Review

Ecological Civilizations—A Development Narrative for the Global South?

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ABSTRACT: We explore possibilities for the ecological civilization imaginary of China to become a sustainable development narrative shared by a growing number of GS nations. We first highlight the influence GS countries had on the evolution of the concept of sustainable development. GS nations' interest in retaining economic development options, including energy and materials needed for industrialization and economic expansion, will increasingly contradict global environmentalist narratives of the latter half of the 20th century. The adaptation of GS nations to previously untested energy and material futures will depend on experimentation and learning from initiatives primarily designed and implemented by GS governments at the national, provincial, and local levels. If China succeeds in demonstrating practical examples of ecological civilization construction, it will stimulate other GS countries to learn and adapt lessons to suit their own needs. Multi-country arrangements that China has created could serve as forums to refine the ecological civilization narrative as a development alternative to the dualist conservation vs development thinking and practice of the latter half of the 20th century.

Keywords: Ecological; Civilization; Global south; Energy; Adaptation

1. Introduction

Civilization is a relationship between humans and the natural environment, "recrafted by the civilizing impulse to meet human demands" [1]. The outcomes of that impulse vary depending on the era, scope, reach and intensity of human actions and their impacts on the environment. The slow rise of CO_2 from 8000 years ago, when humans started cutting and burning forests for agriculture, and that of CH_4, 5000 years ago, as people began rice farming and tending livestock in unprecedented numbers, might have prevented an ice-age (Ruddimann [2,3]). After nearly two centuries of fossil-fuel-driven progress, the international community reached an agreement on 12 December 2023, at the 28th Conference of Parties (COP) of the UN Framework Convention on Climate Change (UNFCCC) in Dubai. They committed to pursuing a "swift, just, and equitable transition, underpinned by deep emissions cuts and scaled-up finance" (https://aa.icnn.cn/gjxYh8). The deep emission cuts target CO_2, CH_4 and other greenhouse gases (GHGs).

Civilizational narratives are on the rise in international relations research [4]. They are mostly articulated on ethnic, religious, cultural and/or linguistic continuities that nations trace to historical and, at times, mythical pasts. Constructing an ecological civilization, a strategy adopted by the Government of China in 2012, could provide a much-needed future orientation to civilizational discourses. Civilization is a system manufactured by humans [5]. Manufacturing an ecological civilization calls for reimagining perspectives on the relationship between humanity and nature [6], including rethinking the meaning of "ecological" in development.

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In industrial, agricultural, urban, and other human constructed systems, ecological considerations have mainly been linked to the environmental impacts of such systems. However, energy flows and material cycles are defining features of all ecosystems, including those constructed by humans. To ensure "access to affordable, reliable, sustainable and modern energy" (SDG 7: see Sustainable Development Goals—CDP), a new perspective on "ecological" in civilizational construction is needed. Viewing ecological engineering as "a flexible, iterative process of design, in which the designer must continually update goals, essences, typologies and process of realization" [7] could be a starting point. A civilizational narrative that aims to meet energy and material needs of billions people in the Global South (GS) would take a different direction. It contrasts with the global environmentalists' perspective from the latter half of the 20th century, which viewed "ecological" factors mainly as constraints to development. Shellenberger and Nordhaus [8] have challenged environmentalists' resistance to broaden the "environment" to include humans and economic development.

Gare [9] claims that the term "ecological civilization" may have been first coined in 1984 in the then Soviet Union and explored the philosophical foundations of the phrase [10]. Worster [11] interpreted ecological civilization as an "imaginary," vision of "scientific and technological progress" that seeks the "common good." Hansen et al. [12] perceived ecological civilization as a socio-technical imaginary that aims to integrate cultural and moral virtues into technological, judicial, and political goals. They view it as a step in China's efforts to project the specificity of its sustainable development thinking and practice. Globally, sustainable development discourses emphasize economic, environmental, and social pillars. Economy is only one of the five pillars in China's strategy to construct an ecological civilization; the other 4 are ecological, social, cultural, and political [13]. The inclusion of politics and culture as part of a five-in-one approach to building an ecological civilization introduces greater complexity [14].

In this paper, we first reflect on the under-appreciated influence that developing countries that increasingly identify with the GS collectivity have had on the evolution of the concept of sustainable development. Then, we explore changes needed in thinking and practice related to the two pillars of global environmental ideology: pollution and conservation [15] in building ecological civilizations. On pollution, we limit ourselves to greenhouse gas (GHG) emissions, which are, according to UNFCCC, "the most dangerous anthropogenic interference with the climate system". On conservation, we focus on protected areas and biodiversity. Climate change and biodiversity loss are the two among nine planetary boundaries that scientists believe have already been transgressed [16].

