a crisis point and that we risk collapse without major changes to our economy and infrastructure. As process improvement practitioners, we find ourselves in a place where we can make a significant contribution to this effort by redesigning products, processes, and supply chains to reduce the stress they place on our environment.

Recognizing that these unsustainable practices are wasteful — and at least as important as the traditional waste Lean seeks to eliminate — is a necessary first step to developing the tools that will allow us to ensure a livable world for our children and grandchildren.

References

[1]Goldratt, Eliyahu M. *The Goal: A Process of Ongoing Improvement*. North River Press, 2012.

[2]Faulkner, William, and Fazleena Badurdeen. "Sustainable Value Stream Mapping (Sus-VSM): Methodology to Visualize and Assess Manufacturing Sustainability Performance." *Journal of Cleaner Production*, Vol. 85, 15 December 2014.

Kevin Brennan is an independent consultant in product management and business architecture and a Professor at George Brown College, Canada. He has led organizations through strategic and business unit planning and execution, played a leadership role in enterprise change, developed and launched multiple products for a global audience, and managed a product portfolio through the entire product lifecycle. Mr. Brennan is best known for leading the creation and development of the Guide to the Business Analysis Body of Knowledge (BABOK® Guide) *and other business analysis standards and is a Lean Six Sigma Black Belt. He earned a bachelor's degree in history and political science from the University of Toronto, Canada, and is currently completing his master's degree in corporate entrepreneurship and innovation at Penn State University. He can be reached at kevin@newba.com.*

THE BIGGER PICTURE

How Corporations Can Change Systems Through Innovation

by Pratima Bansal, Ju Young Lee, and Alice Mascena

When Nespresso launched the coffee pod in 1986, its parent company's executives had much to celebrate. They had found a way to deliver coffee in easy-to-use, recyclable, aluminum capsules that kept the coffee fresh and office workers/home coffee drinkers happy. Not long afterward, competitors started to appear. Green Mountain Coffee Roasters, now Keurig, developed its own version of a coffee capsule.

Keurig's capsule, however, was plastic, which was much more difficult to recycle than Nespresso's aluminum one. Keurig's innovation sparked unintended outcomes, with disposable plastic coffee capsules generating mountains of waste. By 2020, approximately 40% of US coffee drinkers owned at least one capsule coffee-brewing machine.[1] Every minute, 39,000 capsules were made worldwide, of which more than 75% were ultimately landfilled.[2] The capsules were good for consumers but bad for society and the environment. Keurig's K-Cup inventor, John Sylvan, says he now regrets inventing the K-Cup.[3]

It's an inconvenient truth that many of the best corporate innovations create severe, unintended social and environmental consequences. Even the most progressive innovations emit carbon into the atmosphere or add plastic to landfills.

Nevertheless, there is an approach to corporate innovation that creates value for the firm *and* a positive social impact. It is called *systems innovation*. In this manner, companies make money while contributing to more resilient and sustainable systems and societies. Success is measured not just by return on investment, but also by positive social impact. In this article, we discuss systems innovation and its ability to mobilize sustainability.

Traditional Innovation Models & How They Went Wrong

Before we describe systems innovation, it is important to outline traditional approaches to corporate innovation and where they went wrong. The two most common are the stage-gate model and design thinking.

Stage Gate

The stage-gate process was designed for new product development and is the most commonly applied approach to innovation. It starts with an idea that passes through several stages that include a business case, technical assessments, product development, and product launch (see Figure 1).[4] Each stage looks at the idea based on successively more intensive criteria. Typical criteria include strategic fit, market attractiveness, and technical feasibility. Each gate is an up-or-out decision. The stage-gate process is methodical and clear, and it efficiently allocates resources.

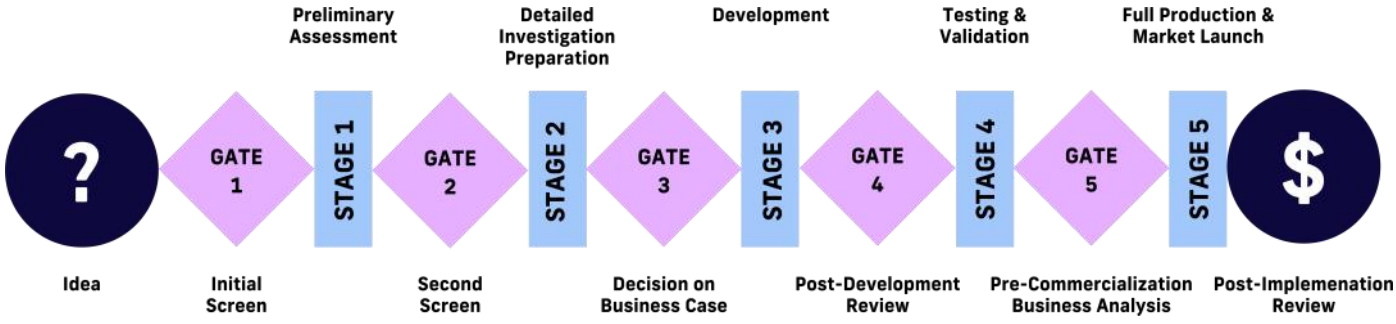

Figure 1. The stage-gate model (adapted from Cooper)

For example, 3M may see an opportunity to offer a new application for its adhesives. It assesses the market potential of the adhesive, ensures the new format meets regulatory hurdles, and determines whether it is financially viable.

However, the strength of the stage-gate process is also its greatest weakness. Its systematic methodology is rigid and inflexible. All those involved in the innovation process know what to do next and how to report success, but they are also constrained in what they can do. Their creativity is stifled, resulting in incremental innovations. Anything radical is killed early. Furthermore, the stage-gate process is guided by clear goals or metrics, such as sales or ROI. Any innovations that risk not meeting those metrics are squashed.

Design Thinking

Rather than starting with an idea, design thinking begins with a problem faced by customers. Taking a human-centered approach to innovation, design thinkers seek to solve customers' problems, thereby uncovering new products and services or improving existing ones. The phases in design thinking are, not surprisingly, humanistic, including building empathy, defining the problem, ideating, prototyping, and testing.

Design thinking differs in another important way from stage gate. It embraces fluidity among the various phases. Projects loop back through the five phases, especially the first three, as ideas are tested and refined (see Figure 2).[5] Design thinking works well when decision makers can see a problem but want to garner a deeper understanding of the users' perspective.

This approach has generated many iconic products like suitcases with wheels and smartphones. Exemplary firms that have embraced and profited enormously from design thinking include PillPack (a prescription drug-delivery service bought by Amazon in 2018 for US $1 billion[6]), IBM, Phillips, and Uber Eats.

Design thinking was also behind the massive success of Airbnb. Founded in 2008, Airbnb was struggling and almost went bankrupt in 2009. The company's revenue was a paltry $200 per week. Applying design thinking, company leaders strove to hear the voice of the customers to understand the problem. Scanning through all 40 listings in the New York area, Airbnb founders identified an absurdly simple problem: low-quality pictures. Customers couldn't see clearly what they were paying for. The solution was simple. The team rented a camera, flew to New York, met with hosts, and replaced the photos with aesthetically pleasing, high-resolution ones. Within a week, the company's weekly revenue doubled, marking an important turning point.

Although design thinking is more fluid and flexible than the stage-gate approach, its laser focus on the end user can blind the innovator to the impact of the innovation on the wider context. Users tend to focus on their immediate interests, and in meeting those needs, companies inadvertently overlook the implications of the new product or service on society and the natural environment.

