METABOLIC

ONE PLANET APPROACHES

Methodology Mapping and Pathways Forward

COLOPHON

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FOREWORD

Planetary changes such as rising global temperatures and persisting downward trends in biodiversity show that humanity is placing increasing pressure on the natural resources and the resilience of our planet. The research around planetary boundaries by Rockström and Steffen et al. reveals that on a global level, the boundaries for biodiversity, phosphorus and nitrogen flow have already been breached; whereas those for land system change and climate are at risk of irreversible and abrupt environmental change. The world community has acknowledged the need for action and adopted the Sustainable Development Goals (SDGs) to address these issues.

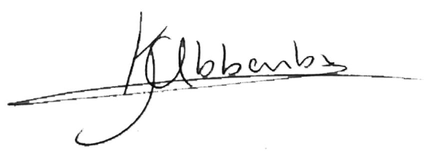
We are convinced that ensuring a healthy and resilient planet for generations to come requires that human development is decoupled from environmental degradation. Moreover, this requires a fundamental transformation that involves a paradigm shift towards an economy that uses natural resources in an efficient and fair manner, in order to preserve the habitability and resilience of this planet for future generations. Unfortunately, even though we see many positive developments towards sustainable consumption and production, a crucial economic transition still awaits. One reason for this is that incremental changes made by many different actors cumulatively do not accomplish the changes needed to reverse the breach of our planetary boundaries. We need to measure success against the boundaries of our planet and transform the way we manage natural resources from what is workable to what is necessary.

There is a strong business case to invest in pathways that are compatible with the limits of our planet. Many companies have developed approaches and strategies to measure and value their impact, define environmental objectives and improve sustainability practices. They include, for example, accounting initiatives such as the Science Based Target initiative (SBT), the Natural Capital Protocol (NCP), and the Global Reporting Initiative (GRI), as well as certification programs for responsible production, such as the Roundtables on Responsible Soy or on Sustainable Palm Oil (RTRS, RSPO) and the Forest and Marine Stewardship Councils (FSC, MSC). These initiatives are all important elements on the path towards more sustainable business models.

Nevertheless, maintaining the habitability and resilience of this planet for future generations requires the need to address the most relevant issues and set targets at sufficient ambition levels. In order to find solutions to these questions, WWF has started the One Planet Thinking initiative based on the planetary boundaries concept. It seeks to unite a broad alliance of partners from business, science, civil society, and governments under the common vision of a world where humanity lives thrives within the planetary boundaries. The initiative aims to support companies throughout the economy to seize business opportunities while staying within the planetary boundaries by developing methodologies and approaches for setting targets and measuring progress.

This report maps and analyzes many existing One Planet Approaches. It acknowledges what is already available and identifies scientific gaps and necessary pathways for further development.

All relevant stakeholders – the research community, governments, civil society, and companies – have to act together in order to set in motion the necessary transformation. We invite the relevant communities under the roof of One Planet Thinking to implement and foster further discussions to make advancements. One Planet Thinking provides companies and governments with the tools to undertake the complex but highly urgent task of setting targets and progressing within the safe operating space of our planet.



Katinka Abbenbroek,
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EXECUTIVE SUMMARY

THE NEED FOR ONE PLANET APPROACHES

Anthropogenic impacts are threatening to undermine the continued functioning of the Earth. Through our actions, humans are encroaching upon several boundaries that may lead to planetary changes so great we refer to them as "regime shifts" (Will Steffen, Richardson, et al., 2015). Despite the many sustainability initiatives currently underway internationally, it is clear that we are failing to halt some of the more concerning global trends, including climate change and biodiversity loss. This suggests that we are not taking enough action, or not acting in the right ways, in order to sufficiently mitigate the impacts of our behavior on the environment.

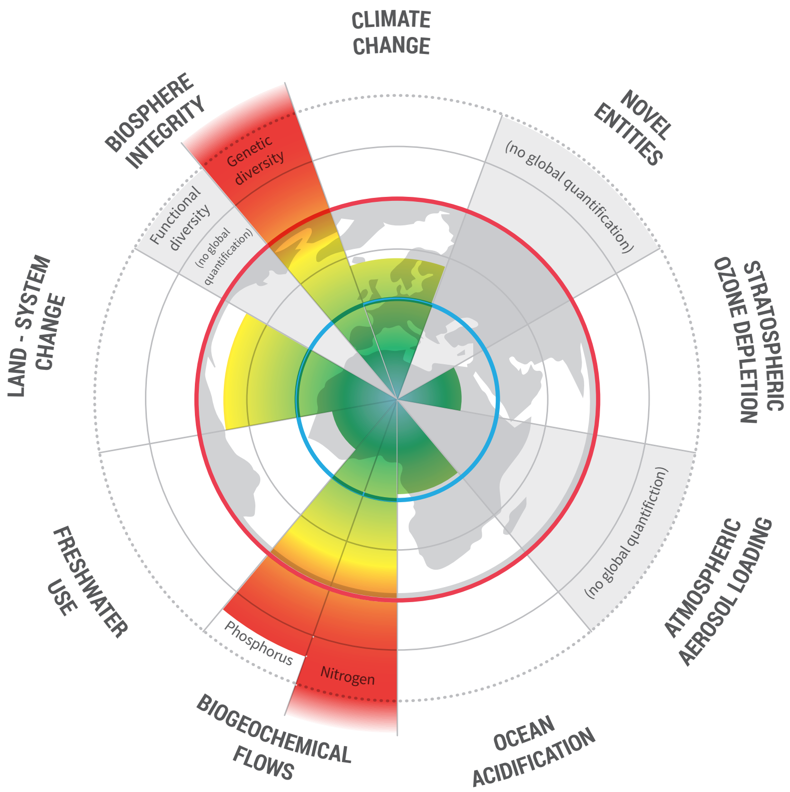
To address this problem, there is an urgent need to measure and communicate the level of individual human impact relative to larger scale planetary boundaries and systemic tipping points. Organizations and governments need to be given consistent and accurate feedback about whether the magnitude of their impact-mitigation efforts is sufficient to halt large-scale planetary change.

Since 2009, the Planetary Boundaries (PBs) framework (Rockström, Steffen, Noone, Chapin, et al., 2009) has become the most commonly used scientific framework for understanding environmental degradation relative to critical Earth system limits.

Over the last 10 years, a broad spectrum of methodologies, tools, programs, and action plans have emerged all of which, like the PBs, share the common characteristic of relating human impacts to critical planetary limits. In this report, we refer to this family of approaches as One Planet Approaches (OPAs).

One Planet Approaches are the complete family of tools, methodologies, frameworks, programs, and action plans, which recognize the need to **measure and reduce human impact in relation to the absolute boundaries of the Earth system.**

Most OPAs are at a research or theoretical level, and very few have been applied in a real-world setting. The overarching purpose of this study is to present and evaluate the current body of OPAs in order to describe the most reasonable pathways for bringing them into practice, particularly in the context of companies.



THE OPA FRAMEWORK

In our research, we reviewed over 60 One Planet Approaches, mapping them based on their attributes and functionality. Through this process, we derived an 8-step framework that describes the full set of actions needed to translate an Earth system boundary to a level that is relevant for a decision-making agent (e.g., a government or company).

Each of the 8 steps can be completed in a different way, and different approaches are better suited to different contexts; applications for companies and countries will be different. We also evaluate the strengths and weaknesses of different approaches and describe how they might best be combined for application in different contexts.

A REVIEW OF ONE PLANET APPROACHES: KEY RECOMMENDATIONS

At each of the 8 steps of our proposed OPA framework, we offer some recommendations for expansion, improvement, or pathways forward towards further development of the OPA methods currently applied.

01 DEFINING THE SUSTAINABILITY OBJECTIVE

This step encodes the rationale behind setting a boundary or defining an operating space. It asks the question, "What are we trying to protect by establishing an impact boundary?"

A majority of OPAs, including the Stockholm Resilience Centre's Planetary Boundaries, are built on a minimum viable objective of "maintaining planetary habitability for humans."

KEY RECOMMENDATIONS:

Based on our research we recommend defining a more ambitious and holistic starting objective that additionally includes:

» Regional targets to complement global ones

» Socioeconomic targets like human access to freshwater, food, and ecosystem services, as well as considerations of intergenerational equity

» Preservation of biospheric integrity as of inherent rather than utilitarian value, striving for zero biodiversity loss

» The maintenance of system resilience

Adding these criteria as part of the rationale to set the boundaries will undoubtedly make them more stringent and potentially more challenging to apply, but the resulting program will be less likely to result in insufficient action or new externalities down the line.

02 IDENTIFYING THE UNDERLYING SYSTEM PROCESSES

The second step of the OPA framework asks, "What Earth system processes are related to the defined objectives?" In other words, if our objective is planetary habitability, what systems have to be kept stable to maintain that goal?

The Planetary Boundaries framework identifies 9 key systems that need to be kept in a safe range (climate change, ocean acidification, stratospheric ozone depletion, biogeochemical flows, freshwater use, land use changes, biospheric integrity, aerosol loading in the atmosphere, and chemical pollution) to meet this objective.

KEY RECOMMENDATIONS:

We propose using modified and additional control variables at global and regional levels. These are all defined as flows that can be used for target setting and consider regional dynamics to preserve biospheric integrity. Because not all of these boundaries are adequately defined, and there are knowledge gaps in many of these areas, we recommend that companies place their greatest efforts on bringing their activities within planetary capacity for the boundaries that are already most transgressed (with a particular emphasis on biospheric integrity).

03 MAPPING THE RELEVANT SYSTEM DYNAMICS

Once the relevant system processes are identified, we must map out how changes in key control variables (e.g., concentrations of atmospheric carbon) impact the functioning of the system.

KEY RECOMMENDATIONS:

Many gaps remain in our understanding of Earth system dynamics, and this is an active field of research, where current trends include the inclusion of social-ecological systems and moving towards regionalized system modeling (see Table 7 for an overview of main knowledge gaps for different Earth system processes).

04 DEFINING BOUNDARIES OR OPERATING SPACE

To define a "safe operating space," or stable range for any of the key systems that have been identified, we need to understand the location of tipping points within the system. A tipping point has been crossed when a system enters a significantly different state as a result of a small alteration. Well-known tipping elements in the climate system include the Greenland ice sheet and the Atlantic thermohaline circulation. A climate change boundary of 2º C was set by the United Nations and the International Panel on Climate Change to avoid triggering these elements.

KEY RECOMMENDATIONS:

Through our review, we note that one of the more significant shortcomings of current OPAs is the lack of sufficient knowledge on tipping points, and the lack of adequate methods to consistently and accurately identify them: this is an essential continued scientific agenda point. Our recommendations for boundary setting within OPAs include:

» Because setting a boundary implies defining a level of socially acceptable risk, we recommend that boundary setting processes include appropriate social consultations.

» Boundaries should be set at both global and regional levels. Additional impact areas roughly in line with the categories selected in current Life Cycle Assessment frameworks are particularly relevant to regional system stability (e.g., biomass extraction, soil acidification, ecotoxicity). If multiple boundaries are set for one system (a global and a regional boundary), then the stricter of the two boundaries should generally be applied.

» The dynamic nature of the boundaries should be taken into account, with some boundaries requiring reassessment at more frequent intervals than others. For example, regional water boundaries may need to be reassessed multiple times per year to account for shifts in local rainfall and water demand. Ideally, we should develop a central database to monitor the state of all system boundaries across the world, to put an agent's impact into the context of carrying capacity.

» To make the boundaries actionable, they must also be expressed in terms of flows or stocks – units that can be quantified and linked to an agent's activities. Many of the Planetary Boundaries are expressed in terms of states (for example, parts per million of CO_2 in the atmosphere), where actors need to understand directly how much CO_2 they can emit over time.

We recommend the development of an online central platform that serves as a "system boundary" database. This database would monitor and report boundary positions (and available operating space) in a geo-referenced and disaggregated manner for all impact categories, at the adequate regional levels. A first step towards this platform would be geographically defining the regional boundaries for all impact categories, a process that is already underway for some systems. For example, information for water basins is readily available.

05 DETERMINING THE EXTENT OF THE AGENT'S ACTIVITIES

Now that the boundaries have been defined, we need to start understanding how the behavior of target agents (like companies or governments) impinges upon these boundaries.

KEY RECOMMENDATIONS

In the context of implementing OPAs for companies, it is critical to consider impacts across the whole supply chain, all over the world, and not only those that are bound to a specific territory. Thus, data must ideally be collected at each of the points where activities take place along the global chain.

06 QUANTIFYING THE FLOWS ATTRIBUTED TO THE AGENT'S ACTIVITIES

In this step, we inventorize all the flows related to a company's activities, including its supply chains and the end of life of its products.

KEY RECOMMENDATIONS

Trade and statistical information can help to complement data gaps in supply chain information. Different tools and initiatives are already under development to facilitate this process, but this is an area where action is needed. In the meantime, companies should increase their efforts to collect reliable and georeferenced data for their products' life cycle.

07 ASSESSING THE IMPACT ON THE OPERATING SPACE

This information can then be translated to actual environmental impact. Most approaches use databases from LCA and/or Footprint accounting methodologies to this end. However, the same environmental pressure will have different impacts in different contexts. To account for this, LCA databases need to be regionalized and consider the actual operating available in each area.

KEY RECOMMENDATIONS

The development of regionalized LCA frameworks can be an important tool in this regard, but in an ideal state companies would have access to the equivalent of a dynamic impact dashboard that would show close to real-time transgression of boundaries in different geographic contexts along their supply chains.

We recommend the development of such a dashboard, connecting to the boundaries database described before. This tool should serve, in particular, to avoid burden shifting between different regions and/or impact categories and would contextualize the agent's impacts to the operating space available at each region of activities. The dashboard would show in a glimpse a company's contribution to each impact category, guiding attention to the most transgressed boundaries and comparing the company's impact intensity to that of best practices in the sector.

08 SELECTING AN ALLOCATION PRINCIPLE

The final step of operationalizing any One Planet Approach is translating how much of the available safe operating space can be used by a given actor. All methodologies choose a principle upon which to base the allocation of operating space:

» Egalitarian approaches aim at allocating an equal share of impact allowance or of access to life quality to every person on the planet or in a region.

» Approaches based on economic throughput use measures such as GDP or production volume as proxies of value, and allocate budgets based on them.

» Approaches based on economic capacity and efficiency result in differentiated allocations depending on the capacity to mitigate impacts or aim at achieving an economically optimal allocation.

» Finally, historical approaches such as the polluter pays principle and the grandfathering principle, take into account responsibility for previous impacts or the need for a continuous access to resources.

KEY RECOMMENDATIONS

Allocation remains a technically and ethically challenging endeavor. The socially ideal principle of egalitarianism is currently impossible to implement in the company context. Considering all feasible alternatives, the best way forward is for companies to establish impact ceilings based on demand trends, sectoral performance and best practices, and costs of impact abatement. The development of these impact ceilings and target setting approaches should ideally be completed under the stewardship of civil society organizations.

For many impacts (e.g., biodiversity loss, nitrogen emissions, the emissions of novel entities), we should ultimately be striving for net positive or no-net loss impact rather than setting targets for "allowable impact." In many cases, technological advancements and alternative system designs should feasibly allow for a near complete elimination of impact (as has occurred to a large extent with Ozone Depleting Substances), though the cost of technological development and switching will certainly play a significant role in the speed of these potential transitions.

Moreover, we recommend the development of a Code of Behavior for One Planet Companies, which would provide decision-making guidance for creating structural shifts towards sustainability (e.g., engaging with underperforming suppliers to encourage improvement rather than simply switching to lower-impact options).

In the long term, we need decentralized allocation mechanisms: market based solutions that internalize costs and provide full information transparently, in combination with redistribution mechanisms to guarantee equal access or life quality to all people, regardless of their actual income. This requires a long-term commitment from governments and society and extensive research and piloting, but we need to start moving in this direction.

NEXT STEPS AND PRACTICAL APPLICATIONS

There are a number of actions and knowledge gaps that need to be taken care of by multiple stakeholders to implement OPAs at the necessary scale.

Companies wishing to implement One Planet Approaches can take immediate action by:

» Joining and supporting initiatives based on OPA philosophies, such as the Science Based Targets Initiative for setting greenhouse emissions goals or the Natural Capital Protocol to aid in decision-making; supporting the development of Context-Based Water Stewardship and similar projects.

» Developing data collection and management capacity by building out corporate data collection programs. Companies should pay particular attention to collecting spatially and contextually relevant data.

» Identifying impact hotspots and priority actions within supply chains. These high impact areas should be related to known global or regional boundary transgressions so that companies can set goals in the highest areas of priority for their particular operations. This hotspot analysis can be done based on a materiality check.

» Explicitly incorporate a One Planet mindset in corporate goal-setting and communications. Even if targets cannot be set relative to specific boundaries.

Governments need to embed this process into development strategies and structurally support the development of One Planet Approaches:

» Supporting the boundary setting process in a socially fair and inclusive way:
- Formalizing and quantifying social access to commons and basic resources
- Hosting dialogues between science and policy

» Leading efforts towards economically efficient impact abatement
- Considering and testing economic instruments – including taxes and trading schemes – at small schemes to gather lessons for future implementation

» Supporting companies and scientists implementing OPA
- Supporting research with statistical information and territorial mapping
- As possible, encouraging these measures through financial or other incentives

» Starting national implementations (a parallel process to the private-sector led initiative)

The research community provides the knowledge base on which OPAs are built, as such scientists can play a role in:

» Expanding our knowledge of the Earth system, in particular:
- Defining regionalization maps - the spatial limits in which to assess boundaries for all regional impact systems
- Focusing on biodiversity loss and habitat loss and degradation, which haven't been addressed as much as other impact categories in the context of boundary setting studies
- Engaging the social dimensions of the Earth system and finding ways to include socioeconomic factors into the biophysical models
- Developing impact accounting methods that take into account planetary capacity, such as the LCAbsolute initiative

» Developing systems to continuously monitor the state of the planet with relation to these issues.

