

# THRIVING WITHIN PLANETARY BOUNDARIES

## TO PROSPER THE WORLD NEEDS A GREAT TRANSFORMATION TO GLOBAL SUSTAINABILITY

Johan Rockström

**T**HE OZONE LAYER protects life on Earth from harmful radiation from the sun. After having committed to outlawing ozone-destroying chemicals through the 1989 Montreal Protocol, there are now strong indications the ozone hole above Antarctica has stabilized and will recover by the end of the century.

This success was based on robust science, policy action, and new technologies and practices that are economically competitive and continue to deliver human wellbeing.

It has always been argued that these criteria for success do not apply to climate change. I would argue that over the past two to three years we may have reached a “Montreal moment” on climate. With the publication of the fifth Assessment

Report of the Intergovernmental Panel on Climate Change (IPCC), we can conclude that the scientific debate—if there ever was one—is over.

We human beings are causing global warming, and we are at risk of destabilizing the climate system. The solutions to reduce the risk of catastrophe are scaling up.

Clean energy technologies to replace health- and climate-harming fossil energy sources are now scalable, and can operate on grid-parity—that is to say, they are economically attractive, and, importantly, they are easier to apply in remote poverty-stricken regions (it is now easier to put up efficient distributed solar-panels rather than invest in large centralized coal-fire plants with huge, costly transmission systems).

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**W**e are thus at a potential watershed moment, one based on a series of momentous achievements. If sustained, it shows that the economic system can decouple from fossil-fuel emissions. But emissions must start falling soon, and they must fall fast. Science clearly shows the necessity of achieving zero carbon emissions globally by 2050 (or shortly thereafter) if we are to stand a reasonable chance of keeping global warming below two degrees Celsius.

**H**uman actions are threatening to trigger tipping points that could knock the planet out of its stable state. Researchers announced last year that parts of the Antarctic ice sheet may have crossed a tipping point and will melt irreversibly. There are still many

uncertainties about the precise point at which a system crosses a tipping point, but that we have hard-wired Earth tipping points is now well-established.

Six years ago colleagues and I published research in the scientific journal *Nature* identifying a safe operating space for humanity on Earth. We updated our analysis in January 2015, confirming in a follow-up article in *Nature* that the Earth has nine planetary boundaries.

Transgressing these boundaries risks approaching or crossing tipping points in the Earth’s system. We concluded that we have already transgressed four of these boundaries, having entered the danger zone with regards to climate, biodiversity, deforestation, and our use of fertilizers (which cause eutrophication and other major environmental problems).

We also identified climate change and biosphere integrity as “core boundaries.” This means that the

scientific evidence indicates that the aforementioned two can, by themselves, disrupt the Earth system.

**R**ecognizing this human predicament, many of my colleagues and I have urged bold political action during 2015—a

year that will culminate in the holding of the Paris Climate Change Summit, colloquially known as COP21. We conclude that the planetary boundary framework forms the scientific foundation for a new framework for sustainable development.

**F**orming the basis for this conclusion are the following insights, which have fallen into place over the past five to ten years:

*The scientific debate—if there ever was one—is over. We human beings are causing global warming, and we are at risk of destabilizing the climate system.*

(1) we have entered a new geological epoch, the Anthropocene, where we humans constitute the largest single cause of planetary change—superseding the geological forces of change on Earth;

(2) the Holocene—the stable state of the Earth system over the past 11,000 years—is the only state of the planet we know that can support the modern world as we know it, making it our sole desired planetary state;

(3) our current business-as-usual pressures on the planet are likely to result in abrupt, irreversible, and potentially catastrophic changes (tipping points) that will push us away from the Holocene state.

*There is essentially no aspect of contemporary societies that is unaffected by the Anthropocene.*

Some of these have contributed to pushing our societies across thresholds, ultimately causing social and ecological collapses—such as those which destroyed the

Mayan civilization and the Mesopotamian irrigation societies.

The scale of impact was, until now, always local or regional. However, over the past 50 years, we have seen ample evidence of a massive shift in the scale and pace of human pressures on the planet.

And, importantly, even though this great acceleration of human pressures started in the mid-1950s, it was only around 1990 that we began seeing the first evidence of critical Earth system thresholds being

is also an opportunity to adopt a sustainable development path that matches the challenges of the Anthropocene era. The UN will adopt new Sustainable Development Goals in September 2015 and world leaders will, as mentioned above, meet in Paris later in the year to forge a new globally-binding climate deal.

