Nature-Based Industrial Revolution for Inclusive Sustainable Development

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Abstract

Capitalizing on the benefits and consequences of past industrial revolutions, technological futures, scenarios and roadmaps for 2030 and beyond are shaped around the next Nature-Based Industrial Revolution, which offers new opportunities for positive impacts on human and planetary health while envisioning inclusive prosperity for all.

The history of the relationship between nature and technology is a fascinating one. Initially, geography significantly shaped our connection with the natural world and technological innovation. However, in recent centuries technological evolution has delivered advancements independently of the ecosystems and habitats in which people live. This has had dire consequences for climate change and social inequality. In "Nature-Based Industrial Revolution for Inclusive Sustainable Development" the authors propose reframing technological transformation and consider developments in bio-economy as a possible entry point for stakeholder engagement in facilitating industrial transformation.

1. A Vision for Nature-Based Enterprises Beyond 2030

Nature-Based Enterprises (NBEs) are emerging, around still poorly understood, business models.[1] The literature begins to shed light on factors that underpin the development of these industries, and the realization of their potential to protect, sustainably manage, or restore natural ecosystems while simultaneously addressing societal and environmental challenges.[2]

Demand dynamics and scalability of proposed solutions, policy, and regulatory frameworks, access to finance and technology, and the interplay of entrepreneurship and innovation should guide the development of NBEs.[3] Ecosystems' unique characteristics will heavily influence the nature of business possibilities and the necessary capabilities to be developed by firms.[4]

To thrive, NBEs would need to carefully balance economic with social and environmental outcomes, which may sound like atypical business behaviors. However, some Multinational Enterprises' (MNEs) responses to the COVID pandemic suggest such rebalancing is possible. MNEs showed a willingness to innovate in business models for social value creation, which is a first step toward addressing other grand development challenges such as those associated with climate change, hunger, or the threat of new, fast-growing digital divides.[5]

The viability of these innovative, social-value-oriented business models involves a mix of sustainable and innovative government policies that support and incentivize firms to engage in social value creation, coupled with a change in education and career reward

[1] McQuaid, Siobhan, Esmee D. Kooijman, Mary-Lee Rhodes, and Sheila M. Cannon. 2021. 'Innovating with Nature: Factors Influencing the Success of Nature-Based Enterprises'. Sustainability 13 (22): 12488. https://doi.org/10.3390/su132212488.

[2] World Bank. 2022. 'What You Need to Know About Nature-Based Solutions to Climate Change'. 2022. https://www.worldbank.org/en/news/feature/2022/05/19/what-you-need-to-know-about-nature-based-solutions-to-climate-change.

[3] Santiago, Fernando, and Niki Rodousakis. 2023. 'Nature-Based Sustainable Industrialization: Opportunities for Developing Countries'. *Industrial Analytics Platform - UNIDO* (blog). 2023. https://iap.unido.org/index.php/articles/nature-based-sustainable-industrialization-opportunities-developing-countries.

[4] Khandekar, Pramod, and Prasanta Kumar Ghosh. 2023. 'Bioeconomy: Different Countries, Different Strategies, Multiple Benefits'. Asian Biotechnology and Development Review 25 (3): 5–38.

[5] Peerally, Jahan Ara, Claudia De Fuentes, Fernando Santiago, and Shasha Zhao. 2022. 'The Sustainability of Multinational Enterprises' Pandemic-Induced Social Innovation Approaches'. Thunderbird International Business Review 64 (2): 115–24. https://doi.org/10.1002/tie.22256.

systems towards new generations of sustainability-conscious managers, investors, and shareholders.[6]

NBEs can advance the knowledge frontier and induce sophisticated technology transfer mechanisms. [7] At the same time, NBEs often involve communities and individuals in rural or peri-urban spaces [8] with distinct forms of social and organizational dynamics around economic activities, innovation, and entrepreneurship.

Socially innovative thinking and a reappraisal of "social innovation" and the "directionality" of attendant innovation policies that give value to developmental business initiatives, should help NBEs to transform from marginal to suitable business propositions within more inclusive development models.[9]

2 Bio-regional Roadmaps and Social Innovation for the Nature-Based Industrial Revolution

Recognizing the ecological habitats of the planet, shaped around five climate zones, offer opportunities that are geography and ecosystems-based.[10] This approach highlights nature-based technologies and social innovation in addition to recent developments in the Third Industrial Revolution associated with computing and the Fourth Industrial Revolution associated with digitalization. It is recommended to consider the historical stages of technological evolution in each climatic biome:

