GREAT TRANSITION INITIATIVE
TOWARD A TRANSFORMATIVE VISION AND PRAXIS

April 2015

Bounding the Planetary Future: Why We Need a Great Transition

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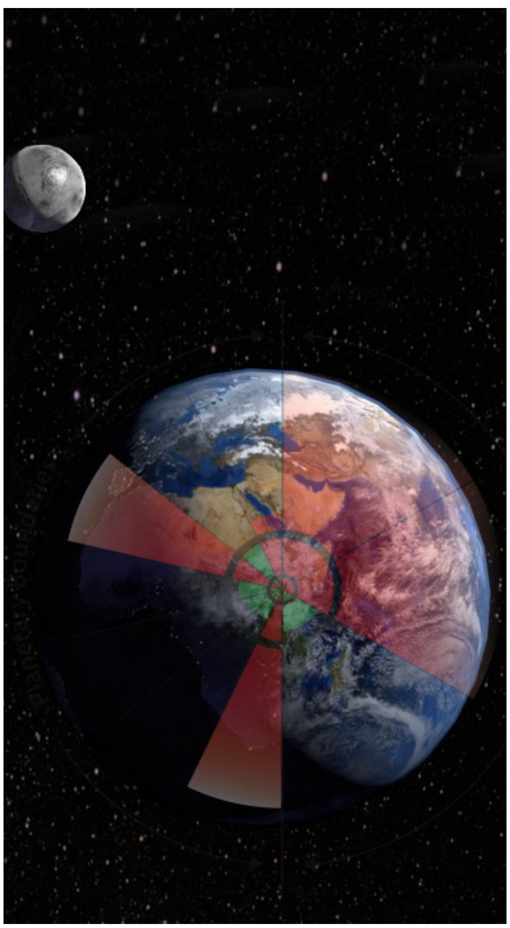

We confront an existential risk without historic precedent: human environmental pressures have reached such a pace and intensity that they may cross tipping points, irreversibly altering the state of the Earth system. As the human enterprise becomes more encompassing and interdependent, the prospect of achieving human well-being within the dominant development paradigm grows dim. However, an alternative sustainable development paradigm that pursues social, environmental, and economic goals separately would likewise prove inadequate. Instead, we need an integrated perspective to calibrate the operation of the human system so that it remains within safe parameters for a stable Earth system. The planetary boundary framework contributes to this new paradigm by delineating a safe operating space, in terms of the degree of human perturbation of environmental processes, consistent with maintaining the planet's stability. The urgency of the challenges ahead demands a two-prong strategy: acting within our current obsolete development framework to bend environmental and social justice curves as much as possible, while simultaneously fostering the longer-term shift in consciousness to values and institutions that equitably integrate people and planet.

Redefining Development in the Anthropocene

Human societies have for millennia faced severe environmental challenges, some of which have even triggered social and ecological collapse. Such was the fate of Mayan civilization and Mesopotamian irrigation societies, among many others. However, the scale of impact remained local or regional—until now. Over the past fifty years, the evidence has mounted of a massive shift in the magnitude and pace of human pressures on the planet. Although this "Great Acceleration" began in the mid-1950s, over the last twenty-five years, we have started to see the first evidence that critical thresholds of the Earth system are in danger of being crossed (Figure 1).[1] Multiple signals sound the alert: the collapse of marine fisheries; accelerated melting of ice sheets, upwelling of warm ocean waters, and methane release from thawing Siberian seabeds; climate volatility and extreme droughts; shifts in ecological regimes in lakes caused by nutrient runoffs from fertilizers and other sources; and the collapse of tropical coral reef systems. Today, we can state with a high degree of confidence that the sheer accumulation of such anthropogenic impacts can disrupt the homeostasis of the Earth system.[2]

> Humanity has become the dominant force of change on Earth.

Humanity has become the dominant force of change on Earth, surpassing in importance the geophysical forces that have heretofore shaped the biosphere.[3] In this new geological epoch, often called the Anthropocene, a profound new risk can be added to the conventional concerns of dwindling resources and local pollution: human action could push the Earth system to abrupt and irreversible shifts of the planetary ecosphere. The repercussions could prove calamitous at local, regional, and global levels.

