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Foundational guiding principles for a flourishing Earth system

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Abstract

In this perspectives article, we maintain that the current local to global sustainable development predicaments we face are the result of humanity's impact on the Earth System (ES)—that is to say, on the very systemic fabric of the ES (i.e., its functioning and configuration), combined with an insufficiently coherent application of sustainable development policy to address and resolve this systemic problem. In response to what is an urgent crisis, we propose four foundational guiding principles, which we contend provide an overarching framing that, if implemented, would offer an approach to steer global sustainable development policy in a manner that would be to the benefit of the ES and the securing of a flourishing future for all. Our principles are applicable at the levels from a local business ecosystem, national-regional networks, to global policy.

KEYWORDS

business and environment, environmental policy innovation, sustainable development

1 | INTRODUCTION

> "Our human environment has become the most critical question that concerns the survival of the human species and our planet"
>
> (Satchidanandan & Chawla, 2023, in *Greening the Earth*, p. v).

In the spirit of Orwellian brevity, a well-crafted thought can encapsulate the entire essence of an essay, and so it is with the quote that begins our paper. As evocatively described, we take as our starting point the most pressing common problem, we all face—the unsustainability of humanity's planetary footprint. We argue that a central component of current local to global sustainable development predicaments results from humanity's impact on the Earth System (ES)—i.e., on its functioning and configuration together with the lack of a coherent application of sustainability interventions to address and resolve this systemic problem. In response to what is an urgent crisis, we propose four foundational guiding principles that we contend provide an overarching framing that, if implemented, would offer an approach to steer global sustainable development policy in a manner that would be to the benefit of the ES and the securing of a flourishing future for all. These principles are applicable from the level of a local business ecosystem, to national-regional networks, to global policy.

2 | MOVING THE LOGIC OF SUSTAINABILITY

While behaving in a sustainable way applies to us all, considering the readership of this journal, highlighting the requirement for responsible organizations of all types, operating in today's world, not only to be cognizant of but also to actively work towards, achieving sustainable development is critical. And the emphasis on organizations (particularly businesses and corporations) to be acting in that way has ratcheted up over time (Ceres & Sustainalytics, 2014). However, whether leaders are defining the materiality of the organization's environmental, social, and governance (ESG) initiatives or corporate social responsibility (Carroll, 1998), clear principles guiding their influence on all of the United Nations Sustainable Development Goals (SDGs) within the planetary boundaries (PBs) is essential for supporting a longer term strategy formulation: with a broader focus (Guimaraes-Costa et al., 2021) geared towards large-systems transformation (Waddock, 2020) and greater flourishing for all (VanderWeele, 2017). Frequently, however, given the enormity of 17 SDGs and 9 PBs, strategy and CSR prioritizing leads to a focus on a fraction of these, to the detriment of those not considered. To be useful to businesses and organizations, within their local ecosystems or national and regional networks, we propose a set of four principles to unify these seemingly competing frameworks (Schwartz & Carroll, 2008), allowing organizations to navigate how to meet their SDG responsibilities within the wider PBs.

In the rest of this paper, we describe the sustainability predicament facing leaders in all organizations (including businesses) as well as society; the scale of the problem; consider why organizations should care about the scale of the problem; a sustainable-development approach that is failing; and foundational principles to resolve the failure.

3 | THE ES-SUSTAINABILITY PREDICAMENT

Without balance between the forces of production and consumption, between generative and transformative processes, without some degree of operative and regulative homeostasis, the dynamic played out between order and entropy—a tightrope of tension existing between the exchange of matter and energy—fundamentally shifts in a direction contrary to the continued persistence and functioning of the "system." In our case, the system we speak of is the ES.

The ES represents a dynamic and interconnected system comprising physical, chemical, and biological processes and structures that form four principal "spheres": (i) the lithosphere (referring to the terrestrial land surface and crust); (ii) the hydrosphere (the sum total of liquid, frozen, and vapor forms of water on the Earth's surface, in the air and below ground); (iii) the atmosphere (the five layers of gasses enveloping the Earth, from the troposphere to the exosphere); and (iv) the biosphere (the zone of life on Earth). Also integral to the narrative of a sustainability-predicament and crucial to the properties and dynamics of the ES is the *Earth's energy budget*, a delicate balance between incoming solar radiation and outgoing infrared radiation, which plays a vital role in maintaining the planet's climate and overall equilibrium (NASA, 2021).

From a dynamic Earth perspective, geophysical and biophysical systems and processes are constituted of matter and energy. But, more importantly, they also synthesize, convert, and transform matter and energy via material throughput, both independently and in conjunction with each other, within the overall limits of the Earth's energy budget. These dynamic processes of matter-energy conversion and transformation, back and forth, into living and non-living organic and inorganic forms, underpinned by physical laws that apply limits to chemical and biological processes, are responsible for the specific creation, composition, and configuration of the ES (Table 1).

Often, the language of poetry is able to communicate and express meaning with greater depth and insight than mere technical description can muster, so it is with the physical system account provided above which is beautifully evoked in a verse taken from the poem *Touching the Ground* (*Earth Day*, *1990*) by Michael Anania: "All growth grows on what has grown. The circle of water, the circle of air, the great circles of plant and soil, the blue circumference of sky converge in the green space of a single leaf. Between leaf vein and leaf's edge the earth offers itself and its long history, a green coincidence balanced briefly on the planet's stem."

This poetic expression conveys what any graduate biochemistry or ecology textbook will attest to, which life and living processes are especially adept at harnessing matter and energy to diversify, proliferate, perpetuate, and maintain structure and function across time and space, drawing on the four spheres of the ES. In that respect, our own species *Homo sapiens* are no exception. Unleashing our creative ingenuity through the development of our science and technology, we have become the unassailable masters at harnessing that matter and energy. Bringing forth "modernity" on the iron forge of the Industrial Revolution, driven by an insatiable growth-based capitalist economic model, humans (significantly in the form of businesses, corporations, and industries in the "Global North") have taken more of the Earth's energy budget for their own ends, redistributing the matter-energy balance, in different configurations between these four spheres, shifting and disrupting the balance and the equilibrium. Astonishingly, today, we capture roughly 25% of the annual global net primary production to provide food, feed, fiber, and fuel (Krausmann et al., 2017). Crucially, the scale of this redistribution, reallocation, and mixing of the Earth's energy budget (Williams et al., 2016) fundamentally undermines essential processes upon which the ES depends and makes aspects of the four

TABLE 1 The connections between the four spheres of the ES and links with the Earth's energy budget

Interplay of Earth's energy budget and major spheres

Lithosphere	Hydrosphere	Atmosphere	Biosphere
The lithosphere, composed of the Earth's solid outer layer, is intertwined with the energy budget through various processes. Solar energy absorbed by the Earth's surface drives geophysical processes such as weathering and erosion. The lithosphere also stores energy in the form of fossil fuels, which, when extracted and burned, contribute to the release of greenhouse gasses, impacting the Earth's energy budget and climate	The hydrosphere, encompassing oceans, rivers, lakes, and ice, plays a significant role in Earth's energy budget. Solar radiation warms the surface of oceans, driving ocean currents and influencing climate patterns. Evaporation from the hydrosphere contributes to the water vapor content in the atmosphere, a key player in the water cycle. Additionally, the reflective properties of ice in polar regions affect the amount of solar radiation absorbed, influencing both local and global energy balances.	The atmosphere acts as a crucial mediator in Earth's energy budget. Solar radiation penetrates the atmosphere, where it interacts with gasses, clouds, and particles. The energy absorbed by the atmosphere warms it, and some is subsequently reradiated back to space. The atmosphere also plays a key role in redistributing energy through processes like convection and wind. This continuous exchange of energy between the atmosphere and space regulates Earth's temperature. Key aspects include the greenhouse effect, the albedo effect, and latent heat release.	The biosphere, comprising all living organisms, is intricately linked to the Earth's energy budget through photosynthesis. Plants, algae, and other photosynthetic organisms in the biosphere convert solar energy into chemical energy, capturing carbon dioxide and releasing oxygen. This process not only sustains life but also influences the composition of the atmosphere by regulating the levels of greenhouse gasses. This process also creates biomass. The biosphere, therefore, acts as both a contributor to and a regulator of Earth's energy balance.

