Guest editors

Margaret O'Gorman
Frank Werner

Contributing authors

Charlie Briggs
Enrique Castro-Leon
Catherine Drumheller
Caroline Hernandez
Laura Lawlor
Matthew Ling
Katrina Pugh
David Jeffrey Ringer
Dan Salas
Jon Wagar
Margaret Waldock
Jose Zero

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Anticipate, Innovate, Transform

Corporate Sustainability Strategies: Part II

Aligning Business with Nature Positive Solutions

CONTENT

CORPORATE SUSTAINABILITY STRATEGIES: ALIGNING BUSINESS WITH NATURE POSITIVE SOLUTIONS

BY MARGARET O'GORMAN AND FRANK WERNER, GUEST EDITORS

In Part I of this *Amplify* series on corporate sustainability strategies, we sought to "shine a light on the challenges and opportunities of unifying sustainability efforts and showcase pragmatic approaches for greater impact."[1] The issue looked at leadership, employees, processes, and industries through the lenses of risk, value, change management, and efficiency. Examples of unifying efforts along the corporate vertical and across entire industries were presented to inspire and guide leaders seeking sustainability strategies that are integrated, efficient, and reflect the reality of change management in complex corporate ecosystems.

Here in Part II, we move outside the company into nature and explore unifying efforts to address climate, community, and biodiversity. We present examples of efforts to recognize the "whole" problem while appreciating the interdependence of the parts. That problem can be framed as the twin crises of climate change and biodiversity loss (as outlined by the sister United Nations conventions on climate and nature). Alternately, it can be framed by the concept of planetary boundaries, which is increasingly being used to explain the multiple pressures on our planet's ability to be stable and resilient.[2]

Regardless of the framing, the crises are real and enduring, despite the best efforts of multiple sectors of society to address them. This issue of *Amplify* explores how a nature-centered approach can direct action that has meaning and impact.

IN THIS ISSUE

Our first article, by Catherine Drumheller, Matthew Ling, and Laura Lawlor, describes an approach for valuing the benefits of nature to ensure investments are made in the most economical and impactful ways. The authors identify six categories of benefits that can be realized from nature-based solutions, and those benefits are associated with indicators and criteria that provide a screening tool for project designers. This tool can be used to develop scores using standard ecosystem accounting principles and other methods to measure impacts on human and nature communities. The measures can be direct or based on reference values.

The authors caution about the limits of efforts where time (a critical factor in returning results) may not be part of the benefit calculus. Another limit is that avoided costs are generally overlooked, decreasing the overall valuation of any nature-based intervention. In the world of nature-based solutions, measurement approaches range from overly simplistic and optimistic to overly complex and expensive. The authors seek to present a middle ground that is both credible and accessible.

A practical middle ground is also the goal of Dan Salas and Caroline Hernandez, authors of our second piece. In their article, they illustrate how existing nature positive programs can be the best choice for companies at certain maturity levels in their nature engagements. Across the world, there are countless such programs, and the authors focus on a particularly successful approach: the Rights-of-Way as Habitat Working Group (ROWHWG) at the University of Illinois Chicago. This group of practitioners, academics, and corporations has developed and deployed the largest multi-stakeholder conservation agreement in the US. A conservation agreement is a voluntary commitment by a landowner to protect and restore natural habitats toward a specific conservation goal. ROWHWG developed the agreement to meet conservation goals for the monarch butterfly, an iconic and culturally important species currently in decline. The agreement spans the 48 contiguous states, includes participants from 70 entities (including many companies), and protects 1.1 million acres of habitat.

The conservation-agreement approach has many benefits for companies seeking to act for nature. Signatory companies share their efforts with the working group and can use the data as a credible foundation for disclosures and reporting against commitments, and ROWHWG provides tools and resources for participating companies. The article describes key elements of a successful collaboration around existing nature positive programs, including understanding the business and biodiversity need, participating within and across sectors, and leveraging third-party agreements and certifications to ensure credibility.

A net benefit for nature is central to the activities happening at Duke Farms in Hillsborough, New Jersey, USA, a campus-like setting in a peri-urban landscape. Our third article, by Margaret Waldock, Jonathan Wagar, and David Jeffrey Ringer, describes how Duke Farms addressed greenhouse gas emissions, biodiversity loss, and carbon sequestration using a science-based approach that supported the location's strategic objectives with smart decision-making and an authentic discussion of trade-offs.

> **UNDERSTANDING RAPID, DRAMATIC OPERATIONAL DECARBONIZATION IS NEEDED TO SECURE A STABLE FUTURE FOR OUR PLANET**

Duke Farms sets an excellent example for corporate campuses through its goals for climate and nature — local action that is scalable and replicable. The challenges faced by Duke Farms as it seeks to reduce emissions, restore ecosystems, and sequester carbon are similar to those faced by companies around the world in which strategic ambitions must bend to operational goals.

Understanding that rapid, dramatic operational decarbonization is needed to secure a stable future for our planet, Duke Farms worked with researchers to model emissions-reduction and carbon-sequestration scenarios. The model prioritized specific intervention points that were checked against reality, and trade-offs were made to maintain the overall vision of the organization and allow for human behavior. The article points to the fact that not all interventions are possible, noting that clarity of vision can help leaders quickly make decisions and act on them.

Duke Farms demonstrates that unified approaches can succeed when guided by a clear purpose, an openness to necessary trade-offs, and a science-based framework that values insights from researchers and experts with a deep understanding of both the ecology and psychology of place.

Next, Charlie Briggs unifies science-based targets and reporting requirements to show that adopting such targets can satisfy current and pending reporting while allowing companies to use targets to take action, build institutional knowledge and capacity in nature, secure buy-in and funding for future nature-related needs, and enhance stakeholder relationships with credible targets that can be openly communicated. The article uses examples from business and other sectors to show the future-focused benefits of adopting science-based targets that contribute to business resilience.

To close the issue, Enrique Castro-Leon, Katrina Pugh, and Jose Zero take another approach to supporting business resilience. They believe we need a carbon-accounting system that is clear, credible, transparent — and can stretch along supply chains and be compared across businesses. Starting with US generally accepted accounting practices, the authors advocate for an approach based on the accrual method to provide a more accurate picture across time and promote the idea that carbon investments in impermanent solutions like forest planting should be accounted for just like a commodity with a value that changes depending on circumstances. They present a suite of characteristics for such a system and call for greater collaboration to build strong systems of accounting that could yield progress toward global goals for climate and nature.

This *Amplify* series presents unified approaches to advancing corporate sustainability — both internally, in terms of change management, and externally, within nature and the environment writ large — to align climate, nature, and society to achieve resilience, stability, and prosperity. Reading these articles from experts in the field, it's clear there is no single solution and no shortcuts. There may even be a lot of "wheel reinvention," which is a shame.

As guest editors of the series, we understand that we must meet companies where they are in terms of sustainability maturity, engagement with the issue, resources, and the ability to affect meaningful change. But when we look at the planetary boundaries and see that six of the nine have been crossed, we also know that meaningful change needs to happen now — and it needs to be dramatic.

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About the guest editors

MARGARET O'GORMAN AND FRANK WERNER

Margaret O'Gorman operates at the intersection of business and nature as CEO of Tandem Global (established from the merger of Wildlife Habitat Council [WHC] and World Environment Center). Currently, as President of WHC, she helps multinational corporations integrate nature-based solutions into their sustainability efforts. Ms. O'Gorman is also a member of Arthur D. Little's AMP open consulting network. She uses her platform and audience to promote private sector engagement in conservation action to restore ecosystems, recover species, connect communities, and make a positive difference to people and the planet. Ms. O'Gorman has consulted with *Fortune* 500 companies like General Motors, Exelon, Chevron, BASF, and many others to develop nature strategies and frameworks. She helps companies drive long-term sustainability through WHC Certification, a recognition program powered by Tandem Global that connects C-suite ambition to site-based action. In addition, Ms. O'Gorman inspires companies to consider the human element in their sustainability efforts through community and employee engagement. She is the author of *Strategic Corporate Conservation Planning*. Ms. O'Gorman is a member of BASF's Nature Advisory Council and an appointee to the Guidance Committee for the North American Biodiversity and Climate Change Assessment. Prior to her work with WHC, she led the Conserve Wildlife Foundation of New Jersey and also steered fundraising efforts for New Jersey Future and Pinelands Preservation Alliance. Ms. O'Gorman earned a master of science degree in micropaleontology from the University of Southhampton, UK. She can be reached at mogorman@wildlifehc.org.

Frank Werner is Director of the Global Thought Leadership program at Tandem Global (established from the merger of Wildlife Habitat Council [WHC] and World Environment Center) and also leads the organization's European office. He facilitates sustainability information exchanges among multinational companies and provides guidance on creating both societal and corporate value. Mr. Werner develops and implements Tandem Global Executive Roundtables in partnership with global companies, focusing on critical corporate sustainability challenges across the US, Europe, and other regions. Previously, over 20 years, he held positions in other organizations where he helped companies of various sizes develop and strengthen their sustainability strategies, advised global companies on sustainability reporting, and evaluated the sustainability performance of multinational enterprises. Mr. Werner also has experience in sustainable water management and research in both Germany and Chile. He has authored several publications in the fields of sustainable water management, environmental business strategies, and sustainability reporting. Mr. Werner earned a master's-equivalent diploma in geography from the University of Heidelberg, Germany. He can be reached at fwerner@tandemglobal.org.

UNDERSTANDING THE VALUE OF NATURE-BASED SOLUTIONS THROUGH THE LENS OF BENEFIT

Authors

Catherine Drumheller, Matthew Ling, and Laura Lawlor

The global community faces several interdependent challenges: decreases in biodiversity and rising levels of species extinction, climate change and its impacts on human and social systems, and global inequality and related socioeconomic impacts on vulnerable populations.

The Intergovernmental Panel on Climate Change (IPCC) "Climate Change and Land" report says scenarios to limit increases in mean global temperature are heavily reliant on land use.[1] Unfortunately, nature and the biodiversity contained within (and the critical functions and services we derive from them) are under increasing pressure and in decline, resulting in approximately 1 million species being at risk of extinction.[2]

We are reliant on nature to an enormous degree, and if valued monetarily, the services/benefits it delivers would have vast sums attached to them. However, we continue to direct massive amounts of public and private finance to processes that negatively impact nature, amounting to US $7 trillion per year.[3]

In 1997, the landmark Nature paper "The Value of the World's Ecosystem Services and Natural Capital" estimated that the value of services we receive from nature (known as "ecosystem services" or "nature's contributions to people") was $33 trillion, a figure that was widely derided as being either a gross under or overestimate.[4] In 2020, research by the World Economic Forum attributed $44 trillion of economic value generation to nature and its services.[5]

Nature-based solutions (NbS) can be part of mitigating our interconnected global challenges. NbS are defined by the United Nations Environmental Programme (UNEP) as:

> ... actions to protect, conserve, restore, sustainably use, and manage natural or modified terrestrial, freshwater, coastal, and marine ecosystems which address social, economic, and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience, and biodiversity benefits.[6]

NbS are seen by the preeminent conservation organizations and many others as critical to achieving the goals of the Paris Agreement and the Kunming-Montreal Global Biodiversity Framework. However, only $200 billion flows to NbS annually, about a third of what's needed to meet the goals and targets set out in those agreements/frameworks.[7]

NATURE-BASED SOLUTIONS CAN BE PART OF MITIGATING OUR INTERCONNECTED GLOBAL CHALLENGES

CURRENT METHODOLOGIES

Current methodologies and tools for understanding the benefits we receive from NbS tend to be overly simple or overly complex. Sometimes, benefits are evaluated at an extremely high level based primarily on the evaluator's knowledge and experience. Other times, companies perform cost-benefit analyses that require applying highly detailed scientific and economic data to expensive models.

At both the screening and project levels, initiators may not be able to bear such expenses, and predominantly subjective determinations may lead to undervaluation, lack of transparency, and/or unintended negative consequences to ecologies and societies.[8] This may contribute to underinvestment in NbS due to fear of failure and absence of quantified benefits from proposed or implemented interventions. In other cases, guidelines, instructions, and case studies for the valuation of specific solutions and scenarios are documented, but no method or tool for combining qualitative and quantitative evaluations is provided, so there are gaps in capturing realized benefits across natural, climate, and social systems.

Simplistic evaluations of NbS can obscure the range of both environmental and social opportunities they offer.[9] A holistic approach is needed to tackle the problems of protecting and restoring biodiversity, mitigating and adapting to climate change, and supporting human well-being.

Screening NbS for their potential to deliver multiple benefits to nature and societies can address the challenges we face by integrating qualitative and quantitative measures and evidence.[10] This article proposes a benefit-screening approach for evaluating and documenting the holistic value and impact potential of NbS that can be used in decision-making. Our methodology was developed by combining best practices and guidelines in NbS benefit-performance development indicators with ecosystem services and accounting.

We used a process-based approach to achieve integration, first constructing a representative model for the interaction of Earth systems (nature and biosphere) with societal systems that support human well-being. For the purposes of this article, the model takes the form of a framework for multi-criteria analysis (MCA). After the MCA framework was constructed, we developed quantitative and qualitative screening and scoring approaches. Our process is shown in Figure 1.

Our proposed framework includes indicators and criteria associated with six categories of benefit. The benefit categories, indicators, and criteria are based on a survey of literature performed in accordance with the process steps in Figure 1 and are organized in a hierarchical evaluative schema (see Figure 2).

These categories function as the benefits list and are documented in an MCA framework. The detail associated with the assessment of these benefits provides transparency during the qualitative scoring process by clearly outlining the considerations and reasoning involved.

Table 1 in the Appendix contains a preliminary benefits list, along with corresponding indicators and criteria developed for the representative model. This approach acknowledges both use values (direct benefits) and non-use values (existence and bequest values).