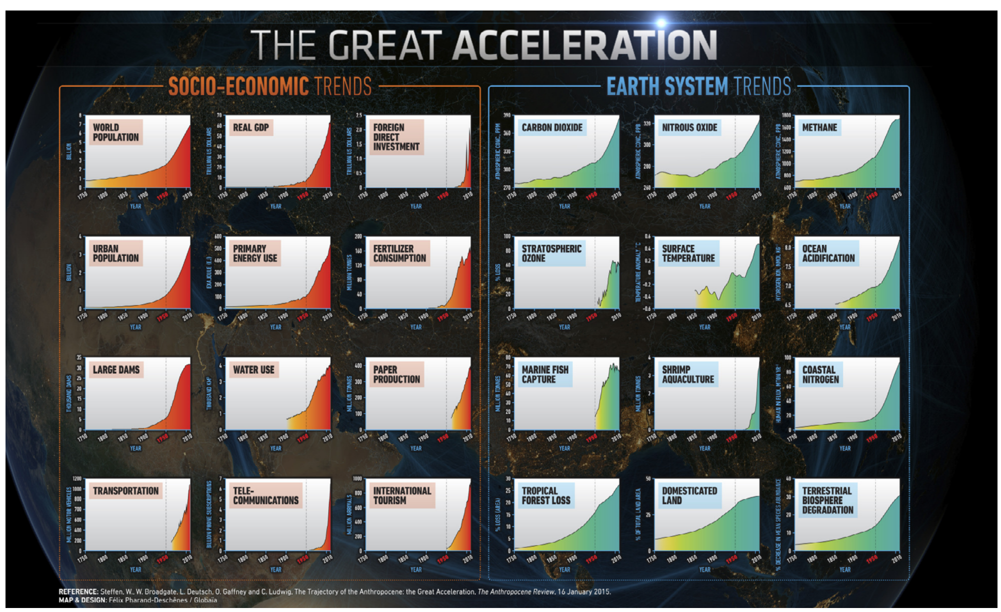

Figure 1: Great Acceleration, the 2015 update[4]

As a result, if humanity continues on its current trajectory, it will likely be unable to meet the needs of a world population that is expected to reach at least nine billion by 2050.[5] As human biophysical pressures rise, threatening the stability of the planet, our understanding of development must transcend the current paradigm. We must urgently address the twin challenges of shrinking the human footprint and equitably sharing the limited resources and ecological space of Earth.

The concept of sustainable development is key, but the oft-employed "three pillar" approach (with its separate social, ecological, and economic goals) cannot meet the challenges of the Anthropocene. First, the framework has led to a fragmented approach to the development process, where economic growth trumps natural and human capital. Second, it has failed to recognize that human-environmental interactions transcend their immediate scale of influence. Despite progress in reducing environmental impacts at local levels, cumulative global effects have increased in an uncontrolled way (e.g., relative improvements in fuel efficiency and catalytic cleaning in cars, but exponential rise in greenhouse gas concentration from overall global transport).

We need an integrated approach that reconnects human development with the biosphere.

Instead of this piecemeal approach, we need an integrated one that reconnects human development with the biosphere. Such a shift necessitates a new paradigm in which the economy is seen as a means to achieving social goals and generating prosperity within the limits of the Earth—not as an end in itself (Figure 2).[6] Establishing an economy that functions as "an open sub-system of a finite and non-growth ecosystem" will require the collective effort of nations, businesses, citizens, and institutions.[7] The goal of transforming our unsustainable economy into a steady-state economy in which energy and material throughput is stable needs to be incorporated into policymaking at all levels. Such change would not preclude growth in certain sectors (e.g., renewable energy, energy efficiency) and regions, but it would require a transition to a new, holistic form of development bounded within a stable and resilient planet. The UN Sustainable Development Goals, to be released later this year, offer an apt opportunity to start moving in this direction.[8]