**THE GREAT ACCELERATION**

Climatic and environmental challenges are of course nothing new to human societies. We have faced environmental challenges for millennia.

crossed. These include the collapse of marine fish stocks, accelerated and self-reinforcing melting of ice sheets, and the collapse of tropical coral reef systems.

Today, science increasingly has enough evidence to state with a high degree of confidence that humanity has become the dominant force of change on planet Earth, surpassing in pace and magnitude the geophysical forces of change that have regulated life conditions on Earth in its geological past.

In this new geological epoch, called the Anthropocene, the world faces not only the risk of dwindling resources and gradual decline of human wellbeing, but also rising risks of crossing critical thresholds, which can result in abrupt and irreversible shifts in Earth's life-support systems—potentially undermining the possibilities for human development at regional to global scales.

The most recent update of the great acceleration of human pressures on Earth confirms the continued rise in the global pressures on the planet affecting critical Earth system processes such as loss of biodiversity and destabilization of Earth's climate system.

*The planetary boundary framework forms the scientific foundation for a new framework for sustainable development.*

**RETHINKING DEVELOPMENT**

In this new situation, it is increasingly clear that the world's current development trajectory threatens to undermine humanity's ability to meet the needs of a rising world population, predicted to reach at least nine billion in 2050.

It is also increasingly clear that we fundamentally need to rethink development. At least two reasons come to mind. The first is that human pressures have hit, or are rapidly approaching, the biophysical ceiling of hard-wired Earth system processes that regulate the ability of the systems on Earth to remain stable. This is triggering a rising risk of inducing catastrophic tipping points.

The second is the immense social implications of humanity having reached a saturation point in terms of exploiting resources and “filling up” environmental space. This is leading to an acute need to address the equity dimension of sharing limited resources and ecological space on Earth.

Our current three pillar approach to sustainable development—economic, social and environmental—is, however nobly conceived and applied, not up to the challenges of the Anthropocene.

Simply put, we need to reconnect human development with the biosphere. We now have ample Earth system science support for a world development paradigm where the economy serves as a means to meet social goals and generate human prosperity in societies that evolve within the safe operating space of the Earth system.

This requires nothing less than a great transformation involving nations, businesses, citizens and institutions—and, in particular, a great transformation to a new type of economy that would function as “an open sub-system of a finite and non-growth ecosystem,” to quote former World Bank economist Herman Daly’s definition of a steady-state economy.

These insights, in turn, translate to a framework for global sustainable development, where social goals and aspirations—manifested for instance in

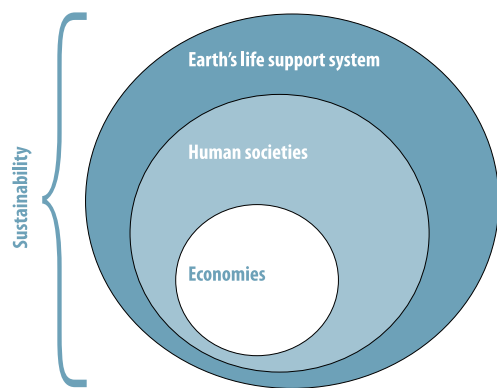


Figure 1. Sustainable development paradigm in the Anthropocene.

the upcoming UN Sustainable Development Goals (SDGs)—must evolve within the confines of a safe operating space on Earth, as illustrated in Figure 1.

**PLANETARY BOUNDARIES**

The planetary boundary framework builds on decades of advancements in Earth system science. It offers a framework for world development within a safe operating space on Earth. Based on our current state of knowledge of Earth system processes, it defines safe boundary levels for the environmental processes that regulate the stability of the Earth system.

This framework emerges from the three critical insights mentioned above: the advent of the Anthropocene means that humanity is now “in the planetary driving seat” of the Earth system; the Holocene (the period since the last glacial phase) is the only state of the planet we know that can support modern contemporary societies; ample scientific evidence now shows that the Earth system has hard-wired tipping points, where sub-systems (such as the Greenland ice sheet) and the Earth system as a whole can shift between different stable states (separated by thresholds) in irreversible and often abrupt ways.

The Holocene has been an extraordinary state of the planet. For over 10,000 years, global average temperatures have oscillated within a maximum

plus minus range of one degree Celsius. Civilization emerged from this stability. It is during the Holocene period that the rainforests, wetlands, grasslands, temperate and boreal forests, inland glaciers, polar ice-sheets, fish stocks and coral reefs, and in particular the global hydrological cycles—with its distribution of (remarkably stable) rainy seasons—settled into predictable rhythms.