Civil Society Organizations, like the WWF and IUCN, have a central role protecting the ambitious spirit of One Planet Approaches by:

» Serving as mission keepers:
- Challenging sustainability objectives to more than habitable levels: zero level biodiversity loss, zero-impact targets, etc.
- Defending the rights of the biosphere, future generations, and unrepresented minorities in allocation exercises

» Serving as agenda setters in OPA development:
- Ideating ways to adapt and bring OPA to the primary sector (agriculture, raw material extraction)
- Identifying and focusing on impact hotspots in terms of geography, supply chain, and sector

» Supporting implementation and decision making:
- Developing the One Planet Code of Behavior or similar decision-making sets of principles.
- Developing tools for widespread implementation of OPA: OP boundaries database, impact dashboard, feasibility studies

Regardless of the remaining challenges with the practical implementation of OPAs, it is certain that they are already having a catalyzing effect on moving towards more sustainable practices through the narratives that they elicit. With proper design and further development, OPAs will be a critical tool in identifying priorities in our progression towards a genuinely sustainable future.

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01 INTRODUCTION

INTRODUCTION

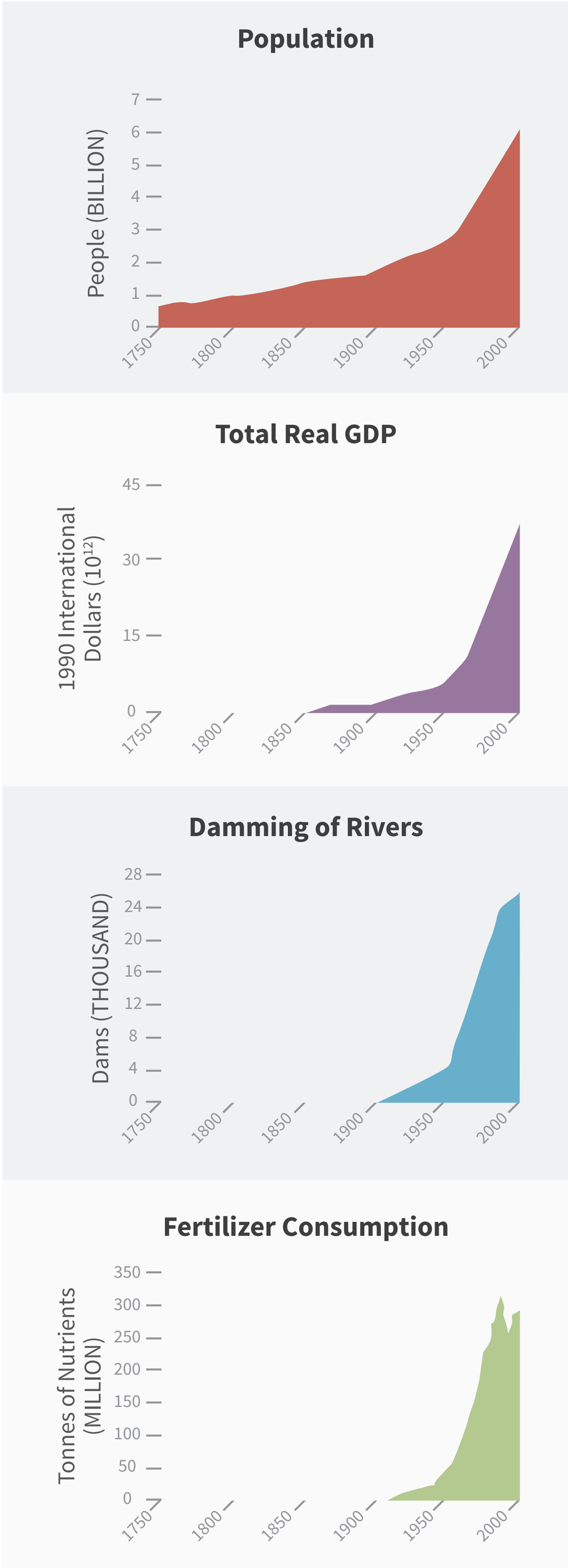
Modern humans have existed for roughly 200,000 years. The geological epoch known as the Holocene began roughly 11,700 years ago (Walker et al., 2012), marking a period of relative warmth and stability that enabled rapid human development. The global human population, which until that point had never exceeded around one million individuals, suddenly began growing exponentially as we invented agriculture, introduced the widespread domestication of animals, and later developed industrial systems, which significantly expanded our capacity to extract planetary resources and transform them into goods (Scarre, 2005).

In the 1950s, the world entered a period of perceptible ecological turmoil. Almost all parameters that matter for human or ecological well-being began to show exponential modification in problematic directions: atmospheric greenhouse gas concentrations, ocean acidification, land use, ozone depletion, fisheries exploitation, biodiversity loss, and resource extraction (see Figure 1). As one of many concerning outcomes of this disruption, between 1970 and 2012, biodiversity has fallen by a staggering 58%, as measured by the Living Planet Index (WWF International, 2016).

The period from the 1950s onward is sometimes referred to as the Great Acceleration (Steffen, Broadgate, Deutsch, Gaffney, & Ludwig, 2015). Through our activities, humans are effectively pushing many key Earth system processes outside of the Holocene range, leading many scientists to claim that we have entered a new planetary epoch: the Anthropocene (Steffen et al., 2004).

The global scientific community is now in broad agreement that anthropogenic impacts are threatening to undermine the continued functioning of the Earth system by encroaching upon several Earth system processes that may lead to planetary changes so great we refer to them as regime shifts (Steffen, Richardson, et al., 2015). In 2012, as an output of the Planet Under Pressure conference, the attending group of 3,000 leading scientists released a State of the Planet declaration (Brito & Smith, 2012), calling for immediate action and policy reform, stating: “As consumption accelerates everywhere and world population rises, it is no longer sufficient to work towards a distant ideal of sustainable development. Global sustainability must become a foundation of society (…). The defining challenge of our age is to safeguard Earth’s natural processes to ensure the wellbeing of civilization while eradicating poverty, reducing conflict over resources, and supporting human and ecosystem health.”

Figure 1: The Great Acceleration



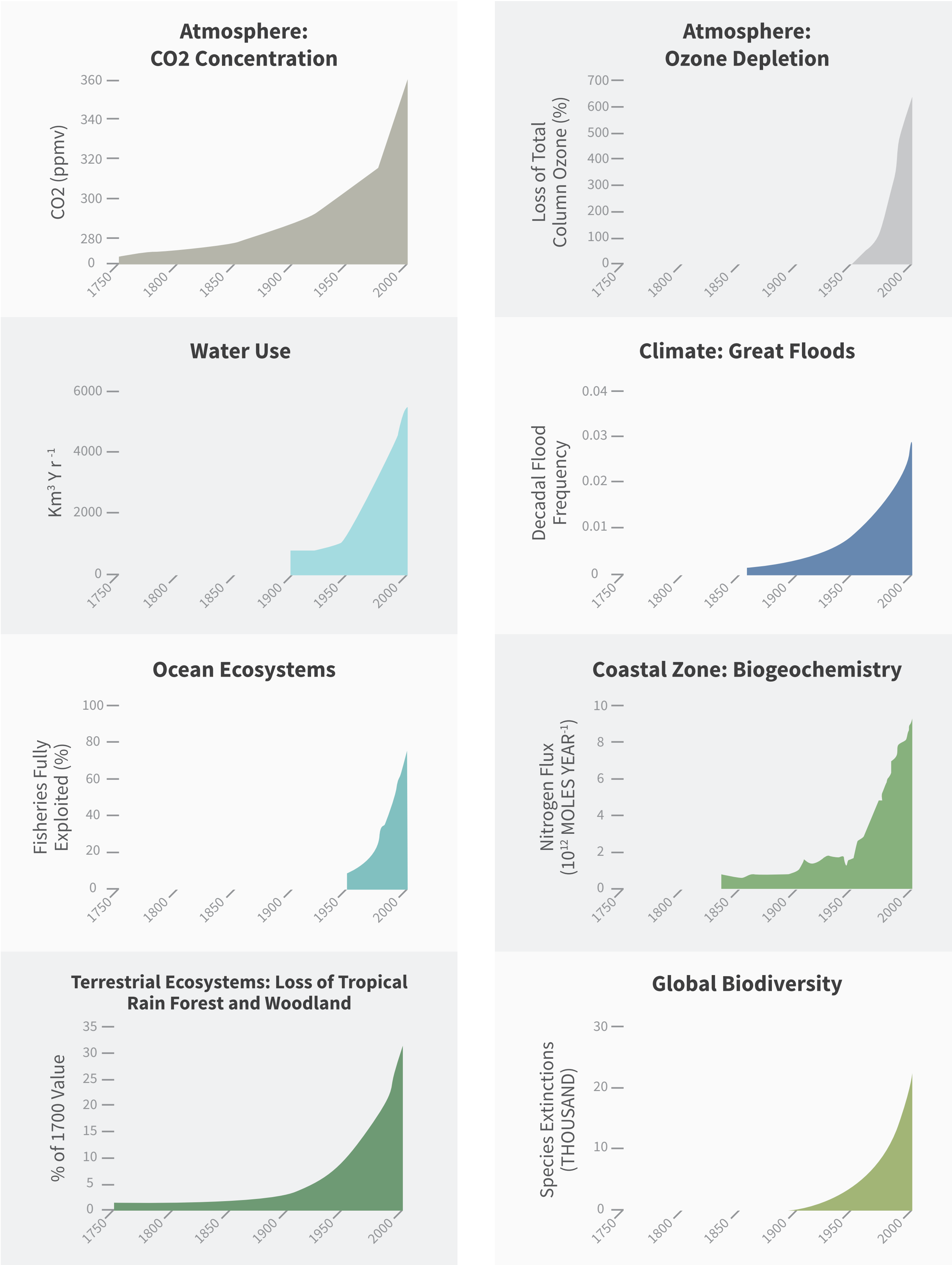


Figure 1. *Since the 1950s, most of the parameters relevant for human or ecosystem well-being began to show modification at a scale significant enough to disrupt the stability of the Earth system. Source: Speth (2009).*

1.1 THE NEED FOR A ONE PLANET APPROACH

Humanity has indeed mounted a response to these problems. Among decision-makers in both the public and private sectors, the urgency of shifting the pattern of human activities onto a more sustainable path is broadly accepted and has been actively integrated into both national policies and Corporate Social Responsibility (CSR) plans. Organizations and governments have launched many sustainability initiatives around the world, with many success stories. Society at large is also undergoing a progressive shift in consciousness with regards to environmental awareness. However, given the magnitude of the risks we face, and our continued failure to stop two concerning global trends in particular, climate change and biodiversity loss, the question arises of whether we are doing enough. Global population is expected to reach 9.7 billion by 2050 and 11.2 billion in 2100, from an estimated 7.5 billion today, and, with economic growth, will translate to additional pressures on the environment (United Nations, 2015).

ECO-ECONOMIC DECOUPLING: THE LEADING STRATEGY

A strategy that has defined approaches to environmental impact reduction in both public and private sectors is that of eco-economic decoupling. Decoupling is defined as a reduction of resource throughput and environmental impact per unit of economic activity, typically measured as GDP. The generation of revenue is intricately tied to the extraction and use of resources. For every product made, resources are extracted, processed, and transported. This necessarily requires physical changes to the world, which are associated with different kinds of impacts. Decoupling involves delivering the same amount of value for a much lower amount of resource use and, subsequently, lower impacts on the environment. The concept of decoupling has held broad appeal for businesses and policymakers alike, because it creates a theoretical pathway where sustainability and economic growth can safely coexist.

In 2007, the United Nations Environment Programme (UNEP) established the International Resource Panel (IRP), one of whose explicit core objectives is to provide policy advice and scientific assessments geared at accelerating decoupling (UNEP, 2014[1]). Decoupling also featured prominently as a goal of both the Sixth and Seventh Environment Action Programmes of the European Community[2] and was cited as a key issue in the deliberations that led to the development of the Sustainable Development Goals (SDGs). Decoupling is relevant for most SDGs but explicitly mentioned in SDG target 8.4 and strongly related to SDG 12 (Ensure sustainable consumption and production patterns).

With sustainability efforts squarely on corporate agendas for around two decades now, and decoupling measures in the policy world for almost as long, we can start to take stock in terms of the success this approach is delivering.

Every economy in the world can be assessed on its "resource intensity" or "impact intensity," which gives a broad sense of that economy's efficiency. For example, global carbon intensity amounted to around 1 kg of CO_2 emitted per US dollar in 1980, and only 770 g in 2006 (Jackson, 2009[3]). Despite the reduction of CO_2 emissions per dollar, the total amount of emissions of CO_2 has clearly continued to grow overall; our absolute emissions have increased in that same time period by 40%.

There are two kinds of decoupling: relative and absolute (see Figure 2 for an illustration of these concepts). What we have observed with global CO_2 emissions is an example of relative decoupling. Even though efficiency has improved in many areas of the global economy, CO_2 emissions have continued to grow because the economy continues to grow faster than the rate of resource efficiency gains. The result is that we are still emitting a lot more CO_2 into the atmosphere than we were in 1980 and we have a much larger economy as measured by GDP. What we would need to achieve, however, is absolute decoupling, in which impact and resource intensity actually fall in absolute terms while economic growth continues.

Globally, there have been mixed results with regards to decoupling objectives. One study of China's eco-efficiency efforts between 1978 and 2010 found relative decoupling for resource utilization, energy consumption, and emissions for air and water. But between 2001 and 2010, decoupling stopped. Resource utilization was nearly coupled with GDP growth due to increased consumption and a dramatic rise in mineral extraction (Yu, 2013). Decoupling in the EU has been primarily relative, with only a few instances of absolute decoupling, notably the emissions of acidifying gases and tropospheric ozone (smog) precursors (Jackson, 2009[4]).

[1]There are many good arguments to be made regarding the fact that the current economic growth model is not per se necessary for addressing humanitarian development objectives, and that it may in fact be incompatible with a sustainable future. However, this extended discussion is beyond the scope of this report.
[2]These programs included explicit objectives "to achieve a decoupling of resource use from economic growth, through significantly improved resource efficiency, dematerialization of the economy and waste prevention."
[3]"Improve progressively through 2030 global resource efficiency in consumption and production, and endeavor to decouple economic growth from environmental degradation in accordance with the 10-year framework of programs on sustainable consumption and production with developed countries taking the lead."

Figure 2: Relative and Absolute Decoupling

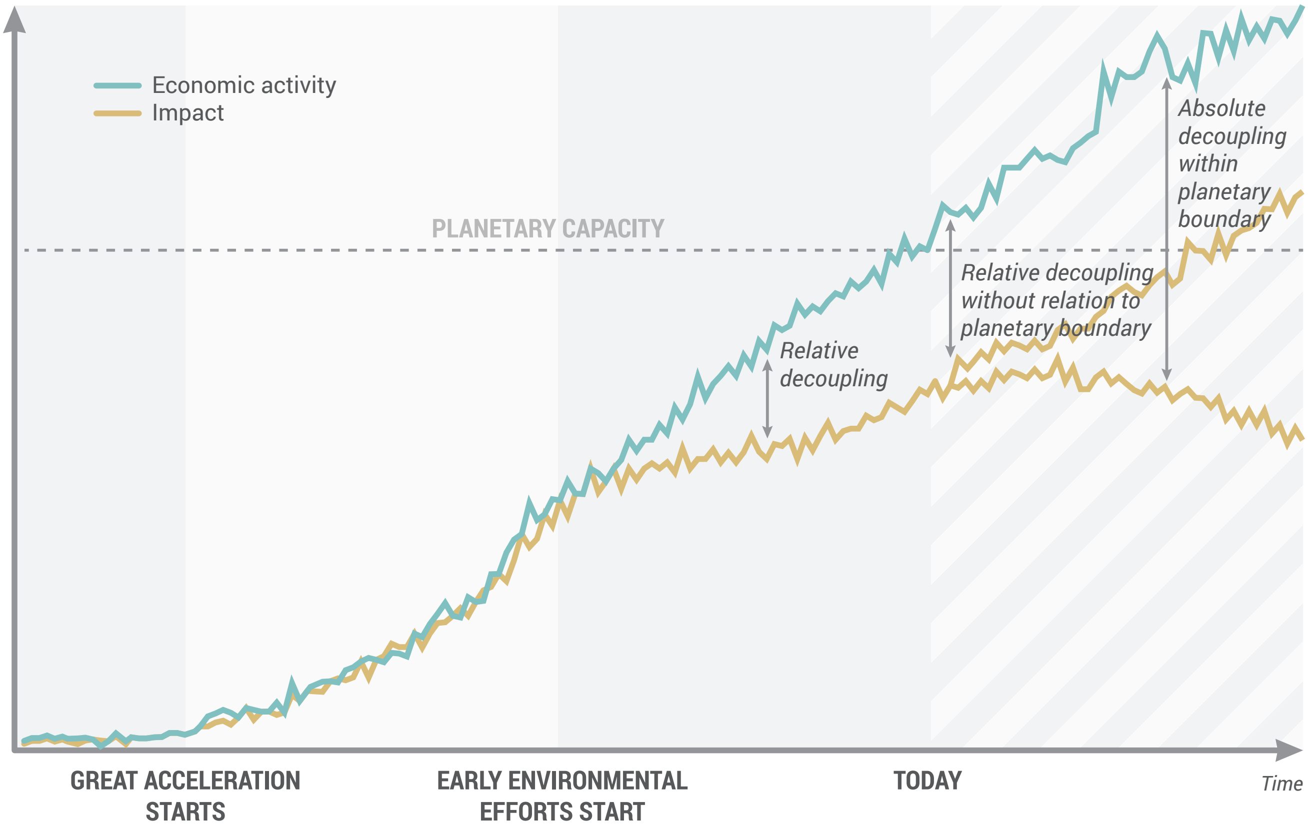


Figure 2. *This image hypothetical illustrates how environmental impact can decrease relative to economic activity (relative decoupling), while still crossing planetary boundaries. What we need to achieve is an absolute decrease in impact despite changes in economic throughput (absolute decoupling) in order to avoid crossing planetary boundaries.*

But the targets for decoupling set out in the 7th European Environmental Action Program (EAP) have not been met. Moreover, a great deal of the decoupling seen was further offset by rebound effects, defined as increases in consumption as a result of gains in efficiency. It is still uncertain to what extent, within Europe at least, observed decoupling has resulted from outsourcing industrial production to countries outside of the EU. When that is factored in, the relative decoupling that has been observed may actually be completely eliminated.

In short, though the theoretical potential for decoupling is enormous, in practice, the results have been far from sufficient, despite significant efforts and investments.

THE NEED FOR AN ABSOLUTE IMPACT FRAMEWORK

There are many reasons that we can point to for which decoupling as a strategy has not been delivering the magnitude of results that we need to see on a global scale. While assessing and evaluating all the likely causes is beyond the scope of this report, our main focus is on addressing one of the drivers of this underperformance: the lack of a measurement framework in relation to planetary capacity for evaluating anthropogenic impacts on the planet.