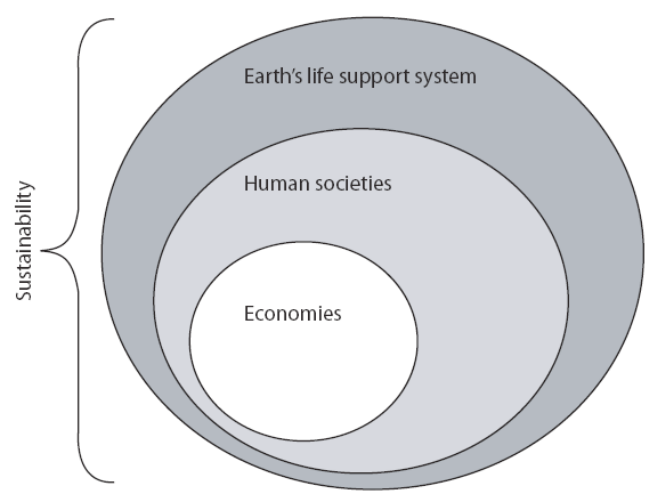

Figure 2: Sustainable development paradigm for the Anthropocene

Planetary Boundaries

The Scientific Origins

Building on decades of advancements in Earth system science, the planetary boundary (PB) approach offers a framework for keeping world development within a safe operating space. PB analysis relies on the latest research to define tolerance levels of environmental processes that regulate the stability of the Earth system.

The framework emerges from three fundamental insights. First, the advent of the Anthropocene places humanity "in the planetary driver's seat" for determining the future state of the Earth. Second, human activity has brought the Earth system—a complex, self-regulating biogeophysical system with mutual interactions among the cryosphere, atmosphere, hydrosphere, biosphere, and stratosphere—to tipping points, where both subsystems (e.g., the Greenland ice sheet) and the whole planet can shift states in irreversible and abrupt ways. Third, the Holocene, the interglacial epoch of the past 10,700 years, is the only known state of the planet that can support the world as we know it.

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Holocene: Eden's Garden for Human Evolution

The conditions of the Holocene have been propitious for social evolution, with average global temperature remaining within a narrow range of plus or minus 1ºC (1.8ºF). Although life in its spectacular diversity has existed for many millions of years, only in the Holocene does the biosphere appear in its contemporary form: rainforests, wetlands, grasslands, temperate and boreal forests, inland glaciers, polar ice sheets, fisheries, marine coral reefs, and hydrological cycles with predictable and stable rainy seasons.

The ecosystems and natural processes that underpinned the formation of early civilization crystallized in this unique era, eventually giving rise to our globalized economy.[9] These conditions enabled agriculture to rise and flourish. Indeed, the domestication of plants occurred independently in at least five different regions between 10,000 and 7,000 BCE: wheat and barley in the Fertile Crescent; millet and then rice in China; coffee and teff in Africa; corn and beans in Mesoamerica; and taro, yams, and perhaps even bananas in Papua New Guinea.

Now, however, we have a world of 7.2 billion people (and growing), and surging human action may be disrupting the very conditions that enabled growth and development over the last ten millennia. In this context, the ethical responsibility to guarantee a universal right to development carries a scientific imperative as simple as it is dramatic: we need to preserve the conditions of the Holocene. Our current predicament is unsettling, but at least our understanding of the Earth system—especially, the hard-wired biophysical systems and processes regulating the Holocene—is increasing. These processes include cycles of carbon, nitrogen, and phosphorus; the hydrological cycle; the ocean conveyor belt that distributes heat and regulates climate; the living biosphere that regulates the climate system (and vice-versa); and the vital ice-covered polar regions that keep the planet in an intermediate equilibrium between a "hot" ice free planetary state and a "cold" snowball state.

Concept and Theory

PB theory combines scientific knowledge of Earth-system functioning, an appreciation of the virtues of the Holocene, and an understanding of Earth's capacity for resilience along with its potential tipping points. This perspective takes into account the existence of multiple stable states and focuses on how interactions and feedbacks can cross critical thresholds, inducing a shift in the state of the system itself.[10] The PB approach asks two overarching questions: What are the processes and subsystems that keep Earth in a Holocene-like state, and what levels of human pressure on each of these could reach a threshold, thereby disrupting the continuity of the Earth system?