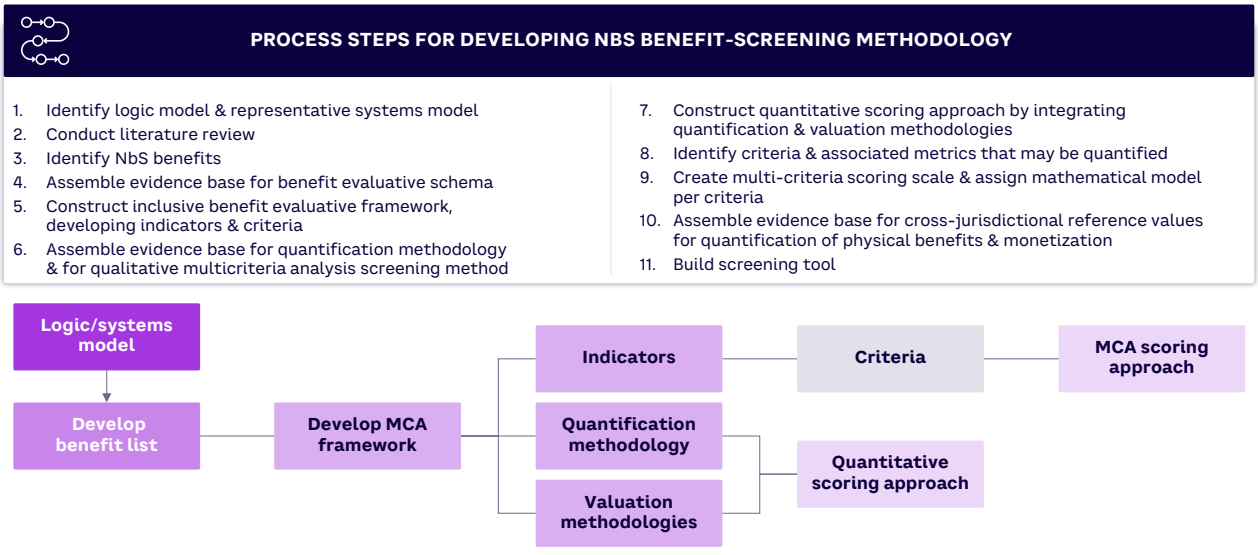

Figure 1. Development of the NbS benefit-screening methodology

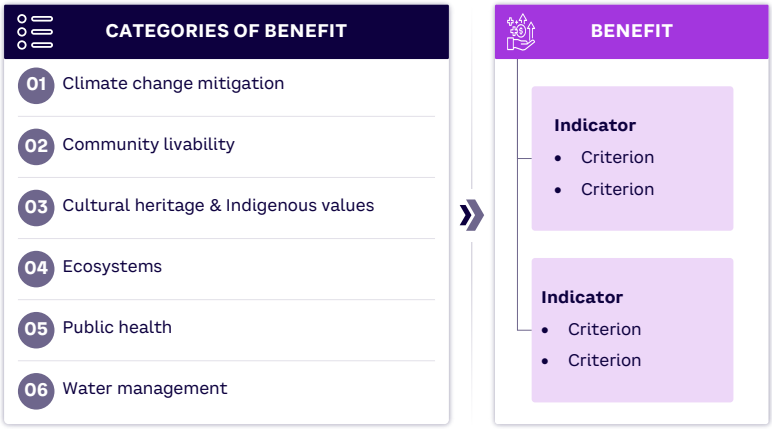

Figure 2. Benefits list and screening structure

Once the MCA framework is developed, quantitative and qualitative screening and scoring methodologies can be constructed. For the benefit-screening approach proposed here, benefit quantification includes the two primary steps shown in Figure 3. The qualitative screening and scoring methodology applies a five-point scoring scale and impact-estimation model at the criterion level to the MCA framework.

Physical benefits are quantified by applying ecosystem services accounting principles to identify the resource units associated with a benefit and the resource-unit inputs relevant for benefit evaluation. The individual inputs are then aggregated to calculate the total measured benefit.[11] Once the total measured benefit is calculated, it can be monetized using methods like direct market valuation, contingent valuation, or benefit transfer.[12]

These calculations often rely on reference values from specific case studies or regions, meaning that the resulting values could have limited applicability. Therefore, when using generalized reference values, the outputs should be considered suitable for preliminary decision-making. If the methodology used specific reference values from selected geographies, the accuracy and precision of the outputs would improve, making them more relevant to the specific area.

The full-benefit-screening process includes MCA benefit scoring, quantifying physical benefits, and monetizing these quantified benefits. The outputs generated are inclusive of performance scores in all three steps, as shown in Figure 4. Combining the comprehensive scoring output with a discrete quantification of physical benefit and monetization outputs provides a more transparent statement of holistic benefit. As the physical quantification process step requires technical input for some indicators, there may be gaps in data due to information limits.

In this scenario, the MCA evaluation provides the basis for evaluation and scoring, so all indicators are considered, despite potential data and information gaps. In addition, reporting the biophysical scores separately from the monetary scores provides transparency in the quantification process, highlighting that the benefits extend beyond financial aspects to include natural systems and human well-being.

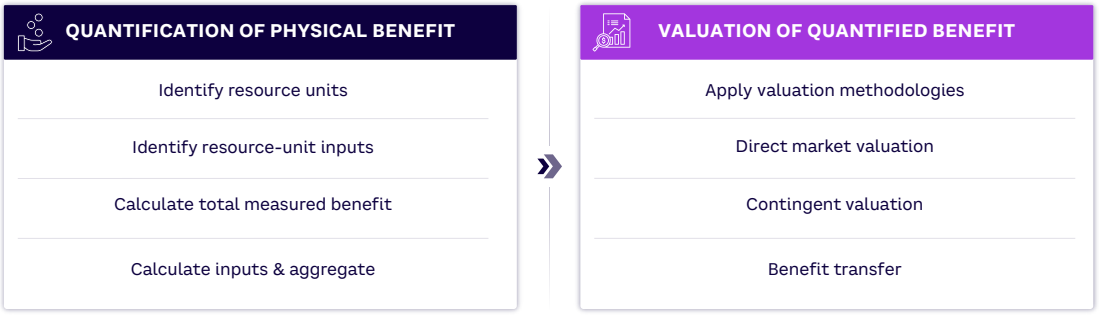

Figure 3. Benefit-quantification steps

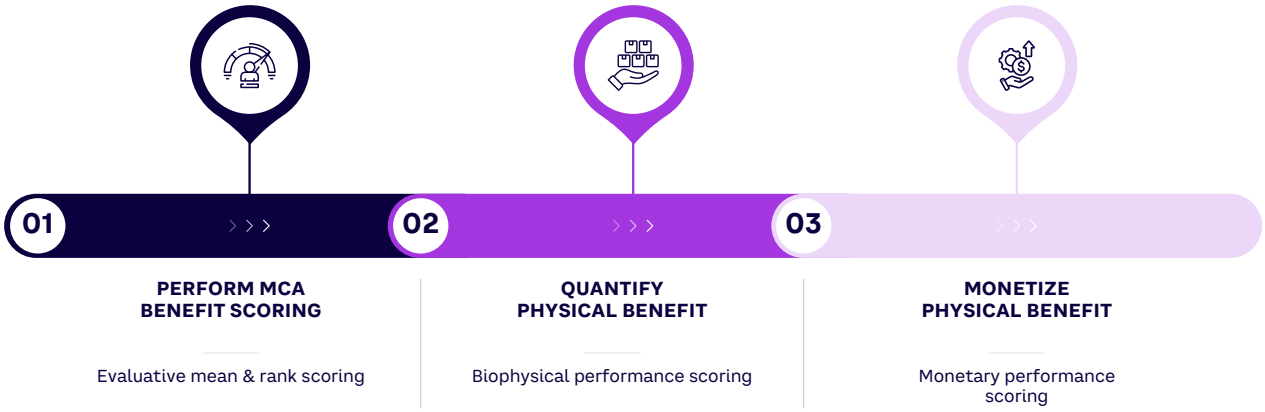

Figure 4. Process steps and outputs for benefit screening

PRACTICAL USES

There is often a disconnect between the timelines required to deliver benefits and progress toward targets and methods of economic valuation, partly because traditional cost-benefit analyses tend to value economic activities associated with direct use.[13] These models may overlook avoided costs, which can bias analyses against NbS or obscure benefits like reduced human-health costs and climate change–related expenses.

> **THERE IS OFTEN A DISCONNECT BETWEEN THE TIMELINES REQUIRED TO DELIVER BENEFITS & PROGRESS TOWARD TARGETS**

Our holistic model addresses this by evaluating and documenting both use and non-use values over longer time horizons and connecting impacts to avoided costs in climate, natural, and human systems. This methodology is particularly valuable during the program development and planning phases for infrastructure projects. It can also support mobilizing commercial capital investment in NbS by showcasing their potential beneficial impacts across human, natural, and climate dimensions. Such investment mobilization may be particularly relevant for areas like water infrastructure development, in which past failures in operational and maintenance phases and longer ROI timelines have hindered commercial capital investment.[14]

For example, Green Climate Fund (GCF) estimates that 25% of cities (representing more than $4 trillion in economic activity) are water-stressed due to climate- and infrastructure-driven water security–related losses. Yet this reality has failed to create a compelling financial case for water-elated investment.[15]

One of the primary barriers for this financial case is "difficulty in monetizing benefits." As summarized in GCF's 2022 "Water Security Sectoral Guide Consultation Version 1," water management provides public and private sector co-benefits, but the challenge of monetizing those benefits reduces potential revenue flows and credit availability.[16] A screening approach that captures benefits across economies, communities, ecosystems, and the climate addresses this barrier by showcasing value specific to the proposed project. This is particularly relevant for NbS, where cross-cutting benefits are integral to the solution.

CONCLUSION

Current benefit-screening valuation tools and methodologies often fall into one of two categories: either they are complex, expensive models organized as instructional guidelines for discrete quantification methods, or they are highly qualitative and subjective. By combining quantitative and qualitative methodological elements, our approach broadens the basis of value in benefit-evaluation decision-making.

By providing a comprehensive MCA framework with transparent indicators and criteria based on best and leading practices, our methodology improves transparency, captures expert knowledge, and demonstrates impacts across benefit categories. Coupling this approach with quantification and monetization of physical benefit has the potential to support holistic screening-level decision-making, facilitate identification of opportunities for impact and further inquiry, and connect to financial cost analysis in short- and long-term timelines.

This can support the evidence base for financial investment in well-designed NbS for climate change mitigation and adaptation efforts, protection of and support for biodiversity, and improvements to human well-being.

APPENDIX

BENEFIT	INDICATOR	CRITERIA
Climate change mitigation	Reduced embodied carbon	Are emissions from embodied carbon reduced through reduction of material & service consumption?
	Reduced & avoided energy use	Is lifecycle energy demand & use decreased (in comparison to grey infrastructure alternative)?
	Carbon storage (soils, vegetation, wetlands, ocean)	Is carbon storage maintained or capacity increased (unit weight carbon/year [C/yr])?
	Carbon sequestration	Is carbon (& GHG) directly sequestered (unit weight C02 emissions [CO2e]/unit area/year)?
	Carbon emissions avoided	Are carbon emissions avoided (e.g., Scope 2 emissions from heating, cooling & water/wastewater treatment & direct emissions from fossil fuel use) (CO2e/yr)?
Community livability	Property values, improved aesthetics	Will mean land and/or property value in proximity to green space (change in mean house prices/rental markets & average land productivity & profitability) increase?
	Increased recreational opportunity	Will proportion of population with proximity & access to green/blue spaces be improved?
		For those with access, will area of green & blue space per person or per unit area be increased?
	Reduced noise pollution	Will proportion of population exposed to noise levels be reduced?
	Improved community cohesion	Is solution an expression of shared community values?
		Does solution facilitate social connection across & among diverse demographic groups?
		Does solution increase sense of place & well-being?
	Tree canopy increase	What is expected increase in number of trees in project area?
		Will tree types & distribution be optimized for intended purposes & longevity?
	Increased urban agriculture/horticulture opportunity	Will solution increase irrigation water availability (volume), access (proximity) & opportunity (storage & cooperative management) for urban food production/community gardens?
		Will solution support food cultivation & improve access to high-quality food & food security for proportion of population with food insecurity?
Cultural heritage & Indigenous values	Alignment with expressed cultural values	Does solution improve alignment of infrastructure development trajectory with Indigenous values & cultural heritage as expressed by impacted Indigenous communities (survey data, interviews, public meetings, engagement & alignment with community-based organizations, results of participatory governmental processes)?
	Alignment with expressed cultural practices	Does solution improve alignment of infrastructure development trajectory with Indigenous cultural practices as identified by impacted Indigenous communities (see above)?

Table 1. Example MCA benefits, indicators, and criteria (continued on next page)

BENEFIT	INDICATOR	CRITERIA
Ecosystems	Natural habitat avoided	Will there be an increase in area & condition of native habitat avoided?
		Is habitat considered critical for threatened and/or endangered species?
	Natural habitat improved	Is habitat considered critical for threatened and/or endangered species?
		Will there be an increase in area & condition of native habitat improved?
		What is estimated percentage (range) of impacted habitat receiving management interventions?
	Natural habitat restored	Is habitat considered critical for threatened and/or endangered species?
		Will there be an increase in area & condition of native habitat restored?
		What is calculated area of habitat restored?
	Reduced soil loss & preservation of natural soils	What is calculated or estimated percent of soil retained onsite (per year)?
		Is total suspended solid pollution loading into waterways mitigated?
	Increased biodiversity	What is calculated or estimated percentage of Biodiversity Net Gain?
	Maintains natural hydrology	Is rate (magnitude, timing, frequency duration) of stream flow maintained or improved?
		Is water temperature improved?
Public health	Heat stress & urban heat island effect mitigation	Will there be reductions in mean or peak day-time temperatures?
		Will cooling day increases be mitigated or cooling days reduced from current baseline number?
	Improved air quality	Will there be reductions in air pollutants concentrations due to direct update?
		Will there be reductions in air pollutants due to avoided emissions?
	Improved mental health outcomes	What percent of potentially impacted community will receive improved access to blue/green spaces & opportunity for improved mental health outcomes?
		What percent of potentially impacted community is underresourced or disadvantaged based on applicable jurisdictional & community definitions?
Water management	Water quality	Are removal pollutant & contaminant removal rates improved and/or optimized?
		Reduced nutrient & TSS concentrations/loading
		Reduced pathogen & viruses
		Reduced metals & contaminants
	Reduced runoff, treatment, process & conveyance volumes	Will runoff volumes or flow velocity per event over given area be reduced?
		Will infiltration volumes be increased?
		Runoff volume reduced compared to precipitation quantity
		Will solution reduce grey infrastructure needs or processing loads (volume & pollutant loading)?
	Reduced flooding	Will areal extent of flood plain (unit area measurement) be reduced?
		Will flood peak reduction & peak flood height delay be improved?
		Reduced flood depth (unit depth in flood level/interval)?
		Reduced flood risk (reduced flood interval)?
	Increased in available water supply (e.g., rainwater-harvesting opportunity)	Will solution result in increases in available water supply (e.g., rainwater harvesting)?

Table 1 (cont'd). Example MCA benefits, indicators, and criteria

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About the authors

Catherine Drumheller is Senior Advisor at GHD. Her background includes leading climate-related water security evaluations, blue-green infrastructure benefit evaluations, and applied social-ecological systems theory. Ms. Drumheller has extensive experience in creating methodologies for implementing holistic and sustainable development projects, utilizing social-ecological systems analysis and scenario-based planning. She has conducted climate-related market analyses and practice reviews of climate finance mechanisms, including parametric insurance, green bonds, blue bonds, and blended finance instruments, as well as mechanisms for national adaption planning. Ms. Drumheller played a key role in developing a resilience-focused water infrastructure program, incorporating an implementation and lifecycle approach tailored for urban and peri-urban regions in low- to middle-income countries. She earned a master of theological studies degree in environmental ethics from Iliff School of Theology, USA. She can be reached at catherine.drumheller@ghd.com.