A significant gap exists between the macro-scale understanding of the state of the world (e.g., rapid declines in biodiversity) and a means of translating this knowledge into concrete actions and constraints for societal actors like companies or governments (e.g., procurement guidelines for products or the development of new policies). Most of the sustainability metrics in use today, such as the commonly applied “Environmental, Social, Governance” (ESG) framework used in evaluating businesses, effectively indicate relative levels of performance. Using these, a company can understand whether it is doing well relative to its peers or its own performance in the past.

However, none of the commonly used ESG indicators successfully evaluates how well a company is doing in relation to absolute global constraints. Moreover, how can we assess the performance of individual problems in this context?

In the end, it does not matter if a company or nation is performing ten times better than its peers if this still means that it is contributing to the gross transgression of a critical environmental limit, for instance, in terms of global greenhouse gas emissions or regional freshwater depletion. Through this lens we can begin to understand how many of the apparent successes within environmental policy and eco-innovation could have collectively fallen short of the mark: we have lacked the correct metrics to evaluate progress or to guide decision-making towards the most systemically impactful places for intervening in the global economy.

PLANETARY BOUNDARIES AND THE HISTORY OF ONE PLANET APPROACHES

The need to measure and communicate the level of individual human impacts relative to absolute boundaries and systemic tipping points has a long history. The idea that we are living on a finite planet that will eventually reach limits in terms of resource provision can be traced back to Thomas Robert Malthus, who in his 1798 An Essay on the Principle of Population first raised these kinds of concerns regarding the global food supply. However, it is not until the 1950s that scientific frameworks for relating environmental degradation to critical system limits began to appear in greater number. Some of the most prominent frameworks include: safe minimum standards (Crowards, 1998), limits to growth (Meadows, Meadows, Randers, & Behrens, 1972), critical loads (UNECE, 1979), carrying capacity (Daily & Ehrlich, 1992), and tolerable windows or guardrails (Bruckner, Petschel-Held, Leimbach, & Toth, 2003; Petschel-Held, Schellnhuber, Bruckner, Tóth, & Hasselmann, 1999). The Planetary Boundaries (PBs) framework, introduced by the Stockholm Resilience Centre (SRC) in 2009, is currently the most broadly studied and utilized, and therefore plays a central role in the discussions of these methodologies throughout this report (Rockström, Steffen, Noone, Lambin, et al., 2009; Steffen, Richardson, et al., 2015).

The PB framework identifies nine key Earth systems that need to be kept stable in order to keep the biosphere functioning so the planet remains habitable for civilization as we know it. For seven of these systems, an attempt has been made to define “boundaries” that represent the amount of change each of these parameters can absorb without hitting an unsafe and destabilizing level. Out of the nine boundaries identified, SRC has estimated that we have already transgressed four: climate change, biodiversity loss, both phosphorus and nitrogen biogeochemical flows, and land system change.

This framework was developed by a multidisciplinary effort led by the Earth sciences community and originally to serve as a tool to advance and coordinate the scientific understanding of the Earth system - particularly regarding its higher level stability and resilience. It was not purposed to be a policy instrument. Nevertheless, the framework has been extremely influential in global agenda setting (for example, in the development of the SDGs) and is now inspiring national policy making. Indeed, while the framework is conceptually compelling, in practice, the Planetary Boundaries remain difficult to define and measure - and thus difficult to implement directly in policy making or sustainability strategies. There is a lack of scientific knowledge about the exact nature of biophysical thresholds, what kinds of impacts are likely to cross these thresholds, or how the many complex processes within the Earth system interact through processes such as feedback mechanisms (Rockström, Steffen, Noone, Lambin, et al., 2009).

Since its publication, the PB framework has become a focal point of study in the global research community, with various groups focusing on improving methods for the assessment of individual boundaries, suggesting additional Earth system processes that should be included in the framework, considering the temporal and spatial variations of the processes included, and developing new approaches for understanding the interactions between different Earth system processes.

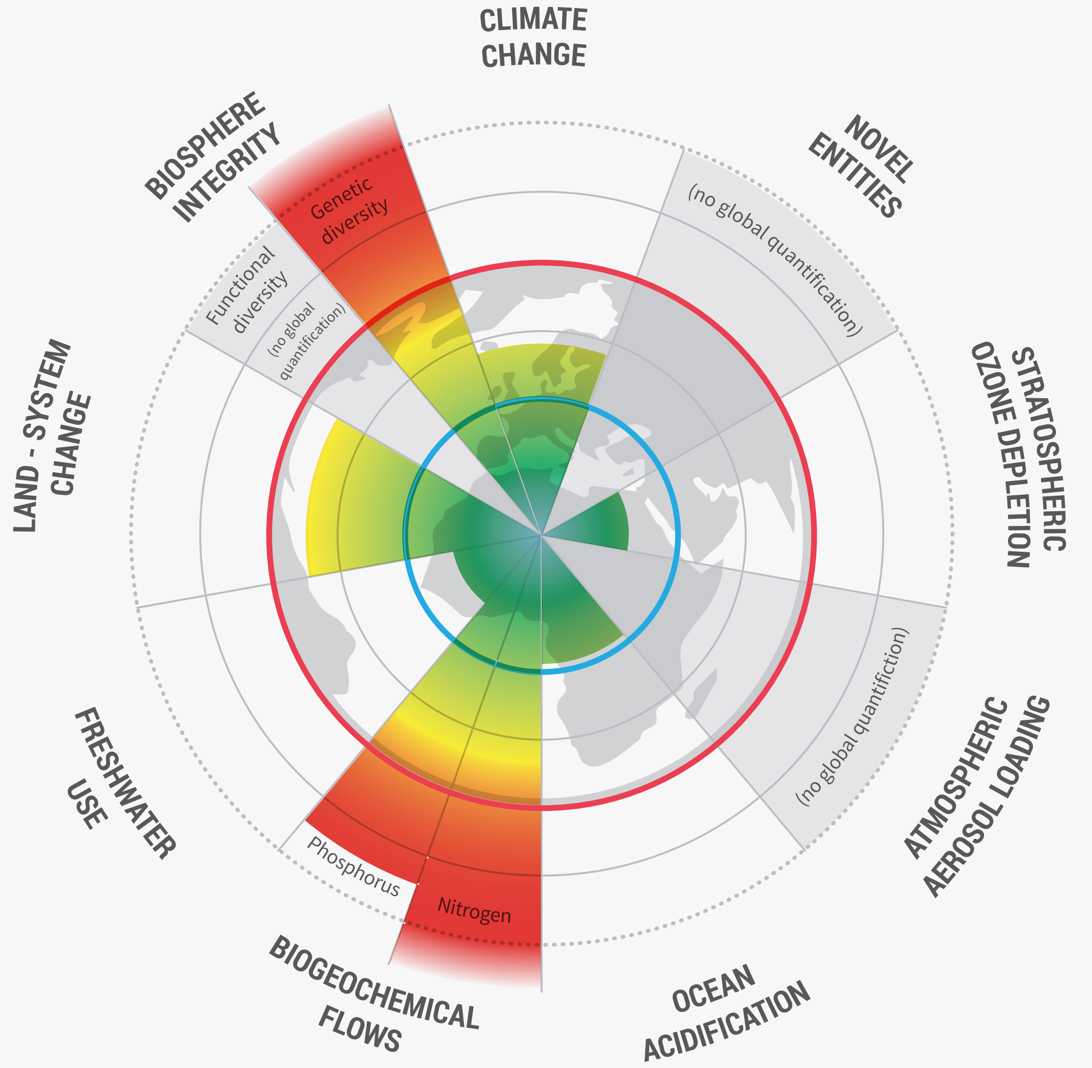
The Planetary Boundaries have also become an important topic in global policy discourse, where they have recognizably impacted the UN 2030 Agenda for Sustainable Development. The SDGs integrate the concept of a biophysically safe operating space as a core component of sustainable development.

To a lesser extent, the PBs have started to become an explicit discussion point in the development of corporate sustainability strategies. At present, around 5% of companies refer to ecological limits or PBs in the development of their CSR strategies, although most of this have yet to actually base their sustainability targets on these limits (Bjørn, Bey, Georg, Røpke, & Zwicky, 2016).

The corporate focus on planetary limits has been most notable with regards to the discussion around climate change impacts. For example, the Science Based Targets initiative, a joint development between CDP, UN Global Compact, WRI, and WWF, focuses on giving companies the tools to set carbon reduction goals that will be sufficient to keep the global economy on track to avoid 2ºC of average global temperature increase (one of the PBs). Another example is WWF’s One Planet Thinking program, which aims to bring the impacts of companies more broadly within the range of the Planetary Boundaries, for areas including and beyond carbon emissions.

Over the last decade, this active field of research and practice has resulted in a broad spectrum of methodologies, frameworks, tools, programs, and action plans, all of which share the common characteristic of recognizing the need for human activities to respect absolute boundaries within the Earth’s system. In this report, we refer to this family of approaches as One Planet Approaches (OPA).

Figure 3: The Planetary Boundaries Framework



Beyond zone of uncertainty (high risk)
In zone of uncertainty (increasing risk)
Below boundary (safe)
Boundary not yet quantified

Source: *Steffen et al. Planetary Boundaries: Guiding human development on a changing planet, Science, 16 January 2015.*
Design: *Globaia*

Figure 3. *Image from Steffen et al. Planetary Boundaries: Guiding human development on a changing planet. Science 16 January 2015. Design by Globaria. This illustration depicts the 9 "wedges" of the Planetary Boundaries defined by the Stockholm Resilience Centre and the degree to which each of them has been transgressed.*

1.2 OPERATIONALIZING THE ONE PLANET APPROACHES

The overarching purpose of this study is to present and evaluate the current body of OPAs in order to describe the most reasonable pathways for bringing them into practice, particularly in the context of companies.

Based on a mapping exercise and review of existing OPAs, we have characterized a sequence of eight steps, the OPA Framework, that describe the complete series of actions that any One Planet Approach should cover in order to effectively characterize and translate of a planetary boundary to a level that is applicable to a target actor (i.e., national government, company, individual, etc.).

Through this project, we have considered the relative advantages and disadvantages of the various OPAs and described the range of existing gaps and uncertainties that still stand in the way of practical implementation. We have also conferred with leading researchers and practitioners in the field to verify our findings and gain additional insights with regards to the current priorities.

There are many types of methods, tools, and ethical frameworks that can be used at each of the eight OPA steps that we have identified, allowing for a multitude of choices. Moreover, because of their varied characteristics, the different Earth system processes cannot all be evaluated using the same sequence of steps. For instance, carbon emissions will contribute equally to impacting the global atmospheric concentrations of CO_2, regardless of where they are emitted. On the other hand, the impacts associated with the withdrawal of freshwater are highly dependent on the location and time of its extraction. This ultimately means that multiple methods need to be used in combination in order to develop an “ideal” OPA that will be able to robustly address the original objective. We discuss how current methodologies can potentially be used in combination to achieve this outcome.

It is important to note that on the basis of our conversations with OPA experts, there is a consensus that there remain a number of fundamental challenges to successfully develop and implement OPAs in practice. Most notably, we face serious limits in our knowledge of global system dynamics. It is an enormous challenge to identify and model the interactions between Earth system processes, as many of these are nonlinear and operate at different, overlapping scales (often at smaller scales than the global level). Few methods exist to predict the location and triggers of systemic tipping points, and most are far from robust. The question remains: can we genuinely model the planet to a level of sufficient accuracy to be able to define boundaries or assess how these will be impacted through human behavior? Fragmenting the system into subsystems provides can simplify the modeling process, but at the expense of capturing the nature of the system as a whole.

In addition to exploring related technical challenges, throughout this study we also discuss the ethical questions that inevitably arise when considering practical applications of the OPAs. Assuming that we have correctly defined critical boundaries for key Earth systems, the final, critical step in translating these boundaries into functional use is the allocation of “impact allowances” of some form to different societal stakeholders. It is inherently challenging to determine a fair mechanism for distributing scarce resources among a global population. Indeed, the allocation process for carbon emissions rights has been a central difficulty throughout the lengthy, and often ineffective, global climate negotiation process that has unfolded over the last decades. Top-down methods of allocating rights to impact, as in the form of budgets, may not be the ultimate pathway forward for the successful deployment of OPAs in practice.

A final, more philosophical consideration is that all of the One Planet Approaches examined, including the PBs, take a strictly anthropocentric and utilitarian objective as their starting point. The ultimate goal that dictates the level at which “safe” planetary boundaries are set is exclusively concerned with maintaining the planet’s utility and habitability for humanity. As practitioners, we need to question whether this conception of nature should be our guiding principle and consider the implications of this decision. Setting the boundary for biodiversity loss at the minimal theoretical level to ensure human survival implies the acceptance of a great deal of additional species loss.

Regardless of the remaining challenges with the practical implementation of OPAs, it is certain that these approaches are already having a catalyzing effect triggering shifts towards more sustainable practices, simply through the narratives that they elicit. With proper design and further development, OPAs will be a critical tool in identifying priorities in our progression towards a genuinely sustainable future. In this study, we hope to shed light on the aspects of OPAs that can already be put into practice and sketch the likely development pathway that lies ahead.

02 MAPPING ONE PLANET APPROACHES

MAPPING ONE PLANET APPROACHES

In our research, we reviewed 58 different One Planet Approaches, mapping them based on their attributes and functionality. Through this process, we derived an 8-step framework that describes the full set of actions needed to translate an Earth system boundary to a level that is relevant for a decision-making agent (e.g., a government or company). For an illustration of the framework, see Figure 4.

In this chapter, we walk through these eight steps in the OPA framework, drawing on examples from existing approaches. These examples illustrate how different groups have addressed the questions and uncertainties at each step of the process. The chapter is structured along the 8 steps, calling out the main types of solutions used at each step as applied in the OPAs we reviewed.

Unfortunately, a direct comparison or selection of a "best approach" is impossible due to the different sustainability objectives and contexts in which the OPAs are used, their selection of different ethical principles, and the fact that most approaches focus only on some steps of the process. By mapping OPAs developed in business and academia, and examining their relative strengths and weaknesses on different points, we can see opportunities for how these different approaches can potentially be integrated for a stronger result or tailored to different applications (i.e., land use boundaries versus ozone depletion boundaries).

This chapter is primarily descriptive, exploring the palette of options for assembling an OPA. In Chapter 3, we delve into a discussion of these results and suggest priorities for further OPA development and pathways to practical implementation.

AN 8-STEP FRAMEWORK FOR OPERATIONALIZING ONE PLANET APPROACHES

The Planetary Boundaries, on which most OPA frameworks are based, are, in principle, set at the global scale. Even if boundaries are to be defined at a less aggregated, regional-level, the scale of what we are assessing is very large (a region or the whole planet). In contrast, human decision-making, which is the source of impacts, occurs at much smaller scales. National governments make decisions about national policy, businesses make decisions about production practices and product design, and citizens make decisions about what to consume and how to behave.

CHALLENGES THAT OPAS MUST ADDRESS

To connect the high-level, aggregated impacts at the basis of OPAs with the relevant scales for decision-making, there must be some manner of relating the behavior of individual actors accurately and consistently to the larger scale effects of concern evaluated by the global framework. This translational challenge is at the heart of the complexity of developing an operational OPA framework, and requires adequately solving a number of key problems.

First, we must identify the Earth system processes that are critical to maintaining the biophysical integrity of our planet. The PB framework has selected nine such processes, but it is possible that other systems could also be included. We must also have enough knowledge about these Earth systems in order to confidently set a "safe" boundary that will prevent any critical destabilization from occurring in these key processes.

Secondly, we must understand how the underlying dynamics of each system work in sufficient detail that we are able to correctly predict how certain impacts will affect these critical Earth processes. What are the effects of releasing man-made chemicals into the environment? How might these influence ecosystem health, and in turn, what impact could this have on global nitrogen cycling (for example, by changing the makeup of soil ecosystems)? There is an uncountable number of interactions that need to be accounted for to, at the very least, understand the macro-level dynamics of the systems' behavior.

Once we understand these interactions, we are able to identify which human activities are likely to influence these, and in what way. We must then define adequate methods for measuring the scale of impact associated with each human activity, and assessing its severity relative to the end boundary. This way we can map the relationship between individual human activities and system level boundaries.

Ultimately, to make OPAs operational, we must develop tools of some sort that will give actors – whether they are governments, companies, or individual consumers – a point of reference for understanding whether the impacts they are causing through their resource consumption and behavior are "reasonable" (i.e., how much of my carbon allowance should I be spending on the clothing I buy each year?). In an egalitarian interpretation of the term, "reasonable" refers to whether an individual's behavior, if applied at an equal level by all people, would still keep us in the "safe operating space" that has been defined by the systemic boundaries.

THE 8-STEP FRAMEWORK

Academics, practitioners, and businesses have developed many ways to solve these problems, adapting existing tools from other disciplines, considering different goals, and selecting a range of ethical principles and priorities for determining how the "safe operating space" should be distributed among actors. Some approaches rely on LCA databases while others use dynamic system models. Some methods strive for economic optimization while others prioritize social egalitarianism. Different OPAs also focus on different actor groups: some translate global capacity to the level of individual, while others focus on national or company levels.

Through this study, we have seen that, despite the variability among OPAs, they must all follow a common sequence of steps in order to implement a One Planet Approach at the agent level. It is on the basis of these commonalities that we have defined the 8-step framework described here. Very few of the OPAs that we have reviewed follow the entire process we describe. Rather, most focus on a subsection of the steps. However, in order to resolve the challenges identified above, and, indeed, to implement a notion of "sufficient individual action to remain within planetary capacity at the aggregated level," the entire process is required.

The first of the eight steps involves defining the objective of the boundary-setting process: what are the underlying goals that we are aiming to uphold by setting a boundary? In most currently defined OPAs, the primary underlying goal is to maintain the planet in a habitable state for humanity, though, as we discussed, it is possible to select broader goals. This choice of objective critically informs the next three steps in the framework, which involve identifying and mapping the system processes that relate to the end goal (steps 2 and 3) and, finally, defining the "boundary" that should not be crossed (step 4) in order to successfully uphold the original objective (e.g., maintaining the planet in habitable state). For example, international climate change mitigation efforts consider a boundary of 2°C of global average temperature increase before the climate system becomes unacceptably volatile and dangerous for society.