Planetary boundaries delineate a safe operating space in which humanity can operate while preserving the continuity and resilience of the Earth system.

To implement this analytic program, "control variables" identify the state of each PB process/system. Needless to say, establishing the critical point at which a threshold is crossed poses a difficult challenge, given scientific uncertainty and the inherently complex interactions between boundaries. Consequently, each control variable is associated not with a sharp boundary, but with a scientifically determined zone of uncertainty. The PB is then placed at the lower end of this range, a procedure consistent with the precautionary principle. In this fashion, each PB signifies a level below which the probability of crossing a threshold is low. Above the boundary, we enter a danger zone characterized by increasing risk of crossing thresholds. Finally, if the high-risk zone at the upper end of the uncertainty range were to be reached, irreversible systemic change would be likely to take place.

The boundary levels delineate a safe operating space in which humanity can operate while preserving the continuity and resilience of the Earth system. Figure 3 displays the 2015 PB update: the green inner circle represents this safe operating space; the yellow zone, the zone of uncertainty with heightened danger of crossing thresholds; and the red areas, the zone of high risk of triggering severe dangerous imbalances.[11]

PB Assessment and Advancements

The first PB analysis was published in 2009 after a two-year research and consultation exchange among global change scientists.[12] They focused on nine planetary boundary processes and systems for sustaining a Holocene-like state of the planet. Quantitative boundaries were proposed for seven of them, with three having relatively robust scientific support (climate change, stratospheric ozone depletion, and ocean acidification) and four carrying large uncertainties (land use change, freshwater use, rate of loss of biodiversity, and interference with nitrogen and phosphorous cycles). For the other two (aerosol loading and chemical pollution), limited information did not permit the determination of quantified boundaries. The analysis further suggested that humanity had transgressed three of the nine planetary boundaries: biodiversity loss, climate change, and nitrogen loading.

The initial effort met a major goal: to stimulate further research for refining criteria for safeguarding a stable Earth system. A wave of scientific discussion ensued, spurring engagement among researchers, civil society, policymakers, and the business community, and shaping the global change research agenda. More than five years on, more than thirty scientific articles have been published with "planetary boundaries" in the title, with the original paper garnering more than 1,000 citations.[13] Encouraged by this response and mindful of advancements in Earth system science, a new round of PB research was conducted, with the update published in January 2015.[14]

The updated analysis concludes that four out of nine boundaries have been transgressed.

In the latest findings, the original nine PBs remain germane. At the same time, the revised analysis includes several improvements. Chemical pollution has been renamed "introduction of novel entities" to include the release of radioactive materials and nanomaterials. The biodiversity boundary (referred to now as "biosphere integrity") now has two dimensions: genetic diversity (as before) and functional diversity (using the "biosphere intactness index," a measure of species abundance). The land use change boundary now considers minima for rainforests, temperate forests, and boreal forest cover, instead of the original proxy of maximum cropland. The nitrogen boundary has been extended to include human-induced reactive nitrogen from modern cultivation. The phosphorous boundary now has two definitions: one for oceans (the original boundary), the other for freshwater systems. Finally, the uncertainty range for the climate change boundary has been narrowed to 350 to 450 ppm CO2 (from 350 to 550 ppm CO2).[15] The new analysis, furthermore, treats climate change and biosphere integrity as "core boundaries," high-order manifestations of how breaching the other boundaries by can disrupt the Earth system.

Four Boundaries Transgressed

With these refined metrics, the analysis concludes that four out of nine boundaries have been transgressed (Figure 3). Two are in the high risk zone (biosphere integrity and interference with the nitrogen and phosphorous cycles), while the other two are in the danger zone (climate change and land use change). For illustrative purposes, this essay will largely focus on climate change.

Reconciling a respect for limits with principles of justice presents the profound challenge of imagining sustainable development.