Earth sphere interactions

Atmosphere-biosphere	Atmosphere-hydrosphere	Atmosphere-lithosphere	Biosphere-hydrosphere	Biosphere-lithosphere	Hydrosphere-lithosphere
The atmosphere and biosphere share a dynamic relationship characterized by the exchange of gasses, particularly oxygen and carbon dioxide. Through the process	The atmosphere and hydrosphere are linked through the water cycle. Evaporation from the hydrosphere leads to the formation of water vapor in the atmosphere, which later condenses to	The lithosphere and atmosphere interact through various geological and atmospheric processes. Volcanic activity in the lithosphere releases gasses and particulate	The biosphere and hydrosphere have intricate relationships as all ecological systems rely on water for survival. Aquatic life, from microorganisms to large marine species,	The biosphere and lithosphere are closely intertwined as the lithosphere provides the physical substrate for life. Soil in the lithosphere is a critical component for plant growth, supporting the	The hydrosphere and lithosphere interact through processes like erosion and sedimentation. Rivers, for instance, transport sediment from the lithosphere to the hydrosphere, shaping

TABLE 1 (Continued)

Atmosphere-biosphere	Atmosphere-hydrosphere	Atmosphere-lithosphere	Biosphere-hydrosphere	Biosphere-lithosphere	Hydrosphere-lithosphere
of photosynthesis, plants in the biosphere absorb carbon dioxide from the atmosphere and release oxygen. This exchange is fundamental to sustaining life on earth. Key interactions include photosynthesis, respiration, transpiration, biogenic volatile organic compounds, methane emissions, particulate matter and aerosols.	form clouds and precipitates as rain or snow. This continuous cycling of water is essential for maintaining the planet's water balance. Key interactions include evaporation and water vapor, condensation and cloud formation, precipitation, humidity and atmospheric moisture, cyclones and atmospheric circulation, ocean currents and heat redistribution, hydrological cycle.	matter into the atmosphere. Erosion of rocks and soil also contributes minerals to the atmosphere through dust particles. Key interactions include weathering and erosion, chemical weathering, volcanic gas interaction, dust and aerosol transport, land-atmosphere heat exchange, carbon cycle.	depends on the hydrosphere for habitat, sustenance, and reproduction. Key interactions include marine and freshwater food webs, pollination and water-dependent flora, water filtration and purification. In terrestrial systems, water acts as a carrier for essential nutrients within the soil. Dissolved minerals and nutrients become available for uptake by plant roots. Access to freshwater sources is vital for drinking, thermoregulation, and maintaining physiological functions for mammals, birds, reptiles, amphibians and insects.	various ecosystems within the biosphere. Key interactions include soil formation, nutrient cycling, erosion and sedimentation, landform development, biological weathering, biogeomorphology, volcanic activity and soil fertility.	landscapes and influencing the physical characteristics of water bodies. Key interactions include erosion and sedimentation, sedimentary rock formation, weathering and coastal processes, aquifer recharge and groundwater movement, delta formation and estuarine and coastal geology, karst landscapes.

Source: (a) Amundson et al. (2015). (b) Bonan (2008). (c) Burton et al. (2013). (d) Cornell (2012). (e) Davis and Fitzgerald (2004). (f) Hartmann (1994). (g) Le Treut et al. (2007). (h) Martin (2016). (i) Milliman and Farnsworth (2013). (j) Mitsch and Gosselink (2015). (k) Turcotte (1999).

spheres less available and accessible. Ultimately, human activities have become a dominant force shaping the Earth's energy budget, with profound consequences for the planet's climate and ecosystems, creating interconnected and widespread impacts and perturbations affecting the interactions and composition of Earth's major spheres (Richardson et al., 2023).

4 | THE SCALE OF THE PROBLEM

Below, we briefly explore some of the key human activities dramatically influencing and disrupting each sphere and relations between spheres, which affect the availability of and equitable access to clean minerals and nutrients, water, air, plants, and animals.

4.1 | Lithosphere

As masterfully surveyed in the *Rofutledge Handbook of the Extractive Industries and Sustainable Development* (Yakovleva & Nickless, 2022), mineral extraction rates have risen rapidly over recent years and decades, driven by technological developments, industrial and manufacturing demands, and renewable energy production (Kinnaird & Nickless, 2022; Krausmann et al., 2017; Maus et al., 2020; Sonter et al., 2020). The scale of extraction is startling, as the International Resources Panel (2019) report *Natural Resources for the Future We Want* details. The yearly global extraction of materials between 1970 and 2017, grew threefold from 27 billion tonnes to 92 billion tonnes (IRP, 2019). This translates to a per capita demand increase from 8.3 t in 1970 to 13.2 t in 2024 (UNEP, 2024). The list of materials extracted is long, but significant within that include iron, aluminum, and copper ores and other non-ferrous metals and particularly sand, gravel, and clay (IRP, 2019). Given the scale of material resource use, as the recently published *Global Resources Outlook 2024* report describes: "Without urgent and concerted action to change the way resources are used, material resource extraction could increase by almost 60 per cent from 2020 levels by 2060, from 100 to 160 billion tonnes, far exceeding what is required to meet essential human needs for all in line with the SDGs." (UNEP, 2024, p. xiv).

Looking ahead, the intensity of extraction of so-called rare earth elements (REE)[1] is expected to grow significantly, up to sixfold by 2040, due to their centrality in key automotive, scientific, and telecommunication technologies, as well as military and defense sectors and renewable energy technologies (Mudd, 2022; Nayar, 2020; Talan & Huang, 2022). Demand for elements such as lithium and cobalt are expected to increase up to 20 times by 2050 as the transition from fossil fuel powered to electric powered cars continues, while for similar reasons, demand levels for dysprosium and neodymium may reach as high as 26 times over the same period (Christmann et al., 2022; Nayar, 2020). Recent concerns over the potential scarcity, supply, and availability of minable concentrations of REE (Talan & Huang, 2022) has precipitated a shift to prospecting the ocean seabed, with the seafloor now considered the next big frontier in mineral exploitation (Sakellariadou et al., 2022). This includes, as Sakellariadou et al. (2022, p. 329) state, a focus on the extraction of "… polymetallic sulfides, polymetallic nodules, cobalt-rich crusts, phosphorites, and rare earth element-rich muds" in areas ranging as far and wide as the Atlantic, Indian, and Pacific oceans.