The next three steps in the framework focus on identifying and quantifying the impacts resulting from the behavior of a particular actor that can bring us closer to or farther away from the established boundary. For example, in the case of the climate change boundary, we consider the different types and sources of greenhouse gas emissions, and how each of these collectively impact the boundary target (in this case, defined in terms of the concentration of CO_2 in the atmosphere and the energy imbalance at the top of the atmosphere in watts per square meter). The final step of the process, which departs into much more subjective territory, involves deciding on the principles and approach for sharing the defined impact allowance among different actors (countries, sectors, businesses, or individuals). Based on this global limit, we have developed an estimate of how much CO_2-equivalent can be emitted by while maintaining the planet within a safe climate zone. On that basis, countries have negotiated how to allocate this challenge among them by allocating emissions targets.

Figure 4. The 8-Step Framework for One Planet Approaches

Figure 4. *This schematic illustrates the 8-step process one must follow to define and operationalize a complete One Planet Approach. The boxes in each of the steps describe the methodological or procedural options that are most commonly used for fulfilling each of the steps.*

The first step of any OPA framework is the selection of the overarching objective behind the need for a system boundary (the "why"). In other words, what do we want to preserve (or avoid) by remaining within the boundaries that we will set up? What changes do we want to lead to, and which decisions do we want to influence with the definition of a boundary? At its core, this is an ethical question. When we impose boundaries on a finite world, this will eventually translate to behavioral restrictions for people. This means that the selected boundaries must be justified by a shared, higher objective that all affected parties, implicitly or explicitly, agree upon. Through our review of the literature, we have identified four categories of objectives that have or could be used (either alone or in combination) as the basis for an OPA.

PLANETARY HABITABILITY

In the Planetary Boundaries framework (Rockström, Steffen, Noone, Chapin, et al., 2009; Steffen, Richardson, et al., 2015) and other approaches based on it, the sustainability objective is to preserve the biophysical habitability of the planet for humanity. In this context, habitability is defined as the state of the planet in the Holocene. This Holocene-like state is contrasted with the systemic perturbations that may occur as a consequence of human action (i.e., an increase in global average temperatures greater than 2°C). In the PBs, the behavior of the system is evaluated at a global level. This sustainability objective implicitly assumes that the Holocene does indeed present ideal conditions to support human life.

SOCIAL JUSTICE

Other approaches define different objectives addressing sustainability in more holistic or ambitious terms, for example achieving fair living conditions for society or equality across people and intergenerationally. In the Social Doughnut, Raworth's (2012) modification to the PB framework, she includes objectives of social justice with categories such as for food security and representation (Raworth, 2012). She calls not only for environmental habitability, but for a fair and inclusive world. Initiatives such as the Sustainable Development Goals have a more broadly defined sustainability objective and combine social requirements into the global agenda.

RESOURCE PRESERVATION

It's also possible to establish entirely material and economic objectives, such as the preservation of natural resources for posterior economic use (non-renewables like fossil fuels and metals). The Earth has a limited supply of these resources, which means they can also be part of One Planet Approaches. These resources would, ultimately, serve to fulfill the material needs of society, and their preservation is, strictly speaking, more of a means than an end. Crépin (2014), for example, discusses the importance of economic models that can provide pathways within the boundaries, but also achieve efficient allocation and fair distribution of resources (Crépin & Folke, 2014).

BIOCENTRIC AND ECOCENTRIC OBJECTIVES

All the approaches we reviewed are anthropocentric; ultimately defined to satisfy human needs. Biodiversity is included in these frameworks as a control variable because it provides ecosystem services that serve humans. A theoretical, alternative consideration could be a biocentric approach, recognizant of the intrinsic, non-utilitarian value of the biosphere, or an ecocentric approach that conceives the planet as a global, interconnected ecosystem and matrix of life. Defining these types of objectives would imply setting apart some operating space for the needs of other living entities, irrespective of their usefulness to people. This would entail more ambitious environmental conservation measures, leaving aside more natural areas and resources for biodiversity - and leave a smaller operating space for people. An example of a more ecocentric approach is how e-flow (environmental flow requirement) is applied in the management of freshwater basins. E-flow considers the quantity of water that must stay in the system at all times to maintain the functioning of the system, including essential ecological demands beyond human needs (Smakhtin, 2008).

As Rottman (2014) argues, the capacity to find intrinsic value in nature is ingrained in human psychology, with empathy and spirituality two distinct and viable moral justifications to this worldview. We could recognize, for example, the interdependence of all organisms that creates the environmental conditions in which biodiversity has historically thrived (Rottman, 2014).

SETTING MORE AMBITIOUS OBJECTIVES

From our literature review, it is clear that a majority of the current OPAs are based on the minimum viable objective of ensuring human survival. The reasons for this are generally not philosophical intention, but rather, the practical challenges that are likely to ensue in political discussions in order to enforce the proposed boundaries. It is already difficult to agree to international covenants on climate action, even with general consensus on the fact that preventing changes in the climate system is critical to maintaining the survival and well-being of the human population. Imposing restrictions on human economic activity based on more holistic, less utilitarian goals will likely be even more challenging. That said, from our review, we conclude that there are a number of additional goals that should be taken into an ideal OPA that go beyond the minimum viable objective of human survival and will be further discussed in Chapter 3.

02 IDENTIFYING THE UNDERLYING SYSTEM PROCESSES

The second step of the framework involves identifying the Earth system processes that we need to keep in check in order to achieve the previously defined sustainability objective. In the Planetary Boundaries, nine different biophysical processes were determined as necessary to guarantee the habitability of the planet (See Figure 3).

Many approaches based on the PBs take these as they are, while some others modify or expand them to account for additional objectives. The inclusion of added processes is in practice influenced by the availability of data to measure the respective control variables.

Figure 5: Earth System Processes and Planetary Habitability

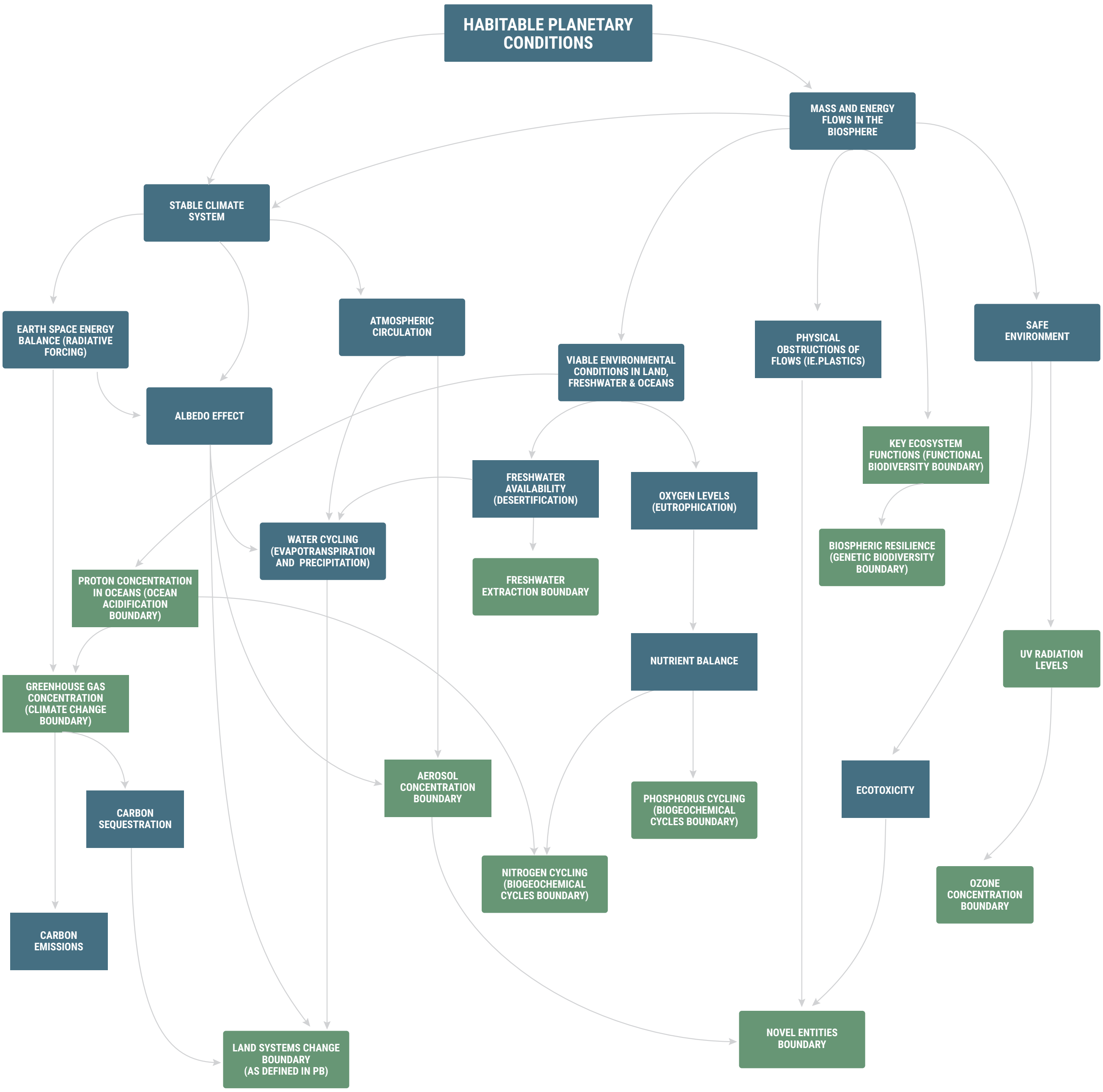


Figure 5. *The relationships between different Earth system processes and their underlying importance to planetary habitability. Processes selected to keep in control - the Planetary Boundaries - are shown in green.*

Table 1: Justification for the Inclusion of Each Planetary Boundary

PLANETARY BOUNDARY	CONTROL VARIABLES	UNDERLYING PROCESS AT PLANETARY SCALE	JUSTIFICATION IN RELATION TO SUSTAINABILITY OBJECTIVE
CLIMATE CHANGE	Greenhouse gas concentration Radiative Forcing	Climate stability, in terms of energy balance of the planet	GHG affect the energy balance of Earth through radiative forcing
OCEAN ACIDIFICATION	H+ concentration in oceans Aragonite saturation rate	Acidity of water impairs calcium fixation in marine organisms, causing species decline	The loss of coral reefs and other organisms might cause ecosystem collapse in oceans
OZONE DEPLETION	Ozone concentration in the stratosphere	Ozone balance in the upper atmosphere	Ozone serves as a barrier against solar UV radiation
LAND SYSTEMS CHANGE	Remaining forest cover, globally and per biome (tropical, temperate, boreal forests)	Evapotranspiration and Carbon sequestration (ie, regulation of the hydrological and carbon cycles)	Forests regulate energy and water exchange between soil and atmosphere, and serve as carbon sinks
BIODIVERSITY LOSS	Biodiversity Intactness Index (BII) for functional biodiversity Phylogenetic species variability (PSV), with global extinction rate as a proxy, for genetic biodiversity	Ecosystem self-support, self-provision, and self-regulation services Maintenance of maximum biodiversity (not an Earth system process per se)	Biome or key functional losses in ecosystems can have substantial impacts in distant regions of the world Biodiversity functions as a genetic information bank, providing resilience to the biosphere
FRESHWATER USE	Consumptive blue water use at global level per annum; Freshwater withdrawal at river basin level per month respecting EWF needs	The environmental water flow (EWF) is the water necessary to sustain ecosystem services in inland and coastal landscapes	Water withdrawal affects climate regulation and the stability of aquatic ecosystems
AEROSOL LOADING	Aerosol optical depth	Aerosol concentration in the atmosphere (release and deposition-capture balance)	Aerosols affect the hydrological cycle, radiative balance, albedo effect, and biological processes
BIOGEOCHEMICAL FLOWS OF NITROGEN AND PHOSPHORUS	Combined input of N from Haber-Bosch process and intended biological fixation Flow of P to the ocean Flow of P to freshwater, to erodible soils, and total mass of erodible P in continents	Eutrophication caused by unbalanced algal and phytoplankton population growth	Eutrophication from nutrient imbalance can reduce available water for human use. In coastal zones, it depletes oxygen, disrupting food webs.
NOVEL ENTITIES	No control variable	No process selected	Chemical pollutants can damage ecosystem functioning They can also affect abiotic processes (ghg effect, ozone chemistry)

Table 1. *This table, based on the 2015 update of the PBs, presents the rationale for including each of the nine boundaries as a system underlying planetary habitability, (Rockström, 2009; Steffen, 2015, and supplementary materials). As the interest of our project regards the design of OPA, we are not including the quantification of the boundaries here, but rather their justification and selected control variables.*

ADDITIONAL BIOPHYSICAL SYSTEMS AND BOUNDARIES

The appropriation of biocapacity, a boundary on the process of biomass production, has been proposed as a complement to the original nine original PBs in the SRC framework. Running (2012) proposed it in the form of net primary productivity (Running, 2012), while Cole (2014) addresses it in terms of biomass extraction for fisheries (Cole, Bailey, & New, 2014). The Ecological Footprint approach (Wackernagel et al., 1999) is on its own primarily a measure of global biocapacity. A measure based on captured biocapacity, such as the Human Appropriation of Net Primary Production (HANPP) (Haberl, Erb, & Krausmann, 2014) could serve as a proxy indicator to evaluate the amount of bioenergy available to sustain biodiversity and thus, most ecosystem services. All of these metrics evaluate how much ecological biomass is produced globally in relation to what is extracted for human needs.

Some LCA-based approaches include slightly different categories than those proposed in the PBs, such as acidification of freshwater and terrestrial ecosystems and photochemical ozone (smog) formation. These metrics could allow for the monitoring of regional environmental conditions. The ReCiPe database (Goedkoop & Huijbregts, 2013), includes material scarcity and/or resource depletion as an economic boundary. However, the links between these processes and the potential collapse of the Earth system is relatively weak (compared to the nine processes included in the PB) (S. Cornell, personal communication, February 2017). Nevertheless, they can be regionally relevant and useful control variables to determine operating spaces at sub-global levels.

SOCIOECONOMIC SYSTEMS AS CONTROL VARIABLES

Do socioeconomic processes affect planetary habitability or other sustainability objectives? Their inclusion is complicated because most of these are not finite processes nor quantifiable in material terms, but there is a consensus by practitioners and academics that these issues need to be addressed in some way in sustainability efforts - not only as an objective but also as underlying system processes.

The most salient example is the inclusion of “technological development” in the World3 model, which underpinned the conclusions presented in Limits to Growth (Meadows et al., 1972) as a key variable impacting food production. More recent examples include the socio-ecological models used by Schellnhuber (1997) in the Syndromes of Global Change, which take a systems perspective to model the interactions occurring in socioecological systems (Schellnhuber, 1997).

Once system processes have been identified, the next step is to map or capture their dynamics in some form. This includes determining 1) their interactions and potential tipping points and 2) the correct spatial and temporal scales at which they operate.

As an example of systemic interactions, as atmospheric CO_2 increases, plant water-use efficiency (WUE), which is the ratio of carbon dioxide uptake relative to water loss through transpiration, is expected to increase. However, WUE is also expected to decline as local relative humidity decreases, potentially creating a corrective feedback loop. WUE is an important metric in assessing the productivity and functioning of the terrestrial biosphere, and reveals one of the many interactions between some of the boundary processes (Dekker, Groenendijk, Booth, Huntingford, & Cox, 2016).

INTERACTING AND ISOLATED PROCESSES

When an OPA framework includes multiple processes, the question emerges of whether the interactions between these processes should be integrated into the model and to what extent. One of the main challenges of OPAs lies precisely in the integration of different processes. The dynamics between them are rarely fully captured when defining system boundaries.

The Planetary Boundaries framework, for example, acknowledges that interactions occur between biophysical processes, but does not directly include them as part of its model - for a good reason. The assumption within the PB framework is that as long as all of the control variables are within their safe range, no global tipping points have been reached, and therefore the safe operating space of the other systems remains unchanged.

Though there is consensus that all of the critical Earth system processes interact in some way, many OPAs choose to focus on single processes. This can result in more robust individual methodologies, but often at the expense of the whole picture, and often with the unintended consequence of encouraging burden shifting. For example, by focusing on greenhouse gas emissions, a framework can encourage the reduction of these emissions at the possible cost of impacts on other systems.

This burden shifting would have been prevented if the framework had considered the interactions and trade-offs between different systems. The Ecological Footprint methodology (see Text Box 2: Selection of Earth system processes in Ecological Footprint Methodologies) uses a single variable (global hectares) to directly aggregate the impacts of different processes: climate change, land use change, biocapacity. However, the interactions between these issues are not accounted for. In these frameworks, the changes in one variable do not change the operating space of the others.

Some OPAs do take into account the interactions between systems, and incorporate them into their system models. Dearing et. al (2014) modeled how soil stability, water quality, and air quality interact with a series of social variables in two different regions in China (see Text Box 4: Dynamic modeling in social-ecological systems). The World3 model, used in the Limits to Growth model, also included a combination of different processes, including biocapacity and pollution, as well as some non-biophysical systems. In these frameworks, changes in one variable will affect the other ones, effectively reducing or increasing their operating space. As a theoretical example, an increase in pollution might have a severe effect on biodiversity, which could then translate to a more stringent redefinition of the land use change boundary. Section 3.4 includes a more detailed description of these models.

Text Box 1: The Science Based Targets

The Science Based Targets initiative helps companies determine how much they must cut their greenhouse gas emissions, with the greater goal of keeping global temperature increase below 2º C. The targets have been developed as a collaboration between WWF, the United Nations Global Compact (UNGC), and the World Resources Institute (WRI). In order to allocate emissions reductions, one of the methods it uses is the Sectoral Decarbonization Approach (SDA), which allocates targets to companies based on their sector and their place within it, and taking into account the sector's growth and mitigation potential (Pineda, Tornay, Cummis, & CDP; WRI; WWF, 2015).

The Science Based Targets are an example of a methodology based on a single issue: in this case, climate change. As discussed in this report, this can potentially lead to unintended consequences through burden shifting. For example, reductions in GHG emissions can be achieved by switching to nuclear energy but this is associated with a high level of risk and dangerous waste streams. Alternatively, a reduction can be achieved by transitioning to biofuels, but these can lead to competition with food production and to the expansion of the agricultural frontier (leading to biodiversity loss). Technologies such as solar PV or fluorescent lighting, while promising, can also lead to downstream toxicity, mining impacts, and human rights issues in the material supply chain. Preventing this burden shifting is an important argument for taking a multiple process approach.