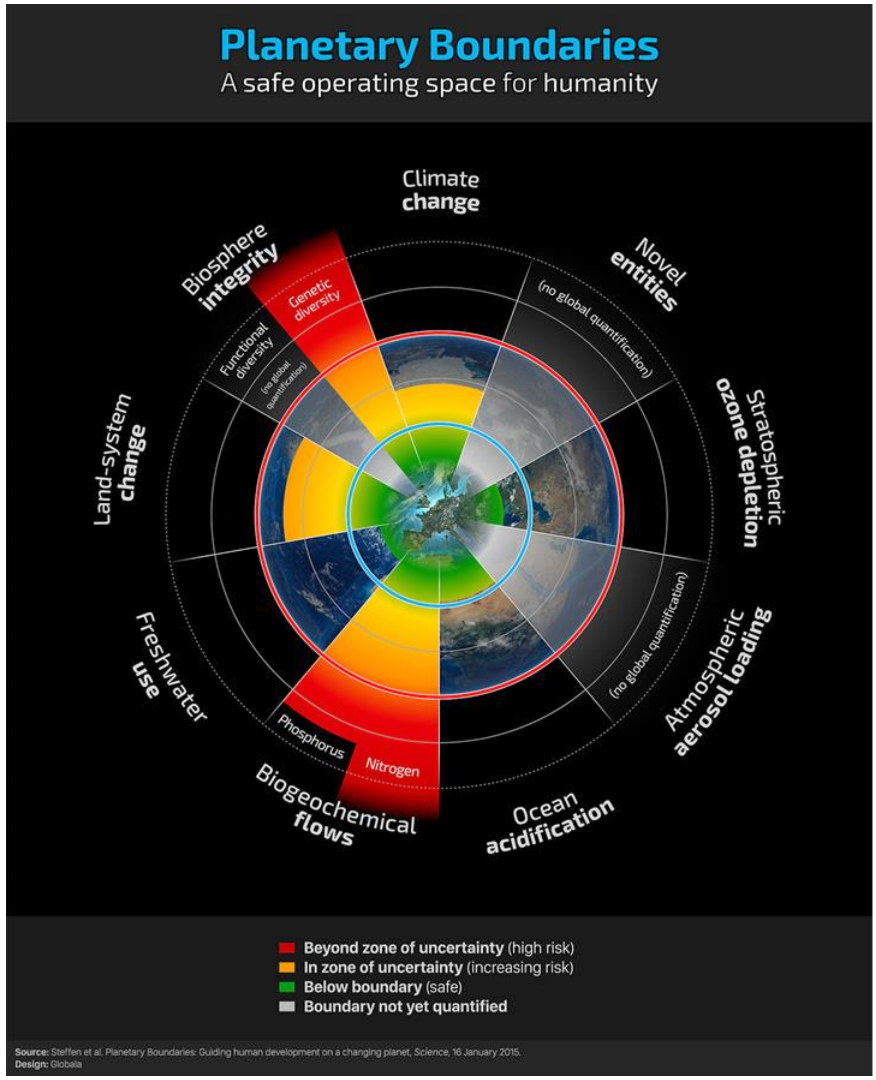

Figure 3: The 2015 update on planetary boundaries

The Need for a Great Transition

The PB framework emerges from the reality of the Anthropocene, the risk of systemic tipping points, and the importance of the Holocene for humanity's flourishing. This fresh point of view underscores the need for a form of world development that can evolve within Earth's safe operating space. Reconciling a respect for limits with principles of justice presents the profound challenge of imagining and creating a basis for sustainable development, i.e., good lives for all on a resilient and stable planet.