The unprecedented scale and pace of mineral extraction have significant repercussions for land appropriation, alteration of biogeochemical cycles, carbon dioxide (CO_2) emissions, chemical pollution/solid waste generation, and degradation and fragmentation of ecosystems and loss of biodiversity (IRP, 2019; Krausmann et al., 2017; Maus et al., 2020; Sakellariadou et al., 2022; Talan & Huang, 2022; UNEP, 2024). Two examples are illustrative. In relation to REE mining, as Nayar (2020) highlights: "For every ton of rare earth produced, the mining process yields 13kg of dust, 9,600–12,000 cubic meters of waste gas, 75 cubic meters of wastewater, and one ton of radioactive residue." From the perspective of biodiversity impacts, across the mining sector as a whole, as Sonter et al. (2020, p. 1) describe, mining activities may "… influence 50 million km^2 of Earth's land surface, with 8% coinciding with protected areas, 7% with key biodiversity areas, and 16% with remaining wilderness."

4.2 | Hydrosphere

Acidification of the world's oceans is increasing, presenting a real challenge to marine life. Since the onset of the Industrial Revolution, the engines of economic growth have pumped more and more CO_2 into the atmosphere. As the concentration of atmospheric CO_2 has risen, so the oceans, acting like a giant sponge, have absorbed more and more—approximately 30% (Jewett et al., 2020). Over a 200 year or so period, the pH of the oceans has fallen by 0.1 pH units. While this may sound rather trivial, remember, pH is measured on a logarithmic scale, so this is equivalent to a 30% increase in acidity (Jewett et al., 2020), and by the end of this century, the pH is predicted to fall by a further 0.2 pH units (Figuerola et al., 2021).

Moving from more alkaline to acid conditions starts to radically alter seawater chemistry: specifically, oceanic partial pressure of CO_2, bicarbonate concentration, and calcium carbonate saturation. Reduction in the availability of carbonate ions as they bind with the excess (acid) H + ions to form bicarbonate means decreasing overall levels of calcium carbonate (Figuerola et al., 2021). The under availability of calcium carbonate will have unprecedented impacts on the performance and distribution of carbonate ecosystems, especially species such as corals and oysters that create shells and skeletons from calcium carbonate. Further increases in acidity may also start to dissolve these structures as well as in some species affect their density (Figuerola et al., 2021; Jewett et al., 2020; Mollica et al., 2018).

While ocean chemistry is changing, elsewhere, water is undergoing a colossal physical transformation, from solid to liquid. Between 1994 and 2017, Slater et al. (2021) estimate that 28 trillion tonnes of ice were lost. This mass melting is the result of the cryosphere (the frozen component of the Hydrosphere) taking up "3.2% of the global energy imbalance" (Slater et al., 2021, p. 233). Most ice losses are from atmospheric melting (68%) with the remainder (32%) driven by oceanic melting. The global distribution of this loss is staggering: "Arctic Sea ice (7.6 trillion tonnes), Antarctic ice shelves (6.5 trillion tonnes), mountain glaciers (6.1 trillion tonnes), the Greenland ice sheet (3.8 trillion tonnes), the Antarctic ice sheet (2.5 trillion tonnes), and Southern Ocean Sea ice (0.9 trillion tonnes)" (Slater et al., 2021, p. 233). Increasing volumes of melted ice entering the Atlantic Ocean are thought to affect circulation patterns—though the extent to which this may happen is not fully clear (Armitage et al., 2020; He & Clark, 2022)—with consequences for fisheries (Spooner et al., 2020) weather conditions (Yin & Zhao, 2021) and broader implications for "… biodiversity, structure, and function of sea ice biota, pelagic and benthic communities, and […] the composition distribution, and productivity of all species in these ecosystems" (Linse et al., 2021, p. 1). The other considerable consequence of ice sheet loss, especially for low-lying coastal communities, is sea level rise (SLR). A new analysis indicates that ice loss from the Greenland ice sheet commits the globe to at least 274 ± 68 mm SLR from $59 \pm 15 \times 10^3$ km^2 of ice retreat (Box et al., 2022).

Groundwater depletion and pollution are also undermining the proper balance of the Hydrosphere. The United Nations (2022) *World Water Development Report* makes for glib reading, outlining how humans are appropriating groundwater at unparalleled rates, with global aggregated storage depletion around 100 to 200 km^3 annually (UN, 2022). Of the abstracted groundwater, 50% is for domestic purposes and 25% for irrigation. This should be ringing alarm bells, groundwater represents 99% of all liquid freshwater on Earth and is an essential resource, yet our use is highly profligate, we also continue to undermine its quality through pollution derived from agricultural sources and manufacturing, industrial and mining activities (UN, 2022) as well as increasingly from microplastics (Viaroli et al., 2022). It should be of greater concern than is generally acknowledged that the polluting of groundwater is considered a strongly irreversible process (UN, 2022).

4.3 | Atmosphere

Climate change and its direct and indirect impacts represent humanity's greatest challenge in the 21st Century (IPCC, 2018). While there are several drivers of climate change, one of the greatest root causes is the combustion of fossil fuels (e.g., oil, gas, and coal). The mass burning of fossil fuels, which is deeply embedded in, and supports, our current political and economic models, transforms our ancient geological history in the form of decomposed prehistoric plant, bacterial, and animal life and returns it back to the atmosphere principally in the form of carbon dioxide. Crucially, we are returning this carbon material back to the atmosphere at unprecedented rates, and at speeds that far exceed, by orders of magnitude, the rate at which it was buried and can be dealt with via the carbon cycle. As the Intergovernmental Panel on Climate Change (IPCC, 2022) report *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* makes very clear, at present, "Global net anthropogenic GHG emissions were 59 ± 6.6 $GtCO_2$-eq in 2019, about 12% (6.5 $GtCO_2$-eq) higher than in 2010 and 54% (21 $GtCO_2$-eq) higher than in 1990 [...] Growth in anthropogenic emissions has persisted across all major groups of GHGs since 1990, albeit at different rates" (p. 12).

Despite the grave scientific warnings, together with much of the recent political rhetoric regarding commitments to decarbonization and net zero, the trend of increasing greenhouse gas (GHG) emissions is not abating. The World Meteorological Organization's latest analysis shows that the key GHGs—carbon dioxide, methane (CH_4), and nitrous oxide (N_2O)—all reached new highs in 2021, being at 149%, 262%, and 124%, respectively, above pre-industrial, i.e., 1750 levels (WMO, 2022). The bulk of these emissions (total net anthropogenic GHGs) come from the energy sector (34%), industry (24%), and agriculture, forestry, and other land use (22%) (IPCC, 2022). The problem is, that collectively, these gasses plus dichlorodifluoromethane (CFC-12) and trichlorofluoromethane (CFC-11) represent 96% of the radiative forcing due to GHGs: that is to say, their increasing accumulation and retention in the atmosphere reduce the energy radiating back into space from Earth, ultimately contributing to a situation in which we have more heat entering the ES than leaving it, which then drives climate change (WMO, 2022).

Alongside the accumulation of GHGs in the atmosphere, another growing issue of concern is air pollution. Air pollution is not a new phenomenon—remember the "dark satanic mills" of William Blake's poem *Jerusalem* (c. 1808), but its geographical scale and scope has expanded massively in line with the expansion of industries, urbanization, transportation and transport infrastructure, and domestic energy use (Fowler et al., 2020). A key issue is ambient particulate matter of 2.5 μm or less, known as $PM_{2.5}$, which is produced from a variety of domestic and industrial sources (Shaddick et al., 2020). According to the *State of Global Air 2020* report, produced by the Health Effects Institute, in 2019, more than "90% of the world's population experienced annual average $PM_{2.5}$ concentrations that exceeded the WHO Air Quality Guideline of 10 μg/m^3" (HEI, 2020, p. 6). At the same time, other pollutants such as tropospheric ozone are also rising to levels way above historic baselines, in the region of 30–70% compared to a century ago (HEI, 2020). Prolonged exposure to air pollution poses severe health risks. According to a recent study, 10.2 million premature annual deaths, especially from respiratory related illnesses, can be attributed to the $PM_{2.5}$ from fossil fuels (Vohra et al., 2021). While there have been some improvements in $PM_{2.5}$ levels in some regions of the world, there has been little long-term progress made in the most polluted regions such as China and India and other parts of Asia as well as sub-Saharan Africa (HEI, 2020; Shaddick et al., 2020; Vohra et al., 2021).