Text Box 2: Selection of Earth System Processes in Ecological Footprint Methodologies

The Ecological Footprint Accounting (EFA) method (Wackernagel et al., 1999) was a landmark achievement in sustainability assessment, measuring the total land area required to maintain the food, water, energy, and waste-disposal demand of an agent (or product or city) (Kumar, Murty, Gupta, & Dikshit, 2012).

Galli (2015) argues that this method overcomes some of the issues of evaluating trade-offs between different types of activities by providing a final aggregate indicator that includes both economic and environmental activities (Galli, 2015). The EFA method includes two main components. On the supply side is the biocapacity, which is the ability of the Earth to provide resources and ecosystem services, and on the demand side is the ecological footprint, which measures how much pressure is currently being put on the systems that provide these resources and services.

The EFA method requires adding all the demands of ecossystem services on a per hectare basis. While this accounting method succeeds in bringing together multiple factors into a single indicator, it does not incorporate a degree of dynamic interaction between the different subsystems or explore the causal chains which lead to impacts. Interactions between environmental systems or between environmental and economic systems cannot be sufficiently explored with this type of static model. For this reason there have also been attempts to expand the EFA method into a dynamic model that includes these interactions and causal chains (Lenzen et al., 2007).

See also Text Box 8: The Footprint Family (Section 2.7)

REGIONAL AND GLOBAL PROCESSES

There is a debate about whether Earth system boundaries should be defined at a global or regional scale. Earth is certainly an integrated whole, a single system composed of a multitude of overlapping and interacting subsystems, which supports the argument of defining boundaries at the planetary level. Some processes, primarily those that occur in the atmosphere such as climate change and ozone depletion, are indeed genuinely global. Greenhouse gases will have similar effects on climate change and ocean acidification regardless of where on Earth they are emitted.

Using a global framework provides a strong narrative for international cooperation on these issues - one of the successes of the Planetary Boundaries. However, the validity of directly downscaling a globally-defined boundary for a regionally-operating system has been questioned. It is very challenging to scale down geographically-dependent boundaries, such as freshwater use, nitrogen cycles, land systems, or biodiversity, or indeed, to even define these boundaries on a global scale. For instance, the global freshwater use boundary has been set at ~2600 km3yr-1 in the PB framework. However, it would be plainly incorrect to simply divide this total extraction limit equally across every unit of the Earth's surface: it is clear that different regions have varying levels of water availability and different competing human and ecological demands for that water. These contextually-dependent boundaries have variable scales of relevance, and are inherently dynamic in nature. If a water extraction budget is allocated based on a typical amount of rainfall, it becomes inaccurate after a period of extended drought. Likewise, the impacts associated with the use of a parcel of land cannot be looked at in isolation from the uses for the adjacent parcels; the whole landscape or local context needs to be considered.

Indeed, most of the processes included in the PBs operate at regional scales. It is true that severe perturbations in the water cycle and land systems change can trigger the collapse of regional ecosystems, and that such collapses could aggregate to have serious global consequences (as discussed in Table 1). However, there is no reason to expect these aggregation and effects to be linear (in a regional to global direction) or to expect finding a global tipping point for these systems (in the opposite direction) (Brook, Ellis, Perring, Mackay, & Blomqvist, 2013; Nordhaus, Shellenberger, & Blomqvist, 2012). Taking a globally-defined boundary to manage ecosystems at local level will lead to misguided policy and actions (van Vuuren, 2016). We could remain within the operating space at the global level while collapsing half the systems at the regional level.

For these systems, it is important to define scales that are consistent with the processes' dynamics. For example, water catchment and availability is strongly affected by topology and it's better to define boundaries at the water basin level (see Text Box 12: Business Approaches in the Context of Water Systems). Similarly, biodiversity functions need to be modeled at the level of ecosystems.

Text Box 3: Regional Scales for Land and Water Systems

Aggregating water or land system thresholds and targets in a uniform manner at global level is illogical, as water catchments and bioregions operate as relatively autonomous units which can thrive or collapse individually. One of the debates around the Ecological Footprint Accounting method has been the issue of aggregating biocapacity on a national level, which ignores the distinct problems associated with different bioregions (Van Den Bergh & Grazi, 2015).

Thus, it makes most sense to scale methods for examining water issues at the level of a water basins or catchment areas. While water management has typically focused on practices such as water use efficiency and the quality of discharge water, there is still too little consideration for the context of the catchment area as a whole (Morgan & Wenban-Smith, 2015). Morgan & Urr (2015) propose a framework for water stewardship which not only looks at water issues within the context of a water basin, but also within the context of its use and value for companies, society, and ecological systems.

Once the interactions between different processes have been assessed, boundaries can be defined. A boundary will define the operating space for society and our actions. A boundary is set based on a combination of scientific data and risk acceptance in order to establish the point beyond which we believe further impacts are increasingly likely to lead to system destabilization. In this context, a boundary is not the same as a tipping point nor the same as the very real physical limitations of our planet.

BOUNDARIES AND TIPPING POINTS

a tipping element in the Earth system is a component that can be switched to a significantly different state by a relatively small disturbance. A tipping point is the moment that this qualitative alteration takes place, which can be defined based on the amount of a particular disturbance that system can absorb. Well-known tipping elements that will possibly be impacted by changes in the Earth's climate system include: the Greenland ice sheet, the Atlantic thermohaline circulation, or the Indian summer monsoon (Lenton et al., 2008). At certain increases in average global temperature, the probability of sudden transformation in these tipping elements becomes increasingly likely: the Greenland ice sheet could melt (leading to significant sea level rise), the Atlantic thermohaline circulation could be disrupted or halted (leading to a likely dramatic cooling of European climate), and the Indian summer monsoon could be strongly strengthened or weakened (leading to the disruption of local ecology and agricultural practices).

Through the study of system dynamics, we aim to identify these tipping points, yet methods for robustly doing so are few and far between (see Text Box 4: Dynamic Modeling in Social-Ecological Systems). There are still a lot of uncertainties over how the Earth's processes operate and interact, which means that we remain in relative darkness about the location of tipping points.

A boundary, on the other hand, is a social construction, defined at what is determined to be a safe distance from a tipping point. This safe distance accounts for risk aversion, variability across time, and uncertainties; yet how much risk is acceptable and what is considered safe remains up for debate.

In cases of non-linear impacts, where an increase in an activity can push the system beyond a critical threshold (as described earlier in the case of known climate system tipping points), boundaries are set at points that are deemed to be at a safe enough distance from a dangerous threshold. In cases where systems behave in almost linear ways, the notion of "safe distance" is meaningless, because there is no tipping point to avoid. For example, if every additional release of a carcinogen into the environment

Figure 6: Boundaries and Tipping Points

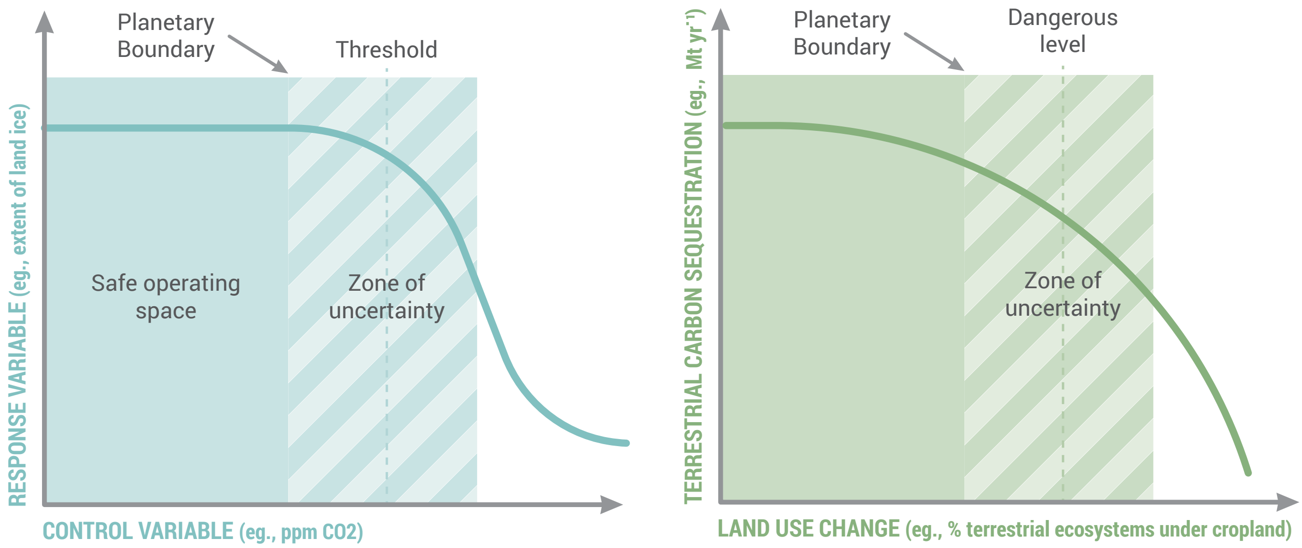


Figure 6. *Difference between boundaries and tipping points, and possibility of determining boundaries also in the absence of tipping points. Source: Rockström, 2009.*

reliably results in X new cases of cancer, then it is clear that this activity results in a linearly problematic impact that should ideally be avoided entirely. In these situations, a boundary can be defined simply at what is considered a desired or acceptable level by society. It is therefore, possible, and also desirable, to establish boundaries for impacts that do not necessarily portend system collapse.

Through our research, we found that there are three main ways currently used to define boundaries: system modeling, estimations and extrapolations, and policy and social demands. They all have different advantages and disadvantages, depending on the context, and can be combined.

SYSTEM MODELING

System modeling is the most complex approach, requiring the most information out of all of the approaches, as well as validation of results with actual data. Modeling uses software and real life data to run simulations of a system state under different conditions, thus aiming to predict system behavior under different conditions.

Models can be useful to identify tipping points, but this can only occur if they have sufficiently captured all the relevant system dynamics in the previous step. Missing positive feedback loops, for example, can lead to not identifying a tipping point and assuming the operating space is much larger than it is. In an opposite case, by missing a negative feedback loop, we would predict non-existing tipping points, unnecessarily constraining the operating space. If we continuously monitor the system for instability, then we can modify the operating space as required. The more frequently we gather information, the sooner we can react to unexpected changes. An approach currently in development is to look at hysteresis, or system instability, but this can only alert us of risk and proximity, it can not predict a tipping point with certainty.

There are three types of system models that are commonly used: mathematical models, dynamic models, and nested models, which mainly differ by their degree of complexity (J. Dearing, personal communication, January 2017).

Mathematical models, also called Toy Models, use a limited number of variables and establish simple relationships between them. They contain only a handful of equations to capture the main processes, and thus require little computing power. While they're useful as first approximations, they are oversimplifications of reality.

Dynamic and nested models are very similar. Dynamic models are the best known ones, and they consist of a series of interacting elements with equations describing their relationships. A nested model, also called Integrated Assessment Model, is a composition of separate dynamic models, each modeled individually, where the outputs of one component serve as inputs for the next. Nesting models help to divide the work among experts of different fields or geographical regions. However, they fail to capture the interactions that would happen between elements contained in different pockets. A single dynamic model, without the compartmentalization, might be best to model the whole stability and changes at the system level.

Figure 7: Illustration of Nested and Integrated Models

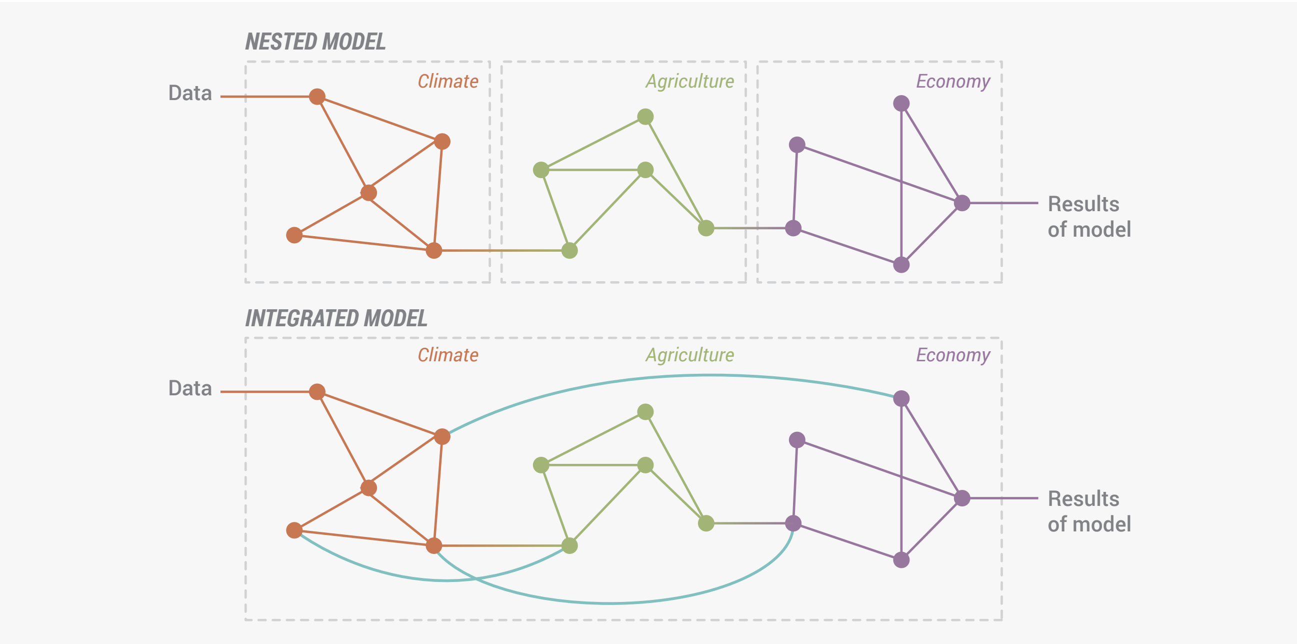


Figure 7. *This illustration shows the main difference between the nested and the integrated approaches to system modeling. Integrated models include interconnections (shown in blue) between variables that would remain isolated in nested models.*

Text Box 4: Dynamic Modeling in Social-Ecological Systems

The use of dynamic models for social-ecological systems started with the World3 model (Meadows et al., 1972), but includes many others like IMAGE, IFS, DICE, TARGETS, GUMBO, and ARIES (J. A. Dearing et al., 2014; J. a Dearing et al., 2012), as well as the social-ecological syndromes modeled by the Potsdam Institute for Climate Impact Research, PIK (Schellnhuber, 1997).

Table 2: Available Tools for Dynamic Modeling of Different Systems

IMAGE: Simulates emissions from energy use and tropical deforestation and consequent climate change in different regions. A few feedback processes, such as CO2 fertilization, are included, mainly to calibrate the model to simulate observed atmospheric CO_2 concentrations (Costanza et al. 2007).
IFS: A tool for thinking about long-term country-specific, regional and global futures by exploring trends (social, economic, political, energy, agricultural) and the dynamics of global systems. (Hughes, 2003)
DICE: The basic approach of the DICE model is to use a Ramsey model of optimal economic growth with certain adjustments and to calculate the optimal path for both capital accumulation and GHG-emissions reductions (Nordhaus, 1995, p.5) This is done by incorporating a greatly simplified depiction of the global atmosphere to form a set of climate-emissions-damage equations.
TARGETS: Seeks to study not just climate change, but broad issues of global change and sustainable development. TARGETS includes five interlinked modules representing trends in population and health, energy and economics, biophysics, land and soils, and water. (Costanza et al., 2007)
GUMBO: The goal of GUMBO is to simulate the integrated earth system and assess the dynamics and values of ecosystem services. It is a "metamodel" in that it represents a synthesis and a simplification of several existing dynamic global models in both the natural and social sciences at an intermediate level of complexity. It is the first global model to include the dynamic feedbacks among human technology, economic production and welfare, and ecosystem goods and services within the dynamic earth system. (Costanza et al., 2007)
ARIES: It is a networked software technology that redefines ecosystem service assessment and valuation for decision-making. The ARIES approach to mapping natural capital, natural processes, human beneficiaries, and service flows to society is a powerful new way to visualize, value, and manage the ecosystems on which the human economy and well-being depend. (Villa et al., 2009)

Figure 8: Interactions between Ecosystem Services and Social Indicators

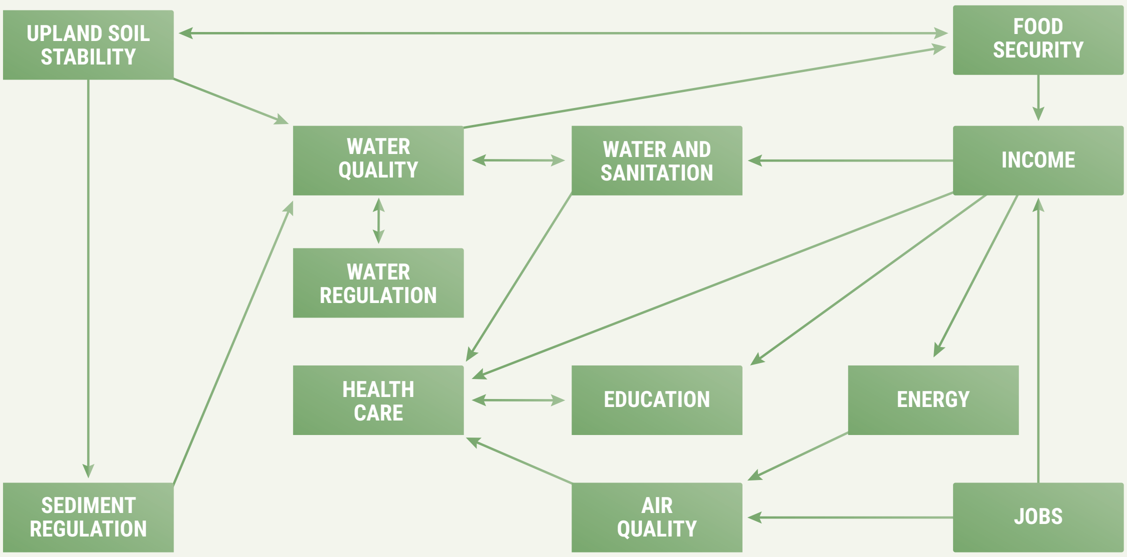


Figure 8. *Mapping of interactions between different social and ecological processes at the regional level in a lake basin region in China. In a similar region, the same variables will have different interactions, reflecting the unique context of each area. Source: Dearing, 2014.*

Well-designed dynamic models can predict a system's response to different pressures and interventions. Social-ecological models attempt to model social, economic, and policy decisions into ecological systems, opening up the possibility to choose different pathways forward to manage the systems in question (J. A. Dearing et al., 2015).