This shift of paradigm must promote anticipatory action, since triggers that set irreversible change in motion can occur much earlier than the later catastrophic tipping points. For example, the East Siberian Arctic shelf holds a vast stock of sea floor methane hydrates (potentially 50 to 500 Gt of carbon compared to the 550 Gt emitted since the industrial revolution). Methane, which is roughly twenty times more potent a greenhouse gas than CO2 even though it stays in the atmosphere for a shorter time, has started to leak in low volumes as the seabed and tundra thaw. The risk lies in a changing climate crossing an irreversible threshold (if it has not done so already) at which methane will flow in rising volumes. Paleo-climatic data shows that rapid global warming of 5 to 6 ºC (9 to 10.8 ºF) within one or a few decades has occurred in the past, phenomena that can only be explained by Earth system feedbacks, such as the abrupt release of methane hydrates from continental shelves.[16]

The self-reinforced warming that results from melting ice sheets as the reduced albedo (reflectivity) feeds back to enhance climate change offers another example of a triggering process in action. In 2012, for the first time, the entire surface of the Greenland ice sheets was observed to be melting in July for about two weeks. Correspondingly, the climate feedback from Greenland shifted from net cooling (negative feedback) to net warming (positive feedback), as the albedo dropped by close to 50%. Approximately 300 EJ of heat, equal to half of global annual energy use, were injected into the atmosphere during this two-week period.

A new paradigm of prosperity within planetary boundaries depends on a fundamental shift in values.

Under business-as-usual projections, the window for stabilizing global warming below 2 ºC (3.6 ºF) will close by 2023, even without sudden surprises like methane outbursts.[17] The same narrow timespan holds for biodiversity loss, where critical functions in ecosystems (such as pollination and the ability of coral reefs to remain stable) may be irreversibly destroyed.

The world thus urgently needs a great transition that rapidly bends the curve of negative global environmental change. Such a turn toward sustainability demands a deep shift in the logic of development away from the assumption of infinite growth toward a paradigm of development and human prosperity within Earth limits. It will require transformations in energy systems, urban development, food systems, and material use. Achieving all this will entail fundamental institutional changes in economic arrangements, financial systems, and world trade.

Transforming the paradigm of world development to prosperity within planetary boundaries depends on a fundamental shift in values, as humanity faces the unprecedented challenge of needing to share the finite global budgets circumscribed by planetary boundaries. To achieve even local aims, the combined effects of local action must conform with globally-defined sustainability criteria established by appropriate governance structures. Our species must thus give up the illusion that a heavy reliance on market-based policy measures—which can, at best, deliver relative, not absolute, improvements—can deliver a flourishing civilization in this century. In place of illusion, we can pursue creativity, combining strategies to nurture the innovation and efficiency of the market with hard regulatory policy measures to set the boundaries of the space in which the market operates.

Local to Global

Navigating to a safe and thriving future will require stronger global governance.[18] Increasing the powers of global governance does not, however, inherently weaken local, national, or regional governance. To the contrary, democratic global governance for meeting PB requirements can stimulate innovation, adaptation, and market-based solutions at the local, national, and regional scales. In such a scenario, global governance, local action, and adjustments in the business sector go hand-in-hand; indeed, the interplay of governance levels becomes a necessity in the Anthropocene.

Countries with high GDP growth have enjoyed a planetary free ride at the expense of the climate system and of poorer nations.

The 1987 Montreal Protocol, the only example of global governance of a planetary boundary, offers a model. The Protocol regulated the use of ozone-depleting substances in order to return to a safe operating space for stratospheric ozone. This planetary scale regulation created incentives for nations to leap-frog to a host of innovative technologies.

Abundance within a Safe Operating Space

Earth subsidizes GDP growth by allowing the systematic undermining of natural resources, ecosystems, and the Earth system at no cost. The prioritization of products and profits fails to reflect the price paid by natural systems. Perhaps the most dramatic example is the double climate subsidy to the world economy. First, GDP growth is closely correlated to energy use and has become dependent on "cheap" energy sources, particularly fossil fuels. Nobody pays for loading the atmosphere with CO2 released by burning them—a subsidy by our modern economies to the users, largely benefitting a rich minority. Second, half of these emission end up sequestered in oceans and terrestrial ecosystems, thereby reducing, at least temporarily, the actual climate impacts (even though CO2 uptake acidifies the oceans very rapidly). This second subsidy—nature's capacity to hide away half of our human caused climate impact—is probably Earth's largest subsidy to the world economy. Through both climate subsidies, countries with high GDP growth have enjoyed a planetary free ride at the expense of the climate system and of poorer nations.