4.4 | Biosphere

Terrestrial landscapes have undergone momentous human-induced changes with widespread land conversion altering land cover and land-use patterns. However, until recently, we were blind to the sheer scale of this change. The work of Winkler et al. (2021) has indicated that 32% of global land area between 1960 and 2019 has been impacted by land use change, a staggering four times higher than previously thought, as the authors describe "This means that, on average, a land area of about twice the size of Germany (720,000 km^2) has changed every year since 1960" (p. 2). Food production and industrial agriculture, in concert with population growth, have been a pivotal global driver of land use change, with startling implications. Humans and our farmed livestock now comprise about 36% and 60%, respectively, of all mammal biomass, while wild mammals now only account for 4% (Bar-On et al., 2018). In other words, we have converted the "natural world" into more of ourselves and our food supply; indeed, over the last 50 years, meat production has increased by 244%, marine fish catch by 47%, and the human population by 107% (WWF, 2022).

Since the 1960s, the world has lost 0.8 million km^2 of forest while witnessing a gain in cropland (1.0 million km^2) and pasture/rangeland (0.9 million km^2) for agriculture (Winkler et al., 2021). For example, the most recent analysis of human impacts on the Amazon ecosystem (e.g., agriculture, timber extraction, edge effects, and fire) indicates that 2.5×10^6 km^2 is degraded: an area equivalent to 38% of remaining forests (Lapola et al., 2023). A prominent driver of this extensive degradation is globalization, as Albert et al. (2023) make clear the rates of "anthropogenic processes affecting Amazonian ecosystems are up to hundreds to thousands of times faster than they are for natural climatic and geological phenomena. These anthropogenic changes have reached the scale of millions of square kilometers within just decades to centuries, as compared with millions to tens of millions of years for evolutionary, climatic, and geological processes" (p. 3). Biodiversity extinction rates in these areas are around 1,000 to 10,000 times higher than background rates (Albert et al., 2023). Indeed, this is part of a wider global phenomenon that has seen wildlife populations decline by 69% on average since 1970 (WWF, 2022). The outlook is not a positive one, as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, 2019) *Global Assessment Report on Biodiversity and Ecosystem Services Summary for Policymakers* makes clear: "The average abundance of native species in most major terrestrial biomes has fallen by at least 20 per cent [...] mostly [...] since 1900 and may be accelerating"

(p. 11). It is worth noting that while there has been a dramatic change in the configuration and composition of the natural world, our human world—in terms of manufactured materials (e.g., concrete and plastic)—now exceeds all living biomass (Elhacham et al., 2020).

5 | WHY SHOULD BUSINESS CARE ABOUT MOVING TOWARDS SUSTAINABLE DEVELOPMENT?

The sustainability of Earth's major spheres—lithosphere, hydrosphere, atmosphere, and biosphere—is not just a concern for environmentalists but a critical imperative for businesses and corporations. As major contributors to global economic activities, businesses (of all varieties) have a profound impact on the health and balance of these spheres. This means there is both a moral obligation to act as well as a strategic business case for proceeding in ways that accord with ES sustainability. Embedding sustainable development practices in businesses or organizations can be challenging. Multiple barriers are often at play, varying according to factors such as industry, geographical location, organizational culture, and regulatory environment. Commonly identified barriers include prioritizing short-term financial and shareholder interests, potential for large upfront capital costs or costs resulting from changing organizational operations, weak or inconsistent regulatory landscapes, limited access to necessary resources and expertise, greenwashing and lack of accountability, and the management of complex and disparate global supply chains (UNGC, 2020; WBCSD, 2022). Despite these barriers, synthesizing a variety of sources (BCG, 2019; Deloitte, 2019; Edelman, 2021; GRI, 2021; GSIA, 2021; McKinsey, 2020; Nielsen, 2015; WBCSD, 2018; WEF, 2022a), we suggest five reasons why businesses and corporations should care about the long-term stability and functioning of the ES.

1. Resource dependence, risk mitigation, and enhancing resilience

Businesses rely heavily on the utilization of natural resources from the biosphere, including raw materials, water, and biodiversity. It is therefore imperative that resources are used responsibly, resource depletion is minimized, and long-term resiliency in supply chains is promoted. Sustainable business practices contribute to enhanced resource efficiency and reduced environmental impact. Initiatives of this kind offer opportunities to better support businesses in navigating environmental, social, and regulatory risks. Clearly, climate change, resource scarcity, and social inequalities pose substantial physical and financial risks to business operations both locally and globally. Embracing an approach to reduce ES impacts is an effective risk mitigation strategy, increasing business resilience in the face of these challenges.

2. Consumer preferences, brand reputation and market competitiveness

Recognizing the diversity within income groups, social statuses, and countries, consumer awareness and preferences, especially among Gen Y, Gen Z, and Gen Alpha, are shifting towards environmentally conscious choices with growing numbers of consumers increasingly making purchasing decisions based on a company's values and ethical practices. Nielsen's Global Corporate Sustainability Report, for instance, reveals that 66% of consumers are willing to pay more for sustainable brands. Businesses that align with sustainable practices can capitalize on this trend, enhancing their brand reputation and improving market competitiveness. Indeed, sustainability through driving innovation, efficiency, and cost-savings, can be a source of competitive advantage, with companies that embrace that ethic often outperforming their peers in terms of financial performance.

3. Regulatory compliance, risk management, and future-proofing business operations

Governments and regulatory bodies worldwide are increasingly implementing more robust and stringent environmental regulations. Businesses that proactively adopt sustainable practices not only comply with these regulations but also position themselves to navigate regulatory uncertainties effectively in an evolving legal landscape. Moreover, anticipating and addressing environmental and social issues early on mitigates the risk of regulatory penalties and operational disruptions. As an example, the Global Reporting Initiative guidelines provide a framework for businesses to transparently report their environmental impact, aiding in risk management and regulatory compliance.

4. Stakeholder trust and social responsibility

Building and maintaining trust with stakeholders, including customers, employees, and investors, is vital for long-term success. Demonstrating social and environmental responsibility fosters positive relationships with stakeholders. According to the Edelman Trust Barometer, 81% of consumers believe that companies should take specific actions to address societal issues. By aligning with sustainability, businesses not only meet these expectations but also build trust and loyalty, fostering long-term relationships with stakeholders.

5. Attracting talent, capital, and investment

Sustainable business models are increasingly attractive to a new generation of employees who prioritize purpose-driven work. Seventy-six percent of millennials, according to the Deloitte Millennial Survey, consider a company's social and environmental commitments when deciding where to work. Embracing sustainability provides a progressively important avenue to enhance a company's ability to attract and retain top talent, fostering a positive corporate culture and innovation. A burgeoning number of investors are also factoring in ESG criteria when making investment decisions. Frequently, these investors are deploying a variety of sustainable investing strategies such as impact investing, socially responsible investing, and thematic investing focused on specific sustainability themes (e.g., clean energy, water conservation, and gender equality). Large-scale institutional investors, such as pension funds, sovereign wealth funds, and endowments, are demonstrating a growing interest in sustainable investments, with sustainable businesses more likely to attract capital and garner favorable borrowing conditions. This direction of travel is clearly on the rise, the Global Sustainable Investment Alliance indicated that global sustainable investment assets reached US$35.3 trillion in 2020.