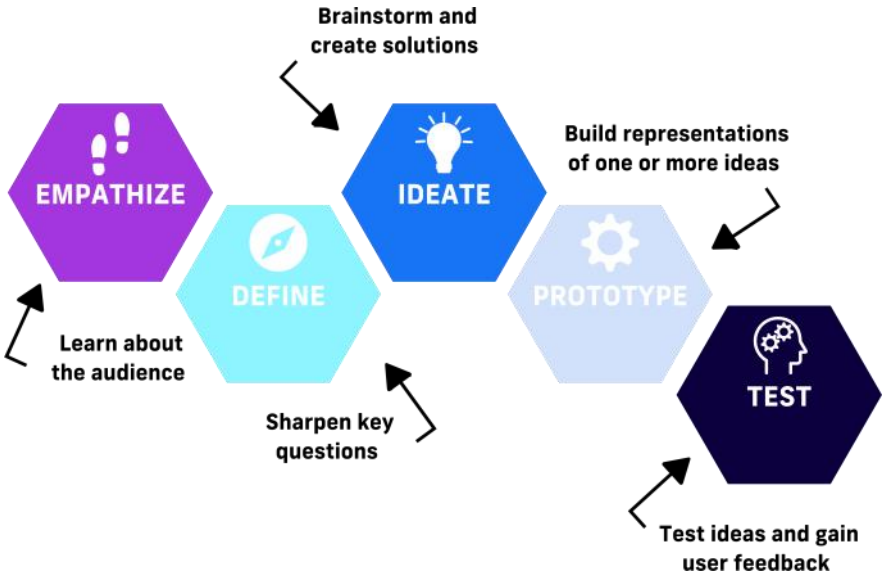

Figure 2. The design thinking model (adapted from IDEO)

Airbnb is still serving its customers' needs well, and the company recorded its highest-ever revenue in 2021 (approximately $6 billion).[7] However, its business model has contributed to social problems in some communities, causing housing shortages, driving up rents, and hollowing out communities. In cities with a large number of tourists, Airbnb has been criticized for driving residents out of central neighborhoods. One prominent example is Barcelona, Spain: the number of local residents in the city's Gothic Quarter has declined 45% in the past decade.[8]

The Case for Systems Innovation

A systems approach to innovation encourages organizations to see the bigger picture. As we explain in detail below, a deep understanding of the system(s) not only enables organizations to better assess unintended impacts but also to better navigate systems risks, barriers, and opportunities.

General Motors (GM) and its EV-1 offers a powerful example. More than 25 years ago, GM introduced the first electric vehicle. Despite the appeal and a strong following among certain consumer groups, GM terminated the production of EV-1 shortly after it was launched. The company did not think the product could gain the mass appeal to make it sufficiently profitable to warrant its continued production. They sent all the EV-1s to crushers, despite protests by customers and environmental activists.

In recent years, the electric vehicle market has grown exponentially. But Tesla, not GM, has led this growth. By mid-2021, Tesla's market share of the overall US electric vehicle market was a whopping 66.3%, making GM's 9% market share seem paltry, especially given that they had moved so early and should have had a technological advantage.[9] Had GM understood systems, they would have recognized the issue was not a bad product, but bad timing. They had to do more than meet market demands; they had to help shape them.

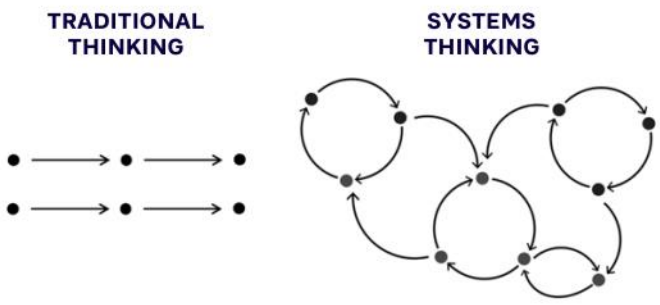

Figure 3. Traditional thinking vs. systems thinking

Traditional Thinking vs. Systems Thinking

Systems are simply interconnected elements organized to achieve a purpose. They make up our body (e.g., the digestive system), the operations of a corporation, and the movement of money in financial markets. More and more places, communities, and organizations operate as a system now that things such as people, money, and information are coordinated and move around the world.

Figure 3 illustrates the difference between traditional and systems thinking. Seeing interconnections offers a more accurate worldview than a focus on the things within a system. When people focus only on things, they believe they can predict and control outcomes through their actions. They apply linear cause-and-effect reasoning.

Systems thinkers, in contrast, recognize that things act and interact, so outcomes are difficult to predict and control. They see everything as part of a system, which extends even to themselves. Thus, anything that they do has implications for others, and others' actions have implications for them.

What Is Systems Innovation?

Innovation through a systems lens means taking a less linear approach. Corporations must see not just things (i.e., products, suppliers, customers, and the natural environment), but also the connections among these things. Corporations must recognize that cities are not just a collection of houses, roads, cars, and people, but also flows of people between work and home, social ties among friends, and the feeling of shared identity of people in a neighborhood. Often, these invisible connections shape how people act, where they shop, and how they spend their time.

When corporations see themselves as part of a system, they go beyond just producing a new product or service to influencing the system and recognizing that their success is influenced by the system. They realize that selling products or ideas is not just a matter of satisfying single users or even a network of users. They realize

that if they can develop products that are good for the environment or society more broadly, those products and services will have more staying power and be more profitable than products that are harmful. For example, even though Uber provided an immensely profitable service, it was only a matter of time before municipalities started to bristle at the added congestion, low wages, and environmental impacts.[10]

Going back to our opening example, Nespresso embraced the need to recognize the broader environmental system in which it operated and worked with numerous municipalities to ensure its coffee capsules could enter recycling streams and be returned to Nespresso. The company also works with couriers and post offices to facilitate the return process of the used coffee capsules. Keurig, in contrast, is experiencing backlash from the waste it generates.[11]

We believe the corporation of the future will approach innovation using a systems lens. These corporations will be attuned to their success while recognizing that success can be better sustained when they consider the sustainability of the systems in which they operate. They understand that what's good for the system is good for the company, which is a far cry from thinking that what's good for themselves is good for the system.

We have been developing the ideas behind systems innovation over the last two and a half years through Innovation North, a university-based research practice lab.[12] Through our work, we have learned how systems innovators see complex interconnections, embrace tensions, appreciate the bigger picture, and expand their perspective through consultation with diverse and relevant others. Organizations engaging in systems innovation are adaptive and open to constant change. By learning more about the system, conducting experiments within it, and constantly reviewing their understanding of problems and solutions, innovation becomes more viable and less risky for the firm and the wider systems.

How to Innovate for Systems

Systems innovation integrates systems thinking with design thinking. By cycling rapidly through all five phases of design thinking, systems innovators learn more about the system and continuously innovate and refine products and services (see Figure 4).

Each iteration of the cycle reveals more about the system. Systems innovation does not seek to develop a single product or service; it works toward a number of tangible (e.g., products and services) and intangible (e.g., changes in identity, language) ideas that solve a problem — whether for a user or a society. This ecology of solutions work collectively to build support for the innovation.

When corporations see themselves as part of a system, they go beyond just producing a new product or service to influencing the system and recognizing that their success is influenced by the system.

The continuous cycling of these multiple steps in the innovation process helps the corporation continuously refine its offerings to be beneficial for both the corporation and the system.