We continue with a discussion to highlight some characteristics of an ecological civilization that need to move away from conservation vs development or pollution vs land/resource use dualisms that have been part of global environmentalist narratives of the latter half of the 20th century. In that discussion, we refer to China's experience in delivering the world's fastest and sustainable economic expansion in recent times [17] and how that experience could inform its efforts to build an ecological civilization. We comment on how China, through multi-country arrangements, such as the New Development Bank (NDB) and the Belt and Road Initiative (BRI), it has advanced, and its ongoing support to delivering UN SDGs could encourage other GS nations to launch country-specific experiments to build ecological civilizations [14]. Finally, we describe our intentions for envisioning a plurality of ecological civilizations instead of a singular ecological civilization.

2. Evolution of the Concept of Sustainable Development

Maurice Strong, a Canadian oil and minerals businessman who became the first Executive Head of the United Nations Environment Program and the Secretary of the Stockholm Conference on the Human Environment in 1972, acknowledged that "it was the less developed countries (LDCs) that forced a clear relationship between environment and development" [17]. Ducret and Scolan [18] noted that the adoption of the 17 sustainable development goals (SDGs) in September 2015, three months prior to the adoption of the Paris Climate Agreement in December 2015, was mainly "sparked" by the interests of developing countries. The Paris Climate Agreement was adopted largely because of the acceptance of nationally determined contributions (NDCs) of Member States for overseeing the Agreement's implementation, a position advocated predominantly by GS countries.

In 2014, a MY WORLD, UN survey of 7 million voices on themes that later came to define most of the 17 SDGs, ranked good education, better health care and better job opportunities on top of the list. Climate change ranked last; however, its ranking was higher in regions like Oceania, where the impacts of droughts and wildfires, attributed to global warming, were directly felt by people (https://aa.icnn.cn/PPNTUt). Climate change, promoted in place of "global warming" as part of the US Republican Party's "environmental communications battle" [19] was thought to be a less alarming phrase. However, respondents to the survey may have ranked global warming higher than climate change, as it better reflects the trend of a changing climate that many in both the Global South (GS) and Global North (GN) experience and acknowledge.

The evolving agendas of the Earth Summits, from environment and development in 1992 (Rio de Janeiro, Brazil) through sustainable development in 2002 (Johannesburg, South Africa) to institutional arrangements and the green economy in 2012 (Rio de Janeiro, Brazil), reflected the interests of GS countries to shift the narrow focus of sustainable development on the environment to a broader agenda inclusive of economic growth. Ducret and Scolan [18] cite the OECD, which noted that green growth is "…not about environmental preservation. It is a no-regrets approach to securing natural resources needed to make development sustainable in the long run". OECD, a grouping of predominantly GN nations, includes Chile, Colombia and Mexico that would identify with the GS. Buseth [20] sees emerging differences in perspectives on developing green economies as a marker distinguishing GS from GN.

Scholarly dissatisfaction with and critique of the shift of sustainable development thinking from an environmental focus to a broader agenda inclusive of economic growth continue to be expressed. Tulloch [21] found this shift in the meaning and interpretation of sustainable development from its early environmental perspective towards mainstream economic development to be an undesirable one. Hickel [22] claimed that the set of environmentally favored SDGs (6, 12, 13, 14, 15) and others promoting continuing economic growth (SDG 8) contradicted one another. Hickel [19] and, for example, Sandberg et al. [23] considered degrowth a necessary condition for sustainable development. However, the importance of the economic pillar emerges even in conservation initiatives. In a recent study that analyzed a mix of 17 environmental, economic, and social, ecological civilization targets of restoration technologies in China, economic targets ranked higher than that of social and environmental ones [24].

A study of Voluntary National Reviews of 19 countries (at least 14 of them from the GS) revealed that many prioritized SDGs 1 and 8 on poverty eradication and economic growth, respectively. The authors counseled against such selectivity at the national level and urged international development organizations to counter unfavorable and selective goal prioritization [25]. Wang et al. [26] analyzed spatial variability in delivering SDGs in China and found that China's Green Development Index and Provincial GDP per Capita were positively correlated with the country's SDG index. They recommended prioritizing economic development in the western provinces and trade-offs between economic development and environmental protection in the eastern provinces. Horn and Grugel [27] observed that SDGs serve rather than help to set development agendas of local governments.