6 | KNOWING BUT NOT DOING: A SUSTAINABLE DEVELOPMENT APPROACH THAT IS FAILING

It should be evident from the preceding discussion that our impact on the ES has created a series of immense sustainability challenges and that it is in our collective interests to resolve those. In essence, our activities so far have led to mixing spheres faster than biological systems can balance them back out or replenish them (Cousins et al., 2022). The deeper purpose behind the creation of the SDGs, the central pillar of the UN's 2030 Agenda, is to achieve a rebalancing of the ES through its more holistic and universalistic approach to leverage large-scale transformational change (UN, 2015). For example, clean water and sanitation, climate action, and life below water and life on land are SDGs focused on balancing the lithosphere, hydrosphere, and atmosphere faster than they are mixed. Distributing access equally to the balanced and replenished resources of the lithosphere, hydrosphere, biosphere, and atmosphere is a core dynamic for the SDGs focused on inequalities, partnerships, strong institutions, and access to education, clean energy, and decent work.

However, progress towards delivering the outcomes of the SDGs continues to be considerably off track. Based on current trajectories, none of the SDGs will be achieved by 2030 (Sachs et al., 2023). Sustainable development goals at particular risk highlighted by the *Sustainable Development Report 2023* include 1, 2, 11, 12, and 14–16 (Sachs et al., 2023). Some of the more recent lack of progress can be attributed to the impacts of the Covid-19 pandemic (Yuan et al., 2023). However, we argue, based on the work of several different scholars (e.g., Fu et al., 2019; Liverman, 2018; Nilsson et al., 2018; Pradhan et al., 2017; Stevens & Kanie, 2016; Struckmann, 2018), that progress is hampered by three more fundamental reasons. First, complex interactions between SDGs mask interdependencies that create inherent trade-offs between goals. Second, there is a great deal of ambiguity about how the SDGs should be operationalized, what their sequence of implementation should be, and how they should be "localized." Third, there is a lack of understanding of how to implement the SDGs within PBs (Rockström et al., 2009) of the ES.

These criticisms argue against the notion that the SDGs are integrated and indivisible and, instead, acknowledge the present reality that their application currently undercuts this framing, with two inevitable consequences: first, the continued deterioration of the ES and, second, a fractured assessment of reality. In the latter case, much like an assessment of a patient's temperature, blood pressure, diet, age, and weight give indications of different subsystems within the human body, they do not indicate how they all fit together into one cohesive whole, pushing the practitioner to pay attention to one or two measures and not what can be seen about the essential whole through the complete set.

7 | FOUNDATIONAL PRINCIPLES: A WAY TO RESOLVE THE SUSTAINABLE DEVELOPMENT FAILURE

We contend that to resolve this predicament requires a foundational set of guiding principles, which would enable everyone (businesses, corporations, etc., included) to work towards all the SDGs and PBs in an aligned way to avoid the decline of the ES and deliver sustainable transformational change. Indeed, these principles could be used to guide any post-2030 iteration of the SDGs, such as those focused on promoting a flourishing oriented agenda (Karthikeya et al., 2022).

By foundational, we mean principles focused on, and rooted in, the level of the ES and its continued systemic functioning. The principles, essentially, create a conditional space within which the SDGs can be implemented in a manner that benefits the ES overall. In other words, they recognize the interdependence between human well-being and the Earth's natural systems. Fundamentally, the principles require that implementing the SDGs, cognizant of PBs, accounts for their impact on the ES and is considered in totality and not in a cherry-picked fashion.

Primarily, the principles are about managing and optimizing, equitably, the availability, access, balancing, and replenishment of the matter-energy foundations of the ES. In our approach, the preconditions necessary for sustaining human development and the ES are considered in terms of the mixing and replenishment of the lithosphere, hydrosphere, atmosphere, and biosphere. By adopting a "guiding principles" position, our approach enables global-to-local scaling.

These can be synthesized into four foundational and integrated guiding principles, two that are concerned with the materiality (configuration and composition) of the ES and two that are focused on how ES materiality intersects with human usage and wellbeing, as such the principles have differing operational scales of significance and SDGs and PBs with which they are most attuned (Table 2). For ES materiality, the two principles are (ESM-P1) mix-balance net rate and (ESM-P2) depletion-replenishment net rate and for human systems the two principles are (HF-P1) access distribution and (HF-P2) volume and consumption growth. Transgressing, or failing to abide by these principles, means in the case of ES that the four spheres are being (1) mixed faster than they can balance and (2) depleted faster than they can replenish. For human factors, the consequences are (1) distributing access unequally between the four spheres and (2) expanding the human population in volume and consumption in ways that push the ES limits.

Our operative framing contains what we call two "accumulations," that is: accessible and inaccessible resources in the four spheres. Human life interacts directly with these two accumulations. The amount of change in the accessible resources available depends on the rate at which they are being generated and replenished by biological processes, less the rate at which they are being accessed. The amount of change in the inaccessible resources, which are spheres already mixed with other spheres (e.g., metals from the lithosphere into the atmosphere or hydrosphere), depends on the rate of mixing less the rate of balancing back into their own spheres or of depleting, as they are transformed and removed from the natural circulation process (e.g., burnt fuel). The ability to access "clean" resources depends on the proportion of the total resources that are accessible versus inaccessible. On this basis, arguably, prosperity is

TABLE 2 Foundational guiding principles

Locus of concern	Principle name	Principle description	Scale of operational significance	Specific SDGs and planetary boundaries[a]
ES materiality	(ESM-P1) mix-balance net rate	Mix the four spheres slower than they balance	Global to local	SDG6, 7, 13–15 PB1–5, 8, 9
	(ESM-P2) depletion-replenishment net rate	Deplete the four spheres slower than they replenish	Global to local	SDG1–3 PB6, 7
Human factors	(HF-P1) access distribution	Distribute access equally to the four spheres	Local to global	SDG4, 5, 7, 8, 10, 16, 17
	(HF-P2) volume and consumption growth	Population growth and consumption level within ES limits	Local to global	SDG8, 9, 11, 12

dependent upon the distribution of equitable access of the shifting population to these accessible resources. This formulation of two accumulations with their associated inflows and outflows allows for the description of the state of the accessible resources available for equitable access, from the very local to the global level. In many ways, these foundational principles are central to the argument advanced in the *Global Resources Outlook 2024* report that "Delivering on the SDGs for all requires decoupling, so that the environmental impacts of resource use fall while the well-being contributions from resource use increase" (UNEP, 2024, p. xiv), which arguably underpins the call for "A transition to a circular and sustainable bioeconomy" (UNEP, 2024, p. 46).

Importantly, this set of four principles provides overarching guidance, how they are applied depends on the context: here, we would argue that relevant and affected stakeholders (e.g., particular businesses and corporations) through deliberative processes, and in line with local conditions, would set and determine specific standards, actions, and forms of monitoring appropriate for each scale. For businesses and corporations, actions such as focusing on circular economy models and practices, enhancing sustainable supply chain management, increasing product life extension and repairability, investing in sustainable technologies and innovation, reducing energy and resource consumption, engaging in community and stakeholder collaboration, advocating for policy changes and industry standards, and setting and reporting on SDGs are some of the potential pathways for meeting these principles (Ellen MacArthur Foundation, 2015; WEF, 2022b).