Here we include the relationships between different processes in a lake ecosystem in China, as presented in by Dearing (2014) and note that a second, similar ecosystem, showed different relationships. Hence, models need to be adjusted to the particular conditions of the region of study, as the same processes will behave differently in different situations.

EXTRAPOLATIONS AND ESTIMATES

Extrapolations and estimates rely on expert opinion and understanding of the system in question. They might be based on observed trends or calculations but at the the end of the day they remain recommendations that may be subject to questioning by the scientific community or other actors.

For example, in the PB framework, the boundary for land-system change was defined through expert opinion, by recommending acceptable levels of carbon emissions and biodiversity impacts from forest loss in three types of forest biomes. In the PB framework, the boundary for freshwater extraction was also defined in this way, but in this case calculating total freshwater flows (inputs, extractions) at the global level (Rockström, Steffen, Noone, Lambin, et al., 2009), and then proceeding to regionalize it (Steffen, Richardson, et al., 2015).

POLICY AND SOCIAL DEMANDS

Policy directives and social demands are more applicable at the regional level and are based on social demands (sometimes conveyed by policy directives). This method is useful when determining boundaries at regional scales that coincide with countries or provinces. The justification for setting the boundary is to meet national development agendas, which often results in higher standards and requirements than those expected from global frameworks. For example, lower thresholds of aerosol loading are sufficient to impact human health than climate patterns. As a result, in many countries health standards effectively define stricter boundaries for air pollution than those recommended by the Stockholm Resilience Centre to preserve planetary habitability.

Text Box 5: National Applications and Social Consultations

There have been several works downscaling the planetary boundaries to the national level, particularly focused on the cases of several European countries (Hoff, Nykvist, & Carson, 2014; Nykvist et al., 2013; Dao et al., 2015) and South Africa (Cole et al., 2014). Dao et al. (2016) further performed a downscaling to the world's most important economies in the blueDot project (see http://bluedot.world).

A consistent theme in these approaches has been the collaboration with national governmental authorities which, in many cases, requested defining different boundaries than those recommended by the Stockholm Resilience Center.

For example, Dao (2015) defines boundaries for land -system change based on landscape preservation objectives. Meanwhile, Cole (2014) uses South Africa's national commitments for climate change mitigation, instead of an equal per capita approach, to define an operating space for the country. Policy directives are valid social requirements and, especially at the regional level, can be effectively combined to determine the limits of the operating space. In this regard, the development of science-policy dialogues, such as the 2016 interchange on Planetary Boundaries and Resource Efficiency, and other processes to link OPA efforts with governmental planning can strengthen the legitimacy of these frameworks, facilitate adaptation to local circumstances, and increase the sustainability ambitions of these measures.

In a different approach, Teah (2016) considers social requirements to define a regional safe operating space in the Heihe river basin, in China. He combines top-down and bottom-up approaches. He considers national environmental standard requirements (on water, food, and air quality) and other governmental goals (natural landscape), but then assesses the local perception on these issues to gauge public opinion on the impact of particular environmental issues on people's livelihoods. For some issues, society demanded higher protection levels than those recommended by the government (Teah et al., 2016).

The next step requires choosing what "filter" to apply to an agent's activities to eventually measure what their current operating space is. Regardless of what type of agent we create targets for (individuals, companies, sectors, countries, etc.), we need to determine how far their actions reach.

There are basically two approaches to solve this: taking a territorial focus or an economic focus. International trade and global value chains mean that the spheres of operations of all agents are cross-cutting and overlapping. The impact of individuals, sectors, and companies extends beyond national borders.

TERRITORIAL FOCUS

A territorial focus considers the actions that occur in a defined space. This is usually done with countries (or other sub- or supranational regions) and often, but not necessarily, through a lens of production.

A territorial focus is easier to implement than an economic one, as it uses data that is normally collected and provided by governments. While these approaches are practical, they tend to miss most impacts. This is especially the case for wealthier countries where many impacts of consumption happen abroad.

ECONOMIC FOCUS

An economic focus considers all the actions across value chains that ultimately provide an agent with a service or product, regardless of the space in which these occur. The economic focus is also referred to as consumption focus or footprint approach. In this report, we use the term "economic" for simplicity, alluding to the fact that it follows economic value chains, and in order to avoid confusion with "Ecological Footprint Accounting" and the footprint family of methodologies. This is the usual approach when addressing companies (see e.g. Daub, Weber, & Bern, 2016), but it can be applied to countries or individuals too. This is often done through the lens of consumption.

An economic focus is harder to implement, as it requires taking into account trade patterns and supply chains, and then requires spatially detailed data in the following steps of the framework (6 and 7). However, these types of methods offer a more fine-grained and complete picture of an agent's impacts. We have noted through our research that the current trend is to move towards this type of approach. For example, in the Greenhouse Gas Protocol this is covered in the Scope 3 Standard assessments, and can be further be split in upstream and downstream impacts.

IN COMPARISON

While these two approaches are complementary, their scope is overlapping, which makes them impossible to aggregate. The only instance when they could be comparable is if budgets were assigned and allocated for 100% of the territorial units (e.g., countries) and for 100% of the organizational units (e.g., companies) in the world and under the same allocation principle (see step 8 below). For all processes that occur regionally (such as land use change), the comparison is only valid in that same space, and only so long as scopes don't overlap (as with nested freshwater basins).

This means that the only scope at which we can freely aggregate budgets is for global ecological processes (climate change and ozone depletion), but this has not been done in practice.

06 QUANTIFYING THE FLOWS ATTRIBUTED TO THE AGENT'S ACTIVITIES

SUPPLY CHAIN INFORMATION

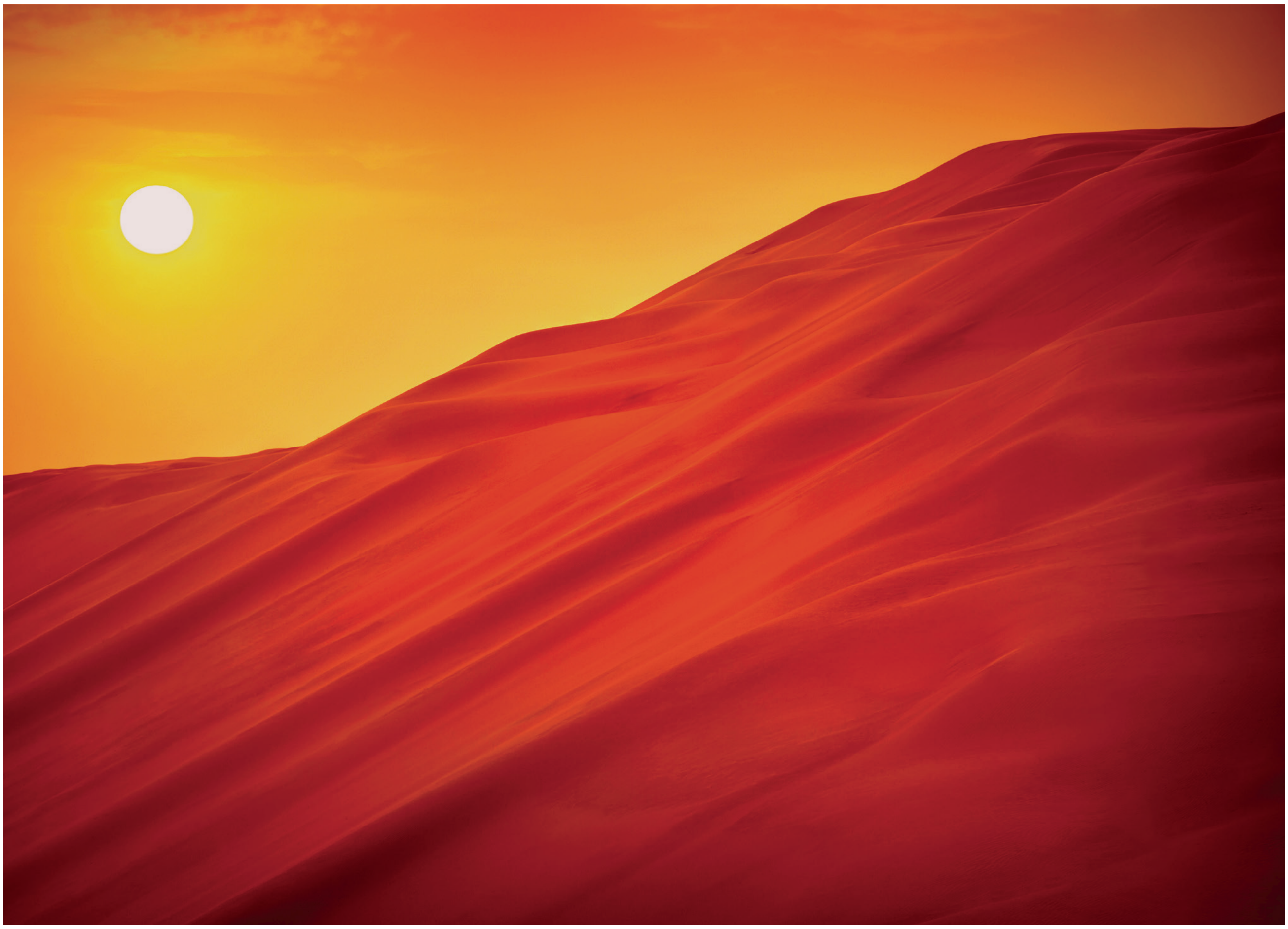
AGGREGATED STATISTICAL INFORMATION

Once the extent of the agent's activities has been determined, it is time to quantify the environmental flows embedded in these activities. This step is usually an inventorying process that draws data directly from companies' production information or from statistical information collected by government agencies.

When a territorial focus is chosen in the previous step (usually only for countries), environmentally extended national economic accounts serve as catalog of the country's consumption. When an economic focus is chosen, some approximation of trade flows is necessary. Some approaches use supply chain information, but when this information is limited, Multi-Regional Input Output Tables and LCA databases combined with trade statistics can be used to account for the imports and exports. These tables can serve as a rough indication of the likely origin of goods and materials used by a company or individual.

This information provides an additional layer of context, and it can be used to estimate impact (in the next step) in the area where environmental pressures actually occur (sites of production or waste disposal). For this information to be useful, it needs to be paired (in the next step) with regionalized impact assessment methods. Such databases are not often available.

There are a number of concerns with the quality of the methods used for flow quantification. Every private, governmental, and inter-governmental organization that collects data uses different protocols, scales, and methodologies, hindering the compatibility of the databases. In some countries, there are additional difficulties from data scarcity and the potential of working with falsified information. A company's supply and production inventories are often confidential information and many methodologies are subject to IP protection.



In the next step, a conversion from environmental flows (or pressures) to actual impact is carried out. In the context of One Planet Approaches, the "impact" refers to the occupation of operating space. However, the relationship between a flow and an impact is not direct or immediate, which means that a causal chain needs to be mapped to link these two events. The clearest example is that of greenhouse gases, where different substances have different effects in terms of the actual global warming potential they represent. This issue has been extensively addressed in different approaches, as we discuss below.

CAUSAL CHAIN MAPPING

The approaches we reviewed take variations of the pressure-state-response model of the OECD, the driver-pressure-state-impact-response model of the EEA, or midpoint-endpoint relationships as done in LCA work. We do not observe significant advantages or disadvantages using either of them, and authors generally adapt the models to their needs. Simpler methods (i.e., with three instead of five steps), might have the advantage of being more practical. It's important though, that as authors select different causal chains, it makes it impossible to directly compare targets defined through different methods.

CONVERSION TO IMPACT

Once this relationship has been established, it's possible to convert pressure to impact. There is a wide variety of methods that could be used to assess impact on sustainability - Sala (2015) provides an overview of the most common ones used in general sustainability issues (Sala, Ciuffo, & Nijkamp, 2015). In the specific context of implementing the Planetary Boundary, two approaches have been generally favored (and sometimes combined): based on LCA methodologies and based on the Footprinting accounting methodologies.

In any case, the conversion to impact is usually done through databases with multiplying factors that should ideally be in accordance to the context where the pressure takes place. When multiple planetary processes are considered, there is an impact estimation for each type of process. This means that the agent's activities have been converted to a certain amount of impact on the climate system, a separate amount on biodiversity, etc.

LCA methodologies include such databases with factors that standardize the damage potential for different substances. In general, LCA methodologies have a lot of versatility - they address a lot of impacts, including human health and material scarcity issues, and their life-cycle approach gives them a broad look at a product's possible impacts. There is an important push by LCA practitioners to adapt this tool to the planetary boundaries (see Text Box 7: LCA and the Planetary Boundaries).

However, LCA-based approaches have a number of drawbacks. They cannot fully assess impacts that are dependent on the circumstances in which the environmental pressure occurs - local contexts that include geography, time effects (such as duration of exposure), and capacity of local sinks or sources (although there are efforts going in this direction, see discussion on LCA regionalization in Section 3.3). Examples of impact categories that are harder to assess through LCA include habitat degradation and biodiversity loss (while there are some developments in this area, as we discuss in Chapter 3). The "per unit of product" approach inherent in LCA means the impact assessment escalates at a linear rate, when in reality impacts do not escalate in this way. Moreover, LCA databases are developed considering real life data that is only representative in similar geographic contexts and are thus not valid for all regions of the world. The general approach in the community is to assume that substances will behave in similar ways in different contexts.

The ecological footprint approach uses internally developed conversion factors to connect consumption to an equivalent impact measured in hectares. This methodology has received a lot of criticism for an oversimplification of the causal relationships and inadequate standardization of impact potential. For example, it doesn't distinguish the effect of sustainable versus unsustainable production practices.

Text Box 6: LCA and the Planetary Boundaries

Many researchers have adapted LCA databases to measure impact, at the product scale, in the context of the planetary boundaries or other ecological limits. The nascent "LCAbsolute" research network aims to create LCA indicators to assess whether a product's impact is sustainable in reference to its "fair share" of carrying capacity (Bjørn & Hauschild, 2015; Bjørn, Margni, Roy, Bulle, & Zwicky, 2016; Doka, 2016; Sandin, Peters, & Svanström, 2015; Tuomisto et al., 2012; Jørgensen et al. 2014).

Bjørn (2015) developed normalization references that link LCA indicator scores with the actual carrying capacity of the affected ecosystems, at global and European scales, and are divided on a per capita basis to the population in the area. These references express the midpoint indicators in person-equivalents of carrying capacity occupation (i.e., occupation of "operating space"; Bjørn, Margni, et al., 2016).

Doka's (2016) methodology uses LCA data for different midpoints to operationalize the boundaries. This method does not redefine the boundaries, but takes them as they are from Steffen (2015). The contribution lies in the calculation of an "allowance" and linking this to LCI results. An allowance is a fair share of the global operating space for each boundary, on a per capita basis of allocation and for an annual period (Doka, 2016).

Doka also offers the possibility to aggregate all allowances into a single indicator, but advises against this, as aggregating all impacts under one category implies that impacts are exchangeable and that all impact categories are equally important.

Most recently, Ryberg et al (2016) concluded that there are currently too many unresolved challenges in order to operationalize a functioning Life-Cycle Assessment methodology based on the PBs, though they assert that the insights provided by such a tool would be novel and relevant, which should make it a target for further research (Ryberg, Owsianiak, Richardson, & Hauschild, 2016). In the corporate world, several companies have also made efforts to relate their organizational impacts and choices to PBs, though this is an approach that is only recently gaining traction (Bjørn, Bey, et al., 2016).

Figure 9: Relationship between LCA Variables and the Planetary Boundaries

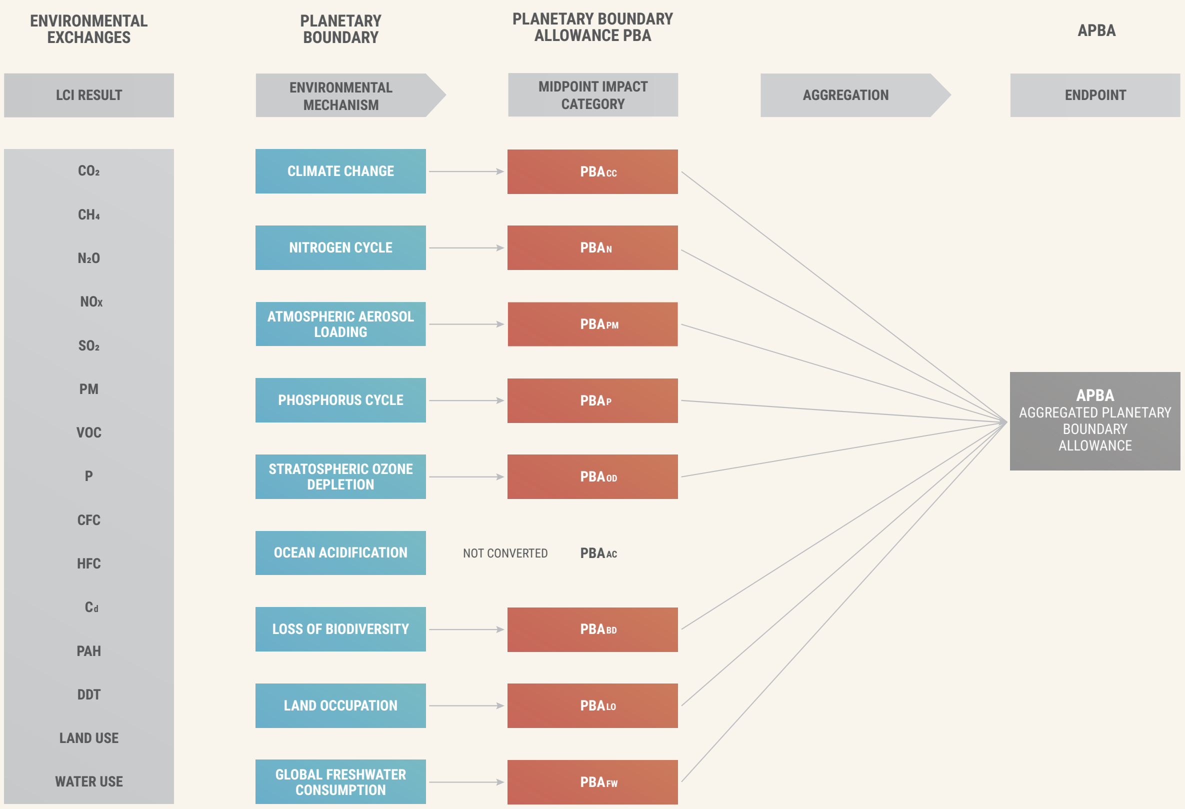


Figure 9. *This "Method overview", used in Doka's PBA impact assessment methodology, shows the relationships between different LCA variables and the Planetary Boundaries. Source: Doka, 2016.*

Text Box 7: The Footprint Family

Since its introduction in scientific literature (Reese, 1992), a variety of footprints have been developed, differing in scope (local, national, global) and focus (e.g. atmosphere, biosphere, hydrosphere) (Fang, Heijungs, & Snoo, 2015; Galli et al., 2012), but similar in linking human consumption to PBs expressed in global hectares (gha). By translating the environmental pressure of human activities to the regenerative and assimilative capacities of Earth's surface, the impact placed on PBs became visible (Galli et al., 2012; Mancini et al., 2016; Daly, 1990) and, in a way, more relatable. The most commonly used footprints are the ecological-, carbon- and water footprints, as they complement traditional analyses on human demands by coupling consumer and producer perspectives (ibid.). An evident application of footprint-methodology was published in the 2010 Living Planet Report by WWF (2011), which concluded that humans were exceeding the planetary boundaries by a staggering 50%. In other words, 1.5 planets were needed to sustain the world in 2010 and, under a Business As Usual scenario, this would increase to two planets by 2030. The annual capacity of Earth to generate the ecosystem services needed by mankind (biocapacity) is related to society's ecological footprint (for example: by 2030 the ratio between the biocapacity and ecological footprint will be 2:1).