This is very reassuring. Why? Because we know the Holocene fairly well. We increasingly understand the hard-wired biophysical systems and processes that regulate the Holocene—for example, the three large global cycles of carbon, nitrogen, and phosphorus; and the living biosphere that regulates the climate system (and vice-versa).

Staying within the planetary boundaries provides humanity with a safe operating space on Earth (shown in green in Figure 2) with regards to the hard-wired biophysical processes that regulate Earth resilience. Entering the danger zone, where unwanted surprises lurk, is shown in yellow, and exceeding the scientific uncertainty range and entering the realm of high risk tipping points is shown in red.

**A GREAT TRANSFORMATION**

The recent conclusions that we have entered the Anthropocene, that we face real risks of Earth system tipping points, and that the Holocene is our desired planetary state, naturally lead to

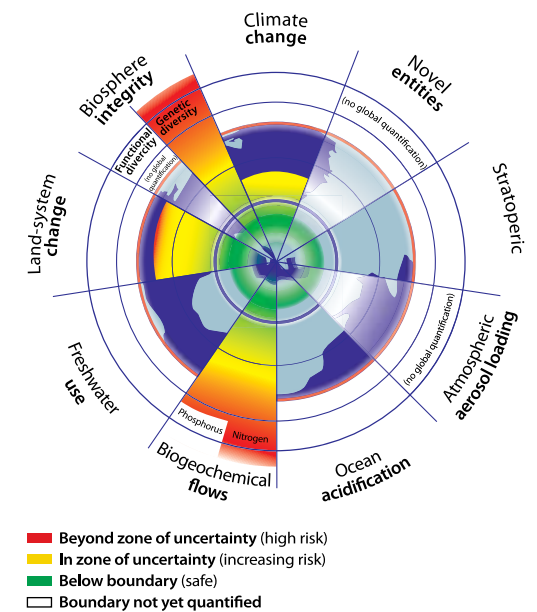


Figure 2. Current state of human pressures on the Earth system

the recognition that world development must now occur within the confines of a safe operating space on Earth. This in turn, suggests that we need to redefine sustainable development—e.g. to create the possibilities of good lives for all on a resilient and stable planet.

As shown by Thomas Stocker of the IPCC, the window for stabilizing global warming below two degrees Celsius—even without considering the risk of sudden surprises, such as methane outbursts—effectively shuts down in 2027 under a business-as-usual scenario. The same narrow time-span of five to ten years almost certainly also applies to loss of biodiversity, where critical functions in ecosystems (such as pollination and

the ability of coral reefs to remain stable) may be irreversibly lost.

The conclusion is that the world urgently needs to undertake a transition to global sustainability that rapidly bends the curves of negative global environmental change. This entails a great transformation, requiring a profound shift in the logic of world development—from assuming infinite growth with no limits, to a paradigm of growth/development within Earth limits.

It will necessitate deep transformations in global energy systems, urban development, food systems, and material use. This, in turn, will force us to make fundamental changes to our economies, financial systems, and world trade.

**T**ransforming global development to a paradigm of prosperity within planetary boundaries will also require a fundamental shift in values as humanity, for the first time, enters the realm of having to share finite global budgets of planetary boundary entities—a finite global budget for carbon, phosphorus, nitrogen, freshwater, and land. This means that all local actions need to add up to meet absolute global sustainability criteria (goals or targets), which in turn implies that humanity has evolved beyond the possibility of “only” applying market-based policy measures. This has profound, systemic implications for societies, the economy, and for businesses.

**N**avigating world development within a safe operating space will require new thinking and strengthening of global governance. This does not imply a weakening of local, national, or regional governance. Quite the contrary. The hypothesis put forward in this essay is that the global governance of planetary boundaries—based on democratic principles—will stimulate innovation, adaptation, and market-based solutions at local, national, and regional levels. Global governance and action from local communities, businesses, and economies go hand-in-hand; they are, in fact, necessary to bring together in the Anthropocene age.

This is where the precedent of the Montreal Protocol—the only example of global governance of a planetary boundary—gives us hope that we can make it past the finish line. Let us not forget that the Montreal Protocol, as a planetary scale regulation, created incentives for major leap-frogging in novel technologies and improved efficiency in heating and cooling technologies.