1) Baseline technologies – often affiliated with manual labor evolved for around 12,000 years since the development of agriculture, often called low-carbon technologies, are embedded in sociocultural community contexts.[11]
2) Intermediate technologies – affiliated with resource-focused nature-based research and development of the next technological evolution, yet not market-ready for the industrial scale.
3) Hybrid technologies – which attempt to capitalize on a combination of traditional Baseline technologies, their evolution through a combination with the Third and the Fourth Industrial Revolutions[12] including the so-called 'Biotech Revolution'.[13]
4) Digital technologies – which advanced more rapidly than any innovation in our history - reaching around 50 percent of the developing world's population in only two decades - transforming societies.[14]

The scale of cities from small to intermediate to megapolis, shows variations in population density and urban concentration[15]. Adaptation of traditional technologies often affiliated with agriculture, such as the cultivation of date palm or coconut palm, can serve as an entry point for new forms of sustainable industrialization especially in less densely populated regions, and catalyze economic activities for a better urban-rural continuum.

An example can be found in natural resources used to construct architecture before the First Industrial Revolution indicating a strong affiliation with the bio-regional character of the built environment made at the time from natural resources[16]. This model could be adopted contemporality with modern technology and act as a catalyst for innovation. Tax-free zones, federal and regional government incentives,[17] and biotech innovative startups, can act as an incentive for scaling up new forms of technology while respecting socio-cultural characteristics. These approaches can be embraced by various social innovation models for the future Nature-Based Industrial Revolution.

The transformational forces of technological advancement, globalization, climate change, demographic shifts, and migration, combined with socio-economic uncertainties due to the ongoing polycrisis are all impacting the need for new skills to meet the new demands of technology.

The rapid speed at which the work world is changing, raises challenges for policymakers and requires changes in

[6] Peerally et al. 2022
[7] McQuaid et al. 2021; Khandekar and Kumar Ghosh 2023
[8] Lieuw-Kie-Song and Pérez-Cirera 2020
[9] Santiago 2014
[10] Piesik, S, et al 'Enablers for Transformative Change to Sustain People and Nature Centred World', STI Forum 2023 Science Policy Brief
[11] Piesik, S, et al 'Habitat – Vernacular Architecture for a Changing Climate' 2023, Thames & Hudson
[12] Schwab, K, 'The Fourth Industrial Revolution', 2017 Penguin
[13] Grushkin, D 'Grow the Future: Visions of Biodesign', Biodesign Challenge, 2023
[14] UN – 'The Impact of Digital Technologies' https://www.un.org/en/un75/impact-digital-technologies
[15] UN-HABITAT, 'World Cities Report' 2022 https://unhabitat.org/wcr/
[16] Piesik, S, et al 'Habitat – Vernacular Architecture for a Changing Climate' 2023, Thames & Hudson
[17] Piesik, S 'Urban-Rural Dynamics Policy Recommendations' 2019, UNCCD

education and how skills are developed, designed, provided, and accessed.[18]

North-South, South-South and Triangle Collaboration[19] will remain a pivotal tool for new research and innovation, and technological development, including the skills needed to deliver a transformational bio-economy and various industries shaped around nature-based solutions.

3. "Green Value Tax" (GVT) and Nature-Centred Development

Exploring participatory tools for fostering development that equally prioritizes human needs and nature's well-being marks a significant pivot towards an economic paradigm inspired by natural ecosystems' automated and complex features. This model is underpinned by the core principles observed in nature: efficiency in resource use, adaptability to changing conditions, circularity in processes, and symbiosis among diverse entities. It aims not merely to sustain, but to regenerate and enhance the ecosystems it interacts with. It envisions an economy where every byproduct is reimagined as a resource, thus embodying nature's ethos of generating no waste.

Such a model advocates for a structural shift towards decentralization, promoting resilience and empowering local communities through initiatives that draw upon global insights for local advantages. This strategy suggests a profound re-evaluation of our current economic values and resource management, potentially initiating a paradigm shift akin to a new industrial revolution.

This forthcoming revolution could redefine our value and resource utilization conceptions, emphasizing a more harmonious coexistence with the natural environment. By valuing biodiversity, ecosystem services, and the health of our planet, this model proposes a fundamental shift from short-term financial gains to long-term sustainability and communal welfare as the cornerstones of economic prosperity.

Central to this economic philosophy is the recognition of nature's inherent balance, regenerative cycles, and mutual support systems, steering us toward an economy that champions harmony, efficiency, sustainability, and collective well-being. Emphasizing collaboration over competition, this model nurtures a culture ripe for innovation and mutual prosperity, encouraging diverse entities to work together towards common goals. It envisions an economy that supports and nourishes the planet and its inhabitants, calling for a critical reassessment of our priorities and values in favor of a more ecological and socially prosperous future.