Galli et al., (2012) describes ecological footprinting (EFP) as the process of monitoring a wide range of human activities that create a combined metric for human impact on the biosphere and its composing ecosystems. By combining impacts that are otherwise assessed separately (e.g. CO_2 emissions, fish consumption, and land-use change), one can theoretically get an quick overview of the total pressure humans are exerting on the Earth's life supporting systems. EFP aims to measure one key aspect of sustainability: the human appropriation of Earth's regenerative capacity. The underlying assumption is that the Earth's regenerative capacity will most likely be one of the main limiting factors for the economy (Galli et al., 2012).

EFP is measure of the area required to provide or regenerate a resource flow annually (the biocapacity). While bioproductivity varies between land types, use practices, and regions, an average value is used considering global yields.

For example, human activities place an important pressure on the climate system through GHG emissions. The carbon footprint (CFP) represents the total amount of emissions, expressed as CO_2-eq, directly and indirectly associated to a product or service or alternatively, from a territorial perspective, the cumulative emissions from all activities in a region (including imports and exports). Comparing the CFP with the Earth's carbon sequestration capacity (mainly from oceans and photosynthesis) provides insights on the accumulation of GHG in the Earth's atmosphere.

The volume of freshwater required, directly and indirectly, to support human consumption is expressed in the water footprint (WFP) (Hoekstra, 2009). A distinction is made between fresh surface- and groundwater (blue water), precipitation and soil moisture (green water), and fresh water that is needed to assimilate pollutants (gray water) (Hoekstra, 2009). The main use of the WFP is to indicate the often hidden links between human consumption and water usage (not necessarily in the same region) and the between global trade and water resource management.

The first successful attempt to integrate different footprints into one coherent and applicable framework is the OPEN:EU project, which aims to integrate different consumer-based indicators into a single suite (Galli et al., 2012). With a footprint family (FPF), policy-makers and researchers have a more comprehensive method of monitoring the environmental pillar of sustainability (ibid.).

It is, however, important to note the overlap between the different footprints (CFP, WFP, and EFP), which creates a risk of double-counting, and to emphasize that footprinting methods are limited by their inability to address social and financial issues.

Although footprinting has many advantages as a method (e.g., it is easy to understand and communicate, it provides practical outcomes), it has also received considerable critique. This has focused mainly on the contradictions between its semantics (what it accounts for) and its syntax (the FP protocols to account for impacts) (Giampietro & Saltelli, 2014). In other words, it does not measure what it intends to measure, which can cause confusion and misinterpretation. Furthermore, it is argued that the FP method oversimplifies (or neglects) the interactions within and between systems (ibid.). Other factors, such as soil quality and land degradation, non-renewable resources, ecosystems eutrophication, and nuclear waste and energy, are not taken into account.

Some of these shortcomings could be overcome with standardized and robust indicators for these impacts (e.g., footprints focusing on the lithosphere), making the FPF more comprehensive and reliable. However, due to the existing limitations and shortcomings, the use of footprinting methods will remain a point of contention.

Text Box 8: The Natural Capital Protocol

The concept of natural capital can be defined as the stock of renewable and non-renewable natural resources that yield benefits to humans (NCP, 2016). These benefits entail the products and services provided by nature (ecosystem services) on which our economy and society are built (Costanza et al., 2006). These ecosystem services can be expressed in the monetary value that society attributes to these benefits (ibid.). Despite its benefits and potential applications informing national and business decision-making, natural capital accounting is not seldom used. This is partially due to a critique on the inconsistencies of the outcomes, their openness to interpretation, and ethical arguments against valuating nature (NCP, 2016).

In response to these critiques, the Natural Capital Coalition developed a method to generate trusted, credible, and actionable information that can be used by organizations for better-informed decision-making, referred to as the Natural Capital Protocol (NCP) (NCP, 2016). The NCP includes a framework that integrates existing approaches into a standardized tool to identify, measure, and value dependencies and impact on natural capital (ibid.).

This framework aims to assist in generating natural capital information, which can then be integrated into business processes (e.g. risk assessment, procurement, financial planning) and can help make better-informed decisions. Furthermore, it seeks to connect organizational functions to support more integrated thinking. As a framework designed to assist decision-making, the be combined or integrated with other approaches.

The NCP framework identifies nine steps to assess a business's environmental impacts and dependencies, spread out over four stages (frame, scope, measure and value, and apply). In these steps, we can identify similarities and differences with OPAs. Stage 1 (Frame) seeks to answer the question of why to conduct a natural capital assessment and mainly aims to create understanding of the basic concepts and the underlying interactions.

In stage 2, the NCP describes three steps to define a scope for the analysis. It does so by selecting the relevant stakeholders, setting the boundaries of the analysis, and identifying the environmental impacts that should be taken into consideration.

After the scope is defined, stage 3 elaborates on how to measure and value these impacts. This is done by mapping the interactions between business activities and natural capital, assessing the changes made over time in the natural capital (which can be both positive or negative), and identifying the consequences of these changes and the associated costs. Stages 2 and 3 of the NCP show similarities with the steps 4 to 7 of the 8-step OPA framework presented in this report.

Stage 4 includes the final two steps of the framework, which focus on interpreting and validating the results (comparable to step 7 of the 8-step OPA framework) and incorporating them into business decision-making processes (which falls outside of the OPA scope).

In brief, the NCP and OPA demonstrate similarities, mainly between stages 2 and 3 of the NCP and steps 4 to 7 of OPAs. Stage 1 and 4 of the NCP can be seen as additional steps (placed outside the OPA scope) and thus deliver additional insights on the reasons for the analysis and what to do with its outcomes.

Missing from the NCP, however, are steps 1, 2, 3 and 8 of the OPA framework, which could be integrated to the Protocol in the future. This is a major added value and opportunity for OPT to strengthen organizational decision making under the NCP, as these steps emphasize the interactions between the organization and the system in which it operates.

The following step is the most contentious one, as at this point the process shifts completely away from the realm of the natural sciences and moes onto social questions, with their ethical and philosophical implications. Once an acceptable boundary has been defined for each process and at the correct scale, it is theoretically possible to downscale it to the level of specific agents: companies, countries, sectors, or individual people.

Regardless of the type of agent, all methodologies choose a principle upon which to base the allocation of operating space. This allocation can be understood as the distribution of "impact budgets" or the distribution of "solution or reduction efforts (a contribution approach)." Based on our research, these are the main allocation principles used in the literature and in practice. Shue (1999) makes a thorough analysis of the ethical implications for inequality of some of these:

» **Egalitarian**
» **Economic throughput**
» **Economic capacity and efficiency**
» **Historical justice and inertia**

EGALITARIAN PRINCIPLES

Egalitarian approaches consider that all people should have equal access to planetary capacity. They are considered the fairest approach and are based on a straightforward division of total capacity by population. In some cases, modifications are considered to take into account expected demographic trends or differentiated needs for different population ages. For example, Dao's (2015) methodology considers population for a 100-year span (Dao et al., 2015), while Doka's (2016) methodology simply uses a future expected population of 10 billion people to allocate resources (Doka, 2016).

Ecological Footprints can also be divided per capita, but, more often, the available carrying capacity is divided by the population in the area which may be of interest from a strategic point of view, since it is an indicator of a country's resource dependency. Using such a territorial downscaling approach a as a reference for fair shares would, however, be a misinterpretation: For example Canadian or Australian residents could cause excessive amounts of CO_2 without approaching their national fair share while residents from densely populated countries such as Bangladesh or Singapore would transgress their fair share even by consuming very tiny amounts of products.

When individuals are not the target of the approach, and the intention is rather to set a target for a company or a country, then the allocation needs to be "transferred" from individuals to the company or country in question. For countries (or other regions), this is a simple multiplication of individual share times the population size.

For companies, it is theoretically possible to transfer the allocation individual share to the organization via the consumption of products and services it offers. For example, a company could aim to keep within the operating space allocated proportionally to the market share it serves within its sector. However, sectoral shares of operating space would need to be defined beforehand. In practice, the amount of data required to calculate this transfer accurately would make it currently an impractical implementation. We found no approaches in our research that attempted this calculation.

The egalitarian principle of allocation does not require completing steps 5 to 7 beforehand (because allocation is independent of current activities), but the information provided in these steps is nevertheless necessary to assess whether an individual is currently over or below their share of operating space.

ALLOCATION BASED ON ECONOMIC THROUGHPUT

Approaches based on economic throughput are often applied to allocate operating space directly to companies. There are different possibilities, for example, taking value added as a base, the larger the value of a company's products or services (or of a sector's), the larger its share of allocated resources. Considering output, for example, a company's share might be allocated on the basis of its production volume - the more goods it produces, the larger a share of operating space it should receive. Finally, labor inputs can be considered as the basis for allocation - the more person-hours that go into a company, the larger the share of resources.

According to Mark McElroy of the Center for Sustainable Organizations (M. McElroy, personal communication, January 2017), the use of value added as a proxy is often preferred by companies as a better principle, as it is often considered the most readily available proxy of social value and as a company's GDP contribution is available financial information.

These approaches are particularly appealing for larger companies, which would receive a larger share of planetary capacity - and which are the ones likely to implement sustainability measures. Despite their practicality and appeal they have many negative repercussions and are particularly concerning on account of the potential entrenchment of economic inequality and the continued market distortions they could generate.

GDP is not a complete nor democratic measure of social value. It measures monetary exchanges, but in our economic system an important part of social value escapes from this measure: all externalized costs and many positive economic activities that do not invovle financial transactions (such as childrearing, housekeeping, or voluntary work) or activities that are not in the formal economy.

Furthermore, and even under the (impossible) assumption that all value could be monetized, market value is not an egalitarian proxy for social value. Market value is derived from people's willingness to pay, which depends on their available income. In other words, market value does aggregate the value awarded to an activity or product by all members of society, but it does so in a disproportionate way that over-represents the wealthy at the expense of the poor.

Finally, we should consider that there is no correlation between the fulfillment of social or human needs and economic throughput (regardless of whether that is measured in the form value, tonnage, or labor inputs), when we compare between different products or especially across economic sectors. Hence, these measures should not be used as a basis to prioritize some economic activities over others when allocating operating space. A diamond is worth many times more than a piece of bread, but it can't supply any basic human need.

ALLOCATION BASED ON ECONOMIC EFFICIENCY AND CAPACITY

Economic efficiency and capacity are another, seemingly fairer alternative to economic throughput. These principles can also be used to allocate operating space directly to companies or to countries, regardless of the market share or population they represent.

Under the principle of economic capacity, we would allocate smaller shares of operating space (in the form of higher contributions or more ambitious reduction targets) to those who have more means to reduce their impact. In other words, we distribute a higher amount of burden to those who can bear it the most. This principle was part of the international negotiations on climate change, and ultimately became one of the ideas supporting the "common but differentiated responsibilities" principle used there (See Text Box 9: Climate Change Negotiations and Carbon Allocations).

Allocating on a principle of economic efficiency works in a similar way. The objective is to allocate higher contributions or reduction targets to the agents (companies, countries, or sectors) for which reductions are less costly, effectively optimizing the total reduction costs for society. This principle has also been applied in the context of climate change mitigation, but to distribute emissions reductions burden across economic sectors, as in the Sectoral Decarbonization Approach of the SBT, or within a single country, where a government would establish sector-wide mitigation targets considering financial and technological resources.

Since in both principles (capacity and efficiency) an economic optimum is desired, these principles also provide an opportunity to establish markets to buy-and-sell reduction efforts (or operating space). Markets can encourage faster action and, indeed, become viable solutions to coordinating burden sharing across society towards an economically-efficient optimum. There are a number of practical considerations to market-based solutions that lie beyond core focus of this report. Nevertheless, they should be considered in the context of OPA development, as discussed further in Section 3.5.

In a theoretical exercise, Fang & Heijungs (2014) use modeling tools to maximize total affluence for economic different sectors, trying different allocation combinations that could meet total reductions of CO_2 emissions. As they mention, the approach is not useful for individual sectors, as it's meant to optimize for the economy as whole (Fang, Heijungs, & De Snoo, 2014). Another limitation is that the models currently only optimize for one impact category (carbon emissions), while we would need to deal with several more. Pursuing this process at the level of specific products, considering all regional contexts, as well as changing social needs and policy directives (that may be economically suboptimal but preferred due to other reasons), would make this process impractical to set allocations of operating space.

HISTORICAL JUSTICE AND INERTIA

The two previous principles (efficiency, capacity) are closely related to those that have a historical perspective, and, in practice, they can be used in combination. Taking a historical principle means considering previous actions, such as consumption of resources or contributions to environmental impacts, as a basis to allocate present and future operating space. Historical principles can lead to two completely different outcomes, depending on how they are used.

The three different principles of polluter pays, historical responsibility, and development rights posit that those who have historically contributed to a problem should have a higher responsibility to remedy it and bear those costs; while those who have not benefitted from the use of resources or environmental sinks, and have not contributed to the problem, still have a right to do so, especially if this is necessary for their development. The Greenhouse Development Rights Framework and the Contraction and Convergence Frameworks are applied examples of these principles. These approaches strive for historical justice in favor of the disadvantaged.

On the other hand, under the grandfathering principle, it's argued that those who have been using a resource have a higher need to continue using it, basically creating inertia on existing use patterns. Agents advocating to use this approach argue that their existing economic activities are dependent on the use these resources - they basically have sunk costs compelling them to continue their activities. Instead of seeking historical justice, this approach protects existing economic interests. In some cases these can be legitimate concerns and in protection of vulnerable sectors or societies that, indeed, have no option but to continue using these resources to ensure their livelihoods.

The only experiences we found of the use of these allocation principles comes from countries. The polluter pays and historical responsibility principles can be translated to the case of companies in a straightforward way. They require holding a company accountable to repair impacts historically derived from its activities. To be effective, it is important that the repairs generally happen at the site of damage, and not in other regions.

Text Box 9: Climate Change Negotiations and Carbon Allocations

Climate change negotiations have been receiving an increasingly prominent role in the international political arena. The main outcome of these negotiations have been translated into international agreements, of which the most outstanding ones are the Kyoto Protocol (mid 1990s) and the Paris Agreements (2015). During the negotiations, as well as in the outcome of these reports, the tension between followers of different allocation principles became evident.

During the Kyoto negotiations, 192 countries agreed to mitigate climate change by reducing greenhouse gas emissions to a level that would not interfere with the climate system to a dangerous extent. The allocation principles applied were twofold. Developed countries were to set legally binding emissions reduction targets, reasoning that their historic actions are the cause of the current emissions levels in the atmosphere (historic justice-principle). Developing countries, on the other hand, only committed to keep the increase in emissions as low as possible (without affecting their economic growth), as they argued that they were entitled the same right to develop as the developed countries (right to develop principle). Fearing economic harm, as well as a loss of economic power, the United States (at the time accountable for 36% per cent of global emissions) refused to ratify the agreement, while Canada withdrew from the agreement due to the economic costs associated with attaining their target reductions (both calling upon the grandfathering-principle). As a result, the countries following the Kyoto protocol accounted for only 14% of global emissions, whereas the large polluters remained inert to emission reduction actions. Due to the conflicting interests between parties, and disagreement on the fairness of the applied allocation methods, the Kyoto protocol never gained the traction or impact it was aiming for.

Recognizing the limitations of these international climate change negotiations, a new approach was introduced -formulated in the Bali Action Plan 2007-, in which sectors were stimulated to collaborate across borders to attain the necessary emissions reductions to limit man-made climate change. The main rationale behind this sectoral approach was that major emitting countries were not prepared to accept binding reduction targets due to anticipated nation-wide technical and institutional challenges (as well as economic protectionism). A sectoral approach, on the other hand, could secure commitments in areas where emissions trends were more easy to understand, making policies and measures more effective (UNEP, 2009). Furthermore, some of the high-emitting sectors are dominated by a few corporations. Having fewer parties - who share a common interest - will likely smoothen and simplify the negotiation process (UNEP, 2009). Adapting a sectoral approach creates an incentive to shift to low-carbon technologies rather than moving high-emitting facilities to countries with lower emission standards (e.g. developing countries) (ibid). Simultaneously, it

Continued on next page...

lays a foundation for collaboration - in the form of knowledge sharing and access to financing - between developed and developing regions. A downside of the sectoral approach, however, is their legal status, which precludes sectoral initiatives from imposing binding legal obligations to individual companies. Consequently, the sectoral approach is by many seen as an add-on to international agreements, rather than stand-alone initiatives

It is therefore surprising that in the 2015 Paris Agreements, emphasis remained on national GHG emissions, rather than incorporating the sectoral approach into the agreement (Bedanksy, 2016). In the 2015 Paris agreements, members were asked to assess (prior to the conference) how much they thought they could reduce emissions - based on BAU or on historic levels - resulting in Intended National Determined Contributions (INDCs). These proposals were based on how much each country could afford or how willing they were in their ambitions to reduce GHG emissions (capacity- and voluntary allocation). On top of that, consensus was found to limit the global temperature rise well below 2 degrees Celsius. This method proved to be a diplomatic solutions to the frictions caused by contradicting allocation philosophies. However, research has shown that the current INDCs do not suffice in limiting global warming to a 2oC increase (Rogelj et al., 2016). The INDCs demonstrated how much countries were willing to contribute, rather than how much they need to in order to comply with the Paris Agreement's ambitions. It could be argued that, over time, the willingness to adapt more rigorous INDC targets increase; as the effects of global warming become more evident. A counter-argument, however, is that due to the complexity and dynamics of system Earth, the 'time to act' may be far before the effects of climate change reach critical levels. A faster and more feasible approach would be to include the large emitting sectors (such as the transportation by boat and air) into the Paris Agreements.