Redclift [28], tracing the maturing of the concept of sustainable development from its origins in the 1980s to the early years of this new millennium, called for linking the concept's future to "new material realities, the product of our science and technology and associated shifts in consciousness". In our view, the decreasing reliance on fossil fuels as the primary energy source for sustainable development futures is a material reality that humanity must adapt to. Sophisticated modelling and scenario building capabilities resulting from advances in science and technology have strengthened GN's environmental advocates to promote planetary visions that fail to integrate the development aspirations of billions of people in the GS. The shifts in consciousness must include reimagining the meaning of "ecological" in sustainable development and civilizational construction.

3. Greenhouse Gas (GHG) Emissions

Yearly average temperatures were below the average for the 1880–2022 period until the early 1940s, when they began, intermittently, to inch above the long-term average. From the 1980s, yearly average temperatures have always been above the 1880–2022 global average (https://aa.icnn.cn/SzNkQA). The early 1980s, marking the beginning of the uninterrupted rise in yearly temperatures above the long-term average, coincided with China opening its economy to accelerated growth. China industrialized and advanced economically to become the world's -largest economy within about 25% of the time taken by early industrializers of the 18th and 19th centuries. In 2003, China consumed half of the world's cement, a third of steel, a quarter of copper and one-fifth of aluminum to reach a 2004 per capita income of US$ 4700 [29].

A replication of China's pace of development is an aspiration of nearly all developing and emerging economies, such as the more than 50 countries in Africa, and India. The implications of such development aspiration of at least 3 billion people repeating China's post-1980s performance in industrialization and economic growth could have triggered GN interest groups to raise climate change to the top of the global environmental agenda. Gupta [30] cited a study that showed that without the influence of environmental NGOs, the UNFCCC would not have been adopted.

Setting the reduction in global average temperatures to a pre-industrial baseline, and not the early 1980s when the irreversible rise of yearly temperatures above the long-term global average began, could be read as an unintended yet unfortunate intention to slow or halt industrialization in GS countries. In the GN this may have been driven by a genuine concern, based on scientifically modeled planetary scenarios for the new millennium, to avoid additional tipping points, like that reached in the early 1980s, but above today's higher yearly average baseline temperatures.

However, pollution during the rise of industrial civilization in today's GN countries did not attract immediate mitigation measures. Recalling the work of Svante Arrhenius (1859–1927) and his first calculations on doubling of global temperatures from pre-industrial levels of atmospheric CO_2, Smil [31] noted the "virtual absence" of "global warming" in Google's Ngram Viewer before the 1980s. Still, that phrase, together with others like "global climate change," returned over a billion items in Google searches by 2020, far exceeding "poverty," "malnutrition," and "economic inequality," which are of greater interest to GS countries.

IPCC was established in 1989; the UNFCCC was adopted in 1992. Both likely contributed to climate change advocacy, overtaking the focus on a broader range of GS countries' development challenges. These challenges are reflected in the 17 Sustainable Development Goals (SDGs) adopted by the UN, three months before the Paris Climate Agreement in 2015.

Global warming, driven by industrial emissions of greenhouse gases (GHGs), was scientifically proven a century ago. However, it gained a new dimension in global environmental policy, fueled by data, technology, and modeling, and supported by an intergovernmental scientific panel and a UN treaty. This shift coincided with a time when a major Global South nation, China, was successfully catching up with the Global North industrially and economically.This could have contributed to deepening the GS countries' apprehensions that global environmentalism, an outcome of the development experience of GN nations, was becoming a tool for limiting development options in the GS.

More recently, fossil fuel producing and exporting nations have been leaning towards the GS collectivity. Iran, Saudi Arabia, and United Arab Emirates joined the New Development Bank (NDB) in 2023, originally established by the BRICS-5 (Brazil, Russia, India, China, and South Africa). Fossil fuel use is embedded in the production of many critical materials of today's civilization; for example, 4 billion people worldwide would not be alive without synthetic ammonia, and half of the world's population could not be sustained without synthetic nitrogenous fertilizers [31]. Since the 1950s, China invested heavily in building its fertilizer production capacity to feed a large and growing population.

Chemical nitrogen application during the rice growing season in China expanded significantly between 1950 and 1990, before stabilizing and showing slight reductions in recent years (Figure 1).

Although nitrogen fertilizers have well-known negative impacts, such as the eutrophication of water, increasing food production is a basic need in most nations of the GS. In the pursuit of sustainable development, trade-offs between SDGs that aim at zero hunger (SDG2) and those of several environmentally relevant ones (SDG6, SDG14) are inevitable.