Systems innovation builds on design thinking, but with key differences. First, systems innovation does not focus exclusively on short-term end-user interests; it also considers the wider problem and the long-term implications. Because it's sometimes hard to see the bigger problem or imagine the long term, systems thinkers are good listeners, especially of diverse perspectives.

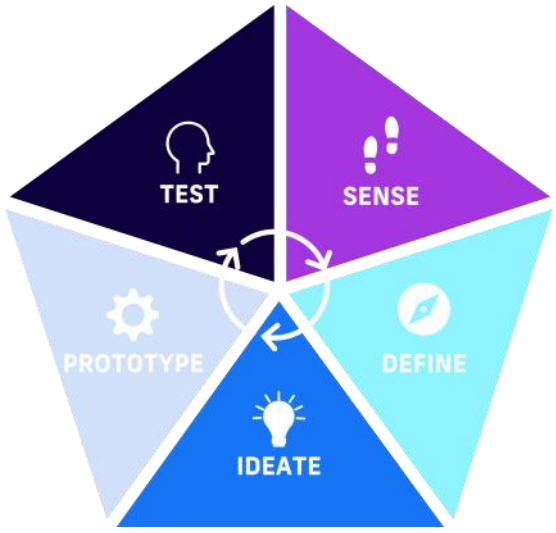

Figure 4. Systems innovation process

For example, had Airbnb integrated systems thinking, it would have engaged municipalities, residents, sellers, and buyers to ensure their needs were met. The company would have not just done this once, but regularly as it kept improving its product. This would have ensured that Airbnb accommodations did not hollow out neighborhoods, so that Airbnb customers could still experience the authenticity and connection experience that is central to the company's value proposition.

Systems innovation requires continuous iteration throughout the process (from sensing to testing). Because a system cannot be fully known, prototyping and testing are critical in exposing insights into it. Systems thinkers move forward incrementally, constantly experimenting, learning, and adapting.

Once the organization develops prototypes, it uses them to further sense the system. Consequently, systems innovation becomes a series of nudges, rather than major product/service launches. Systems innovation doesn't end with a new product or service launch, but each action, no matter how small, is a step toward understanding the system.

Conclusion

Businesses need to understand how they can innovate not just for themselves and immediate stakeholders, but for systems. System-wide disruptions such as climate change and pandemics pose hidden risks, but they also create opportunities for innovations that are beneficial for both companies and the wider systems in which they are embedded (social, environmental, and economic systems). By engaging in systems innovation, we argue, corporations can not only better prepare for systems disruptions, they can also become beacons for positive systems change.

References

[1]Ridder, M. "Share of US Consumers Who Own a Single-Cup Coffee Brewing System from 2005 to 2020." Statista, 13 January 2022.

[2]Burrows, David. "Have We Solved the Problem of Coffee Pods That Harm the Planet?" *Caffeine*, No. 26, 2017.

[3]Evans, Pete. "K-Cup Creator John Sylvan Regrets Inventing Keurig Coffee Pod System." CBC, 5 March 2015.

[4]Cooper, Robert. "Stage-Gate Systems: A New Tool for Managing New Products." *Business Horizons*, Vol. 33, No. 3, February 1990.

[5]"Design Thinking Defined." IDEO, accessed May 2022.

[6]Huddleston, Tom. "Meet the 32-Year-Old CEO of the Online Pharmacy Amazon Just Bought for $1 Billion." CNBC, 28 June 2018.

[7]Menze, Jill. "Airbnb Ends 2021 with 25% Revenue Growth over 2019." PhocusWire, 15 February 2022.

[8]Mead, Rebecca. "The Airbnb Invasion of Barcelona." *The New Yorker*, 22 April 2019.

[9]Miller, Marty. "While EV Registrations Grow Through the First Half of 2021, Non-Electric Remains Dominant." Experian, 18 October 2021.

[10]Thorpe, David. "Why Uber Is Bad for Cities." The Fifth Estate, 26 November 2019.

[11]Imbler, Sabrina. "The Best Keurig Machine (But We Really Don't Recommend It)." *The New York Times*, 10 September 2021.

[12]Innovation North website, accessed May 2022.

Pratima (Tima) Bansal is Professor of Strategy and Canada Research Chair in Business Sustainability at Ivey Business School, Western University, Canada. She has been researching the intersection of sustainability and strategy for almost three decades, especially through the dimensions of time, space, and scale. Dr. Bansal has published her research in more than 50 peer-reviewed articles and in two books. She has also helped to foster research, through her role as Deputy Editor and Associate Editor of Academy of Management Journal. *Dr. Bansal's research has been cited in* The Wall Street Journal, The National Post, *CBC (Canadian Broadcasting Corporation),* The Globe and Mail, *and* The Independent. *She gave a TEDx talk in 2013 and writes a blog for the Network for Business Sustainability and a column for* Forbes. *She can be reached at tbansal@ivey.ca.*

Ju Young Lee is a Postdoctoral Associate at Ivey Business School, Western University, Canada. His research interests include understanding the processes of transformational changes, or the lack thereof, at different levels (i.e., systems, field, and organizational). Dr. Lee is particularly drawn to change initiatives that address grand societal challenges, such as poverty, inequalities, and climate crisis. At Ivey, under the supervision of Dr. Pratima Bansal, he is working on convening leading organizations and co-creating knowledge on how to innovate better in the age of disruption. Dr. Lee earned a PhD in organization studies at Boston College. He can be reached at julee@ivey.ca.

Alice Mascena is a Postdoctoral Associate at Ivey Business School, Western University, Canada. She recently completed her PhD at IESE Business School and her research interests consist of understanding how businesses integrate notions of social and environmental impact, and how they organize for it either at their inception or at later stages. Alice is working under the supervision of Dr. Pratima Bansal on co-creating knowledge with leading Canadian and multinational organizations on how to achieve systems innovation. She can be reached at amascena@ivey.ca.

"R" WE READY?

Greening Data Management for AI

by Rohit Nishant and Thompson S.H. Teo

With an increased focus on climate change, green IT (environment-friendly and sustainability-related technologies) has gained prominence. This includes green data centers with low carbon footprints and environmental management systems to help firms "green" their operations.

Artificial intelligence (AI) that can help firms measure their environmental footprint or optimize their energy consumption and carbon footprint are a recent green IT addition. Because AI is a disruptive technology based on to its ability to learn, it's expected to bring impactful sustainability transformation.[1] However, achieving such transformation will require a significant change in the system surrounding AI.[2]

In this article, we focus on the data centers forming the foundational infrastructure for data-intensive AI and the system surrounding AI. Specifically, the proliferation of personal and business AI applications and consumption of data are interacting with each other and fueling data center growth. We discuss that system — primarily an extension of the system surrounding traditional IT— and its emerging challenges. We then discuss how a new system rooted in regenerative economics and doughnut economics can help AI achieve its potential of facilitating sustainability transformation and present a framework aimed at bringing about the necessary systemic changes.

AI's Data-Centric System

The current discourse on AI emphasizes data as the key driver of the economy. We see glimpses of this discourse in phrases such as "The world's most valuable resource is no longer oil, but data."[3] Growth in AI is accelerating the growth of data centers, which store massive amounts of data. Hyperscale data center revenue is expected to exceed US $60 billion in the next five years.[4] These data centers are the major sources of carbon footprint and are detrimental to environmental sustainability. Consequently, companies that deploy AI are faced with serious environmental challenges.

Recent studies have found that data centers' carbon footprints are exceptionally high.[5] An International Energy Agency estimate pegs their energy consumption at approximately 200 terawatt-hours of electricity. That equates to nearly 1% of global electricity demand or 0.3% of all global CO2 emissions.[6]

AI that can help firms measure their environmental footprint or optimize their energy consumption and carbon footprint are a recent green IT addition.