Matthew Ling is Nature-Based Solutions Lead at GHD and an environmental professional with over 15 years' experience spanning consultancy, local government, the third sector, and academia, focusing on environment, ecology, conservation, and climate. Dr. Ling is a highly motivated and passionate advocate for conservation, sustainability, nature, and the environment, striving to apply accrued knowledge, experience, and skills to achieve positive impact and change the "business as usual" approach. Prior to GHD, he led a three-year green infrastructure climate investment pilot project, supporting a UK local authority in enhancing city-wide climate resilience and advancing its net zero carbon emissions target. Dr. Ling has authored numerous reports on natural capital, ecosystem services, ecosystem assessment, biodiversity, and green infrastructure. He earned a PhD in restoration ecology from Bangor University, UK. He can be reached at matthew.ling@ghd.com.

Laura Lawlor is Principal at GHD with over 20 years' experience in multidisciplinary consulting. She works with clients, partners, stakeholders, and rightsholders developing tailored approaches to addressing complex challenges. Ms. Lawlor thrives on the opportunity to help clients tackle today's sustainability challenges through a suite of nature-based solutions that prioritize natural capital, biodiversity, ecosystem services, and blue-green infrastructure. Her broad technical knowledge together with an instinct for holistic solutions drives sustainable and pragmatic outcomes for nature, society, and clients. She earned a master of science degree from Queen's University, Canada, and is a Certified Senior Ecologist. She can be reached at laura.lawlor@ghd.com.

LEVERAGING EXISTING NATURE POSITIVE PROGRAMS FOR CORPORATE SUSTAINABILITY

Authors

Dan Salas and Caroline Hernandez

With biodiversity loss emerging as a critical concern, the urgency to address climate resilience has companies searching for solutions. Even as they recognize the importance of integrating nature positive actions into their sustainability strategies, many companies struggle with operationalizing nature positive actions.

Should new positions and programs be created or pilot projects implemented? As companies explore what being nature positive means, many find that existing compliance, conservation, and stewardship certifications already contribute to positive nature and biodiversity.

In this article, we explore how leveraging established nature positive programs can enhance corporate sustainability efforts. Here, we define "nature positive programs" as formalized government-led conservation efforts, proactive industry standards, or data-driven or science-based environmental certifications. These programs help businesses align their practices with global biodiversity goals, improve ecosystem restoration, and reduce environmental risks. By engaging with existing nature positive programs, companies can contribute to habitat creation and other positive environmental outcomes.

THE CRITICAL ROLE OF NATURE & BIODIVERSITY IN BUSINESS SUSTAINABILITY

Everything we have as a society (including businesses) relies on nature. Nature comprises the lands, waters, air, and other natural resources that provide raw materials and ecosystem services. Biodiversity constitutes the ecosystems and species comprising nature, which create resilience and enhance many ecosystem services. Together, nature and biodiversity support the ecosystem services, raw materials, and support networks we rely on for all facets of life (see Figure 1).

Nature and biodiversity loss poses a significant threat to ecosystems and human well-being. Declines in biodiversity disrupt ecosystems vital to food security, resource availability, climate regulation, and pest/disease control.

Global frameworks like the Kunming-Montreal Global Biodiversity Framework (GBF) and the United Nations Sustainable Development Goals (UN SDGs) emphasize the need for urgent action to address biodiversity loss.[1] As recently stated at the *2024 United Nations Biodiversity Conference (COP16)*, companies play a crucial role in achieving these goals by adopting nature positive practices that contribute to conservation and sustainable use of natural resources.[2]

NATURE & BIODIVERSITY LOSS POSES A SIGNIFICANT THREAT TO ECOSYSTEMS & HUMAN WELL-BEING

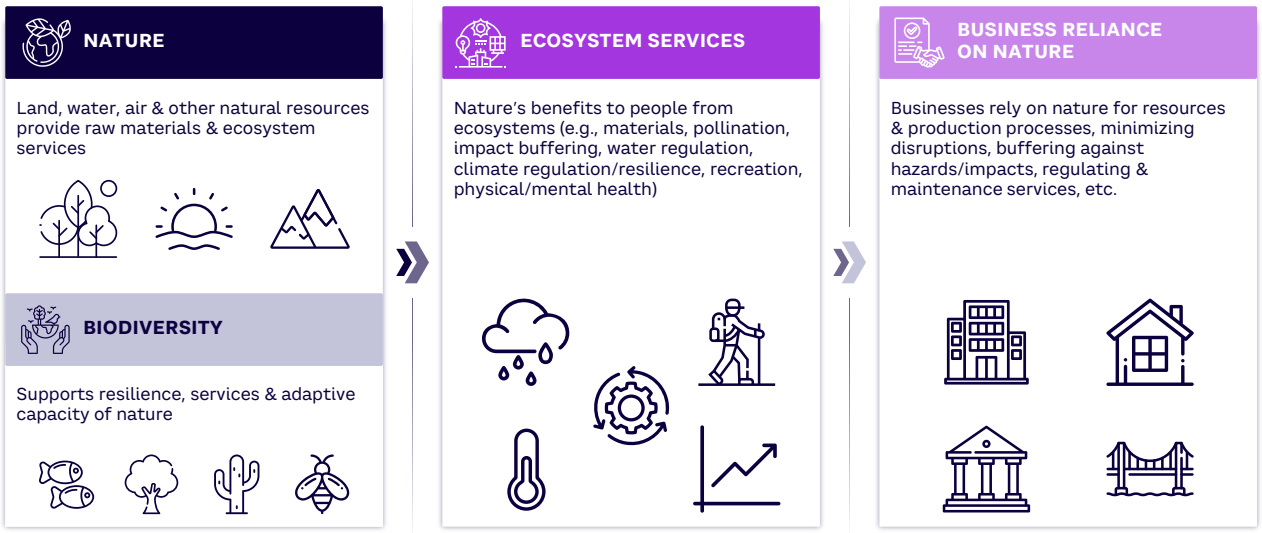

Figure 1. Nature and biodiversity's relationship with ecosystem services and business

INCREASING DEMAND FOR NATURE-RELATED DISCLOSURES

Not surprisingly, given business reliance on nature and biodiversity, the financial sector is acutely interested in understanding and addressing biodiversity risk. Investors, customers, and regulators are demanding greater transparency regarding corporate impacts on nature.

Disclosure frameworks such as the Global Reporting Initiative (GRI), the Corporate Sustainability Reporting Directive (CSRD), and others have expanded their nature-related disclosures. These disclosures help businesses identify and manage their environmental impacts with the goal of mitigating financial risks, enhancing company reputation, and improving competitiveness. By reporting on nature-related metrics, companies demonstrate their commitment to sustainability goals (including being nature positive) and build trust with stakeholders.

The Taskforce on Nature-related Financial Disclosures (TNFD) provides an assessment framework for businesses to identify, assess, and manage nature-related risks and opportunities. TNFD's Locate-Evaluate-Assess-Prepare (LEAP) planning approach helps companies understand how their operations depend on and impact nature. By integrating TNFD assessments into their sustainability planning, companies can mitigate risks from nature and biodiversity loss, such as operational exposures, supply chain disruptions, and regulatory penalties, while capitalizing on opportunities like species conservation, resource efficiency, and new market development.

SPECIES LOSS AS A CONSERVATION CONCERN & BUSINESS RISK

According to WWF "2024 Living Planet Report," there has been a 73% decline in global wildlife populations in just 50 years (1970 to 2020).[3] This loss poses significant risks to businesses, including direct impacts on the bottom line. Loss of pollinators like bees can directly affect agricultural productivity. Decline of fish stocks can impact the seafood industry. Companies that do not directly rely on individual species may also be impacted by biodiversity loss in more nuanced ways (see Table 1).

When considering these risks in light of their own operations, companies increasingly recognize that species declines are not just an ecological concern but a business risk. Proactive conservation efforts can help mitigate these risks, ensuring the sustainability of natural resources that businesses depend on. Reporting mechanisms like those previously mentioned help companies track and communicate how nature affects their business as well as what actions they are taking to reduce ecological and financial risks.

NATURE-RELATED DEPENDENCY	DESCRIPTION	FINANCIAL RISK EXAMPLES
Resources directly harvested for consumption	Species loss can reduce availability of consumable goods (e.g., timber, food stocks & raw materials).	In the US, production of pollinator-dependent crops is valued at more than US $50 billion per year.[1] Loss of pollinator habitat & pathogens can impact crop production.
Resources used in production processes for consumable products	Many wild species are used to create products processed into other consumables such as wild crop relatives (for genetic modifications), maple trees (for syrup) & hardwood trees (for construction materials). Species loss can disrupt supply chains & resource availability.	An outbreak of mountain pine beetle in British Columbia in the 1990s affected more than 18 million hectares of forest, causing nearly a 50% loss of the total volume of commercial lodgepole pine in that province.[2]
Supporting consistent regulatory environments with minimal disruption	Species losses may result in changing or additional restrictions that lead to added time & cost to operations, adding complexity & resulting in lower productive output.	Possible oil-vessel restrictions in the Gulf of Mexico for Rice whale protections risked an estimated $31 million to $49.6 million of reduced revenue (assuming $50 to $80 per barrel estimates).[3]
Buffering against visual & noise impacts	Trees, shrubs & other vegetation can provide physical buffers between commercial, industrial & other business facilities that reduce noise & visual impacts to the surrounding community. Loss of vegetation can reduce or eliminate the buffering services provided.	Properties buffered from sights & sounds of neighboring properties are valued more highly. A study in Tucson, Arizona, USA, noted a $16,520 value (in 2015 US dollars) premium on properties near riparian zones.[4]
Buffering against physical hazards	Protection of natural lands (e.g., wetlands, grasslands, floodplains & riparian corridors) can reduce impact of flooding & severe weather. Loss of these habitats or species diversity can increase risk of flooding, fire & storm damage.	Coastal wetlands in the US provide an estimated $23.2 billion in storm-protection services each year.[5]
Regulating & maintenance services	Plant diversity can support phytoremediation, carbon sequestration & ambient air cooling. Species diversity protects against long-term impacts from land use, pollution, changing climate, pests, or disease.	The cooling benefit of green & blue infrastructure in London was estimated at £13.9M (US $17.5 million) for a single year.[6]
Supporting business reputation	Maintaining habitats supports an organization's reputation as a good steward of nature at local, economic & societal levels. Loss of species reduces or eliminates this opportunity.	In survey of global executives, respondents estimated ~63% of their company's market value is attributed to its overall reputation. Some executives attributed as much as 76% of market value to company reputation.[7]
Reducing nature-related legal liability	Supporting local, national, or international laws & regulations regarding protection of species may involve protecting habitat relied on by regulated endangered species.	In the US, the financial costs of legal liability for a company violating the Endangered Species Act can include criminal prosecution for knowingly taking a listed animal, which can result in a fine of up to $200,000 and/or imprisonment.[8]

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Table 1. Examples of nature-related dependencies impacted by nature and species loss

ADDRESSING BIODIVERSITY VIA EXISTING NATURE POSITIVE PROGRAMS

Companies exploring their nature-related dependencies or impacts (and the corresponding risks and opportunities) will find a myriad of programs and tools to support their needs. This lets businesses explore new frontiers while rethinking how their existing operations and risk mitigations can help reduce nature risks. Available tools include:

- **TNFD's LEAP planning approach** — helps companies understand how their operations depend on and impact nature
- **Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE)** — helps financial institutions and companies take initial steps to understand their dependencies and impacts on nature[4]
- **The Natural Capital Protocol** — helps companies measure and value their impacts on natural capital, which can include aspects of biodiversity that support capital dependencies[5]
- **The Science Based Targets for Nature (SBTN)** — guides businesses in setting measurable biodiversity goals[6]

With risks and opportunities identified, a company can consider how to address its business concerns. Because biodiversity loss has been an ongoing concern over the past few decades, many programs have already been developed by government agencies, not-for-profit conservation organizations, private investors, and public-private partnerships to address biodiversity loss and support nature positive actions. However, this rush to fill a market need has caused poor results in some cases and criticisms of greenwashing in others. Companies engaging in nature positive programs must carefully choose where to invest time and money to avoid reputational risks. Third-party audits and verification programs are needed to reduce the risk of underperforming biodiversity programs.

Many third-party verification programs are already in place. These initiatives provide frameworks and tools for businesses to integrate conservation into their operations. Below, we highlight a few such programs available to the energy and transportation sectors via the Rights-of-Way as Habitat Working Group (ROWHWG), which administers voluntary conservation agreements, convenes industry peer exchanges, and supports other nature-related sustainability efforts.[7] By participating in programs like these, companies can enhance their sustainability strategies and contribute to conservation efforts.

CONSERVATION AGREEMENTS

Conservation agreements are voluntary commitments by businesses to protect and restore natural habitats. Unlike offset mitigation, these agreements are developed cooperatively to create a net benefit in which the benefits to a species or its habitat clearly outweigh the impacts created by the business. Mitigation agreements focus on minimizing negative impacts on biodiversity, often through habitat restoration or creation. Net-benefit agreements go beyond mitigation to enhance biodiversity through proactive conservation actions.

These agreements can take various forms. In the US, the Endangered Species Act (ESA) allows voluntary agreements that "enhance the survival" of species at risk of extinction in exchange for regulatory predictability. These take various forms based on the scope, legal status of a species, and degree of benefit created. Across the US and Europe, other conservation agreements take the form of stewardship agreements, conservation easements or leases, or designated use or payment models.[8]

Conservation agreements may be tailored to the needs of local communities and regulations.[9] Conservation International has 4,000 conservation agreements in 19 countries that collectively protect 4.4 million acres (1.8 million hectares). Comparing approaches and a company's ability to commit to action is important when choosing the most effective strategy for nature-related sustainability goals.

Starting in October 2017, ROWHWG, University of Illinois Chicago (UIC), led a national, multi-sector cooperative effort to develop a voluntary conservation agreement for the monarch butterfly.[10] Representatives from across the energy and transportation sectors collaborated to develop a conservation agreement that encourages the adoption of conservation measures to create net benefits for the monarch butterfly. The unprecedented effort and agreement span the contiguous 48 states of the US. As of January 2025, it was the single-largest voluntary conservation agreement in the US, with nearly 70 participants enrolled in the program committing to more than 1.1 million acres (more than 445,000 hectares) of habitat conserved.