Capturing pollutants at their emission point is an ecologically preferred mitigation strategy. The fossil fuels sector has been using carbon capture technologies for enhanced oil removal (EOR). Carbon capture is becoming an important consideration in controlling CH_4 emissions. However, coal mining activities release the highest levels of methane emissions; at times, those from coal power plants could also be significant [32]. The least polluting of the fossil-fuel trio, natural gas, is nearly 90% methane. Methane, a GHG with a warming potential 25 times that of CO_2, could help speed up the coal substitution rate by natural gas if it could be captured and stored. Capturing GHG pollutants and putting them to use that would favor climate change mitigation and adaptation has increased interest in circular carbon economies [33], which are assigned an important role in constructing ecological civilization [13].

Saudi Arabia, as the Chair of G20, in 2020, raised the profile of the circular carbon economy approach to promote (i) a holistic assessment of various carbon management options and their optimal mix to achieve a carbon balance; (ii) more policy support for carbon capture and storage (CCS) and hydrogen, while continuing the emphasis on renewable energy and energy efficiency; and (iii) conversations to build bridges between fossil fuel importers and exporters for holistic discussions on energy transition [34]. Research on the circular carbon economy has grown since 2016, led by China, Italy, UK, Spain, and the US, with Brazil, India and Malaysia showing increasing interest [35].

Discussions on "more policy support for CCS" have been resisted in the UNFCCC Conference of Parties (COPs). Romanak et al. [36] found that environmental NGOs attending COPs had the strongest negative position on CCS, while scientific and business groups had more favorable ones. PyCCS (Pyrogenic CCS) [37] and BECCS (bioenergy CCS) [38] are linked to biomass availability as source material. Geological CCS, or "returning carbon to nature" [39], was recognized by IPCC in its latest synthesis report [40]: "geological storage capacity could satisfy CO_2 storage requirements to limit global warming to 1.5 °C by 2100 and to isolate CO_2 permanently from the atmosphere if appropriate geological storage sites could be located and effectively managed".

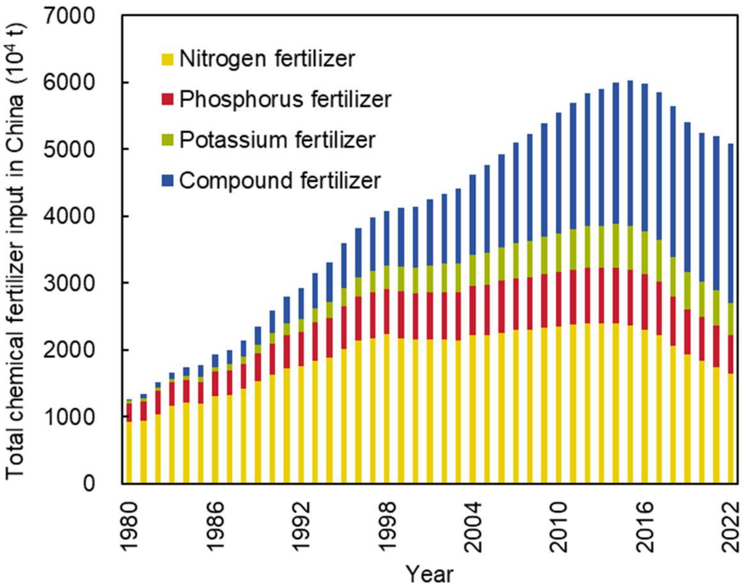

Figure 1. Trends in applications of nitrogen and other fertilizers during the rice growing season in China. Data from: National Bureau of Statistics of China (htts://data.stats.gov.cn/easyquery.htm?cn=C01). See Table S1 for data used in compiling the figure.

4. Protected Areas and Biodiversity

Globally, 6 protected area categories (https://en.wikipedia.org/wiki/IUCN_protected_area_categories) include a mix of land/seascapes, from strict nature reserves to sanctuaries that favor subsistence and non-commercial use of natural resources. At the time of the last UN global survey [41], terrestrial and marine protected areas covered around 17% of the earth's surface. Nearly 50% of the world's protected areas were less than square kilometres. 2% were above 10,000 km^2; of the 10 areas larger than 340,000 km^2, only two, i.e., in Greenland and Saudi Arabia, respectively, were terrestrial; others were in coastal areas and open seas. Future increases in protected area coverage on land will be marginal.