8 | CONCLUSION

Businesses and corporations *ought* to care deeply about the sustainability of the ES. While many may seek profit enhancing avenues of enterprise, being composed of people they are also to some extent morally imbued entities. Prioritizing sustainability not only provides a route to address global challenges such as climate change and biodiversity loss but also positions businesses as responsible and resilient entities in the eyes of consumers, investors, and regulators. Embracing sustainable practices is not just an ethical choice; it is an imperative for businesses to thrive in a rapidly changing world where environmental stewardship and economic success are inseparable. However, the lack of a viable framework within which to comprehensively integrate SDGs and PBs in a way that can be meaningfully accounted for poses significant challenges for business. We hope that our foundational principles can provide an avenue that starts to address this challenge, but not only for businesses, for other types of organizations, and nation states. In setting forth these guiding principles, our purpose is also to stimulate debate and provide a means with which researchers, policymakers, and practitioners working in different sectors and at different scales can come together to think about how to best optimize the operationalization and implementation of global sustainability policy in a way that does work to secure the foundations of the ES, upon which a prosperous and flourishing sustainable future rests. We hope that this approach can also inspire other questions, such as how do we design an economic system that abides by HF-P1 and HF-P2 and does so within the context of also meeting ESM-P1 and ESM-P2, to deliver ecologically and socially sustainable societies.

"Grant us the wisdom to survive—like trees that live long, enriching the planet; loyal protectors of the realm, standing firm, asking nothing in return of heaven or earth" (Taken from *Imagine* by Shanta Acharya, in Greening the Earth, 2023).

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ENDNOTE

[1] According to the American Geosciences Institute, rare earth elements (REE) are "a set of seventeen metallic elements. These include the fifteen lanthanides on the periodic table plus scandium and yttrium."

REFERENCES

Albert, J. S., Carnaval, A. C., Flantua, S. G. A., Lohmann, L. G., Ribas, C. C., Riff, D., Carrillo, J. D., Fan, Y., Figueiredo, J. J. P., Guayasamin, J. M., Hoorn, C., de Melo, G. H., Nascimento, N., Quesada, C. A., Ulloa, C., Val, P., Arieira, J., Encalada, A. C., & Nobre, C. A. (2023). Human impacts outpace natural processes in the Amazon. *Science*, *379*, eabo5003. https://doi.org/10.1126/science.abo5003

Amundson, R., Berhe, A. A., Hopmans, J. W., Olson, C., Sztein, A. E., & Sparks, D. L. (2015). Soil and human security in the 21st century. *Science*, *348*(6235), 1261071.

Armitage, T. W. K., Manucharyan, G. E., Petty, A. A., Kwok, R., & Thompson, A. F. (2020). Enhanced eddy activity in the Beaufort Gyre in response to sea ice loss. *Nature Communications*, *11*, 761. https://doi.org/10.1038/s41467-020-14449-z

Bar-On, Y. M., Phillips, R., & Milo, R. (2018). The biomass distribution on Earth. *Proceedings of the National Academy of Sciences (USA)*, *115*(25), 6506–6511. https://doi.org/10.1073/pnas.1711842115

BCG. (2019). *Total societal impact: A new lens for strategy*. Boston Consulting Group. https://www.bcg.com/publications/2019/total-societal-impact-new-lens-strategy.aspx

Bonan, G. B. (2008). Forests and climate change: Forcings, feedbacks, and the climate benefits of forests. *Science*, *320*(5882), 1444–1449.

Box, J. E., Hubbard, A., Bahr, D. B., Colgan, W. T., Fettweis, X., Mankoff, K. D., Wehrlé, A., Noël, B., van den Broeke, M. R., Wouters, B., Bjørk, A. A., & Fausto, R. S. (2022). Greenland ice sheet climate disequilibrium and committed sea-level rise. *Nature Climate Change*, *12*, 808–813. https://doi.org/10.1038/s41558-022-01441-2

Burton, M. R., Sawyer, G. M., & Granieri, D. (2013). Deep carbon emissions from volcanoes. *Reviews of Geophysics*, *51*(3), 125–160.

Carroll, A. B. (1998). The four faces of corporate citizenship. *Business and Society Review.*, *100-101*(1), 1–7. https://doi.org/10.1111/0045-3609.00008

Ceres and Sustainalytics. (2014). Gaining ground: Corporate progress on the Ceres Roadmap for sustainability. Ceres. Available online at: https://www.ceres.org/sites/default/files/reports/2017-03/Ceres_GainingGround_FullReport_112316.pdf (accessed 15.11.2023)

Christmann, P., Ayuk, E. T., Pedro, A. M. A., & Kumar, V. S. (2022). Current global patterns of consumption of non-energyminerals and metals: trends and challenges of life in a material world. In N. Yakovleva & E. Nickless (Eds.), *Routledge handbook of the extractive industries and sustainable development* (pp. 61–82). Earthscan, from Routledge. Routledge, Taylor & Francis Group.

Cornell, S. E. (2012). *Understanding the earth system: Global change science for application*. Cambridge University Press.

Cousins, I. T., Johansson, J. H., Salter, M. E., Sha, B., & Scheringer, M. (2022). Outside the safe operating space of a new planetary boundary for per- and polyfluoroalkyl substances (PFAS). *Environmental Science & Technology*, *56*(16), 11172–11179. https://doi.org/10.1021/acs.est.2c02765

Davis, R. A., & Fitzgerald, D. M. (2004). *Beaches and coasts*. Blackwell Publishing.

Deloitte. (2019). Deloitte millennial survey 2019. Deloitte LLP, London, UK. Available online at: https://www2.deloitte.com/global/en/pages/about-deloitte/articles/millennialsurvey.html (accessed 15.11.2023)

Edelman. (2021). Edelman Trust Barometer 2021. Retrieved from https://www.edelman.com/trust

Elhacham, E., Ben-Uri, L., Grozovski, J., Bar-On, Y. M., & Milo, R. (2020). Global human-made mass exceeds all living biomass. *Nature*, *588*, 442–444. https://doi.org/10.1038/s41586-020-3010-5

Ellen MacArthur Foundation. (2015). Towards a circular economy: Business rationale for an accelerated transition. Ellen MacArthur Foundation. Available online at: https://www.ellenmacarthurfoundation.org/towards-a-circular-economy-business-rationale-for-an-accelerated-transition (accessed 15.11.2023)

Figuerola, B., Hancock, A. M., Bax, N., Cummings, V. J., Downey, R., Griffiths, H. J., Smith, J., & Stark, J. S. (2021). A review and meta-analysis of potential impacts of ocean acidification on marine calcifiers from the Southern Ocean. *Frontiers in Marine Science*, *8*, 584445. https://doi.org/10.3389/fmars.2021.584445

Fowler, D., Brimblecombe, P., Burrows, J., Heal, M. R., Grennfelt, P., Stevenson, D. S., Jowett, A., Nemitz, E., Coyle, M., Liu, X., Chang, Y., Fuller, G. W., Sutton, M. A., Klimont, Z., Unsworth, M. H., & Vieno, M. (2020). A chronology of global air quality. *Philosophical Transactions of the Royal Society A*, *378*, 20190314. https://doi.org/10.1098/rsta.2019.0314

Fu, B., Wang, S., Zhang, J., Hou, Z., & Li, J. (2019). Unravelling the complexity in achieving the 17 sustainable development goals. *National Science Review*, *6*(3), 386–389. https://doi.org/10.1093/nsr/nwz038

GRI. (2021). GRI standards. Global Reporting Initiative. Available online at: https://www.globalreporting.org/how-to-use-the-gri-standards/gri-standards-english-language/ (accessed 15.11.2023)

GSIA. (2021). Global sustainable investment review 2020. Global Sustainable Investment Alliance. Available online at http://www.gsi-alliance.org/wp-content/uploads/2021/06/GSIR_Review2020F.pdf (accessed 15.11.2023)

Guimaraes-Costa, N., Farias, G., Wasieleski, D., & Annett, A. (2021). Seven principles for seven generations: Moral boundaries for transformational change. *Humanistic Management Journal*, *6*(3), 313–328. https://doi.org/10.1007/s41463-021-00116-y

Hartmann, D. L. (1994). *Global physical climatology*. Academic Press.