Companies engaging in this program have leaned on their conservation agreement commitments to support their nature-related sustainability claims because of its third-party verification mechanisms. The agreement requires that annual habitat monitoring and reporting be sent to UIC, which administers the program. UIC reports on the conservation delivered through the program and its partners to the US Fish and Wildlife Service, which authorizes the program via a permit under the ESA. This creates a robust third-party verification structure that is scientifically defensible and simple to implement. As a result, companies like NiSource, Duke Energy, Phillips 66, and TC Energy all leverage the agreement in their sustainability reporting.[11-14]

A new voluntary conservation agreement is being developed by UIC in partnership with the US Fish and Wildlife Service, Wisconsin Department of Natural Resources, and dozens of industry and conservation organizations. It encourages conservation for 11 species of at-risk bumble bees native to parts of the US. Like the one for monarchs, the agreement formalizes company commitments to conservation in exchange for regulatory predictability and flexibility under the ESA. Mirroring the tracking, monitoring, and reporting requirements of the monarch agreement, the bumble bee agreement will further strengthen the biodiversity-protection claims made by companies enrolled.

In addition to US-based agreements, international conservation agreements offer valuable models for businesses committed to nature positive practices. For example, the Business and Biodiversity Offsets Programme (BBOP), a global initiative, has developed various frameworks to support companies in achieving net-positive biodiversity outcomes.[15]

CONSERVATION AGREEMENTS ARE VOLUNTARY COMMITMENTS BY BUSINESSES TO PROTECT & RESTORE NATURAL HABITATS

Another notable example is Brazil's Atlantic Forest Restoration Pact (Pacto pela Restauração da Mata Atlântica), which is a collective, voluntary conservation agreement.[16] This initiative involves businesses, nongovernmental organizations, and government bodies working together to restore and protect the critically endangered Atlantic Forest. Participating companies commit to protecting and restoring key areas of the forest, supporting habitat restoration, and achieving long-term biodiversity conservation goals. The pact provides a framework for companies to make biodiversity commitments that contribute to regional and global conservation efforts.

TOOLS FOR BIODIVERSITY & SUSTAINABILITY CLAIMS

In addition to conservation agreements, other tools are widely available to support biodiversity. In particular, companies wanting to avoid greenwashing allegations often seek tools that offer independent confirmation of positive outcomes.

These include:

- **Conservation verification by government agencies, conservation organizations, or another third party** — allows independent confirmation of actions and outcomes.
- **Defensible, reliable data and information** — help dispel negative perspectives. By conducting direct research or using appropriate indirect inferences from related studies, a company can ground its outcomes in science-backed information.
- **Tracking and quantifying acres (hectares) of managed habitat** — simple, verifiable method of demonstrating habitat commitments. Using satellite and unmanned aerial vehicle data collection, this method produces a cost-effective metric that can be used across many programs.
- **Third-party methods** — help companies evaluate the success of habitat conservation efforts. These include scorecards, benchmark assessments, and habitat-evaluation indices that use science-based and transparent methodologies to assess success.

These tools may be used individually or in concert, depending on company needs and goals. For example, ROWHWG offers open source tools to support biodiversity and sustainability claims for the energy and transportation infrastructure sectors. (Tools and resources are available to other sectors via organizations such as Conservation International, International Union for Conservation of Nature, Wildlife Habitat Council, and the WWF).

ROWHWG tools include:

- **The Habitat Geospatial Database** — lets users track location-specific data on habitat quality and conditions for effective biodiversity management
- **The Pollinator Habitat Scorecard** — helps companies evaluate and improve habitat suitability for pollinators in a given area
- **Working Group peer-exchange meetings and roundtables** — facilitate collaborative learning and sharing of best practices among industry professionals
- **The Resources Library** — offers a centralized hub of guidance documents, case studies, and tools to support habitat conservation efforts
- **The Pollinator Habitat Aligned with Solar Energy (PHASE) study** — provides specialized tools for integrating pollinator habitat into large-scale solar energy development sites.

These are adaptable and can help inform decision-making, document habitat outcomes, and support sustainability reporting (see Table 2).

ENGAGEMENT EXAMPLES

Effective stakeholder engagement is essential to the success of nature positive programs. Examples of successful engagement include partnerships with conservation organizations and other academic institutions, community involvement in habitat-restoration projects, and collaboration with government agencies. These engagements help build trust and support for corporate sustainability initiatives, ensuring long-term success and positive outcomes. The examples listed in Table 2 are the products of effective engagement between conservation and industry stakeholders and have contributed to large-scale conservation across the US.

IDENTIFYING & LEVERAGING EXISTING NATURE POSITIVE PROGRAMS

Recognized by TNFD as an example for nature positive outcomes, ROWHWG highlights how cooperative approaches can enhance biodiversity and support nature positivity, encouraging companies to leverage such partnerships in their sustainability efforts.[17] Other conservation, industry, and academic-led programs include the Right-of-Way Stewardship Council, Utility Arborist Association, Wildlife Habitat Council, and Xerces Society's Bee Better certification program.

BIODIVERSITY STRATEGY NEEDS	THIRD-PARTY VERIFICATION OF CONSERVATION FOR AT-RISK SPECIES	SUPPORTING BIODIVERSITY CONSERVATION WITH DEFENSIBLE, RELIABLE DATA & INFORMATION	TRACKING & QUANTIFYING ACRES (HECTARES) OF HABITAT MANAGED	EVALUATING SUCCESS OF HABITAT CONSERVATION EFFORTS
Monarch CCAA	√	√	√	√
Nationwide Agreement for At-Risk Bumble Bees	√	√	√	√
Habitat Geospatial Database		√	√	
Pollinator Habitat Scorecard		√		√
Working Group peer-exchange meetings & roundtables		√		√
Working Group Resources Library		√		√
PHASE resources		√		√

Table 2. ROWHWG tools and resources to support biodiversity for energy and transportation infrastructure

Identifying the best-aligned program can be a challenge. Using observations from ROWHWG, we recommend companies navigate the various programs and opportunities available by:

- **Identifying programs that help address nature-related business risks.** Engaging with programs that address aspects of physical and transitional risks can reduce company risk.
- **Participating in programs offering cross-sector and peer exchanges.** Sustainability programs help companies benchmark their efforts against others and foster new knowledge/research connections by allowing them to engage with industry peers and those in other sectors with similar objectives. Programs that facilitate this type of engagement can be a long-term asset.
- **Leveraging third-party agreements and certifications that demonstrate nature positive outcomes.** Many companies have created their own biodiversity metrics and frameworks to demonstrate nature positivity. Although this approach offers the most adaptation, it forces companies to justify findings and opens them up to real or perceived greenwashing accusations. By engaging in third-party conservation agreements/certifications (or leveraging their resources), companies can prove that defensible, robust systems are in place to support their nature positive claims. This approach also enhances the transparency and accountability needed to meet investor/stakeholder expectations and regulatory requirements.

CONCLUSION

Collaborative efforts like ROWHWG serve as models for nature positive outcomes and enhanced sustainability reporting. By leveraging existing nature positive programs, businesses can contribute to global biodiversity goals, mitigate risks, and engage communities then leverage these opportunities for sustainable growth. Integrating nature positive actions and partnerships with established conservation programs into corporate sustainability strategies is not only beneficial for the environment, it's good for business.

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About the authors

Dan Salas is Director of the Sustainable Landscapes Program at the University of Illinois Chicago's Energy Resources Center, where he leads a team focused on the integration of biodiversity and infrastructure. The program facilitates the Rights-of-Way as Habitat Working Group, driving key initiatives such as the nationwide Monarch Candidate Conservation Agreement with Assurances, the Nationwide Agreement for At-Risk Bumble Bees, research and tools for pollinator habitat on utility-scale solar projects, and other industry collaborations. He is a Certified Senior Ecologist and a Certified Decision Analyst. He can be reached at dsalas4@uic.edu.

Caroline Hernandez is Assistant Director of the Sustainable Landscapes Program at the University of Illinois Chicago's Energy Resources Center. She supports the Rights-of-Way as Habitat Working Group while overseeing programs that engage energy and transportation leaders across the US and Canada in creating and conserving pollinator habitats. Ms. Hernandez is a LEED Green Associate, earned a master's degree in both international relations and natural resources/sustainable development, and has a background in globalization, sustainable development, and climate change. She can be reached at cah272@uic.edu.

NATURE POSITIVE, CARBON NEGATIVE:

REIMAGINING THE ROLE OF CAMPUSES & PERI-URBAN COMMUNITIES

Authors

Margaret Waldock, Jon Wagar,
and David Jeffrey Ringer

How can every campus and peri-urban community drive its greenhouse gas (GHG) emissions sharply downward while managing open space to maximize biodiversity and carbon sequestration?

Duke Farms, a center of the Doris Duke Foundation in peri-urban New Jersey, USA, has developed a holistic operating framework to answer this urgent question. This framework is directly relevant and adaptable for landowners and managers worldwide, including corporate and university campuses and planned communities.

As atmospheric CO2 concentrations surpass 419 parts per million[1] and national governments falter in their Paris climate commitments,[2] putting Earth on track for more than 1.5°C of warming, Earth is entering its sixth mass extinction of species in 4 billion years — this time attributable entirely to human activity.[3,4]

Local action at scale is required to mitigate the threats of extinction and increased warming. By virtue of their mixed land-use regimes (including interwoven developed areas, agriculture, preserves and open space, and other infrastructure), campuses and peri-urban communities in the transition zones between dense urban cores and rural areas are well-positioned to support a global transition to a nature positive and carbon negative future.[5] Their strategic location near major transportation corridors, ability to engage diverse populations, and opportunity for innovation and demonstration amplify their potential for scalable impact. However, lack of knowledge, incentives, resources, and/or ability to balance trade-offs can be significant barriers to progress.[6,7]

Ready or not, leaders across sectors (corporate, nongovernmental organizations, education, healthcare, planning and design, and government) are being pressured to act via:

- Shareholder, employee, citizen, student, and customer demands
- Regulations and transparency requirements
- Resilience and recovery needs as climate and weather become unstable
- Threats to supply chains and operational continuity
- A sense of mission or moral obligation (in some cases)

LOCAL ACTION AT SCALE IS REQUIRED TO MITIGATE THE THREATS OF EXTINCTION & INCREASED WARMING

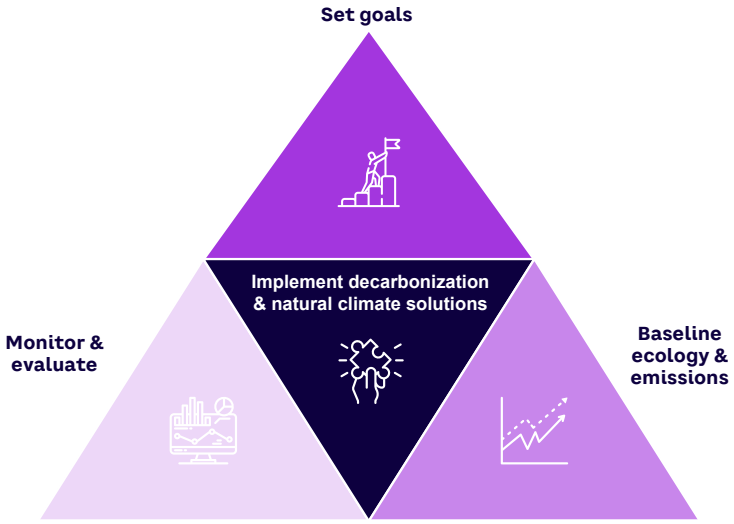

Figure 1. Duke Farms operating framework for moving campuses and communities toward a nature positive, carbon negative future

The Duke Farms operating framework (see Figure 1) is built from four mutually reinforcing components:

1. Setting goals
2. Baselining ecology and emissions
3. Implementing solutions:
    - Prioritizing decarbonization solutions
    - Seeking natural climate solutions
    - Identifying and managing trade-offs
4. Monitoring and evaluating

We depict this framework as a pyramid built from interlocking components. Although the framework could be followed in a clockwise manner, our experience shows us that, ideally, each component influences the other in real time for a true adaptive management approach.

DUKE FARMS

Duke Farms, located in Somerset County, New Jersey, USA, is a 2,700-acre campus that comprises more than 100 buildings, grasslands, working agricultural lands, natural and constructed wetlands, forests, a public park–like landscape, and four miles of frontage on the Raritan River. The surrounding landscape is a matrix of urban and suburban communities, industrial sites, agricultural landscapes, protected areas, wetlands, and riparian corridors. In these ways, the Duke Farms campus is similar to many other of campuses (corporate, education, healthcare, etc.) and similarly situated communities across the country and worldwide.

Once the estate of industrialist J.B. Duke, Duke Farms passed to his daughter, Doris Duke, a lifelong philanthropist who dedicated her legacy to charitable causes and established the Doris Duke Foundation in 1996. Today, it serves as a hub for conservation and sustainability under the foundation's stewardship, connecting more than 150,000 visitors annually with nature through demonstrations, diverse programming, and events grounded in science-informed restoration and stewardship.

Beginning in the mid-1990s, Duke Farms began to catalog and improve the property's biodiversity and ecology through a variety of research projects, restoration efforts, and a comprehensive land stewardship plan implemented in 2014. Duke Farms also invested in efforts like geothermal energy, onsite solar, and LEED Platinum status for several buildings. Five years ago, it started to quantify its annual and 100-year carbon footprints and potential mitigation scenarios.

Initially, staff hypothesized that natural climate solutions could fully offset remaining operational emissions, a common assumption. The real picture is more complex and is applicable to many campuses and communities. Research at Duke Farms shows that achieving net zero or carbon negative outcomes requires implementing natural climate solutions *and* achieving substantial reductions in operational emissions.[8]

Data from Duke Farms reinforces global research showing that natural climate solutions hold immense potential for carbon removal, biodiversity restoration, and delivering co-benefits to surrounding communities. Tactics like reforesting floodplains can achieve multiple outcomes simultaneously. Other proposals, like planting trees in grasslands critical to endangered species, highlight the complexity of balancing biodiversity goals with climate targets. These nuances call for clear goal setting, innovative solutions, and careful monitoring to help institutions and communities maximize ecological and climate outcomes.

So we pose a question to every leader, landowner, and land manager: what part can you play in mitigating climate change and extinction risk through your management choices?

SET GOALS

Every campus and community must set clear goals to balance land-use allocations, infrastructure investments, transportation and access, stakeholder interests, and other concerns in accordance with its overarching objectives and needs.

For example, in 2023, Duke Farms refined its high-level strategic goals:

- Restore nature and ecosystem services in peri-urban landscapes.
- Demonstrate nature positive and equitable climate-transition strategies.
- Engage leaders with the wonder of nature and the power to spark change.

These objectives guide Duke Farms's decisions about land management, resource allocation, and capital investments.

Of course, leaders must also keep high-level and operational goals current in response to emerging needs, knowledge, and opportunities. For example, although Duke Farms has more than three decades of expertise in ecology and biodiversity, its efforts to quantify and mitigate GHG emissions are more recent and have been spurred by scientific data on climate impacts to biodiversity locally and globally, climate impacts to Duke Farms's ecosystems and infrastructure, and the broader goals of the Doris Duke Foundation.