19th century, national parks were originally recreational. The first national park, Yellowstone, was discovered by the Northern Pacific Railroad Company for its potential to serve as America's "popular…..watering place and summer resort" [42]. Cities and towns near western US national parks, or *gateway communities*, attracted nearly 2 million Americans moving away from metropolitan centers towards nature [43]. Tourism dependent gateway communities near national parks in the GS would require transport and business development infrastructure, often discouraged by environmentalists. Access is a necessary condition for entrepreneurial activities. Panta and Tharpa [44] describe tourism's contributions to entrepreneurship and women's empowerment in gateway communities surrounding the Royal Bardia National Park of Nepal. Replicating the gateway community experience from US national parks in GS nations would be limited.

The risks of sole reliance on international tourists to national economies became clear during the COVID pandemic. COVID-19 impacts on international arrivals in Pacific Island nations were significant [45]. In Africa, the reduction in international arrivals led to reduced funding for conservation agencies and increased threats to wildlands and wildlife [46]. Giddy and Rogerson [47] found that many nature-based tourism enterprises faced permanent closure in South Africa without timely government support. If a growing number of environmentally conscious travelers from GN nations opt to forego long-distance flights to lower their carbon footprints, protected areas that rely on international visitors in many GS nations could face challenges. The search for development options for communities around protected areas in the GS must reach beyond the tourism and hospitality sector.

Biosphere reserves (BR), a world network of scientifically designated conservation areas under the UNESCO MAB Program [48], have evolved into land/seascapes for linking conservation and development. The Seville Strategy for BRs [49], adopted 3-years after Agenda 21 for Sustainable Development, stressed the three-zone (core, buffer, and transition) schema and the inclusion of human communities in the design of BRs. The Madrid Action Plan for BRs [50] made the three-zone schema and the presence of human settlements necessary conditions for areas to be nominated as biosphere reserves [51,52].

A significant number of biosphere reserves, nominated and included in the World Network in the 1970s and the 1980s, most of them in GN countries, were withdrawn (Designating new biosphere reserves and review process of existing sites | UNESCO). All countries (https://en.unesco.org/biosphere/wnbr), however, redesigned many sites to satisfy Madrid Action Plan requirements by expanding the area and/or merging two or more previously designated places into a single site. Such enlargement of BRs increased buffer and transition areas where livelihood options for resident communities broadened.

Moving the application of the BR concept from its initial links with conventional protected areas towards ecosystem mosaics harboring communities and varying mix of resource use options for sustainable development took several years [51,53–55]. Resistance to change was partly linked to them being called "reserves." Since 2008, UK decided to call its sites "Biospheres" (https://unesco.org.uk/biospheres/).

Individual BRs in countries of the GS, for example, the whole-island site of Palawan in the Philippines or the biome-specific biospheres of Brazil, are extensive and complex land and seascapes stretching across millions of hectares and several municipal and state/provincial jurisdictions. They have the potential to be managed as areas, referred to in target 3 of the 2030 Kunming-Montreal Global Biodiversity Framework (https://www.cbd.int/gbf/targets/): "well-connected and equitably governed systems of protected areas and other effective area-based conservation measures, recognizing indigenous and traditional territories, where applicable, and integrated into wider landscapes, seascapes and the ocean,….".

In the 10 pilot national park units of China (Table 1) that are part of the country's journey towards an ecological civilization, 8 have 50% or more of their total areas outside the legally protected cores. Nearly all the 10 units include forest reserves that allow some form of timber extraction and other uses normally unwelcome in national parks [56]. Areas outside legally protected zones, integrated into larger land/seascapes, could be targets for encouraging new types of *gateway communities,* including people moving in from urban centers and are willing to experiment with green and sustainable lifestyles linked to renewable energy, sustainable agriculture, forestry, water conservation, waste recycling systems, education, and research etc. They could be locations for the "10,000 Enterprises Energy Efficiency and Low Carbon Program" [13] foreseen in China's strategy to build an ecological civilization. They could be incentivized as low-carbon development zones [57] where people experiment with "green" livelihood and lifestyle options.

Table 1. China's Ten Pilot National Parks and its Constituent Units.