Companies are aware of this and are responding to the issue in a number of ways. Some companies are leveraging green data centers with lower energy use and carbon footprints.[7] Some are switching to renewable energy to power their data centers. Companies like Amazon, Google, and Microsoft that are huge corporate purchasers of renewable energy are developing onsite renewable energy sources and forming partnerships with green vendors.[8]

Of course, these initiatives have limitations. For instance, using energy-efficient data centers might be ineffective if data consumption increases, negating the benefits from energy efficiency. The negation of benefits from energy efficiency improvement due to increased consumption (termed "Jevon's paradox") has been observed in contexts like steam engines.[9] Increased data consumption can also limit the effectiveness of renewable energy in reducing data centers' carbon footprint.[10]

In particular, renewable energy in data centers faces several challenges: managing real-time balancing of energy demand and supply; fluctuation of data center load between peak and normal periods; and properties such as intermittency, variability, and non-dispatchability of renewable power generation.[11]

It can also involve tradeoffs that pose challenges to sustainability. For instance, using a data center with solar energy can reduce a data center's footprint, but solar panel manufacturing creates many environmentally harmful byproducts.[12] Such tradeoffs, if ignored, can make data centers unsustainable. Clearly, increasing data consumption can lead to increased energy and carbon footprint both directly and indirectly, create challenges for sustainability, and make green initiatives ineffective or limit their effectiveness.

A holistic view of the interactions and interdependencies among various components is needed because a positive change in one component could negatively affect other components.

Our consumption of goods and services keeps our economic engine running, leading to high economic growth levels. IT systems like those that inform firms about their carbon footprint and aid in formulating reduction strategies form the part of this system aimed at regular growth in product and service delivery.[13] Even initiatives such as energy analytics, in which energy consumption data is leveraged to formulate ways to improve output relative to energy consumed, aim to achieve growth in product and service delivery, albeit less energy-intensive.[14]

This calls for a shift toward a greener, more sustainable data-centric system. Specifically, a holistic view of the interactions and interdependencies among various components (rather than a focus on individual components) is needed because a positive change in one component could negatively affect other components.

Systems Perspective in Managing AI Carbon Footprint

Recent years have brought discussions about new economic systems such as regenerative capitalism and doughnut economics. Regenerative capitalism, a phrase coined by John Fullerton, refers to business practices that restore and build instead of exploiting and destroying.[15] It is insufficient to stop exploiting and destroying our habitat — we must regenerate what is lost. In the context of environmental sustainability, this means looking beyond achieving net-zero emissions to having a net-positive impact.

Regenerative capitalism emphasizes the importance of creating a positive impact. Doughnut economics espouses similar ideas but is more encompassing, proposing a framework with a doughnut-shaped area representing a socially just and environmentally safe space for humanity.[16] The outer edge of the doughnut depicts the limits of what the planet can endure (e.g., climate change, ocean acidification, chemical pollution, biodiversity loss, air pollution, ozone layer depletion). The center of the doughnut houses social foundation items like water, food, energy, education, social equity, and health.

Doughnut economics discourages endless GDP growth. It views the economy as connected systems embedded within the larger society such that focusing on individual units or actors is not the best approach. Instead, cooperation and altruism are essential to ensure there is no shortfall in the social foundation and no pressure against the ecological ceiling.

Effectively managing AI's carbon footprint would require a shift to a system like regenerative capitalism or doughnut economics that does not emphasize continuous growth or increased consumption.

However, the novel opportunities AI offers society make it difficult for many to accept the idea that data consumption related to AI must be managed. For example, data access and sharing create economic opportunities by enabling everyone to produce their own content and leverage a variety of platforms to access new markets.

The framework shown in Figure 1 acknowledges the benefits of data to various sections of society and presents ways to bring about necessary systemic changes. The three pillars of the framework target the consequences of data centers (first R), data production (second R), and data consumption (third R).

Regenerate Economic Activities to Productive Use (First R)

The first pillar, regeneration, is grounded in the premise that economic activities should not destroy nature. In the context of data centers for AI, this means complementing existing initiatives like renewable energy or energy-efficient data centers with those focused on regeneration.

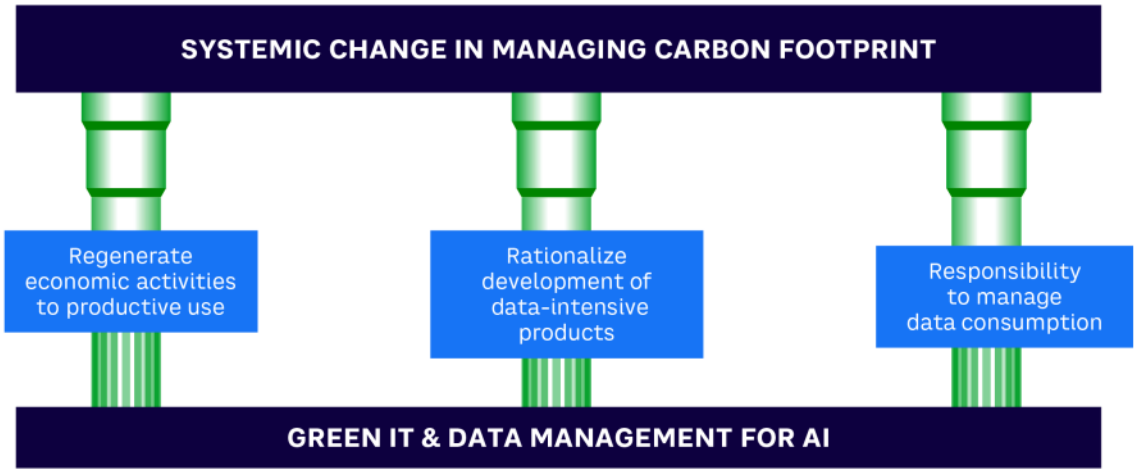

Figure 1. The 3R framework for systemic change in managing carbon footprint

For instance, regardless of the type of energy used by data centers or their energy-efficiency level, they generate heat. Companies can capture this heat and use it to, for example, fuel an in-house greenhouse to grow vegetation. Studies by Béla Waldhauser and others provide guidance on these types of projects.[17] Lately, companies including Facebook have set up data centers in cold locations, where heat recovery and subsequent use for greenhouse farming can help increase food production, contributing to food security.[18, 19]

By viewing data center heat generation and its subsequent use in a greenhouse as interconnected components, companies can bring a systems perspective to their operations. This approach leads to locating data centers in a natural environment that can benefit from the consequences of their use.

Rationalize Development of Data-Intensive Products (Second R)

The second pillar is rationalization, which includes the idea of "create to regenerate" and "embedded economy." The latter conceptualizes economy as embedded in the flow of energy and materials.[20] In a data context, this translates into rationalizing the development of data-intensive products.

Traditionally, companies are always scouting for new product ideas and data; rarely are their associated carbon footprints explicitly considered. Instead, companies could critically examine the market for their AI products and their intended use. They could consider sacrificing products intended solely for entertainment in favor of data-intensive products that serve a larger social purpose or address a societal problem and complement its development with the use of renewable energy or energy-efficient data centers. Companies can follow the regeneration pillar to compensate for the product's carbon footprint.

Some might point out that not every product can serve a larger purpose and that entertainment is not void of purpose. This is a valid point, and companies can address this by comparing the purpose served by various products and prioritizing those with the maximum potential (directly or indirectly) to serve a larger purpose. Companies can involve their various stakeholders in making such comparisons.