#### THE ABUNDANCE TO COME

**A** critical question is whether adopting a planetary boundaries framework imposes limits on conventional economic growth.

Here is not the place to dwell on the complex debate on how to define economic growth and its role in generating

human wellbeing and development. It suffices to say that economic growth, defined in terms of GDP, is unsustainable under all circumstances—irrespective of whether planetary boundaries put biophysical guardrails around development or not.

**I**t is clear that the Earth subsidizes GDP growth by allowing for the systematic undermining of natural resources, ecosystems, and the Earth system at no cost. This business-as-usual approach is no longer something we can sustain.

The Earth subsidizes our damaging way of life. Perhaps the most dramatic example is the fact that nobody pays for loading the atmosphere with greenhouse gases. As long as we had not saturated the atmosphere, this worked reasonably well. However, this logic collapsed with the saturated atmosphere we have had since 1990.

**H**alf of our CO<sub>2</sub> emissions from fossil burning remain in the atmosphere, contributing to the destabilization of Earth’s energy balance. The remaining 50 percent are sequestered in oceans and terrestrial ecosystems. This is probably the Earth’s largest subsidy to the world economy.

Countries with high GDP growth over the past 50 years have allowed themselves a planetary free ride at the expense of both Earth’s climate system and the poorer nations that never joined the GDP growth party.

**T**here is rising evidence that we are approaching a new take-off point in terms of exponential rise in technological advancements—similar

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in pace and scale to the great acceleration of industrial enterprises after World War II and the internet revolution of the early 1990s. The holy grail of the human challenge in the Anthropocene is whether we can now combine the goal of prosperity for all humans on Earth with a stable and resilient

planet. If the world agrees to develop within planetary boundaries, it would very likely generate an ambitious although attainable challenge to business, science, and policy to be even more creative and innovative.

**I**t is very likely that this combination of unprecedented potential of exponential technologies and science-based planetary boundaries will bring about such grand challenges. This would not only trigger new technologies but also generate system shifts towards—for



instance—new business models, institutional changes, fundamentally new models of urban design and mobility, and transformed human values.

**A THREAT TO DEVELOPMENT?**

A massive challenge is that the urgent need for a transition of world development to remain within the Earth’s safe operating space—a window which is rapidly shutting for climate, biodiversity, land, water, and nutrients—occurs at a time when billions of poor people around the world are starting to see the opportunity to grasp their right to development.

As a consequence, the planetary boundaries framework has so far been perceived among several poor nations (in the context of the Rio+20 negotiations, for instance) as a threat to development.

This is a depressing but understandable position. It reflects the mistrust among the world’s poorer nations and the (increasingly obsolete) belief that the only way to effectively create wealth is to adopt the unsustainable fossil fuel driven growth model of the OECD countries.

If world development needs to occur within the confines of a finite biophysi-

cal space on Earth—which translates to finite global budgets of carbon, phosphorus, and so on—it will require a fair distribution of this finite space among all world nations.

There is little in the history of multilateral collaboration on sustainable development, however, to suggest that richer nations would be willing to share the remaining ecological space on Earth with poorer nations in a sustainable manner.

This is very likely a key reason for the nervousness in some quarters, at least, about adopting a planetary boundary framework—and not the sometimes proposed explanation

that developing countries continue to adhere to the perception that economic development has to occur at the expense of global sustainability.

The conclusion is therefore dual. One, there is little support for the conventional view that economic growth cannot be combined with global sustainability. On the contrary, a world paradigm of abundance within planetary boundaries seems plausible (the key question is whether the world can transition in time to avoid crossing thresholds of irreversible change).

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Two, a major challenge is to combine safety with fairness—that is to say, to integrate global boundaries with a fair distribution of global boundary budgets.

A third, much too little debated, issue is that we have growing evidence that a business-as-usual approach will simply not deliver wealth for nine to ten billion people. It will very likely hit a number of physical and risk-related walls.

These include peak factors related to phosphorus, oil, and certain rare-Earth metals—each of which will grow more scarce and thus cost much more. They also include extreme shock physical events, such as floods, droughts, heat waves, and disease—each of which are associated with high social and economic costs. Additionally, in a business-as-usual scenario, we will see rising health hazards, such as non-communicable diseases related to unhealthy food, environment, and lifestyle choices; already, air pollution, for instance, kills seven million people per year on average. Lastly, we shall face a rapidly rising risk of collapse of ecosystem services that are a precondition for human development, such as agricultural systems, marine resources, and forest resources.