Pilot Unit Name	Number of Constituent Units	Total Area of Legally Protected Zones/km^2	Total Area Outside of Legally Protected Zones/km^2	Comments/Observations
Sanjiangyuan National Park	16	90,570	100,130	The first and largest national park in China, in the cradle of the Yangtze, Yellow and Lancang Rivers.
Giant Panda National Park	40	20,140	6994	Giant panda, a symbol of global wildlife conservation since the 1960, is found in the wild only in China. This National Park aims to conserve 70% of the remaining giant pandas in the wild.
Northeast China Tiger and Leopard National Park	12	7585	6476	The important breeding area where high frequency of northeast tigers and leopards have been observed.
Hainan Tropical Rainforest National Park	9	2331	1938	The largest, most concentrated, and best preserved tropical rain forest area in China.
Wuyishan National Park	7	505.76	495.65	Conservation of the Danxia landform is characteristic of this part of China.
Qilianshan National Park System Pilot Site	5	27,500	22,700	Qilian Mountains is a critical watershed for the Yellow and inland rivers.
Hubei Shennongjia National Park System Pilot Site	4	1089.27	80.73	An isolated green wonder at 31° N where the occurrence of deserts is more common.
Hunan Nanshan National Park System Pilot Site	4	352.72	283.22	It has one of the largest peat moss swamp wetlands and a completely preserved mid subtropical low-altitude evergreen broadleaf forest and represents an area of landscape, forest, field, lake, and grass" life community.
Yunnan Bodaco National Park System Pilot Site	2	321.02	281.09	Includes important areas of the "Three Parallel Rivers" World Heritage area and scenic spot.
Zhejiang Qianjiangyuan National Park System Pilot Site	2	151.33	101.63	It is an ecological barrier and water retention area in East China and is key habitats for the white necked long tailed pheasant and black muntjac, both endemic to China

Compiled by the authors using information from the website of the National Forestry and Grassland Administration, individual websites of some of the parks, master plans of National Parks, National Park bulletin and other sources. See Table S2 for the names of constituent units of each of the pilot sites.

In Wudalianchi Biosphere Reserve in northeast China, about 5000 residents were incentivized to move out of the core zone dedicated to biodiversity conservation into a purpose-built eco-city with necessary development infrastructure [58]. Eco-migration schemes in China have been criticized for their potential for aiding coercive environmentalism [59]. The memory of people being forcefully evicted from areas set aside as national parks during the 19th and early 20th centuries has built an aversion against any movement of people away from biodiversity conservation areas. People in biodiversity conservation zones where development infrastructure such as schools, hospitals, travel, and transport are prohibited would have to be offered alternative development options for themselves and their future generations; those options could include moving into zones outside of legally protected cores.

UNESCO BRs are to provide "site-specific examples of sustainable development" and shape the "international agenda on biodiversity and reach its main target to increase Planet's Protected Areas to 30% by 2030" [60]. Bringing 30% of the earth's surface under mixed conservation/development regimes of the BR model could open opportunities to integrate climate change adaptation and mitigation with conservation and sustainable use of biodiversity. As the host of the 5th World Biosphere Reserve Congress in Hangzhou in 2025, China could promote discussions on how illustrating "site-specific examples of sustainable development" in BRs could be part of building ecological civilizations in GS nations.

5. Discussion

Jax [61] traced the evolution of ecology from scientific natural history to ecosystem research and identified H.T. Odum [62] as one of the pioneers who emphasized the flow of energy and matter in ecosystems. Smil [31] quotes Odum on the central role of energy in civilizational advancement: "all progress is due to special power subsidies, and progress evaporates whenever and wherever they are removed".

Ecosystem language is now used in many development sectors. We now speak of tourism, managerial, research, internet or even energy ecosystems, emphasizing connectivity between people and organizations that constitute the ecosystem and not energy or material needs to sustain ecosystem functioning. Energy and materials have not been included as part of provisional ecosystem services; efforts to define geosystem services—benefits to humans derived from the subsurface—[63] may open the role of energy and materials as provisional services provided by subsurface ecosystems. However, unlike in the case of ecosystem services, addressing energy and materials provision by geosystem services as necessary conditions for sustainable development will be a challenging task for researchers and practitioners, given the long history of viewing those provisions predominantly from the perspective of their environmental impacts.

In constructing ecological civilizations, ensuring adequate energy flows and material recycling for economic growth and societal needs will be necessary conditions for sustainable development. Each nation must derive the mix of energy sources for its sustainable development vision. Accessing and processing minerals and their use in manufacturing key components of renewable energy generators will be energy intensive. Smil [31] observed that producing large, high-purity silicon wafers for solar energy generation is three orders more energy intensive than smelting iron and making steel.