BASELINE ECOLOGY & EMISSIONS

Designing solutions for biodiversity conservation and carbon reductions (both avoidance and removal) requires an understanding of site ecology and baseline GHGs. Many entities have spent years trying to quantify their carbon footprint but are just now beginning to wrestle with biodiversity. For example, a 2024 survey of corporate sustainability professionals found that "only one-quarter treat protecting nature and biodiversity as a high priority, compared to two-thirds that prioritize reducing greenhouse gas emissions" and that only one-tenth of the surveyed companies based in North America are taking "significant actions" for biodiversity.[9]

ECOLOGY

Every human place on earth, from a community college campus to a large city, is deeply influenced by landscape features like rivers and mountains, climate variables like rainfall and temperature, and the interactions between life forms, from plants to animals to microorganisms. In addition, every landscape is shaped by its history, and in much of North America, that history includes millennia of human influence.

At the site level, building an understanding of how these factors interact (and have interacted over time) is foundational to identifying local biodiversity conservation opportunities and effective natural climate solutions. Failure to do so can deepen biodiversity losses or doom well-intended natural climate solutions projects, or both, as shown in recent research that points to:

> ... major administrative and governance failings in Australia's carbon credit scheme and a significant missed opportunity to restore biodiversity-rich woodlands and forests in previously cleared lands via legitimate carbon-offset projects.[10]

Ecology at Duke Farms is shaped by its location in the Northern Piedmont EPA Level III Ecoregion, its Raritan River frontage, and centuries of agriculture and other human uses of the land that created a mosaic of variously aged forest, grasslands, agricultural fields, designed landscapes, buildings, roads, and wetlands (see Figure 2).

Ecological research to help Duke Farms manage for biodiversity has included vegetation studies, wildlife surveys, and hydrology assessments. In 2019, Duke Farms partnered with Rutgers University to study the carbon-sequestration potential of its habitats and land management practices to help inform natural climate solutions.

Duke Farms has relied on many partnerships and resources to build its base of ecological knowledge. Those looking to build their own scientific foundation for biodiversity and natural climate solutions should consider the following resources and entities as a starting point:

- EPA Level III and IV Ecoregions[11]
- Watershed maps
- Nearby college and university departments and extensions
- Local environmental consulting firms
- State natural heritage programs and/or master naturalist programs
- Local nonprofits like native plant societies and Audubon chapters

EMISSIONS

In 2019, researchers from Rutgers University began to create a 100-year Duke Farms carbon footprint using operational data from 2016. Researchers estimated a baseline footprint of 1,879 metric tons of CO2 equivalent over a 100-year period, excluding natural carbon capture. The researchers also modeled various emissions reduction and natural climate-solution scenarios, ultimately

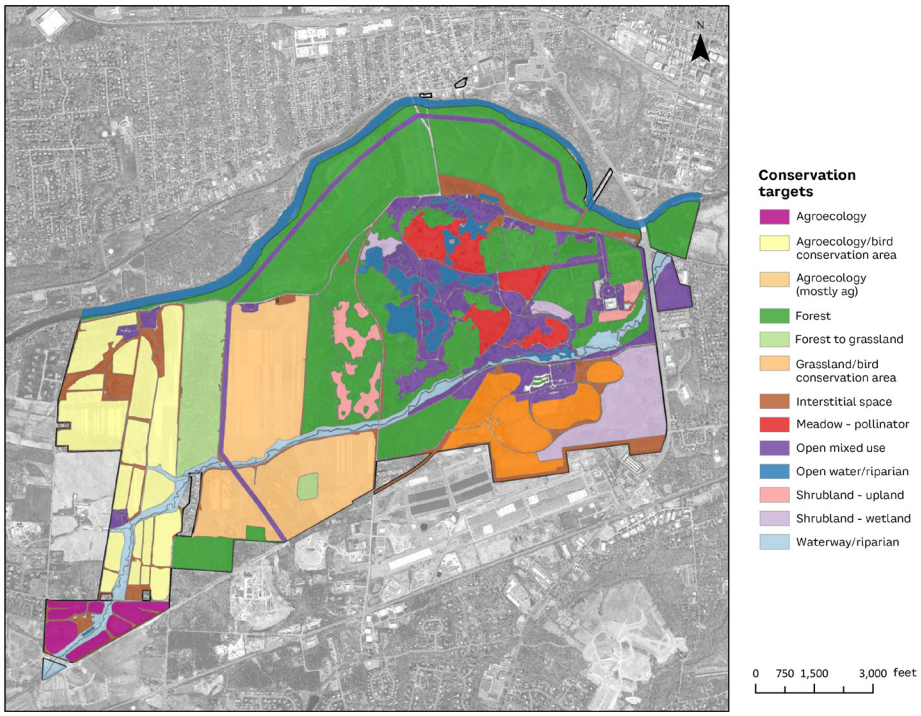

Figure 2. Duke Farms land-use types

concluding that there is no viable pathway to achieving net zero or carbon negative outcomes without combining aggressive emissions reductions and targeted, data-informed restoration and land management strategies to optimize carbon sequestration.[12]

In response, Duke Farms engaged energy consultant Gabel Associates to develop a comprehensive operational carbon footprint and specific intervention points. The analysis used utility data from both grid-supplied and onsite solar-generated electricity, natural gas, and fuel used for vehicles and equipment. In addition, a detailed energy audit evaluated efficiency and energy-conservation measures.

Many energy consultants use cost savings to the client as their primary metric to measure. Instead, Duke Farms and Gabel Associates worked together to quantify carbon emissions as the primary metric of the analyses. This approach better supports the goal of meaningful emissions- reduction solutions.

This experience shows that no entity should rely on assumptions or on modest good-faith efforts, like tree planting, to get meaningful, measurable emissions reductions. Rapid and dramatic operational decarbonization is needed to meet the challenges facing our communities and our world.

IMPLEMENT DECARBONIZATION SOLUTIONS

Building effective strategies to cut emissions and decarbonize emissions can be complex, even with supportive leadership and financial resources. The work at Duke Farm illustrates the importance of phasing the big challenges, cultivating internal champions, and engaging stakeholders along the path to decarbonization.

PHASE THE BIG CHALLENGES

The Rutgers University analysis found that 75% of Duke Farms's emissions came from building operations, despite a solar array built in 2012 that provided about 50% of the campus's electricity. Duke Farms has more than 100 buildings on campus, many more than 100 years old, creating a challenge similar to those faced by many communities and campuses with aging infrastructure.

Urgent as the decarbonization challenge may be, the work cannot be done overnight. Gabel Associates and Duke Farms developed a phased approach to drive campus emissions down as close to zero as possible (see Figure 3).

	2025	2030	2035	2040
Goal	**CLEAN ELECTRICITY**	**REDUCED EMISSIONS**	**CARBON NEUTRAL**	**CARBON NEGATIVE**
What it means	**100% clean** electricity	**Clean** energy -> **80% emissions reduction**	**No harm**	**Positive impact & restoration**
Why it matters	Significantly cleaner, enables electrification	Mitigate climate crisis & public health harm	Achieve long-term operational sustainability & environmental health	Reduced emissions isn't enough: those who can do more, must do more
How measured	100% of all **electricity** use from renewable sources on **net annual basis**	Most **energy** use from renewable sources on **hourly basis (no offsets)**	**Resilient** operations with zero carbon footprint on **Scope 3** basis	**Sequester more carbon than all operations emit, net generator of renewable energy**

Carbon negative focus (energy) → **Nature positive focus (ecosystem)**

Figure 3. Duke Farms natural systems energy plan

In fall 2024, Duke Farms constructed a 1,159-kW solar array and 1,600 kWh battery storage system, moving from 50% to 100% of current electricity needs and reducing emissions by 13%. The older system was paused to enable the new installation, but it remains a strategic asset that can be reactivated as Duke Farms electrifies more systems, ensuring flexibility and scalability along the decarbonization journey.

Building a data-backed roadmap to decarbonization with clear phases and milestones provides both an operational plan and an accountability framework for staff, management, and overseers. Many decarbonization efforts set only an end point 10, 20, or 30 years out, with no intermediate milestones, a sure recipe for failure.

CULTIVATE INTERNAL CHAMPIONS

As Duke Farms began to explore electrifying its vehicle fleet, analysis showed that the fleet's biggest carbon emitter was a security truck. To management, that seemed an obvious place to start, but staff were quick to raise reliability and safety concerns about replacing the truck with an electric vehicle (EV). The effort came to a halt in the face of operational and cultural barriers.

A PLAN BY MANAGEMENT TO DECARBONIZE THE FLEET WAS NOT ENOUGH

However, Duke Farms's electrician emerged as a staff champion for fleet electrification. He needed a new vehicle and requested an electric van, of which he became a vocal proponent. At the same time, Duke Farms's motor pool coordinator learned all he could about EVs with a goal of figuring out how to make EV adoption feasible and effective on site.

A plan by management to decarbonize the fleet was not enough — it took identifying and cultivating champions who could demonstrate the effectiveness of EVs to their peers, dispel myths, problem solve, and accelerate broader adoption.

ENGAGE STAKEHOLDERS

Some of the more difficult aspects of decarbonization require strong stakeholder engagement. For example, transportation emissions are a major source of Scope 3 emissions for Duke Farms and the largest contributor to carbon emissions in New Jersey. Although Duke Farms's carbon negative roadmap does not directly include Scope 3 emissions, it recognizes the opportunity to educate and engage a broader community on transportation.

In alignment with New Jersey's commitment to electrifying transportation, Duke Farms installed a car fast-charging station in 2023, leveraging state and utility incentives.[13] Powered by on-site solar, the station serves employes, visitors, and the public, addressing a critical gap as the only fast-charging facility in the immediate area. Through initiatives like this, Duke Farms advances state goals and fosters community engagement and advocacy, building momentum for broader societal shifts while contributing to the collective effort to address Scope 3 emissions.

IMPLEMENT NATURAL CLIMATE SOLUTIONS

There is significant investment and interest in carbon-capture technology, but natural climate solutions remain the most readily available and proven methods for removing atmospheric carbon at scale and storing it in soils and plant biomass. Well-designed approaches also promote biodiversity and healthy ecosystem functions that benefit people. Unfortunately, poorly governed carbon-credit schemes and misguided tree-planting efforts have tarnished natural climate solutions.

Duke Farms found that relying *only* on natural climate solutions is, indeed, foolhardy. In the year 2025, every leader must be pursuing aggressive decarbonization strategies across Scopes 1, 2, and 3. However, dismissing natural climate solutions is also foolish, akin to fighting climate change with one hand tied behind our backs, not to mention ignoring the co-benefits for people and nature that come with well-designed natural climate solutions.

The Doris Duke Foundation has long supported research into natural climate solutions and provided research funding that led to a seminal paper that found:

> [Natural climate solutions] can provide over one-third of the cost-effective climate mitigation needed between now and 2030 to stabilize warming to below 2°C. Alongside aggressive fossil fuel emissions reductions, [natural climate solutions] offer a powerful set of options for nations to deliver on the Paris Climate Agreement while improving soil productivity, cleaning our air and water, and maintaining biodiversity.[14]

Governments like the State of New Jersey are pursuing national climate solutions, as are private sector initiatives like 1t.org.[15,16] Work at Duke Farms shows that to be effective, natural climate solutions must be backed by data, promote biodiversity win-wins, and focus on long-term gains in sequestered carbon.

PURSUE DATA-BACKED SOLUTIONS

Research by Rutgers University scientists at Duke Farms shows that the biggest opportunity for onsite carbon sequestration lies in the deep, wet soils of the Raritan River floodplain. Intensive soil and forest carbon-quantification and gas-exchange analyses show that reforesting these lands for 100 years or more will result in significant carbon sequestration.

After working on two test plots, Duke Farms has now partnered in a 112-acre reforestation project in this vital floodplain. The project fulfills a downstream responsible party's obligation to restore floodplain, riverbank, and wetland resources, and it will maximize carbon sequestration by growing new forest in abandoned agricultural fields previously drained and cleared for farming. The new forest will absorb river flooding and create new habitats for wildlife along this heavily urbanized river.

Work at Duke Farms also shows that "proforestation" solutions (helping existing forests grow to full potential) are important to keep existing forests healthy and sequestering carbon for the long term.[17] In peri-urban environments with many stressors, forest health can decline over time, leading to a loss in carbon-sequestration capacity. Research at Duke Farms shows that the following land management tactics are important to maximize forest carbon storage:[18]

- Managing white-tailed deer population density to sustainable levels
- Leaving deadwood in place wherever safe and practical (and reusing onsite [e.g., for mulch, when needed])
- Enhancing forest-block connectivity to reduce carbon losses due to windthrow events, invasive species, and other threats

PROMOTE BIODIVERSITY WIN-WINS

Research at Duke Farms shows that the Norway maple (*Acer platanoides*) has high carbon-sequestration potential. That tree, however, is native to Eurasia. In North America, it is an invasive species that chokes out native species and does not support the insect populations on which native birds and other wildlife depend, weakening the food web.

By planting with native North American tree species that have high carbon-sequestration potential, like red maple (*Acer rubrum*), Duke Farms can promote biodiversity and local ecosystem health through floodplain forest reforestation work and other initiatives.

FOCUS ON LONG-TERM GAINS

Fires, droughts, storms, floods, and changes in land management practices can kill vegetation, disturb soils, and release accumulated carbon back into the atmosphere. As much as possible, building long-term maintenance funding into projects, creating durable governance structures, and mitigating threats like deer-browse and drought in the first few years of a plant's life must be part of the work, along with a long-term commitment to monitoring and assessing carbon- sequestration gains.

IDENTIFY & MANAGE TRADE-OFFS

Optimizing for both carbon mitigation and biodiversity requires identifying and managing trade-offs. For example, when researchers from Rutgers University assessed the carbon-sequestration potential of land management practices at Duke Farms, they found that reforesting Duke Farms's grassland habitats could sequester more carbon over time than maintaining the historic grasslands. Furthermore, because Duke Farms maintains grasslands through rotational grazing of a small cattle herd to improve soil health and support biodiversity, converting the grasslands to forest could significantly reduce or eliminate ongoing GHG emissions from the cattle operation (about 8% of Duke Farms's total carbon footprint).

However, as discussed, one of Duke Farms's top-level goals is to protect and restore biodiversity, particularly threatened and endangered species. In North America, birds that depend on grassland habitats have declined more dramatically since 1970 than any other group of terrestrial birds, due to large-scale conversion of grasslands into other land-use regimes.[19] Duke Farms's agricultural grasslands have become a vital habitat for several imperiled grassland bird species like bobolink, Savannah sparrow, and grasshopper sparrow and have natural heritage designation by the state.[20] Converting these grasslands to forest would send these bird populations further into decline, so this course of action is not a viable option for Duke Farms.