He, F., & Clark, P. U. (2022). Freshwater forcing of the Atlantic meridional overturning circulation revisited. *Nature Climate Change*, *12*, 449–454. https://doi.org/10.1038/s41558-022-01328-2

HEI. (2020). *The state of global air 2020: A special report on global exposure to air pollution and its health impacts*. Health Effects Institute.

IPBES. (2019). In S. Díaz, J. Settele, E. S. Brondízio, H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, et al. (Eds.), *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the intergovernmental science-policy platform on biodiversity and ecosystem services* (p. 56). IPBES secretariat.

IPCC. (2018). Summary for policymakers. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, & T. Waterfield (Eds.), *Global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (pp. 3–24). Cambridge University Press.

IPCC. (2022). Summary for policymakers. In P. R. Shukla, J. Skea, R. Slade, A. al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, & J. Malley (Eds.), *Climate change 2022: Mitigation of climate change. Contribution of working group III to the sixth assessment report of the intergovernmental panel on climate change*. Cambridge University Press.

IRP. (2019). Global resources outlook 2019: Natural resources for the future we want. A Report of the International Resource Panel. United Nations Environment Programme, Nairobi, Kenya.

Jewett, E. B., Osborne, E. B., Arzayus, K. M., Osgood, K., & DeAngelo, B. J. (2020). In J. M. Mintz (Ed.), *Ocean, coastal, and great Lakes acidification research plan: 2020–2029*. NOAA. https://oceanacidification.noaa.gov/ResearchPlan2020

Karthikeya, R., Antonacopoulou, E., Keating, B., Mountbatten-O'Malley, E., Nevin, A., Neill, E., Ritchie-Dunham, J., & Lee, M. (2022). *The global flourishing goals: An invitation*. The Harvard Human Flourishing Program.

Kinnaird, J. A., & Nickless, E. (2022). Global trends in mineral resources consumption and production: An overview. In N. Yakovleva & E. Nickless (Eds.), *Routledge handbook of the extractive industries and sustainable development* (pp. 5–12). Earthscan, from Routledge. Routledge, Taylor & Francis Group.

Krausmann, F., Schandl, H., Eisenmenger, N., Giljum, S., & Jackson, T. (2017). Material flow accounting: Measuring global material use for sustainable development. *Annual Review of Environment and Resources*, *42*, 647–675. https://doi.org/10.1146/annurev-environ-102016-060726

Lapola, D. M., Pinho, P., Barlow, J., Aragão, L. E. O. C., Berenguer, E., Carmenta, R., Liddy, H. M., Seixas, H., Silva, C. V. J., Silva-Junior, C. H. L., Alencar, A. A. C., Anderson, L. O., Armenteras, D., Brovkin, V., Calders, K., Chambers, J., Chini, L., Costa, M. H., Faria, B. L., … Walker, W. S. (2023). The drivers and impacts of Amazon forest degradation. *Science*, *379*, eabp8622. https://doi.org/10.1126/science.abp8622

Le Treut, H., Somerville, R., Cubasch, U., Ding, Y., Mauritzen, C., Mokssit, A., [...] & Zhou, X. (2007). Historical overview of climate change. In *Climate change 2007: The physical science basis. Contribution of working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Linse, K., Peeken, I., & Tandberg, A. H. S. (2021). Editorial: Effects of ice loss on marine biodiversity. *Frontiers in Marine Science*, *8*, 793020. https://doi.org/10.3389/fmars.2021.793020

Liverman, D. (2018). Geographic perspectives on development goals: Constructive engagements and critical perspectives on the MDGs and the SDGs. *Dialogues in Human Geography*, *8*(2), 168–185. https://doi.org/10.1177/2043820618780787

Martin, R. (2016). *Earth's evolving systems: The history of planet earth* (2nd ed.). Jones & Bartlett.

Maus, V., Giljum, S., Gutschlhofer, J., da Silva, D. M., Probst, M., Gass, S. L. B., Luckeneder, S., Lieber, M., & McCallum, I. (2020). A global-scale data set of mining areas. *Scientific Data*, *7*, 289. https://doi.org/10.1038/s41597-020-00624-w

McKinsey & Company. (2020). How Gen Z is approaching consumerism. Podcast, retrieved: https://www.mckinsey.com/industries/retail/our-insights/how-gen-z-and-millennials-are-shaping-the-future-of-us-retail?cid=other-eml-shl-mip-mck&hlkid=c0e628ccaa3346eaa0f18f9a36d8a7fb&hctky=andrew_cha@mckinsey.com_PROOF&hdpid=bca1a8ee-b7ba-4ca0-9168-4e3c877d3812

Milliman, J. D., & Farnsworth, K. L. (2013). *River discharge to the coastal ocean: A global synthesis*. Cambridge University Press.

Mitsch, W. J., & Gosselink, J. G. (2015). *Wetlands*. John Wiley & Sons.

Mollica, N. R., Guo, W., Cohen, A. L., & Solow, A. R. (2018). Ocean acidification affects coral growth by reducing skeletal density. *Proceedings of the National Academy of Sciences (USA)*, *115*(8), 1754–1759. https://doi.org/10.1073/pnas.1712806115

Mudd, G. M. (2022). Future mineral demand: Climate change and materials for the energy transition. In N. Yakovleva & E. Nickless (Eds.), *Routledge handbook of the extractive industries and sustainable development* (pp. 83–100). Earthscan, from Routledge. Routledge, Taylor & Francis Group.

NASA. (2021). Earth's energy budget. The National Aeronautics and Space Administration. https://earthobservatory.nasa.gov/features/EnergyBalance

Nayar, J. (2020). Not so "green" technology: The complicated legacy of rare earth mining. *Harvard International Review*. Available online at: https://hir.harvard.edu/not-so-green-technology-the-complicated-legacy-of-rare-earth-mining/ (accessed 20.01.2023)

NielsenIQ. (2015). The sustainability imperative: New insights on consumer expectations. Available online at: https://www.nielsen.com/us/en/insights/report/2015/the-sustainability-imperative/ (accessed 15.11.2023)

Nilsson, M., Chisholm, E., Griggs, D., Howden-Chapman, P., McCollum, D., Messerli, P., Neumann, B., Stevance, A. S., Visbeck, M., & Stafford-Smith, M. (2018). Mapping interactions between the sustainable development goals: Lessons learned and ways forward. *Sustainability Science*, *13*, 1489–1503. https://doi.org/10.1007/s11625-018-0604-z

Pradhan, P., Costa, L., Rybski, D., Lucht, W., & Kropp, J. P. (2017). A systematic study of sustainable development goal (SDG) interactions. *Earth's Future*, *5*, 1169–1179. https://doi.org/10.1002/2017EF000632

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., & Feulner, G. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, *9*(37), eadh245. https://doi.org/10.1126/sciadv.adh2458

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, S. F. III, Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., … Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*, 472–475. https://doi.org/10.1038/461472a

Sachs, J. D., Lafortune, G., Fuller, G., & Drumm, E. (2023). Implementing the SDG stimulus. Sustainable Development Report 2023. Paris: SDSN, Dublin: Dublin University Press.