Aside from the well-founded critique of GDP, the core question is whether a planetary boundary framework is compatible with economic development (the emphasis on "development" rather than "growth" is key). A highly contested and important debate about whether growth is compatible with sustainability is taking place.[19] Growth is sometimes good and sometimes bad; in particular, the movement of poor countries up the development ladder necessitates equitably distributed growth. However, we must not forget that if our primary goal is human well-being, growth can only be a means to an end, not an end in itself.

Accumulating evidence suggests we are approaching a new take-off point of exponential growth in technological advancement, similar in pace and scale to the great acceleration of industrial enterprise after the Second World War and the Internet revolution in the 1990s. Rapid innovation in robotics, nanotechnologies, biotechnology, and digital technologies promises a "second machine age" that will enable "abundance for all."[20] However, so far, major breakthroughs, while making technologies cheaper and more accessible (and contributing to wealthier and longer lives), have resulted in rebound effects whereby gains in efficiency have been counteracted by rising resource use and environmental damage.

World development is almost certainly reconcilable with staying within a safe operating space.

Our grand challenge in the Anthropocene is to combine the goal of prosperity for all with a stable and resilient planet. Such an agenda, which is a pragmatic and ethical necessity, will create even greater incentives for progressive technological and societal innovation. Under conventional development, with global regulations for keeping within a safe operating space absent, increased efficiency will continue to induce varying degrees of rebound effects. On the other hand, global agreements to develop within a PB for climate, land, water, and phosphorus would challenge businesses, scientists, and policymakers to develop innovative solutions. No longer would it be an incremental journey, but instead an "Apollo type" mobilization for transformative change. The combination of science-based planetary boundaries and exponential technological advancement can generate system shifts towards new values as well as new business models, institutions, and urban designs.

In short, world development is almost certainly reconcilable with staying within a safe operating space. History provides many examples of how environmental regulation has created incentives for technological and system improvements, benefiting social and economic development (e.g., standards on air pollution and car emissions, water quality, and building efficiency and safety). Such regulation can be applied at the global level to harmonize environmental sustainability with the goals of poverty alleviation and economic development.

Ethics within a Safe and Just Operating Space

This urgent need for a global transition has arisen at the same time as billions of people living in poverty around the world are starting to grasp their right to development. The global middle class could rise from 1.5 billion to as much as 6 billion over the coming decades, and under conventional development conditions, the corresponding growth in consumption would greatly exacerbate human pressures on Earth. Combined with the increasing unsustainable and highly unequal character of global development (the ecological footprint per capita of high-income countries is about five times more than that of low-income countries), the conundrum of sustainable development raises deep ethical questions about how to secure world development within a safe and just operating space.[21]

Some developing nations view the PB framework as a threat to development. This is a depressing yet understandable perception, as it reflects a historically-rooted and justified mistrust. After all, little in the history of international collaboration on sustainable development would suggest that richer nations are willing to equitably share the remaining ecological space with poorer nations. This is likely a more fundamental reason for the hesitance among developing countries to adopt a PB framework than a belief that economic development and global sustainability are incompatible, as some have suggested.

Economic growth in the Global South and global sustainability are compatible aims. A world paradigm of abundance within planetary boundaries can be made plausible—if we act with sufficient rapidity, scope, and coherence to avoid crossing thresholds of irreversible change. But robust world development within PBs will need to ensure a fair distribution of this finite space among all nations and people.

Two-Track Strategy

The vision here posits a two-track approach. The fast track would operate within the current obsolete development paradigm through a series of global policy measures to nudge our dangerous trajectory away from the most immediate risks. This alone, however, will not suffice. The longer track of a Great Transition will entail a profound mind shift toward universal values that reconnect world development with a resilient Earth, recognize the right of all to development, and promote a shift from materialistic lifestyles to the pursuit of well-being and fulfillment.

Economic growth in the Global South and global sustainability are compatible aims.