Having made the goal-driven decision to maintain some grassland habitat for the sake of biodiversity, the Duke Farms team can focus on how to minimize GHG emissions from the rotational grazing operation (e.g., by reducing lime and fertilizer applications and by improving cattle diets and genetics) and how to maximize the carbon-sequestration potential of the grassland habitats by promoting native plant species diversity, leaving vegetation in place through the winter, and other tactics.

MONITOR & EVALUATE

Leaders must put data gathering and monitoring protocols in place for emissions-reduction, carbon-sequestration, and biodiversity goals. Setting goals and undertaking activities is not enough — progress must be tracked and reviewed regularly by leaders who are accountable and empowered to make operational changes based on the data.

Duke Farms monitors biodiversity through the efforts of staff, volunteers, consultants, researchers, and students, tracking a wide range of plant and animal species. This collaborative approach informs its science-based restoration and biodiversity conservation efforts as part of an adaptive management framework outlined in the Land Stewardship Plan. In 2024, Duke Farms developed a dashboard system to track monthly and annual operating emissions over time (see Figure 4).

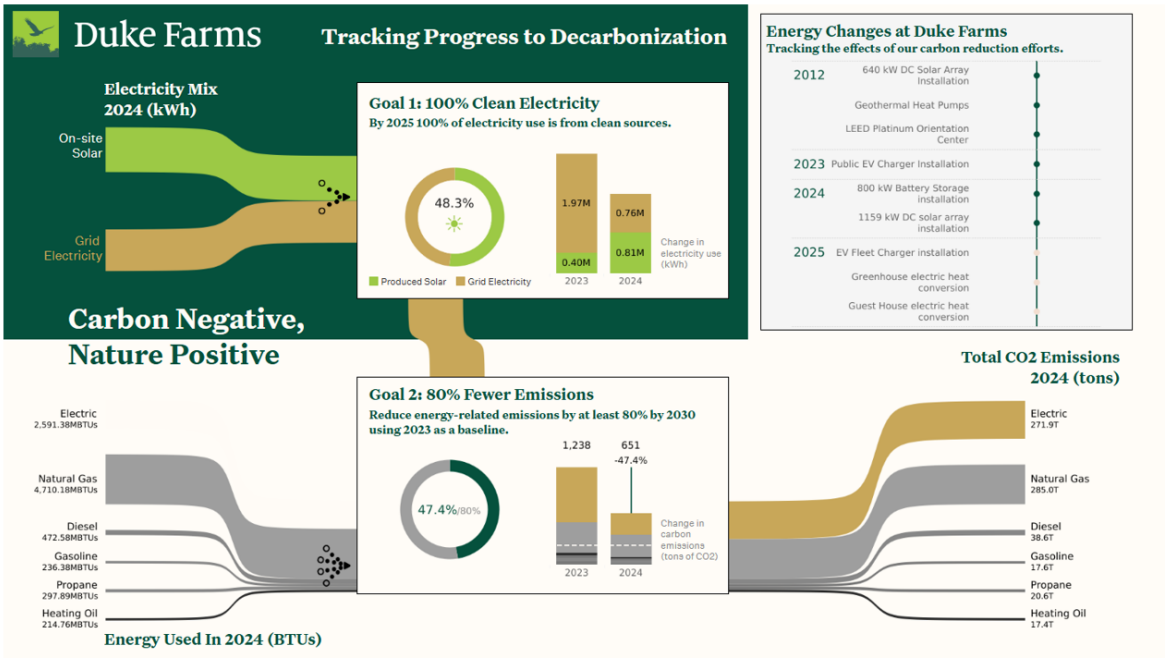

Figure 4. Duke Farms energy and emissions dashboard

The monitoring responsibility extends to external environments and trends. For example, Duke Farms has not yet replaced its diesel tractors with EVs because the technology is not yet commercially available. The farm and fleet staff are charged with tracking technological progress and products on the market to understand when the moment is right to take this critical step.

COLLABORATING FOR SUCCESS

Duke Farms is a place where innovation meets collaboration — a living laboratory designed to inspire and equip others to act. As we tackle the challenges of decarbonization and sustainability, we recognize that success lies in our ability to share what we learn and work across sectors to develop scalable solutions. By serving as a model and a convener, Duke Farms is committed to breaking down barriers, fostering partnerships, and empowering communities to join us in shaping a cleaner, more resilient future.

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About the authors

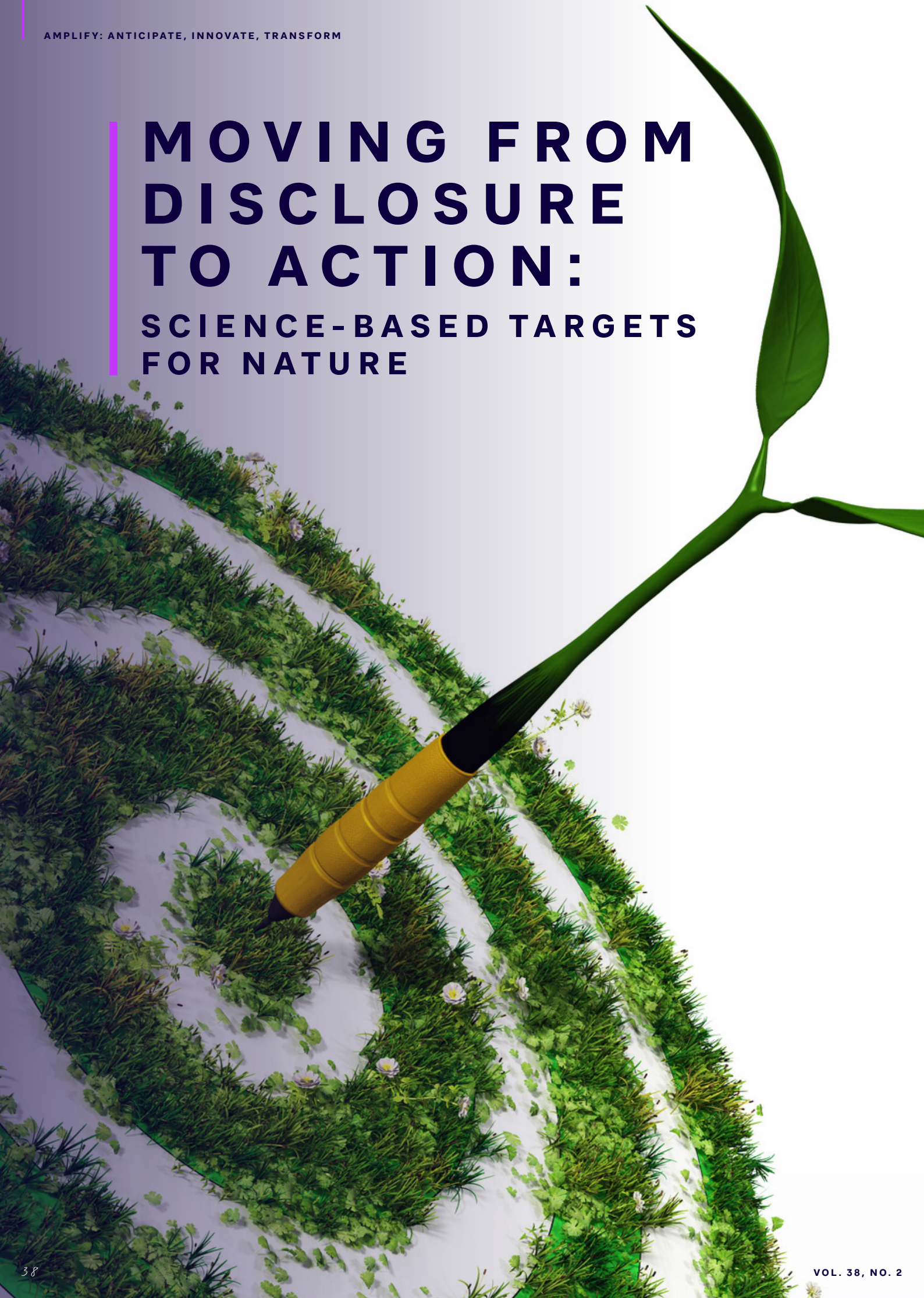
Margaret Waldock is Executive Director of Duke Farms, combining her strategic vision with operational expertise to address the intersection of social, environmental, and climate challenges. She has led complex initiatives and driven impactful outcomes in previous leadership roles at the Geraldine R. Dodge Foundation, Trust for Public Land, and the New Jersey Green Acres Program. Ms. Waldock's leadership is strengthened by her degrees in environmental law, enabling her to provide innovative sustainability solutions and achieve operational excellence. She earned both a JD and an MSL in environmental law from Vermont Law and Graduate School, USA. She can be reached at mwaldock@dorisduke.org.

Jonathan Wagar is Deputy Executive Director of Operations and Sustainability at Duke Farms, where he leads efforts in ecological restoration, sustainable energy innovation, and the adaptive reuse of historic structures. With more than 20 years' experience, he leads initiatives that integrate natural climate solutions, decarbonize energy systems, and advance sustainable practices across the 2,742-acre property. Mr. Wagar also served in the Peace Corps in Guatemala. He earned a master of forestry degree from Yale School of the Environment, USA, and a bachelor of science degree in biology from Stockton University, USA. He can be reached at jwagar@dorisduke.org.

David Jeffrey Ringer is cofounder of Green Jay Strategies, a consultancy offering advisory services to companies, public figures, and nonprofit and philanthropic organizations. An award-winning communications professional and recognized expert on biodiversity and environmental issues, Mr. Ringer has extensive experience in public relations, grassroots networks, professional associations, environmental policy, and science communications. His work spans the US, the South Pacific, Latin America, and Sub-Saharan Africa. He has been an invited guest speaker at Brown University, USA, and at other academic institutions and conferences and is a frequent media spokesman. He can be reached at david.ringer@greenjaystrategies.com.

MOVING FROM DISCLOSURE TO ACTION:

SCIENCE-BASED TARGETS FOR NATURE



Author

Charlie Briggs

The EU's Corporate Sustainability Reporting Directive (CSRD) requires companies to disclose information on their impact, risks, and opportunities concerning environmental, social, and governance (ESG) issues (see Figure 1[1]). It entered into force in 2023, and companies had to apply the new rules for the first time in the 2024 financial year. (Although the disclosure requirements of CSRD are outlined in the European Sustainability Reporting Standards [ESRS], in this article, we refer to the CSRD throughout for consistency and to avoid confusion.)

Beatrice Boarolo, consultant at sustainability consultancy ERM, explains its significance:

> CSRD represents a significant advancement of corporate sustainability reporting, setting a new standard for corporate transparency and accountability on ESG topics. The ambition is to provide standardized, consistent, and reliable sustainability reporting with respect to existing regulatory frameworks worldwide.

SCIENCE-BASED TARGETS FOR NATURE & CSRD

Science-based targets (SBTs) for nature equip companies to address their environmental impacts by taking measurable, place-based action based on ecological and social thresholds.[2] They are developed by the Science Based Targets Network (SBTN), a voluntary civil society-led initiative (see sidebar "SBTs for Nature Basics").

Both CSRD and SBTs for nature support transitions to more sustainable corporate practices. They are complementary yet distinct:

- **Type.** SBTs for nature are developed by SBTN, a voluntary, civil society-led initiative; CSRD is a mandatory EU legislation, although it has some voluntary components.
- **Purpose.** CSRD is designed to increase corporate transparency and provide decision-useful information to stakeholders through disclosures; it does not prescribe sustainability actions or performance beyond disclosures.[3] SBTN's methods focus on setting SBTs and are prescriptive about which targets are set and how this is done.

SBTs FOR NATURE BASICS

SBTN is developing science-based targets for nature for companies and cities, so they can comprehensively address their environmental impacts across land, freshwater, and ocean. Drawing from the best available science on ecological thresholds and societal needs, SBTN's guidance is designed to help companies quantify their environmental impacts across their operations and value chains and then move to precise, credible action.

The SBTN target-setting process is divided into five steps: assess, prioritize, set targets, act, and track. Each step contains methods, tools, and additional resources to guide companies through the process. The first two steps help companies assess and prioritize their environmental impacts. Step 3 involves setting targets, beginning with freshwater and land. Biodiversity is integrated across the guidance. Ocean targets will be available in 2025, and climate targets are set via SBTN's partner organization, the Science Based Targets Initiative.

SBTN has developed detailed technical guidance for the first three steps of the process, and guidance on the final two steps (act and track) is coming in 2025.

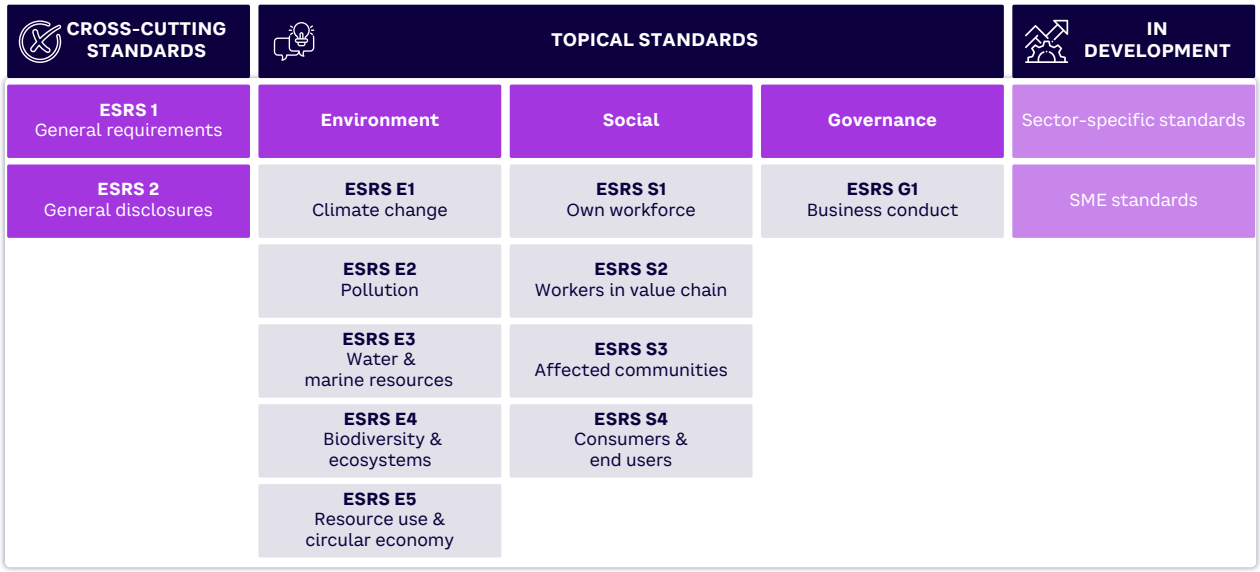


Figure 1. ESRS standards (adapted from AMF)

- **Scope.** SBTs for nature are aimed at corporate end users across the world; CSRD is aimed at companies based in the EU or with significant operations there.[4] CSRD encompasses a broader set of ESG topics than SBTN and more fully accounts for the downstream value chain.[5,6]
- **Focus.** CSRD requires disclosures based on impact and financial materiality, including a company's material dependencies on nature. Financial materiality and dependencies are both considered in SBTN's methods in the prioritization step (2C), although the explicit focus of the methods is on impact materiality.