In short, in a business-as-usual scenario, humanity will no longer be able to thrive on Earth within decades.

**TWO TRACK STRATEGY**

The world urgently needs to adopt a two-track approach. The first is a raft of fast-tracked global policy measures to start reducing the inherent risks of our current trajectory—that is to say, a set of policy initiatives that remain within the framework of our current inept development paradigm.

But this will clearly not suffice. To achieve the promise of abundance within safe and just boundaries, we need an additional fast track pathway. We need a great transition involving a profound mindset shift, the search for universal values that reconnect world development with a resilient and sustainable Earth system, a global ethics rooted in recognizing everyone’s right to development, and the need for deep lifestyle changes.

The second fast track pathway needs to include—but not be exclusively focused on—three critical transformations:

- A decarbonized world economy by 2050–2070;
- Feeding the world through sustainable agriculture by 2050;
- A transition to deep improvements in resource efficiencies, and, ultimately, a circular economy.

Interestingly, more and more evidence indicates that these transformations are possible to accomplish—even within current know-how and technologies. Again, the world is already adopting a planetary boundary framework, but its adoption is based on a maximum planetary limit of two degrees Celsius. This is higher than the planetary boundary of 1.5 degrees Celsius, but has de facto become the climate boundary—a political boundary.

According to the IPCC fifth Assessment Report, such a target translates to a remaining global carbon budget of no more than 1,000 Gt CO<sub>2</sub> from 2011 onwards. Such a budget gives us only about 25 to 30 more years in the current fossil-fuel based world economy.

This gives the world only a 66 percent chance of not breaching two degrees Celsius threshold—only two in three odds to achieve a relatively dangerous global goal. However imperfect this may be, it is an example of planetary boundaries thinking being applied at the global policy level.

Decarbonizing the world by the second half of this century is most likely not only possible—through a wide strategy of energy efficiencies

and applying multiple wedges of renewable energy options—but also compatible with economic development.

Solar and wind is already at non-subsidy grid-parity in many economies, and renewable energy technology will generate new markets, innovations, and jobs. As U.S. Secretary of State John Kerry said in his address at the January 2015 World

Economic Forum, a \$6 trillion market is now emerging, and it is slated to power the world with renewable energy systems.

The issue of agriculture influences almost all planetary boundaries because agro-business is the largest single emitter of GHGs, the largest single user of freshwater, a

trigger of biodiversity loss, a cause of nutrient loading, and requires extensive use of chemicals.

A transformation to sustainable food systems—from production to consumption—is not only necessary to transition into a safe operating space, but also seems increasingly achievable. Sustainable intensification, combining technologies, system improvements, and integrated land-water-nutrient management can go a long way towards clos-

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ing the yield gaps between current and possible yield levels.

The challenge is that “fast track” measures such as these, which aim at bending the global curves through immediate action, will not be enough.

As the results of a recent analysis conducted with colleagues at the Tellus Institute indicate, even a great transition in values and lifestyles, combined with resource efficiencies and technological improvements, will barely succeed in producing a global transformation that allows world development to occur within a safe operating space.

This suggests that technology and resource efficiency will not be enough to safeguard further sustainable world development, raising the question of how to enable a global adoption of universal values in support of a new development logic of human prosperity within a stable planetary space.

### THE WINDOW REMAINS OPEN

We have reached a saturation point in terms of human pressure on the planet and can no longer exclude the possibility of crossing human-induced Earth-scale tipping points. Whether we like it or not, this changes everything. Our current economic logic no longer works, for we

are suddenly facing potentially infinite costs at planetary scale—externalities no longer exist and discounting no longer works.

A novel, planetary-scale regulatory logic needs to spur innovation and technological breakthrough. Ethics needs to change to a point where we adopt, across different value systems, a universal belief that all citizens in the world have the right not only to an equal share of the Earth but also to a stable and healthy environment. There is essentially no aspect of contemporary societies that is unaffected by the Anthropocene.

The window for a prosperous future for humanity on a stable planet remains, as it seems, still open—but barely. Yes, we are in the Anthropocene; but we have not, yet, tipped the planet away from its Holocene equilibrium. The Anthropocene is not yet a new planetary state, it is “only” a reference to the fact that humanity has become the dominant driving force of change on Earth.

Whether we are able to bring the planet back into a safe operating space—thereby creating a chance for a world of around 10 billion to live and thrive—is up to us. In the Anthropocene, humanity is, as never before, truly in the driving seat. ●