Central to realizing this vision is adopting innovative policies such as the "Green Value Tax" (GVT), which aims to recalibrate the economic framework by factoring environmental costs into the valuation of goods and services. This policy seeks to motivate sustainable practices and discourage activities harmful to the environment, steering us toward a future that is both sustainable and equitable.

4. Bioeconomy and Decarbonization in the Built Environment

The building sector is responsible for 39% of energy-related global CO2 emissions, 11% of which are attributed to the extensive use of steel, concrete, and other carbon-intensive materials.[20] To address the climate crisis, the global building industry should embrace bio-based construction with timber, straw, hemp, biochar, and other locally sourced bio-based materials that sequester, rather than emit carbon. Storing embodied carbon in bio-based building materials – rather than merely relying on reducing operational carbon emissions, is critical to meeting global carbon reduction commitments.[21] We need a myriad of new bio-based structural, insulation, and finish materials, to replace fossil-based building products – which could effectively turn buildings into "carbon sinks".[22]

Regional governments, and visionary municipalities, working with engaged stakeholders and communities

[18] ILO and OECD 'Global skills gaps measurement and monitoring: Towards a collaborative framework' 2023

[19] SDG 17.6 https://www.un.org/sustainabledevelopment/globalpartnerships/

[20] IPCC. Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama. Cambridge University Press.

[21] Caplan, Bill. (2021). Thwart Climate Change Now: Reducing Embodied Carbon Brick by Brick. New York: Environmental Law Institute.

[22] Churkina, G., Organschi, A., Reyer, C. P., Ruff, A., Vinke, K., Liu, Z., Reck, B. K., Graedel, T. E., & Schellnhuber, H. J. (2020). Buildings as a global carbon sink. *Nature Sustainability*, *3*(4), 269-276.

are best equipped to develop regional construction-related bio-economies that have the potential to transform cities, croplands, and forests by simultaneously creating jobs and healthy environments.[23]

Yet, these policies should not merely benefit corporate stakeholders. Instead, policymakers should aim to systemically involve, empower, and connect rural and urban communities to bio-based industry stakeholders and cooperatives, all along the supply chain. Only by listening to local voices, and understanding unique ecosystems, will we co-develop innovative bio-based building products that are well-suited to their local contexts.

As the architect Kiel Moe states, the universal/global approach to the bio-economy must be replaced by a territorial/local one.[24] This means timber, hemp, or other biomaterials must be understood within their unique social and cultural milieu, from their molecular structure to their territorial and cultural context.

For example, in the United States, Industrial Hemp is a relatively new agro-environmental industry with an expected growth of $2.2 billion in annual revenue by 2030.[25] Yet, agricultural settings and construction market demands vary significantly from region to region.

Using a bio-regional framework for community/stakeholder engagement and inclusion, policymakers should aim to establish bio-based industrial districts, that are uniquely tailored to the needs of local farmers, processors, workers, and communities.

5. Biodesign and Biotechnology

Technological responses to the Sustainable Development Goals (SDG) require a multidisciplinary approach that appreciates the power of today's technologies, while also recognizing that technologies only serve us under the right cultural conditions. Voices from multiple socioeconomic, regional, and disciplinary backgrounds should contribute to SDG innovation, development, and deployment.[26]

Biotechnology is one of the most powerful emerging technologies today. It has the capacity to help address issues of sustainable development and climate change by replacing toxic manufacturing processes with nature-based industries.[27] That said, identifying meaningful solutions is nontrivial. Historically, scientists responsible for biotech innovation and product designers responsible for new applications and adoption have worked institutionally apart. Bridges across these disciplinary barriers must be built to ensure that SDG technology solutions have the maximum chance for success. [28] Cultural, market, ethical, and policy factors have as much to do with an innovation's success as its technical aspects.[29]

We propose the development and education of a new class of innovation workers called the biodesigner. Such a practitioner would have fluency in state-of-the-art biotechnology, its technical opportunities and limitations, while simultaneously being versed in the cultural, industrial, regional, and market environment in which a biotech solution might be deployed.[30]

Such biodesigners would work alongside scientists to identify innovation opportunities, while also working closely with user communities and industries to

[23] Evanoff, Richard (2011). Bioregionalism and Global Ethics: A Transactional Approach to Achieving Ecological Sustainability, Social Justice, and Human Well-being. New York: Routledge.

[24] Moe, Kiel. "There's more to timber building than trees" *The Architect's Newspaper*, 22 Mar. 2021

[25] Berard, Pierre. (2023) "Seeing the U.S. Industrial Hemp Opportunity." BioSolutions Initiatives.