Sakellariadou, F., Gonzalez, F. J., Hein, J. R., Rincón-Tomás, B., Arvanitidis, N., & Kuhn, T. (2022). Seabed mining and blue growth: Exploring the potential of marine mineral deposits as a sustainable source of rare earth elements (MaREEs) (IUPAC technical report). *Pure and Applied Chemistry*, *94*(3), 329–351. https://doi.org/10.1515/pac-2021-0325

Satchidanandan, K., & Chawla, N. (Eds.). (2023). *Greening the earth: A global anthology of poetry*. Penguin Random House India.

Schwartz, M. S., & Carroll, A. B. (2008). Integrating and unifying competing and complementary frameworks: The search for a common core in the business and society field. *Business & Society*, *47*(2), 148–186. https://doi.org/10.1177/0007650306297942

Shaddick, G., Thomas, M. L., Mudu, P., Ruggeri, G., & Gumy, S. (2020). Half the world's population are exposed to increasing air pollution. *NPJ Climate and Atmospheric Science*, *3*, 23. https://doi.org/10.1038/s41612-020-0124-2

Slater, T., Lawrence, I. R., Otosaka, I. N., Shepherd, A., Gourmelen, N., Jakob, L., Tepes, P., Gilbert, L., & Nienow, P. (2021). Review article: Earth's ice imbalance. *The Cryosphere*, *15*, 233–246. https://doi.org/10.5194/tc-15-233-2021

Sonter, L. J., Dade, M. C., Watson, J. E. M., & Valenta, R. A. (2020). Renewable energy production will exacerbate mining threats to biodiversity. *Nature Communications*, *11*, 4174. https://doi.org/10.1038/s41467-020-17928-5

Spooner, P. T., Thornalley, D. J. R., Oppo, D. W., Fox, A. D., Radionovskaya, S., Rose, N. L., Mallett, R., Cooper, E., & Roberts, J. M. (2020). Exceptional 20th century ocean circulation in the Northeast Atlantic. *Geophysical Research Letters*, *47*, e2020GL087577. https://doi.org/10.1029/2020GL087577

Stevens, C., & Kanie, N. (2016). The transformative potential of the sustainable development goals (SDGs). *International Environmental Agreements*, *16*, 393–396. https://doi.org/10.1007/s10784-016-9324-y

Struckmann, C. (2018). A postcolonial feminist critique of the 2030 agenda for sustainable development: A South African application. *Agenda*, *32*(1), 12–24. https://doi.org/10.1080/10130950.2018.1433362

Talan, D., & Huang, Q. (2022). A review of environmental aspect of rare earth element extraction processes and solution purification techniques. *Minerals Engineering*, *179*, 107430. https://doi.org/10.1016/j.mineng.2022.107430

Turcotte, D. L. (1999). *Fractals and chaos in geology and geophysics*. Cambridge University Press.

UN. (2015). *Transforming our world: The 2030 agenda for sustainable development A/RES/70/1*. United Nations.

UNEP. (2024). Global resources outlook 2024: Bend the trend—Pathways to a liveable planet as resource use spikes. International Resource Panel. United Nations Environment Programme, Nairobi. https://wedocs.unep.org/20.500.11822/44901

UNGC. (2020). SDG ambition—Scaling business impact for the decade of action. United Nations Global Compact. https://unglobalcompact.org/library/5732

United Nations. (2022). *The United Nations world water development report 2022—Groundwater: Making the invisible visible*. UNESCO.

VanderWeele, T. J. (2017). On the promotion of human flourishing. *Proceedings of the National Academy of Science*, *114*(31), 8148–8156. https://doi.org/10.1073/pnas.1702996114

Viaroli, S., Lancia, M., & Re, V. (2022). Microplastics contamination of groundwater: Current evidence and future perspectives. A review. *Science of the Total Environment*, *824*, 153851. https://doi.org/10.1016/j.scitotenv.2022.153851

Vohra, K., Vodonos, A., Schwartz, J., Marais, E. A., Sulprizio, M. P., & Mickley, L. J. (2021). Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem. *Environmental Research*, *195*, 110754. https://doi.org/10.1016/j.envres.2021.110754

Waddock, S. (2020). Achieving sustainability requires systemic business transformation. *Global Sustainability*, *3*(e12), 1–12. https://doi.org/10.1017/sus.2020.9

WBCSD. (2018). Vision 2050: Time to transform. World Business Council for Sustainable Development. Available online at: https://www.wbcsd.org/Vision2050 (accessed 15.11.2023)

WBCSD. (2022). Embedding ESG and sustainability considerations into the Three Lines Model. World Business Council for Sustainable Development. https://www.wbcsd.org/6qs34

WEF. (2022a). Global risks report 2022. World Economic Forum. Available online at: https://www.weforum.org/reports/global-risks-report-2022 (accessed 15.11.2023)

WEF. (2022b). Supply chain sustainability policies: State of play. World Economic Forum. Available online at: https://www3.weforum.org/docs/WEF_Supply_Chain_Sustainability_Policies_2022.pdf (accessed 15.11.2023)

Williams, M., Zalasiewicz, J., Waters, C. N., Edgeworth, M., Bennett, C., Barnosky, A. D., Ellis, E. C., Ellis, M. A., Cearreta, A., Haff, P. K., Ivar do Sul, J. A., Leinfelder, R., McNeill, J. R., Odada, E., Oreskes, N., Revkin, A., Richter, D. B., Steffen, W., Summerhayes, C., … Zhisheng, A. (2016). The Anthropocene: A conspicuous stratigraphical signal of anthropogenic changes in production and consumption across the biosphere. *Earth's Future*, *4*, 34–53. https://doi.org/10.1002/2015EF000339

Winkler, K., Fuchs, R., Rounsevell, M., & Herold, M. (2021). Global land use changes are four times greater than previously estimated. *Nature Communications*, *12*, 2501. https://doi.org/10.1038/s41467-021-22702-2

WMO. (2022). The state of greenhouse gases in the atmosphere based on global observations through 2021. *Greenhouse Gas Bulletin*, No.18. World Meteorological Organization.

WWF. (2022). In R. E. A. Almond, M. Grooten, D. Juffe Bignoli, & T. Petersen (Eds.), *Living planet report 2022—Building a nature positive society*. WWF.

Yakovleva, N., & Nickless, E. (Eds.). (2022). *Routledge handbook of the extractive industries and sustainable development*. Earthscan from Routledge. Taylor & Francis Group.

Yin, J., & Zhao, M. (2021). Influence of the Atlantic meridional overturning circulation on the U.S. extreme cold weather. *Communications Earth & Environment*, *2*, 218. https://doi.org/10.1038/s43247-021-00290-9

Yuan, H., Wang, X., Gao, L., Liu, B., Fang, D., & Gao, Y. (2023). Progress towards the sustainable development goals has been slowed by indirect effects of the COVID-19 pandemic. *Communications Earth & Environment*, *4*, 184. https://doi.org/10.1038/s43247-023-00846-x

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