Affordable, reliable, sustainable, and modern energy mixes, called for by SDG7, are unlikely to be fossil-fuel free in GS nations for the foreseeable future. Hence, it is important to explore and experiment with country-specific, or even province, state, and municipality-specific, "carbon management options and their optimal mix to achieve a carbon balance." [34]. Li et al. [64] called for cooperation based on regional variations in the mix of renewable and non-renewable energy sources in China's efforts to reach carbon neutrality by 2060. Industrial development needed to supply energy and material needs of civilizations can no longer be dismissed as "non-ecological"; as Zhang [13] observed: "(B)uilding an ecological civilization does not mean that we must abandon industrial civilization and return to a primitive way of living. Rather, it means building a civilized society with developed production, affluent living standards and sound ecological environment……".

Boycoff et al. [65] argued that the "fundamental premises" influencing discourses on climate stabilization targets were "badly matched to the actual problem of the intergenerational management of climate change, scientifically and politically, and destined to fail". January 2024 marked the first month when global average temperatures breached the Paris Agreement's target of 1.5 °C below pre-industrial baselines (Global temperatures breached critical 1.5 °C warming threshold for first time over 12 month period | Euronews). Nevertheless, as pointed out by the most recent IPCC report [40], options for maintaining the global average temperatures 1.5 °C below pre-industrial temperatures by 2100 may be feasible if geological storage is included in the mix of learning to adapt to low carbon futures. Stephenson [39] identified around 100-point sources of CO_2, mostly power stations that could be clustered together in the Humber area in East

England to bring down the costs of CCS. Sun et al. [66] presented a similar "hubs and cluster" approach for Spain that could be linked to 21% of the country's emissions. Moreaux and Withagen [67] proposed a unified theory that visualizes CCS as an important component of climate change adaptation.

There is no certainty that humanity's attempts to restore the carbon balance will result in a linear reversal of the increase in temperatures observed since the early stages of industrialization. However, experimenting with and learning from all available approaches, including direct carbon removal from the atmosphere, should be seen as part of the effort to improve "intergenerational management of climate change." [65]. Mitigation of emissions is necessary but not a sufficient condition for adapting to low carbon futures. Currently, the global targeting of sectors prioritized for financial support for mitigation and adaptation (Table 2) appears to follow the dualist approach characteristic of global environmentalism.

Such adaptation-mitigation dichotomy has not facilitated national and local level planners' efforts to integrate the two in spatial planning [68,69], particularly in land/seascapes like those recognized as part of UNESCO's global BR network.

Table 2. Sectors receiving climate financing for mitigation and adaptation.

Sector	Mitigation Financing	Adaptation Financing
Renewable Energy	50%	
Energy Efficiency	25%	
Sustainable Transport	20%	
Low-carbon Technologies	4%	
Agriculture, forestry, waste, and wastewater management	1%	
Management of Water		55%
Agriculture, forests and natural resources		13%
Disaster risks		8%
Infrastructure		7%
Support to National Policies		5%
Coastal Protection		4%
Industries and Services		1%

Source: [18]; see page 49 (mitigation) and 52–53 (adaptation).

Heilmann [16] attributes China's economic and industrial success over the last 4-5 decades to the approach of "proceeding from point to surface": a system of learning through decentralized experimentation before national policy formulation and legislation. This approach could be useful in constructing an ecological civilization, particularly for improving acceptance of "green" alternatives at sub-national user levels. For example, Levitan [70] noted that biochar has the potential to increase the productivity of certain types of soils; this could reduce dependence on the use of N_2 and ammonia-based fertilizer applications, which are sources of agricultural N_2O emissions, a GHG with a global warming potential nearly 300 times that of CO_2. However, biochar application in agriculture could increase risks associated with soil erosion and negative impacts on beneficial soil fauna like earthworms (What Are The Disadvantages Of Biochar?—Green Packs). Although China is a leader in biochar research [71], it has not succeeded in overcoming farmer reticence to its adoption as a low-carbon agricultural development alternative. One study in China [72] found that commercial and farm-produced biochar in China is economically non-viable and recommended mixed biochar-inorganic fertilizer applications. The substitution of fertilizers by biochar or other green alternatives would require "point-to-surface" approach, i.e., localized testing and demonstration of farmer-acceptance before its province or nation-wide adoption. Farmer acceptance of research recommendations would be enhanced if research is *in-situ* in farms and accommodates farmer priorities on minimizing loss of revenues and crop productivity. Science and Technology Backyard (STB) models [73] have successfully influenced farmers to adopt research findings to minimize yield-gaps.