[26] Office of Science and Technology Policy [OSTP].. *Building the bioworkforce of the future: Expanding equitable pathways into biotechnology and biomanufacturing.* Washington, DC, 2023, https://www.whitehouse.gov/wp-content/uploads/2023/06/Building-the-Bioworkforce-of-the-Future.pdf.

[27] Chui, Michael, et al. "The Bio Revolution: Innovations Transforming Economies, Societies, and Our Lives." *McKinsey & Company*, McKinsey & Company, 13 May 2020, www.mckinsey.com/industries/life-sciences/our-insights/the-bio-revolution-innovations-transforming-economies-societies-and-our-lives.

[28] Trott, Carlie D., et al. "Merging the arts and sciences for collaborative sustainability action: A methodological framework." *Sustainability Science*, vol. 15, no. 4, 2 Apr. 2020, pp. 1067–1085, https://doi.org/10.1007/s11625-020-00798-7.

[29] National Academies of Sciences, Engineering, and Medicine. *The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education: Branches from the Same Tree.* National Academies Press, Washington, DC, 2018.

[30] Grushkin, Daniel. "What Is Biodesign?" *Issues in Science and Technology,* June 18, 2021, https://issues.org/biodesign-challenge-synthetic-biology-grushkin.

understand how such innovations would slot into already existing cultures and industrial ecosystems. Biodesigners would hone a panoply of skills associated with market researchers, bioethicists, anthropologists, product designers, and scientists.

At a moment when technology must be brought to bear against the worst effects of climate change, the global population cannot afford false starts and failed promises. Advancing the biodesigner in academia, government, and industry can accelerate the translation of novel biotechnologies into culturally and environmentally meaningful solutions to reach the SDGs and beyond.

Policy recommendations / conclusions

The following policy recommendations and conclusions are made for the Nature-Based Industrial Revolution for Inclusive Sustainable Development.

Targeted audiences are national, regional, and local governments, innovators, think tanks, businesses, fiscal advisors, urban and rural communities, educators, scientists, market researchers, bioethicists, anthropologists, creative industries, product designers, and individuals amongst others.

1. A Vision for Nature-Based Enterprises Beyond 2030

1.1. Advancing knowledge on the determinants of the development of NBEs will assist in the formulation of policies to support suitable markets for the operation of those firms. Such policies should go hand-in-hand with other initiatives to foster entrepreneurship, experimentation, and innovation in NBE-oriented business models, and the creation of incentives for old and new businesses to venture into the broad areas of Nature-based solutions.

1.2. Using SDG's as beacons for the design of policies to support NBEs should help in creating suitable conditions for such ventures to drive, while at the same time fostering more balanced development strategies based on a more harmonic pursuit of economic, social, and environmental development outcomes.

2. Bio-regional Roadmaps and Social Innovation for the Nature-Based Industrial Revolution

2.1 Technological diversification for bio-regions focused on the baseline, intermediate, hybrid, and digital technologies.

2.2 North-South, South-South, and Triangle Collaboration as pivotal tools for new research and innovation, technology development, and transfer. These include skills needed to deliver a transformational bio-economy and industries shaped around nature-based solutions.

3. "Green Value Tax" (GVT) and Nature-Centred Development

3.1. New economic paradigm inspired by natural ecosystems with core principles observed in nature: efficiency in resource use, adaptability to changing conditions, circularity in processes, and symbiosis among diverse entities.

3.2. The "Green Value Tax" (GVT) proposal aims to recalibrate the economic framework by factoring environmental costs into the valuation of goods and services. This policy recommendation seeks to motivate sustainable practices and discourage activities harmful to the environment, steering us toward a future that is both sustainable and equitable.

4. Bioeconomy and Decarbonization in the Built Environment

4.1. To address the climate crisis, the global building industry should embrace bio-based construction with timber, straw, hemp, biochar, and other locally sourced bio-based materials that sequester, rather than emit carbon.

4.2. Using a bio-regional framework for community / stakeholder engagement and inclusion, policymakers should aim to establish bio-based industrial districts, that are uniquely tailored to the needs of local farmers, and processors.

5. Biodesign and Biotechnology

5.1. Biotechnology is an impactful emerging technology that can help address issues of sustainable development and climate change by replacing toxic manufacturing processes with nature-based industries.

5.2. Bridges across disciplinary barriers must be built to ensure that future technology solutions have the maximum chance of success through the introduction of biodesigners as an innovative workforce advancing multidisciplinary collaborations.

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Annex

Figure. The History of Innovation Cycles