Companies could, for example, shy away from developing AI products for markets where several products providing a similar level of entertainment already exist. The rationalization pillar thus complements the mindful consumption view increasingly discussed in public discourse with mindful production.[21] Mindful production helps companies minimize adverse environmental consequences from existing product or service delivery processes, such as the manufacturing of solar cells.

Companies can also aim their resources at developing environmentally friendly processes for developing data-intensive products and services. Again, such an approach would connect data centers, data users/consumers, energy generation, and associated manufacturing, allowing companies to view themselves not

as an isolated entity but as constituents of a system. This realization could help them be more environmentally responsible while making AI greener and more sustainable.

Responsibility to Manage Data Consumption (Third R)

The third pillar emphasizes that companies must be more socially responsible, finding creative ways to reduce their product-related carbon footprint (other than technical solutions, such as using renewable energy or improving energy efficiency). Companies can leverage their consumers in this endeavor. This approach is based on viewing things from a systems perspective and the idea of viewing humans as social and adaptable.[22]

> *The connection between mindful consumption and mindful production allows companies to take a systems perspective, eventually leading to optimization of data consumption.*

As AI and digitization grow more important to lives, we are increasingly consuming and creating data through interactions with various applications and chatbots. However, even as humans continue to consume data, they seek an escape from continuous data consumption. Companies thus have an opportunity to play a role by increasing consumer awareness of how data-intensive products and services influence consumers' lives.

For instance, gaming companies can make gamers aware of the potential adverse mental and social impacts of excessive online gaming.[23] Companies could explore various online features to help curb such behavior. This may sound like a counter-intuitive thing for a gaming company to focus on, but positioning a company as socially responsible is a powerful tool. This position incorporates the idea of mindful consumption, thus complementing mindful production (see second R, above).[24] The connection between mindful consumption and mindful production allows companies to take a systems perspective, eventually leading to optimization of data consumption. Companies can then leverage the 3Rs to effectively manage their data centers' carbon footprint.

The 3Rs framework presents an alternate system grounded in regenerative capitalism and doughnut economics as a way to reduce the carbon footprint of data. Together, the three pillars convey the message that existing initiatives like renewable energy use and improvement in energy efficiency will be inadequate if we continue to emphasize consumption in general and data consumption in particular. In such a system, data infrastructure would not be able to green itself, and goals such as net-zero and net-carbon-positive would be difficult to achieve. It's clear that continuing our existing system is not a realistic approach and that a system and mindset change is the best way to effectively tackle the environmental sustainability challenges we face.

References

[1]Vinuesa, Ricardo, et al. "The Role of Artificial Intelligence in Achieving the Sustainable Development Goals." *Nature Communications,* Vol. 11, No. 233, 13 January 2020.

[2]Galaz, Victor, et al. "Artificial Intelligence, Systemic Risks, and Sustainability." *Technology in Society,* Vol. 67, November 2021.

[3]"The World's Most Valuable Resource Is No Longer Oil, But Data." *The Economist,* 6 May 2017.

[4]Global Market Insights, Inc. "Hyperscale Data Center Market Revenue to Cross USD 60 Bn by 2027." *Cision PR Newswire,* 15 December 2021.

[5]Batmunkh, Altanshagai. "Carbon Footprint of the Most Popular Social Media Platforms." *Sustainability,* Vol. 14, No. 4, 15 February 2022.

[6]Ezra, Asaf. "Renewable Energy Alone Can't Address Data Centers' Adverse Environmental Impact." *Forbes,* 3 May 2021.

[7]"Green Data Centers: 8 Companies Doing Them Right." *InformationWeek,* 5 August 2016.

[8]Ezra (see 6).

[9]Nishant, Rohit, Thompson S.H., Teo, and Mark Goh. "Energy Efficiency Benefits: Is Technophilic Optimism Justified?" *IEEE Transactions on Engineering Management,* Vol. 61, No. 3, August 2014.

[10]Ezra (see 6).

[11]Rostirolla, Gustavo, et al. "A Survey of Challenges and Solutions for the Integration of Renewable Energy in Datacenters." *Renewable and Sustainable Energy Reviews,* Vol. 155, March 2022.

[12]Masili, Alice. "The True Carbon Footprint of Photovoltaic Energy." *Only Natural Energy (ONE),* 16 July 2018.

[13]Nishant, Rohit, Thompson S.H. Teo, and Mark Goh. "Do Shareholders Value Green Information Technology Announcements?" *Journal of the Association for Information Systems,* Vol. 18, No. 8, 31 August 2017.

[14]Melville, Nigel P. "Information Systems Innovation for Environmental Sustainability." *MIS Quarterly,* Vol. 34, No. 1, March 2010.

[15]Stokel-Walker, Chris. "What Is Regenerative Capitalism and Why Is It Important?" World Economic Forum, 24 January 2022.

[16]Raworth, Kate. "A Safe and Just Space for Humanity: Can We Live Within the Doughnut?" Oxfam, February 2012.

[17]Waldhauser, Béla. "Heat Recovery from Data Centers: A Win-Win Situation." *Dot Magazine,* November 2019.

[18]Dawn-Hiscox, Tanwen. "Facebook Plans Third Data Center in Luleå, Sweden." Data Center Dynamics (DCD), 8 May 2018.

[19]Ljungqvist, Hampus Markeby, et al. "Data Center Heated Greenhouses, A Matter for Enhanced Food Self-Sufficiency in Sub-Arctic Regions." *Energy,* Vol. 215, Part B, 15 January 2021.

[20]Raworth, Kate. *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist*. Chelsea Green Publishing, 2017.

[21]Milne, George R., Francisco Villarroel Ordenes, and Begum Kaplan. "Mindful Consumption: Three Consumer Segment Views." *Australasian Marketing Journal,* Vol. 18, No. 1, 1 February 2020.

[22]Raworth (see 20).

[23]Dastoor, Vaspaan. "Mental Health Foundation Calls on Games Industry to Do More." TheGamer, 28 February 2022.

[24]Milne, et al. (see 21).

Rohit Nishant is Associate Professor in the Department of Management Information Systems at Université Laval, Canada. His research has been published/accepted in several international journals, including MIS Quarterly, MIS Quarterly Executive, Journal of the Association for Information Systems, Journal of Strategic Information Systems, Information Systems Journal, Decision Sciences, *and* IEEE Transactions on Engineering Management. *Dr. Nishant has been awarded winner of the SIM Best Paper Competition. He holds a PhD in management from National University of Singapore Business School, where he was valedictorian. His dissertation won the World Future Foundation award for best PhD thesis. He can be reached at rohit.nishant@fsa.ulaval.ca.*

Thompson S.H. Teo is Professor in the Department of Analytics and Operations at National University of Singapore Business School. His research interests include the adoption of IT, strategic IT planning, electronic government, knowledge management, and sustainability. Dr. Teo has published more than 250 papers in international journals and conferences. He has served as Senior Associate Editor for European Journal of Information Systems, *Regional Editor (Asia and Pacific) for* International Journal of Information Management, *and Associate Editor for* IEEE Transactions on Engineering Management. *Dr. Teo is currently on the editorial boards of* Information & Management, MIS Quarterly Executive, *and* Omega. *He has coedited four books on IT and e-commerce and is a four-time winner of the SIM Best Paper Competition. He can be reached at bizteosh@nus.edu.sg.*

COME TOGETHER RIGHT NOW

BIoT: Integrating Blockchain & IoT for Sustainability

by Cigdem Z. Gurgur

The number of Internet of Things (IoT) devices increased dramatically in the past decade. Estimates put the number of connected devices at nearly 25 billion across the globe, and some experts predict that number to double as soon as 2025. These devices employ sensors to establish network connections and transmit collected information to a remote node.