This article discusses how CSRD and SBTs for nature can complement each other.[7] We explore this through three possible use cases for setting SBTs for nature in the context of CSRD:

1. To inform disclosures
2. To go beyond disclosures
3. To create long-term value

Although setting SBTs for nature can help companies meet some of their CSRD requirements to a high standard, it does not guarantee compliance, as CSRD is broader and necessarily has specific requirements.

INFORM DISCLOSURES

SBTs for nature offer a rigorous, prescriptive approach that generates data and insights that can inform companies' CSRD disclosures.

For example, CSRD requires that companies conduct a materiality assessment but does not prescribe how it should be undertaken.[8] Each company must decide how to conduct its materiality assessment, which can have a significant impact on what is included in the disclosures. This flexibility is welcome for some companies, but it leaves others with concerns about whether its stakeholders will approve of its methods.

WWF explains this clearly in its "Corporate Nature Targets" report:[9]

> While some guidance on methodology is given (notably by recommending the use of initiatives like TNFD or SBTN), it's crucial to understand that the main emphasis of the CSRD is on the disclosure of these elements (or a rationale for their omission if the entity deems them not material), rather than on the quality of the information provided (i.e., corporate practices).

In contrast, SBTN's methods are prescriptive, requiring companies to assess and prioritize their impacts, set clear thresholds for materiality, and account for state-of-nature variables. Christopher Rannou of WWF is clear on the usefulness of SBTs for nature for the companies WWF works with:

> Many companies do not know how to generate some insights needed to inform their disclosure requirements because CSRD is not prescriptive about the methodologies or tools that should be used. SBTN brings clarity by providing these.

Peter McCann, a consultant at Biodiversify, echoes this, explaining the benefits of a rigorous approach:

> If you use SBTN methods as a basis for parts of CSRD, your methods will stand up to stakeholder scrutiny. Using an independent set of methods shows that you haven't just cherry-picked the methods.

SBTN is referenced in CSRD as a resource to help companies set targets, including setting environmental thresholds. SBTN's methods provide clear guidance on how these thresholds can be established and how responsibility for them can be allocated.

Companies disclosing through CSRD have also found value in following SBTN's methods when sourcing state-of-nature variables (Step 1B), prioritizing impacts (Step 2), and conducting stakeholder consultations. Companies have reported using SBTN's materiality screening tool and High Impact Commodity List to inform their CSRD reporting. Broad uptake of SBTN methods would help ensure consistency in approaches to assessing impacts, which would help improve comparability between companies.

French multinational Carrefour attests to the usefulness of SBTs for CSRD:

> By applying the SBTN approach, we are more prepared to meet the requirements of the CSRD, thanks to a highly thorough method.

This will only increase over time as SBTN expands methods and guidance, for example on ocean targets, enablers, taking action (Step 4), and validating results (Step 5).

GO BEYOND DISCLOSURES

CSRD focuses on disclosures; SBTN goes a step further by empowering companies to actively address their impacts, showing how much action to take, where to take it, and when to take it, based on what nature needs.

McCann explains why this integrated approach is valuable:

> If you do the bare minimum for CSRD, you might meet the regulatory requirements, but you may not be able to use it to inform business decisions. For a rigorous analysis that can inform business decisions, set SBTs for nature.

WWF concurs, stating that "Nature targets are essential to set the ambition for entities' nature transition planning," and that SBTN's methods "represent the gold standard framework for setting nature targets."[10] This perspective is shared by the companies that piloted this approach, with one reporting:

> We believe in the power of the output and that is what makes it worth embarking on the journey... SBTN's assessment helped in conversations about capital allocation and procurement, and there is benefit in that.

For example, companies piloting SBTs for nature have uncovered risks within their value chains, prompting them to take action where it really matters. One SBTN pilot company says:

> After getting Steps 1 and 2 results, we took quick actions to mitigate risk for some sourcing locations.

Going beyond disclosures helps prove to investors and other stakeholders that the company is committed to addressing its impacts and risks. Carly Sibilia of ERM explains:

> With CSRD, it's clear when companies have done the bare minimum, especially where their assessment of nature-related impacts is disconnected from the ecological context.

For example, in CSRD, a company must disclose whether it has set pollution targets, and if so what these are, but it does not have to actually set them. Where it has set targets, it is optional whether the company takes ecological thresholds into account. Investors and other stakeholders are able to see this, and they may question the usefulness of any targets that have not taken ecological thresholds into account. So, while CSRD does not require that targets be set, it points to a best practice of setting SBTs for nature that use ecological thresholds.

Sam Sinclair of Biodiversify says companies will have to go beyond the bare minimum eventually:

> Standards and frameworks such as CSRD and TNFD are like nesting dolls because sooner or later you have to get to grips with the impacts of your supply chain, and SBTN is trying to do this in earnest.

CREATE LONG-TERM VALUE

In the context of an increasingly ambitious regulatory landscape, setting SBTs for nature helps companies build the capacity and resilience needed to adapt to emerging trends and stay ahead of future requirements, creating enduring value for the business.

CSRD may also anticipate similar regulations in other jurisdictions. Even where this does not happen, it may shift stakeholders' expectations on sustainability reporting. Following SBTN's methods gives companies a way to preempt future requirements and expectations by engaging with more exacting requirements now.

According to Boarolo:

> CSRD requirements will be expanded in the coming years, with sectoral and SME standards in development. By aligning to SBTN's prescriptive approach now, companies will be better able to anticipate future regulatory requests and other nature-related transition risks.

Setting SBTs for nature can provide other long-term benefits, such as building institutional knowledge and capacity in nature, securing internal buy-in and funding, and developing impactful relationships with stakeholders. For example, Holcim, a global sustainable building solutions company, validated SBTs for nature as part of an SBTN pilot. Holcim set an SBT to reduce freshwater withdrawals in its direct operations in the Moctezuma basin (Mexico) by 39% by 2030. Holcim noted that SBTN helped raise ambition and rigor, including expanding freshwater targets to include the company's upstream value chain. The company also said it benefitted from learning from companies across various sectors that were involved with the pilot.

Being part of the SBTN Corporate Engagement Program gives companies an opportunity to learn how other firms are approaching emerging challenges. Setting targets also secures the reputation of companies that decide to take early and decisive action on nature.

For some, this represents a different way of conceptualizing SBTs for nature. Sinclair explains:

> There are lots of misconceptions about SBTs for nature. It is often seen as an endpoint or a box to tick, whereas in reality, it is a powerful tool for informing business decisions, building capacity, and generating value....

CONCLUSION

As a complement to CSRD, SBTN empowers companies to actively address their impacts and quantify their contributions to nature positive outcomes:

- **Inform disclosures.** SBTs for nature offer a rigorous, prescriptive approach that generates data and insights that can inform companies' CSRD disclosures.
- **Beyond disclosures.** CSRD focuses on disclosures; SBTN goes a step further by empowering companies to actively address their impacts, showing how much action to take, where to take it, and when to take it, based on what nature needs.
- **Long-term value.** In the context of an increasingly ambitious regulatory landscape, setting SBTs for nature helps companies build the capacity and resilience needed to adapt to emerging trends and stay ahead of future requirements, creating enduring value for the business.

(Note: This article was researched and finalized before the publishing of the EU Omnibus packages in February 2025.)

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[3] For example, CSRD requires disclosure on whether a company has set nature-related targets but does not require these to be set.

[4] SBTN guidance is being developed for cities to set SBTs.

[5] SBTN defines nature as the diversity of living organisms, including people, and their interactions with each other and their environment. This perspective emphasizes the deep connection between ecological and human well-being.

[6] SBTN is exploring expanding guidance to more fully incorporate downstream impacts.

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[10] Wahl, Rannou, and Pugliese (see 7).

About the author

Charlie Briggs is Technical Content Strategist at Science Based Targets Network (SBTN), which empowers companies to set science-based targets to reduce their impacts on nature. He sits between the technical and communications teams, helping ensure technical communications are targeted and accessible to SBTN's partners, users, and other stakeholders. Mr. Briggs previously worked in the sustainability practice at McKinsey & Company, focusing on food, nature, and land use topics. He earned an undergraduate degree from the University of Cambridge, UK, and a master of science degree in environmental economics from University College London, UK. He can be reached at charlie@sciencebasedtargetsnetwork.org.

ROBUST CARBON ACCOUNTING FOR CORPORATE SUSTAINABILITY STRATEGIES

Authors

Enrique Castro-Leon, Katrina Pugh, and Jose Zero

Clear, transparent, reliable carbon accounting makes good business sense, improving a company's reputation and trustworthiness while providing an opportunity for market differentiation. Unfortunately, there is currently a vast discrepancy in greenhouse gas (GHG) reporting within and across supply chains. Some systems differentiate direct from indirect emissions, some assign scores to various carbon-sequestration approaches, and some focus on alignment with global agreements.

In this article, we highlight some barriers to robust carbon reporting and provide a seven-factor framework for addressing the gaps. The framework focuses on combining data, standardizing the technical architecture, identifying business drivers, and setting realistic policies. The good news is that recent technological advances make it possible to devise systems capable of carrying out this level of rigor.[1]

Around the world, governments and consumers want businesses to work toward reducing carbon in the atmosphere. A dynamic, transparent carbon accounting system would contribute to this goal.

THE NEED FOR MORE ROBUST CARBON ACCOUNTING

We define carbon accounting as methods for assessing GHG discharges and removals from the atmosphere (industrial or natural processes). In carbon accounting parlance, processes that discharge CO2, such as the flaring of methane at an oil well, are said to be net-positive emissions. Those that remove CO2, such as tree growth, are said to be net-negative emissions. All tracked gases have a global warming potential coefficient that is a multiple of the CO2 warming effect defined by the Intergovernmental Panel on Climate Change (IPCC) — see Figure 1.[2,3]

Emissions accounting is an omnipresent concern for organizations seeking to understand and balance their emissions. For example, high-quality data helps companies integrate their sustainability strategies with their corporate processes, and standardized data measurement techniques enable assessments of disparate processes that would otherwise sit in silos. Adding dynamic verification steps helps ensure transparency and helps observers monitor trends. Data integrity procedures (e.g., ongoing traceability to physical carbon, third-party audits, common metadata) can improve reputational integrity, and having emissions data continuously available opens doors to exchanges and markets (e.g., carbon-offset purchases or sales of carbon credits).

> **GOVERNMENTS & CONSUMERS WANT BUSINESSES TO WORK TOWARD REDUCING CARBON IN THE ATMOSPHERE**

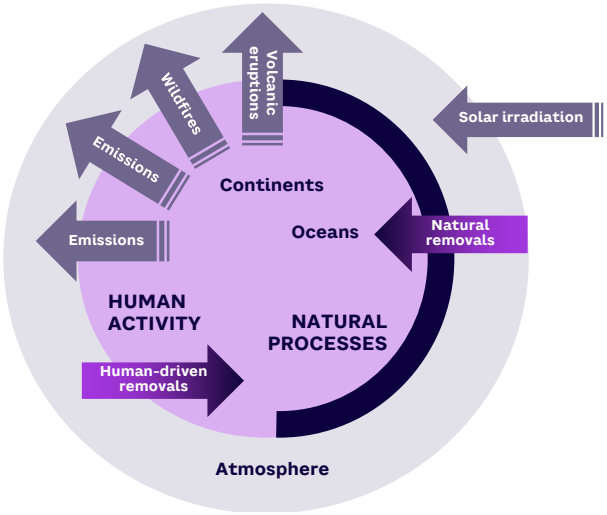


Figure 1. Carbon movement due to human activity and natural processes

The gold standard is to apply the same rigor used in financial accounting to carbon accounting, but with direct ties to dynamic carbon stores. Carbon accounting must reside in business and industrial processes, including tracking carbon movement across supply chains in real time or near real time. Such a system would bring the trust needed to enable GHG transactions, liability identification and delegation, and integration into commodity markets.

ACCRUAL CARBON ACCOUNTING

Imagine a data center operator running a cluster of machines on behalf of a customer. The customer is conducting a computationally intensive machine learning run. For the operator, the direct GHG emissions of that single operation are negligible — but data centers as a whole consume vast amounts of electricity across operators. These emissions can be described as GHG Scope 2 (indirect emissions associated with the purchase of electricity by the data center). They are also Scope 1 (carbon pollution at the utility source) and Scope 3 (peripheral energy consumption by the operator's employees or suppliers).

Actors like the data center operator are linked economically in a supply chain defined by a service provider/subscriber relationship. Although there is no immediate cost from the emissions to any of the members of this supply chain, there is a cost to the commons. This type of cost is known in economic terms as an *externality*. Internalizing the externality collaboratively across supply chains using carbon accounting could lead to more predictable and manageable business outcomes.

Embedding carbon measurement into business and industrial processes is the carbon accounting equivalent of carrying out financial accounting on an accrual basis, in which revenue is recorded when earned (regardless of when the cash is received), and expenses are recorded when incurred (not necessarily when paid).

Doing it this way presents a more accurate, timely picture of an entity's financial health than a cash-based system. If accrual practices were used for carbon accounting, this could align carbon accounting with financial accounting.

Additionally, offsetting of carbon emissions with the purchase or production of carbon sequestration in the same units and quantity would reconcile the accounts, akin to balancing a checkbook. This would allow the organization or its customers to proactively direct climate-conscious purchases. For example, airline emissions estimates would inform the climate-conscious passenger in advance of a ticket purchase. (This would be even better if, in reconciliation, actual carbon emissions were reported to the passenger.)

Some emissions are *potential* or *pass-through*, in the sense that they are emitted by an actor on behalf of another actor downstream in a supply chain. This goes to the core of the definition of Scope 1, 2, and 3 emissions. Certain actors may be entitled to relief from pass-through emissions. A transparent carbon accounting system could turn this into a dialogue across supply chain participants, possibly with the participation of regulatory agencies. Businesses would benefit from such a predictable scenario in which liability is capped.

However, GHG reporting across participants in a supply chain is not possible without a formal accounting system understood and accepted by the supply chain participants. In such a mechanism, carbon emissions would be treated no differently than other costs among suppliers in a supply chain. (It is important to note that carbon accounting provides data to actors; it does not define or impose policies on its own.)