Mazzucato [74] stressed the central role of Governments in guiding transformational shifts in development paradigms. The market friendly *Economist* [75] stressed the role of state-run oil giants, the five top ones in Saudi Arabia, Russia, and China, in making or breaking the energy transition. Government subsidies have been important in incentivizing investments in renewable energy, greening electricity generation, and improving energy efficiencies. They would be needed in all GS nations' search for appropriate energy mixes that combine emission reduction and carbon removal options for adapting to low carbon futures.

Petrone [76] suggested that new Global South-initiated groupings, like BRICS, could strengthen their "soft power" by offering alternative frameworks for discussing issues such as global climate change. The New Development Bank (NDB), joined by Egypt, Ethiopia, Iran, Saudia Arabia, and the United Arab Emirates (UAE) in 2023, has nearly 40 countries vying for membership (https://aa.icnn.cn/cWkg9X). NDB could become the forum for "fossil fuel importers and exporters" to conduct "holistic discussions around energy transition" and an "assessment of various carbon management options and their optimal mix to achieve a carbon balance" [34].

Other multi-lateral initiatives, such as the Belt and Road Initiative (BRI), provide opportunities for China to transfer and share its science and technology expertise in constructing ecological civilizations. A recent editorial in *Nature* (https://www.nature.com/articles/d41586-023-03299-6) encouraged the "West" to engage with, instead of withdrawing from, China's BRI's effort to boost science in partner countries. China, India, and other large GS nations must find new ways of imagining "affluent standards of living" [13] in an ecological civilization. They cannot replicate per-capita income of league table leaders like Luxembourg (US$ 142,414) or Singapore ($127,565). "Affluent standards of living," "developed production," and "sound ecological environment" that Zhang [13] noted as important features of an ecological civilization would have to be based on metrics different from those that have been in use to distinguish developed, middle income, developing, least developed countries etc.

Our use of ecological civilizations in the plural in the title of the paper is intentional. The characteristics that define an ecological civilization still need to be worked out through experimentation, practice and learning. These characteristics will come from economic, ecological, social, cultural and political perspectives on sustainable development. Hence, it is unlikely that an ecological civilization of China or India will have the same mix of distinguishing characteristics of an ecological civilization. Allowing for ecological civilizations would facilitate collaboration between China, India, Brazil and Russia, all of which have ambitions to be leaders of GS nations, in experimentation on giving this new idea diverse, real-life expressions.

Discussions aimed at clarifying the understanding and refining the concept of an ecological civilization could also help connect deliberations on three global initiatives—civilization, development, and security—that China has recently started to promote.

6. Conclusions

Civilizational narratives are on the rise in international relations. But they tend to build on historical and mythical pasts. The adoption of a strategy to build an ecological civilization by China in 2012 opens an opportunity to orient civilizational discourses to the interconnected futures of the planet and humanity.

All members of the UN family of nations are committed to enabling the energy transition, a move away from total dependence on fossil fuels as the prime source for industrial and economic development in search of a mix of renewable and non-renewable sources that will minimize GHG emissions and advance learning to adapt to low carbon energy futures. This transition will be more challenging for Global South countries, including large nations such as China, India, and Brazil, which are late entrants to benefiting from fossil fuel-driven industrial and economic development pathways, compared to the advanced industrialized economies of Global North nations.Future energy mixes at municipal, provincial/state and national levels in GS countries will continue to include fossil fuels for the foreseeable future, albeit at decreasing levels.

Ensuring access to affordable, reliable, sustainable, and modern energy, as called for by SDG 7 is an ecologically necessary condition for sustainable development in GS nations. This requires redefining the meaning of "ecological" in the development context. This redefinition must shift away from the global environmentalists' narrative of the latter half of the 20th century, where "ecological" was viewed as a constraint rather than an essential component of sustainable development.

Ecological civilization, as a process of building and adapting to low-carbon energy futures, provides opportunities for Global South countries to create narratives that prioritize the energy and material needs of billions of their residents in sustainable development thinking and practice. This process requires a significant shift in how nations manage the energy and material demands of sustainable development. Such shifts in GS nations will be guided by Government leadership. Forums like the New Development Bank and the Belt and Road Initiative, in whose creation China had played a pioneering role, could bring together producers and consumers of fossil fuels who identify themselves with the GS collectivity to discuss ways in which GS nations could transition towards ecological civilizations. During this transition, integrating ecosystem conservation, the sustainable use of biodiversity, and the mitigation of emissions and adaptation to climate change at the land and seascape levels must be incentivized.

Supplementary Materials

The following supporting information can be found at: https://www.sciepublish.com/article/pii/296, Table S1: Data used in compiling Figure 1; Table S2: Names of constituent units of the 10 pilot national parks listed in Table 1.

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