IoT couples digital and physical objects using robust communications technologies, introducing a future in which computing systems, users, and objects come together to create social, economic, and convenience benefits. IoT makes it possible to monitor any quantifiable state, such as the temperature of a product in a cold chain or the amount of a certain type of equipment in a supply chain.

IoT applications have grown exponentially in a wide variety of industries, accelerating industrial globalization and requiring enormous amounts of data.[1] As IoT devices become more common, deficits in the way we currently manage data are becoming increasingly apparent. At the same time, networks and supply chains are growing more complex. Thus, data centers need to spend more to improve their ability to process and store data, but data centers with limited supervision cannot guarantee needed data transparency and traceability.

Decentralization is essential if we are to sustainably meet our digital needs. The best model for a distributed, decentralized IoT ecosystem is blockchain.[2] Indeed, the World Economic Forum predicts that by 2027, 10% of global GDP will be stored on blockchains, and major technology players such as IBM have named blockchain as a crucial technology in democratizing IoT.[3]

What Is Blockchain?

Blockchain is a decentralized, immutable, time-stamped ledger that provides transaction transparency and data privacy. It began more than a decade ago as the public distributed ledger for the cryptocurrency Bitcoin. Today, it has evolved from a niche technology used for virtual currency into a critical component of business ecosystems, identity systems, and finance and supply transaction systems.

Blockchain applications let organizations exchange goods, services, and information without the need for a central body to verify identity, validate transactions, or enforce commitments — reducing or eliminating intermediaries. Digital transactions can quickly be disseminated and synchronized across a variety of businesses, increasing efficiency and lowering costs.

Because all participants in a blockchain (everything from a supply chain to a financial transaction, business process, or government project) share access to the data, it cannot be transmuted or corrupted by a single actor. Each participant holds identical copies of the data verified by the others, ensuring the highest level of data integrity. This integrity rests on cryptography that validates and chains together the transactions, contracts, or assets, which are then recorded, making data tampering impossible.

What Is BIoT?

As far back as 2015, blockchain was recognized by the Institute for Blockchain Studies as the fifth disruptive computer paradigm innovation, following the Internet, mobile/social networking, personal computers, and mainframes.[4] Today, blockchain-based IoT (BIoT) is garnering enormous interest and research dollars within the computing community.

IoT devices are beneficial for collecting and analyzing data, but to be useful and relevant, that data must be extremely secure and retain its integrity. This is where blockchain comes in. Blockchain can be thought of as providing a decentralized "fabric" for IoT's web of intelligent objects.

Sensors acquire data like temperature, air pressure, CO2 levels, and smoke. Once a sensor produces a signal, the

signal must be processed and transmitted. Blockchain offers a medium for reliably sharing information to the IoT, creating secure, immutable records by providing "trustless" record-keeping (i.e., no need to trust a third party).

BIoT's ability to provide end-to-end supply chain information in real time supports the circular economy paradigm. It allows businesses and consumers to shift from a linear take-make-dispose model (which relies on large quantities of easily accessible resources) toward an industrial model where effective flows of materials, energy, labor, and detailed information interact with each other in a restorative, regenerative, more sustainable system.

Sustainability, Sustainable Development & the UN SDGs

Sustainability and visibility are closely connected. When a company's supply chain is opaque, its leaders cannot see and track its processes, making it difficult or impossible to guarantee sustainability.

Sustainability is often used synonymously with environmental sustainability in technology discussions. This is in sharp contrast with the United Nations (UN) view, in which social, economic, and environmental sustainability are equally important and interrelated.[5]

The UN's concept of sustainability originates from the Brundtland Commission's 1987 definition of sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs."[6]

Sustainability and sustainable development are closely connected in that context: social and economic sustainability require social and economic development, because many human needs are currently not met.[7] In 2015, the UN launched its 2030 Agenda for Sustainable Development, which names 17 Sustainable Development Goals (SDGs) to address a variety of challenges related to environmental degradation, such as climate change, poverty, hunger and food insecurity, and more (see Figure 1).[8]

Improved Information Sharing with BIoT

The most important reason to introduce BIoT into a supply chain network is to improve information transparency. BIoT offers significant advantages and opportunities over traditional information-sharing technologies like enterprise resource planning and electronic data interchange.

BIoT provides a platform to connect diverse stakeholders with multiple sources of reliable data, generating a rich information landscape. It can enable information sharing between independent, heterogeneous firms in a supply chain, letting them leverage the group's collective knowledge to improve operational readiness and reduce administrative costs.

Some blockchains are private, allowing only authorized users access to the database, whether for reading or writing. These are sometimes called "permissioned blockchains," and they tend to exist behind organizational firewalls to offer transparency, privacy, and control to a defined set of users.[9] Often, permissioned blockchains are created for organizations that are not

Figure 1. UN Sustainable Development Goals (SDGs) (source: Getty)

ready to share information on a platform that could potentially be viewed by competitors.

Permissioned blockchains contain a centralized, trusted identity management system that issues cryptographic certificates to qualified participants and a distributed database under a decentralized administration. This offers an improvement in transparency and auditability across involved parties over traditional distributed databases.

These advancements provide considerable opportunities for improvements in supply chain innovation and sustainable development.[10] Permissioned blockchains can facilitate new means of green production, better monitoring of activities responsible for pollution and environmental degradation, and real-time collection and analysis of green or low-carbon data for timely decision making.

Creating Robust Supply Chains with BIoT

As supply chains become increasingly complex, the challenges of guaranteeing supplies, increasing transportation speeds, and ensuring product quality are becoming evident, particularly when it comes to food, medical supplies, and pharmaceuticals.

Blockchain's ability to securely capture data and ensure consistency across supply chain operations is an excellent way to reduce (or eliminate) human errors and fraud. By simply collecting and recording data that was previously buried in proprietary databases, BIoT strengthens supply chains.

BIoT can also help track the amount of greenhouse gas generated at every point in the supply chain. Its advanced analytics and predictive algorithms can expose how manufacturers are collecting used products from lower echelons and recycling or salvaging them in safe, environmentally conscious ways — information formerly hidden inside closed-loop supply chains.

BIoT's data-passport capabilities can be used to design prescriptive algorithms for allocating inventory or capacity to distribution centers and retailers. Manufacturers and distributors can use blockchain to easily track individual pharmaceutical batches; for example, ensuring that the oldest products move out of the warehouse first and expired products are never delivered to retailers.

The agri-food market is another good industry that can benefit from BIoT. Difficulties certifying the origin and quality of an agricultural product are as much a problem for consumers as they are for farms and distributors. BIoT can guarantee the traceability of the entire production system while ensuring more sustainable use of natural resources (like water) and reducing emissions associated with food production and transportation. IoT makes remote data collection efficient while blockchain ensures its security and perpetuity. In the case of food systems, that means providing omnipresent timestamp data from the raw material phase to the store shelf in a completely confidential manner. In transportation, BIoT can be used to track distances trucks travel, along with fuel use and emissions levels, leading to better-planned routes and more thoughtful warehouse placement.