Three critical transformations lie on the fast track pathway: decarbonizing the world economy by 2050 to 2070, feeding the world through sustainable agriculture by 2050, and improving resource-use efficiency and accelerating progress toward an economy of cyclic material flows. Increasing evidence indicates that these transformations are possible, even with current know-how and technologies. The world is already adopting a PB framework with regard to decarbonization with the recognition of a maximum planetary limit for warming of 2 ºC (3.6 ºF), although this is higher than the planetary boundary of 1.5 ºC (2.7 ºF).

The IPCC has determined that humanity must remain within a remaining global carbon budget of 1,000 Gt CO2 equivalent from 2011 in order to have a good chance of holding global warming under 2 ºC. Such a carbon budget gives us only twenty-five to thirty years more in the current fossil fuel-based world economy. Still, decarbonizing the world by the second half of this century is not only possible (through a wide strategy of energy efficiencies and applying multiple wedges of renewable energy options), but also compatible with economic development. Renewable sources like solar and wind are already competitive (without subsidies) in many economies, and they can and will generate new markets, innovations, and jobs.

Agricultural practices are implicated in almost all planetary boundaries, as agriculture is the largest single emitter of greenhouse gases, the largest single user of freshwater, a major trigger of biodiversity loss, and the main cause of nutrient loading and chemical use. A transformation to sustainable and resilient food systems that integrate water, land, and ecosystems in ways that guarantee the right of all to sufficient, safe, and nutritious food is both necessary and increasingly possible. Sustainable intensification—combining technologies, system improvements, and integrated land-water-nutrient management—can go a long way toward closing the yield gaps between current levels and those possible through ecological farming.[22]

The "fast track" measures, aiming at bending the global curves of negative environmental change through immediate action, are essential but will not be enough. Recent analyses indicate that even a Great Transition in values and lifestyles, combined with resource efficiencies and technological improvements, will barely succeed in keeping world development within a safe operating space.[23] This underscores the critical issue: how to promote wide adoption of universal values and stimulate a broad wave of civil mobilization in support of a new logic of development that pursues human prosperity within a stable planetary space. Such a movement would play a catalytic role in driving change in public awareness and societal institutions.

Our historical condition does, whether we like it or not, change everything.

In the Driver's Seat for the Road Ahead

Scientific advances over the past thirty years have clarified the prospects and imperatives for the human journey on Earth. We are now living in a geological epoch of our own making, the Anthropocene. We have reached a saturation point in terms of human pressure on the planet and risk crossing global ecological tipping points. We understand that the Holocene, apart from being a remarkably stable planetary state, is the only state we know can support modern world development. Together, these insights lead to the PB framework as a way of redefining sustainable development for the globalized twenty-first century—to ensuring good lives for all within the safe operating space of a stable and resilient Earth system.

Our historical condition does, whether we like it or not, change everything. Our current economic logic no longer works, as we confront potentially infinite costs at the planetary scale, rendering concepts like "externalities" and "discounting" useless. The nation-state becomes questionable as a useful unit for wealth creation when policy at the local level depends on regional and global actions and feedbacks. Governance shifts upwards in scale, but still needs rooting and interaction across scales. Sharing finite planetary budgets will require fundamental value changes. Planetary regulation needs to spur innovation and technological breakthroughs. Ethical norms need to evolve to embrace a universal belief that all citizens in the world have the right not only to an equitable share of the available environmental space, but also to a stable and healthy environment. No facet of contemporary society will be unaffected by the Anthropocene.

The window for a prosperous future for humanity on a stable planet remains open, if just barely. We have not yet tipped the planet away from its Holocene equilibrium. Whether we are able to navigate the world back into a safe operating space, thereby creating a chance for a world of nine to eleven billion co-citizens to live and thrive, is up to us. In the Anthropocene, we are in the driver's seat.

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About the Publication

Published as a Essay by the Great Transition Initiative.

Cite as Johan Rockström, "Bounding the Planetary Future: Why We Need a Great Transition," *Great Transition Initiative* (April 2015).

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