7 REQUIREMENTS FOR A GLOBAL CARBON ACCOUNTING & TRADING SYSTEM

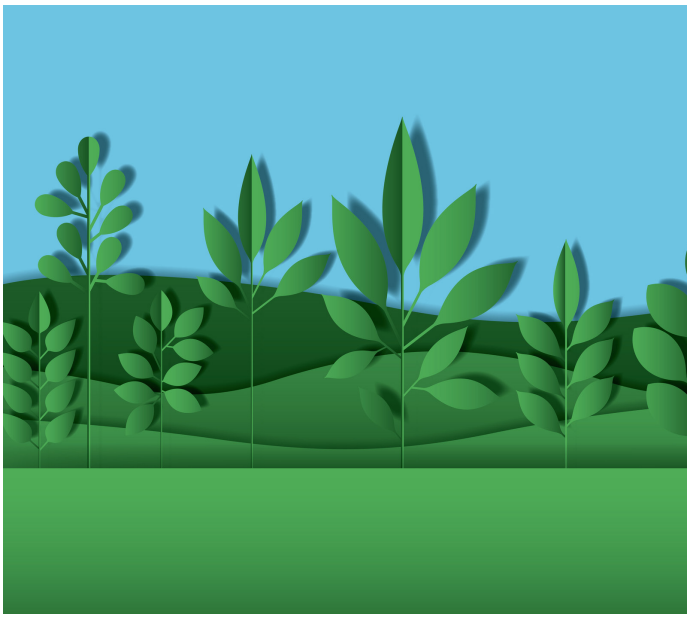
In this section, we describe the seven essential practices of a cross-industry generally accepted carbon accounting principles (GACAP) system:

1. Interoperability
2. Measuring externalities
3. Verifiability
4. Decentralization
5. Privacy
6. Scalability
7. Traceability

1. INTEROPERABILITY ACROSS SECTORS

A global carbon accounting system requires interoperability between industry sectors and verticals.[4] We can represent emission sources as pie slices, with each source accounting for its emissions or natural removals and developing measurement technologies applicable to their specific processes (see Figure 2).

Of course, the sectors do not exist in silos; all emissions go into Earth's one atmosphere. Thus, a federated system is needed, one that accounts for carbon exchanges (emissions or removals) and applies to interactions with the atmosphere and with other industries. A carbon accounting interaction between sectors and various types of emitters and removers introduces the notion of carbon offsetting as a carbon accounting application.



These carbon accounting transactions are included in a GACAP model that applies to all industries, similar to the way traditional business accounting (GAAP) takes place. This model enables distributed, decentralized (yet standardized) carbon accounting, in which each industry sector performs industry-specific scientific or engineering measurements.

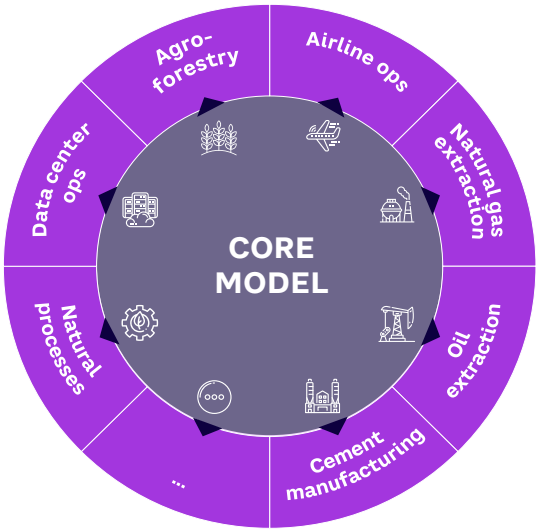


Figure 2. Carbon accounting using a distributed, decentralized model

Merging or integrating data from multiple streams from various sources is efficient, but it requires multimodal measurement in which implementers can balance less expensive, less precise data sources with more expensive, more precise sources. A high-value tract such as a forest with centuries-old hardwood trees, may require measurement on actual specimens or time- and physical-based measurement by ground crews or Internet of Things (IoT) sensors. (Note that the selection of measurement modality, whether event-based or modeling-based, would be determined by policy and affordability.)

2. MEASURING EXTERNALITIES

The main externality for fossil fuels is global warming through combustion (other externalities include contamination from plastic pollution or oil spills from tankers or pipeline breaks). The first step in managing externalities is measurement, formally known as "measurement, monitoring, reporting, and verification" (MMRV). This is required at every stage of a supply chain. For example, supply chain stages for fossil fuels might include exploration and extraction, transportation, refining, distribution, and consumption. Carrying out MMRV at every stage enables carbon-flow assessment and attribution, as well as assignment of emissions liabilities and credits for every player in the supply chain.

One challenge is the impermanence of carbon stored in physical spaces, such as in the agroforestry industry. Improvised mechanisms such as buffer pools are in use in agroforestry-backed compliance markets. Credits from these pools are used after a contingency to restore the credits lost. This mechanism is not foolproof, as losses can be higher than the reserve (e.g., with wildfires), leaving no recourse. As we describe below, various technical verification mechanisms can help with the need to measure externalities.

3. VERIFIABILITY: DIGITALLY TWINNING UNDERLYING ASSETS

Digital twins make audits and tracebacks possible by providing measurement metadata (e.g., timestamps and geolocation). Access to this data should be possible at any moment for technical or legal needs. Stakeholders must be able to track their carbon assets and/or examine the pedigree of any asset being assessed for a transaction. (Blockchain's approach to this is described in the next section.)

For example, the impermanence of forest assets could be treated as variable-price commodities. This would require real-time MMRV, including event-based measurement augmented with historical and predictive growth models.[5] Data-sampling frequency must be based on the underlying business processes. In practice, this means assessing biomass at different intervals depending on the tool (e.g., IoT sensors, light detection and ranging equipment, or satellite infrared remote sensing).

4. DECENTRALIZATION: NO SINGLE POINT OF FAILURE OR INFLUENCE

A concentration of carbon accounting data or services at any point in the supply chain would not be in the interest of participating entities, due to single points of failure or potential bias. Instead, measurement events must be visible across entities as liabilities and assets are transferred by recording them in a permanent, immutable ledger (blockchain). Additionally, smart contract–enabled blockchains would allow decentralized autonomous organizations to manage the system.[6] Although this blockchain implementation is distinct from cryptocurrency, the high-energy, high-carbon costs of blockchain would need to be included on the liability side of the ledgers.

5. PRIVACY: PROTECTING RIGHTS OF COUNTERPARTIES & ASSET HOLDERS

Carbon accounting data sets must be designed to facilitate audits by participating agencies and entities while preserving the privacy of the underlying asset holder. Cryptographic methods include selective attestation (e.g., authorizing a transaction without revealing the identities of the transacting parties or certain details of the transaction), zero-knowledge proof (e.g., doing a task that reveals the existence of knowledge but not the actor's identity), attribute-based credentials (disclosure of verifiable attributes like location or carbon-asset dimensions, without revealing the disclosers' full identity), and homomorphic encryption (performing calculations on data without decrypting it).

6. SCALABILITY

Global warming affects the entire planet, so the scope of a carbon accounting system should be as broad, with accounting across all sectors. An ability to incorporate most industry sectors, actors, and transaction volumes without restriction would require the implementation of nearly all the factors (interoperability, traceability, decentralization, verification, and privacy).

In addition, scale, in the form of market participation, spreads entities' market risk. High levels of participation signal that the market has confidence that the underlying traded assets are reliable.

7. TRACEABILITY

Supply chains are complex, interconnected systems. They can represent physical materials (e.g., oil or cement in the construction industry), abstract materials (e.g., carbon credits), or both. Transparency and visibility across the supply chain are two of the most pernicious issues plaguing today's opaque, voluntary carbon-offset markets. With such complexity, *visibility* into component parts of a carbon offset coming from different origins or processing streams may be difficult. Meanwhile, a participant might be less *transparent* about an asset whose value is precarious if there were no repercussions to its changing after the sale.

Figure 3 shows a carbon supply chain applicable to the agroforestry industry, with carbon removals (credits) and carbon emissions (debits) for data centers. In this example, each stage in the supply chain represents a data type and an industry actor managing the data type.

Following the agroforestry supply chain stages from left to right, a landowner deals with the forested land, forming the basis for carbon capture in the form of biomass. A carbon consolidator makes the biomass estimates and converts them into bulk carbon figures. A carbon registry takes the carbon figures and issues carbon credits on them. A fintech firm takes the carbon credits to a financial platform to securitize the carbon credits, which are passed to brokerage companies that sell the financial instruments to investors. A similar process can be defined for the data center supply chain (see bottom of Figure 3).

Figure 3 connects both carbon emitters and carbon-capture entities to financial markets, eventually bringing them together. Blocks of carbon emissions or removals can be split and/or combined on exchanges. Carbon records can be pooled or sliced into tranches the same way mortgage-backed securities are today.

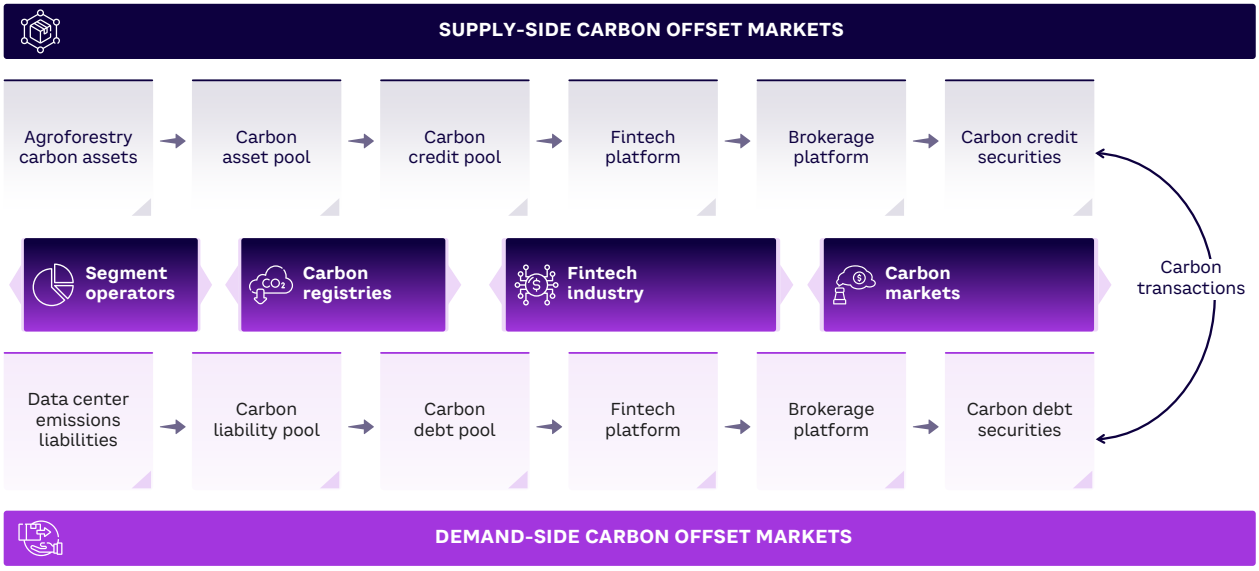


Figure 3. Supply-side and demand-side supply chains for carbon-offsetting securities

AN OPEN SOURCE COMMUNITY

To construct the carbon accounting protocol to meet these seven criteria, we propose an open source community where members codevelop the framework and deliver applications such as gathering data from various parts of the supply chain and sending data horizontally from stage to stage.

The community should adopt reuse as a governing principle. The objective is to connect supply chain blocks representing carbon assets, which, in turn, correspond to blocks in the target supply chain. Reuse would minimize implementation cost and leverage a standard three-tier architecture.[7]

For example, the bulk of the work involved in putting together an agroforestry solution is at the physical (or bottom) layer of the architecture, where the sensor and control structure of a digital twin resides. The digital twin represents the forest's carbon assets and is developed as an API to a carbon registry (carbon-asset pool, at the next layer), which can be aggregated as carbon credits traded by investors (at the top layer).

CONCLUSION

A carbon accounting system could harmonize carbon management across participants in a supply chain, industry sectors, and natural systems while expanding trust in carbon markets. It would require new collaborations among technical, financial, physical science, and business domains but would finally add the type of robustness that has been missing from carbon accounting. Ultimately, this would enable businesses to offer more innovative products and services and make good on their sustainability promises.

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About the authors

Enrique Castro-Leon is CTO and a founding member of OptimiLabs, a start-up focused on systems integration and technology innovation. He currently leads SCOOP, an open source project developing an IT framework for universal greenhouse gas (GHG) accounting, supporting both GHG emissions and removals and offering secure, high-quality data suitable for financial transactions. Dr. Castro-Leon is also Vice Chair of the IEEE P7802 standards working group, focusing on measurement, monitoring, reporting, and verification for climate action projects. Previously, he worked at Intel, driving the transformation of traditional engineering labs into cloud-based, lab-as-a-service environments. Dr. Castro-Leon also led efforts to integrate power monitoring and control capabilities into data center solutions and worked as an enterprise architecture consultant, advising executives on technology integration and strategy. He served as Adjunct Professor at Portland State University, Oregon Graduate Institute, and the University of Costa Rica. Dr. Castro-Leon has authored and coauthored four books, contributed to IEEE publications and *Amplify*, and holds three patents. He earned a bachelor of science degree in electrical engineering from the University of Costa Rica, a master of science degree in electrical engineering and computer science, and a PhD in electrical engineering, both from Purdue University, USA. He can be reached at enrique@optimilabs.com.

Katrina Pugh is a consultant, researcher, and educator focused on strategy, networks, and sustainability. She also co-leads sustainability conversation skills building using the Conversation for Civility model and designs impact networks as a Partner with Weaving Futures. Dr. Pugh leverages AI to analyze how conversation features influence outcomes and employs systems thinking and quantitative modeling to improve knowledge sharing, open source, impact networks, and project performance. She has been published in various journals, including *KM for Development Journal* and *MIT Sloan Management Review* and is the author of *Sharing Hidden Know-How*. Dr. Pugh is Adjunct Professor for Columbia University's Information and Knowledge Strategy master's program, where she also served as Academic Director. She earned a bachelor of arts degree in economics from Williams College, a master of science degree and an MBA from the Massachusetts Institute of Technology, and a PhD in ecology and environmental sciences from the University of Maine, USA. She can be reached at katrinabpugh@gmail.com.

Jose Zero is a seasoned technologist and trusted advisor with over 30 years' experience in cloud computing, AI, and enterprise solutions. He excels in designing and implementing large-scale data center architectures, hyperscale applications, and machine learning algorithms that unlock insights from vast datasets. Mr. Zero's expertise spans server specifications, ground-up data center design, and high-performance computing — guiding clients through technology adoption, migrations, and optimization. With a strong foundation in sales strategy, he bridges technical innovation and business needs, advising on cloud sizing, software efficiency, and vendor ecosystems. Mr. Zero is dedicated to shaping the future of computing through innovative, cutting-edge technologies. Mr. Zero earned a master of arts degree from the University of Pennsylvania, USA. He can be reached at zero@0x1cs.com.

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