In time, BIoT could be used to enhance and improve emissions trading systems (ETSs). A paper a few years back published in *IEEE Access* proposed HyperETS, a Hyperledger-based ETS that would provide "credible" trading services for polluters.[11] Similarly, a more recent article in *Energy, Sustainability, and Society* proposed a blockchain-based Global Carbon Surcharge, which mimics a carbon tax but doesn't require tax collection by governments.[12]

Achieving SDGs with BIoT

Corporate uses of BIoT have already shown the technology's potential to transform our way of thinking and even our society.[13] As such, it holds tremendous promise for helping achieve the UN's SDGs in the following ways:

- **Enhancing supply chains.** Businesses are facing increasing pressures from regulators, activists, and consumers to develop sustainable supply chain systems that target SDGs. For example, a report commissioned by the EU recommended that blockchain technologies be explored as a way to enhance supply chain visibility in developing countries.[14] Other researchers have suggested that developing countries could use blockchain to replace outdated supply chain record-keeping, reverse current public mistrust of sustainability regulators, and encourage more rapid diffusion of modern information and communications technology (SDG 9, 16, and 17).[15, 16]

- **Improving sustainability supervision.** Because monitoring happens in real time, BIoT is an ideal way to improve sustainability supervision. When permissioned blockchain is integrated with IoT, government agencies can act as "nodes" or "peers," allowing them to closely monitor sustainable business activities. In this scenario, third-party certifiers become less relevant because consumers themselves can use BIoT systems to verify sustainability-related information (SDG 3 and 12).

- **Exposing unethical behavior.** Blockchains are only as trustworthy as the data entered into them, so systematically making that data trustable is crucial. We must also remember that, from a business perspective, achieving total transparency is not always attractive. There is an inherent tension between businesses that want to increase their knowledge about their suppliers for quality assurance and ethical reasons and businesses that want to hide this information because they know it will hurt their brand. Nevertheless, BIoT has the potential to improve the flow of labor-related information, presenting an opportunity to expose unsavory practices, including modern slavery (SDG 1, 10, and 16).

- **Supporting sustainable infrastructure and empower communities.** In a 2016 report on fintech, the UN acknowledged the potential for blockchain technology to aid in SDG development.[17] The report showed how blockchain could support sustainable infrastructure (SDG 9) and empower communities (SDG 1, 10, 11). In line with that report, the US state of California is using blockchain to monitor and oversee groundwater usage in Sacramento (an at-risk aquifer), and the UK and EU implemented Share&Charge, which uses blockchain to control an electric vehicle charging system.[18] The role of BIoT in supporting sustainability through service delivery, resource management, and city administration is also being explored.[19] BIoT can address environmental issues by using cryptocurrency as a reward system for improved waste management, water management, energy transaction management, and CO2 emissions management. BIoT has the potential to create more livable communities by monitoring energy consumption and waste (SDG 11), devising mechanisms to reward sustainable behaviors, and penalizing environmentally damaging actions, such as polluting water (SDG 14) or reducing biodiversity (SGD 15).[20, 21]

- **Leveling the playing field.** A 2019 Reuters story highlighted the discrepancies between producers of commodities like oil and gas and those at the "wrong end of the value chain" like Ethiopian coffee farmers.[22] Blockchain supply networks have the ability to level the playing field, giving small producers a way to compete with much larger players (SDG 1, 8, and 10). BIoT can also bring together small and medium-sized businesses to purchase equipment, raw materials, and/or services as a group, boosting their buying power. BIoT groups can also create crowdfunding campaigns to attract potential investors (SDG 8).[23]

- **Improving food chains.** By providing decentralized, incorruptible, transparent records, BIoT helps reduce fraud (SDG 8 and 10) and improve consumer trust in food (SDG 2, 3, and 12). Improved supply chain traceability also means improved monitoring of protected species (SDG 14 and 15).[24]

- **Enhancing accountability.** By providing immutable financial records, BIoT lets communities more easily share resources and work together to develop a region's economy. Without fear of fraud, misuse of funds, or malicious data alterations of data (SDG 8), communities can freely nurture technology development aimed at increasing economic activity (SDG 1, 9, and 11).

- **Achieving clean energy goals.** Blockchain supply networks must not only contribute positively toward sustainable development, they must also be able to continue their operations. BIoT aids in the development of peer-to-peer (P2P) clean energy trading, certified carbon-emissions trading, and enhanced climate-finance flows (SDG 7 and 13). It can also contribute to the deployment of smart renewable energy, smooth international climate finance transfers, fraud-free emissions management, and better green-finance law enforcement.[25] P2P trading gives consumers without rooftop solar arrays access to renewable energy and significantly lowers electricity transportation costs. BIoT offers utility companies worthwhile ways to innovate and opens up new channels for revenue optimization.

Do the Benefits of Blockchain Outweigh the Energy Costs?

Traditional blockchain algorithms such as proof of work (PoW) require large amounts of energy, negatively

affecting the environment. Additionally, server farms are usually located in enormous buildings that have a negative impact on the natural landscape. If the energy being used to power blockchain is nonrenewable, blockchains can have a larger impact on the environment than the problems the technology seeks to alleviate (i.e., climate change).

Recent calculations from Cambridge University's Bitcoin Electricity Consumption Index (CBECI) suggest that Bitcoin mining consumes 148.4 terawatt hours (TWh) a year of electricity, a best-guess tally that has risen consistently for the past five years.[26] CBECI ranks Bitcoin mining just above Norway and Ukraine, at 124.3 TWh of annual electricity consumption, and just below Poland and Egypt, at 149.5 TWh.

However, the proof-of-stake algorithm operates with 99% less computational power compared to PoW, appearing to solve the energy challenge. Expanded use of renewable energy is accelerating, and new, high-performance blockchain technologies are emerging. Blockchain company Solana, for instance, operates without energy-intensive mining. Its network is extremely environmentally efficient due to key technical innovations, including proof of history and parallel processing.[27]

Achieving Holistic Change Through BIoT

Among the UN's SDGs is the guarantee of sustainable models of production and consumption, promoting an efficient, responsible approach to natural resources in which companies do more with less. In this context, BIoT plays a decisive role in improving productivity through technological improvements.

For instance, materials is one of the most carbon-intensive industries. BIoT can help materials companies better understand their product lifecycles so that they can identify inefficiencies, leading to improved productivity and a reduction in negative environmental and social impacts. Resin suppliers Domo and Covestro teamed up with blockchain company Circularise to promote circularity in the plastics industry. Together, they achieved:

- Sustainable management and efficient use of natural resources
- Environmentally sound management of chemicals and all waste throughout their lifecycle
- Reduced waste generation through prevention, reduction, recycling, and reuse
- Provision of relevant information to make people aware of sustainable development and lifestyles.[28]

In another approach to improve productivity, BIoT enables trade-in programs that incentivize consumers to exchange used technology products for newer ones. This increases sales while ensuring the environmental sustainability of products, becoming a value-add strategy for businesses. The use of IoT-ready products and a blockchain-enabled disassembly-to-order system ensures integrative sustainability.[29]

Finally, BIoT can help create sustainability-related standards for regulative, normative, and cognitive institutions, resulting in transformative change; for example:

- **Regulative institutions.** BIoT strengthens the enforcement powers of governments by giving them the evidence they need to sanction individuals or organizations that breach regulations. BIoT promotes transparency and greater accountability in sustainability-related activities, giving smaller players more power to police large corporations.
- **Normative institutions.** BIoT increases transparency, which decreases the need for trade associations, industry bodies, and third-party agencies. BIoT's micro-metering, low cost of investment, and the ability to pinpoint standards of violators leads to attractive operational benefits in swiftly enforcing such standards.
- **Cognitive institutions.** The detailed, verifiable information BIoT provides increases consumer confidence about manufacturers', suppliers', and distributors' claims about their sustainability standards and sustainable development. BIoT's transparency and immutability creates a tamper-proof system that can quickly provide product information to demonstrate realized sustainability, increasing consumer confidence.

Ultimately, BIoT fosters sustainable development and nourishes global supply chains by making them more environmentally friendly, more financially inclusive, less prone to contamination, better protected from health issues and death hazards, and much more accountable to every system tier.

References

[1]Choo, Kim-Kwang Raymond, Stefanos Gritzalis, and Jong Hyuk Park. "Cryptographic Solutions for Industrial Internet of Things: Research Challenges and Opportunities." *IEEE Transactions on Industrial Informatics*, Vol. 14, No. 8, 28 May 2018.

[2]Malik, Nida, et al. "A Comprehensive Review of Blockchain Applications in Industrial Internet of Things and Supply Chain Systems." *Applied Stochastic Models in Business and Industry*, Vol. 37, 3 May 2021.

[3]Aste, Tomaso, Paola Tasca, and Tiziana Di Matteo. "Blockchain Technologies: The Foreseeable Impact on Society and Industry." *Computer*, Vol. 50, No. 9, 2017.

[4]Swan, Melanie. *Blockchain: Blueprint for a New Economy*. O'Reilly Media, 2015.

[5]"Transforming Our World: The 2030 Agenda for Sustainable Development." United Nations (UN) General Assembly, 21 October 2015.

[6]"Report of the World Commission on Environment and Development: Our Common Future." United Nations (UN), accessed May 2022.

[7]Holden, Erling, Kristin Linnerud, and David Banister. "Sustainable Development: Our Common Future Revisited." *Global Environmental Change*, Vol. 26, May 2014.

[8]"The 17 Sustainable Development Goals." United Nations (UN), accessed May 2022.

[9]Babich, Volodymyr, and Gilles Hilary. "OM Forum — Distributed Ledgers and Operations: What Operations Management Researchers Should Know About Blockchain Technology." *Manufacturing and Service Operations Management*, Vol. 22, No. 2, 27 June 2019.

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

[11]Yuan, Pu, et al. "Design and Implementation on Hyperledger-Based Emission Trading System." *IEEE Access*, Vol. 7, 20 December 2018.

[12]Thess, André, et al. "Global Carbon Surcharge for the Reduction of Anthropogenic Emission of Carbon Dioxide." *Energy, Sustainability and Society*, Vol. 10, No. 9, 2020.

[13]Hughes, Laurie, et al. "Blockchain Research, Practice and Policy: Applications, Benefits, Limitations, Emerging Research Themes and Research Agenda." *International Journal of Information Management*, Vol. 49, December 2019.

[14]Deringer, H., et al. "Study on Due Diligence Requirements Through the Supply Chain." European Commission, Directorate-General for Justice and Consumers, 2020.

[15]Kshetri, Nir. "Will Blockchain Emerge as a Tool to Break the Poverty Chain in the Global South?" *Third World Quarterly*, Vol. 38, No. 8, 28 April 2017.

[16]Yermack, David. "Corporate Governance and Blockchains." *Review of Finance*, Vol. 21, No. 1, 2017.

[17]"Fintech and Sustainable Development: Assessing the Implications." United Nations Environment Programme (UNEP), accessed May 2022.

[18]Glavanits, Judit. "Sustainable Public Spending Through Blockchain." *European Journal of Sustainable Development*, Vol. 9, No. 4, 2020.

[19]Mora, Higinio, et al. "Blockchain Technologies to Address Smart City and Society Challenges." *Computers in Human Behavior*, Vol. 122, September 2021.

[20]Ahad, Mohd Abdul, et al. "Enabling Technologies and Sustainable Smart Cities." *Sustainable Cities and Society*, Vol. 61, 2020.

[21]França, A.S.L., et al. "Proposing the Use of Blockchain to Improve the Solid Waste Management in Small Municipalities." *Journal of Cleaner Production*, Vol. 244, October 2019.

[22]Maasho, Aaron, and Nigel Hunt. "Coffee Price Slump Leaves Farmers Earning Less Than a Cent a Cup." *Reuters*, 14 January 2019.

[23]Treiblmaier, Horst, and Roman Beck. *Business Transformation Through Blockchain*. Springer International Publishing, 2019.

[24]Blakstad, Sofie, and Robert Allen. *FinTech Revolution: Universal Inclusion in the New Financial Ecosystem*. Palgrave Macmillan, 2018.

[25]Marke, Alastair (ed.). "Editor's Prologue: Blockchain Movement for Global Climate Actions." In *Transforming Climate Finance and Green Investment with Blockchains*. Academic Press, 2018.

[26]"Cambridge Bitcoin Electricity Consumption Index." Cambridge University Centre for Alternative Finance, accessed May 2022.

[27]Rooney, Kate, Jordan Smith, and Mai Tejapaibul. "Crypto World: Crypto Prices Rebound and Solana's Co-Founder Thinks Bitcoin Needs Proof of Stake." CNBC, 27 April 2022.

[28]Moore, Stephen. "Blockchain Technology Applied to Plastics Traceability and Sustainability." Plastics Today, 23 October 2019.

[29]Tozanli, Özden, Elif Kongar, and Surendra M. Gupta. "Trade-In-to-Upgrade as a Marketing Strategy in Disassembly-to-Order Systems at the Edge of Blockchain Technology." *International Journal of Production Research*, Vol. 58, No. 23, 19 January 2020.

Cigdem Z. Gurgur is Associate Professor of Decision and System Sciences at Purdue University. She is a data and management science expert with experience in optimization models under uncertainty and decision support systems development with algorithmic theory design. Dr. Gurgur's work utilizes meta-analytics, computational models, and statistical analysis for resource allocation and applies mathematical programming integrating financial and operational risk assessment. Her most recent work encompasses blockchain technologies in advancing applied research for data science and the United Nations (UN) Sustainable Development Goals. Dr. Gurgur's consulting and executive education focuses on the healthcare industry, including medical wire and device manufacturing, revenue management, and emerging technology in business and sustainable innovation. Her research has been published in various journals, including Naval Research Logistics, Renewable Energy: An International Journal, Journal on Applied Analytics, *and* Journal of the Operational Research Society. *Dr. Gurgur is Editor of* Data & Policy. *Previously, she was on the faculty at Colorado School of Mines and held an NSF fellowship in environmentally benign manufacturing. Dr. Gurgur earned a master's of science degree in management science from the University of Warwick, UK; a master's of science degree in applied and mathematical statistics from Rutgers University; and a PhD in industrial and systems engineering from Rutgers University. She can be reached at cgurgur@purdue.edu.*

CUTTER

AN ARTHUR D. LITTLE COMMUNITY

Cutter Consortium, an Arthur D. Little community, is dedicated to helping organizations leverage emerging technologies and the latest business management thinking to achieve competitive advantage and mission success through our global research network.

Cutter helps clients address the spectrum of challenges disruption brings, from implementing new business models to creating a culture of innovation, and helps organizations adopt cutting-edge leadership practices, respond to the social and commercial requirements for sustainability, and create the sought-after workplaces that a new order demands.

Since 1986, Cutter has pushed the thinking in the field it addresses by fostering debate and collaboration among its global community of thought leaders. Coupled with its famously objective "no ties to vendors" policy, Cutter's *Access to the Experts* approach delivers cutting-edge, objective information and innovative solutions to its community worldwide.