In sum, the allocation principles used in climate change negotiations have a prominent effect on the negotiation outcomes. They can result in a perceived unfair distribution creating economic (dis)advantages for some countries (Kyoto), or places too much emphasis on what countries are willing or capable to do, rather than what is needed to be done (Paris Agreements). In both cases, the outcome might be insufficient efforts and unfair burden sharing. Integrating a sectoral approach into the negotiations might be a first step in resolving these shortcomings.

Text Box 10: Exploring Science Based Targets: Allocation Methods for Carbon Emissions

The Science Based Targets focus solely on the climate change boundary (see Text Box 1: Science Based Targets), but they provide organizations with methods to assess their impact and define reduction targets to remain within a fair operating space. They propose seven allocation methods that have been developed by different institutes, from which each organization can choose the best fitting according to their specific needs and characteristics. These methods are:

- The SBA (Sectoral Decarbonization Approach)
- The 3% Solution
- BT – CSI (Carbon Stabilization Intensity)
- C-FACT (Corporate Finance Approach to Climate-Stabilizing Targets)
- CSO's Context-Based Carbon Metric
- GEVA (GHG Emissions per Unit of Value Added)
- The Mars Method

All seven methods take a common approach to steps 1 to 4 of the OPA Framework, directly taking the 2º boundary for climate change as defined by the IPCC (Science Based Targets, 2017). Thereafter, the methods vary on how they derive the agent's impact and allocation in steps 5 to 8 of the OPA Framework

As most methods target companies, they generally make the obvious choices of taking an economic focus to the agent's activities, using supply chain information to quantify these activities, and applying databases and LCA methodologies to assess the eventual impacts in steps 5, 6, and 7, respectively, of the OPA framework (Science Based Targets, 2017). The main exception is CSO's Context-Based Carbon Metric method, which can also be applied to municipalities. Here, a territorial focus is applied to determine the extent of the agent's activities and aggregated statistical data is used to quantify the material flows in steps 6 and 7 of the OPA framework (CSO, 2017).

The methods diverge most noticeably in the eventual allocation of operating space in step 8 of the OPA framework. Most use economic throughput, in terms of CO_2 emissions per GDP, as allocation principle.

The SBA additionally accounts for differences in reduction efficiencies between and within sectors. The BT – CSI and CSO methods additionally account for differences in reduction capacity between OECD and developing countries (Pineda et al., 2015).

It is notable that the 3% Solution, which advocates for an annual carbon reduction of 3% by the US corporate sector, decouples GDP and CO_2 emissions by using the economic efficiency allocation principle to differentiate between sectors and to allocate the cost savings that accompany CO_2 reduction measures.

The Mars Method uses the egalitarian allocation principle by scaling down global reduction targets to organizations using absolute metrics rather than intensity metrics; they state that growth through higher production is the responsibility of the company and not of the atmosphere (Science Based Targets, 2017).

These methods individually allow companies and organizations to assess the impact of their activities on the operating space provided by the 2º pathway, and provide a solid basis for reduction strategies to stay within this operating space.

The differences differences between the different SBT methods, however, pose a couple of issues, especially in the allocation of operating space to agents.

Different allocation outcomes arise from selecting different allocation principles, incentivizing agents to choose the method that yields the most favorable targets for them. This can also result in unfair allocation of operating space between agents. Most importantly, the resulting differing targets may provide no meaningful way to measure whether emissions are sufficiently mitigated to meet IPCC's 2º Celsius pathway. As a result, all SBT companies can individually meet their targets but collectively fail to remain within a safe boundary for their sectors.

Text Box 11: Business Approaches in the Context of Water Systems

Several methods have been proposed for defining global water stewardship objectives and subsequently transferring these into boundaries which are based on local water system dynamics. One of these was developed in a collaborative effort of ten organizations that are active in sustainable water resource management, amongst which is the WWF, resulting in the Alliance for Water Stewardship Standard (Alliance for Water Stewardship, 2013). A method that emerged from a more corporate perspective is the Replenish program of The Coca-Cola Company, which sets goals for water balancing and provides methodologies for quantifying water quantity and quality benefits (Rozza et al., 2013). These methods have different approaches to mapping water system dynamics and defining boundaries on a local level accordingly.

The Alliance for Water Stewardship Standard has the objective to drive global water stewardship, which they define by its outcomes on the areas of: good water governance, sustainable water balance, good water quality status, and healthy status of important water-related areas (Alliance for Water Stewardship, 2013). By incorporating governance and cultural indicators, this standard thus extends its scope further than in the Planetary Boundaries (where the objective is maintaining the environmental water flow (EWF)).

No boundaries are, however, set in relation to these water system processes, the performance is instead mostly connected to local stakeholder-inclusive processes that involves site- and catchment-based actions that aim to achieve water stewardship in the four outcome areas (Alliance for Water Stewardship, 2013). This indicates that the operating space is also defined by policy and social demands next to extrapolations and estimates on the water balance.

The Coca-Cola Company defined their "Replenish" goal in 2007, aiming to "safely return to communities and nature an amount of water equivalent to what is used in our beverages and their production by 2020". This globally focused water stewardship goal was translated into action focusing on the water benefits of projects within local communities and ecosystems. A methodology to quantify these water benefits was later developed to measure the progress in the dynamics of the local watersheds (Bass & Larson, 2016). In this methodology, enterprise-level mass balances for water are used to determine the consumptive water balancing needed within the its originating watershed or community. Quantifiable goals are then set for these local watersheds. For Coca-Cola, this meant reducing water impact through improved agricultural management, reducing runoff through land cover improvements, increasing water availability for the ecosystems and communities through surface and groundwater management, and improving the water quality of polluted discharge (Rozza et al., 2013).

These approaches are useful in defining either methods for local water stewardship based on global goal or balancing water local watersheds based on quantitative indicators. An approach that provides a means to translate the planetary boundary for freshwater use to a local context is not provided by the described methods. The Context-based water stewardship targets, a recent effort in translating global goals to a regional context, might however be able to bridge this gap (Pineda et al., 2015; UN Global Compact, 2016).

03 FURTHER DEVELOPMENT OF ONE PLANET APPROACHES

EXPLORING THE IMPLEMENTATION OF ONE PLANET APPROACHES ON A COMPANY LEVEL

The literature review and walk-through of an archetypical One Planet Approach in Chapter 2 reveals the broad range of techniques applied in current OPAs as well as the many gaps and areas of uncertainty that remain in moving towards large-scale implementation. In this chapter, we proceed with a more in-depth discussion of how an idealized OPA framework could be further developed. Our recommendations consider a combination of approaches suited for different contexts, roughly following the 8-step process defined in the previous chapter.

3.1 SETTING THE OBJECTIVES FOR AN IDEAL OPA

01 DEFINING THE SUSTAINABILITY OBJECTIVE

The One Planet Approaches have most recently been inspired by the Planetary Boundaries framework but, fundamentally, they arise from the awareness that the integrity of the Earth system is at risk because of human activity and that most sustainability initiatives are rarely linked to the carrying capacity of the planet. Based on the literature review and additional research through interviews we carried out for this project, it is our assessment that basing the sustainability objectives of OPAs purely on planetary habitability, as is done in the PB framework itself, is not sufficient to ensure a sustainable future in the full sense of the term.

Instead, sustainability objectives need to 1) be locally relevant, 2) strive for more than mere habitability, 3) integrate socioeconomic dimensions, and indeed, 4) ensure planetary habitability over time. Reflecting on the philosophy behind One Planet Approaches and the long tradition of sustainability efforts already implemented worldwide, we would propose a more holistic set of objectives to inform the establishment of system boundaries:

ONE PLANET APPROACHES SECURE BOTH THE LOCAL SUSTAINABILITY AND THE GLOBAL HABITABILITY OF THE PLANET, PROTECTING SOCIAL JUSTICE AND HUMAN FULFILLMENT FOR PRESENT AND FUTURE GENERATIONS, AND ELEVATING THE BIOSPHERE AS A DIRECT BENEFICIARY OF THIS EFFORT, WHILE BUILDING A SYSTEMICALLY RESILIENT WORLD TO PROTECT THESE INTERESTS IN THE LONG-TERM.

This is an ambitious, but not impossible, goal. Most importantly, if we adhere to this broader objective, OPAs will be less likely to result in insufficient action, entrenchment of existing socio-economic inequalities, or the continued trespassing of the rights of future generations and the biosphere. This vision of sustainability involves different components, which we now explain and justify.

3.1.1. SECURE BOTH THE LOCAL SUSTAINABILITY AND GLOBAL HABITABILITY OF THE PLANET

The Planetary Boundaries were designed as a safety check to avoid global systemic collapse, but this does not necessarily guarantee a locally sustainable world because the processes that form the Earth system operate at different levels and timeframes and the relationships between the local and the global are hardly linear.

Global stability does not mean regional stability, and regional stability does not mean global stability. Hence, boundaries need to be defined twice in order to guarantee that both the global and regional levels remain stable and within ecosystem capacity. The lower (more restrained) of the two boundaries should be taken as the actual limit of the operating space (See section 3.2.3 and Figure 12 for an explanation of this concept).

3.1.2. PROTECT SOCIAL JUSTICE AND HUMAN FULFILLMENT FOR PRESENT AND FUTURE GENERATIONS

Guaranteeing global habitability is a necessary requirement for sustainability, but protecting the biophysical processes identified by the PBs is a minimum objective. Building a socially fair and inclusive world is an integral component of sustainable development, and, as in Raworth's (2012) expanded framework, these issues need to be part of the agenda.

Social objectives need to be socially and democratically defined and safeguard the interests of future generations. In practical terms, this means that national policy and development objectives and bottom-up social consultations should be part of the process to define boundaries, particularly at regional scales.

3.1.3. ELEVATE THE BIOSPHERE AS A DIRECT BENEFICIARY OF THIS EFFORT

Biodiversity (or biospheric integrity) is a critical component of the PBs, but even though it's defined as a core boundary, it's still discussed only in terms of the benefits it provides to people through ecosystem services or through the creation of resilience. This utilitarian approach has a strong case and brings a powerful narrative for urgent action. However, it fails to challenge the dominant paradigms of our relationship with nature and to recognize the intrinsic existence value of the biosphere.

As a consequence of this approach, when the PBs define conserving at least 90% of remaining biodiversity integrity as the boundary of our operating space, they normalize the loss of up to 10% of biodiversity. Moreover, the claim that higher biodiversity levels translate into higher resilience for ecosystems has been contested (Ives & Carpenter, 2007) and may not hold true in every circumstance. If this is indeed the case, then a purely utilitarian argument for maintaining planetary habitability could erode the universal rationale for the protection of biodiversity.

This leaves us to question, should we protect only the species that are essential to our survival? OPAs can take a utilitarian approach as a starting ground, but should encourage a higher, spiritual or empathic recognition of the value of the biosphere and the ecosphere. In practical terms and as a minimum, an ideal OPA should adhere to zero biodiversity loss targets, such as the No Net Loss policy defined by the European Commission (European Commission, 2016).

3.1.4. BUILD A SYSTEMICALLY RESILIENT WORLD TO PROTECT THESE INTERESTS IN THE LONG-TERM

The PB framework is influenced by the concept of resilience (indeed, it was proposed by the Stockholm Resilience Center), an emergent system property that describes the capacity of a system to deal with change and continue to develop without collapsing (Stockholm Resilience Centre, 2016).

Resilience can be built into systems through intended human action, both at the biophysical and the social levels, and there is a growing body of literature (See Carpenter, Arrow, and Barrett 2012; Biggs, Schlüter, and Biggs 2012) shedding light on how to tackle this challenge. While resilience is, strictly speaking, not an end in itself, building resilience into the Earth system should be included in the sustainability objectives of an ideal One Planet Approach. For a discussion on how this could be addressed, see Section 4.3.3 The OPT Code of Behavior.

3.2 DEFINING BOUNDARIES FOR AN IDEAL OPA

02 IDENTIFYING THE UNDERLYING SYSTEM PROCESSES

03 MAPPING THE RELEVANT SYSTEM DYNAMICS

04 DEFINING BOUNDARIES OR OPERATING SPACE

One Planet Approaches can build on the rationale of the Planetary Boundaries framework but, to be effective in practice, they cannot just take globally defined boundaries and apply them directly. An ideal OPA would need to redefine the operating space to meet its sustainability objectives. Three issues need to be addressed:

- attending to locally-relevant needs in addition to global needs,
- defining a comprehensive set of impact categories that need to be controlled to meet these needs,
- and converting these into quantified, actionable limits in the form of flow or stock units.

The first point means that we should not try to downscale global boundaries into regional limits, nor to define regional limits only so that they meet global objectives. Instead, an ideal OPA needs a bottom-up process to establish regional boundaries that meet regional objectives in addition to the global objective of planetary habitability.

In other words, the operating space has be to defined so as to be locally-relevant with a focus on preserving biospheric integrity at the regional level.

OPAs will also need to assess boundaries at different scopes depending on the Earth system process being impacted. Quintessentially global systems, like climate, should indeed have boundaries set on the global scale. Other boundaries need to be defined at a regional level as well and additional impact categories need to be considered to guarantee systems will not collapse. The dynamic nature of the boundaries should be taken into account, with some boundaries requiring reassessment at more frequent intervals than others.

In the PB framework, many boundaries are set as the system states required to maintain the planet habitable, such as a maximum change of radiative forcing in the atmosphere. OPA programs, like One Planet Thinking, that intend to define individual targets need to express the planetary boundaries in terms of flows or stocks (not system states) that can be quantified and connected to the activities of individual actors.

As an example: we can't define targets based on radiative forcing, but we can define targets for greenhouse gas emissions, which in turn affect radiative forcing. These targets can be rate-based (e.g., emissions per year) or absolute numbers (e.g., total emissions over a long period), as has been done with GHG emissions ceilings.

In the remainder of this section, we present the best-developed approaches currently available for different kinds of boundary setting, and discuss other considerations that should be kept in mind when going through boundary setting exercises.

Figure 10: Systems Suitable for Global Boundary Setting: Climatic and Oceanic Stability

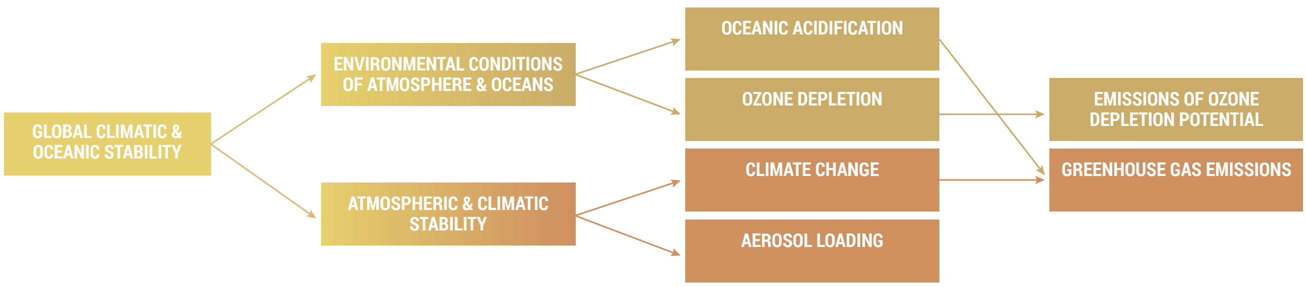


Figure 10. *An illustration of how the systems suitable for global boundary setting, which include Climatic and Oceanic stability, are related to supporting processes and control variables in a One Planet Approach.*

3.2.1 GLOBAL BOUNDARIES FOR STABLE CLIMATE AND OCEANS

02 IDENTIFYING THE UNDERLYING SYSTEM PROCESSES

03 MAPPING THE RELEVANT SYSTEM DYNAMICS

For global processes

Among the nine processes identified in the planetary boundaries, only five operate globally or almost globally: climate change, ozone depletion, ocean acidification, and the climate regulating properties of land systems and aerosol loading. For these global processes, environmental pressures have similar impacts on the Earth system regardless of where in the world they happen.

These boundaries are all concerned with preserving the stability of the atmospheric and oceanic systems, namely preserving the energy balance at the land-atmosphere and atmosphere-space interfaces, maintaining existing circulation patterns in the atmosphere and oceans, and preserving the chemical composition of the oceans (H+ concentration) and stratosphere (ozone concentration).

04 DEFINING BOUNDARIES OR OPERATING SPACE

Because these systems operate globally, we can use global boundaries directly in OPAs – we only need to express them in flow units. In other words, the level of the boundaries can be kept unchanged, as defined in the PB framework or by other relevant global institutions, with their current and future updates. In Table 2, we present an overview of boundaries that have been set at the global scale that can already be applied in practical contexts.

In order to express a boundary, currently defined as a system state, in terms of a flow, we need to change it to units of the relevant environmental pressure. For example, for climate change, we need use the boundary measured in concentration of greenhouse gases in the atmosphere (not the change in radiative forcing) and express it in terms of the corresponding GHG emissions, for a certain period, that will result in that concentration.

For OPAs, we refer to these flow-based units as control variables, as we will define company targets based on these control variables, and not on the boundaries themselves. Table 2 indicates the corresponding control variable(s) for each planetary boundary.

Table 3: Global Boundaries for Stable Climate and Oceans

PROCESS	PLANETARY BOUNDARY	BOUNDARY-SETTING INSTITUTION	CONTROL VARIABLE FOR OPT COMPANIES
CLIMATE CHANGE	>350 ppm CO2-eq	IPCC, UN	Emissions of global warming potential units (tons of CO2-eq), per year
OCEAN ACIDIFICATION	≥80% of the pre-industrial aragonite saturation state of mean surface ocean, including natural diel and seasonal variability (≥80%– ≥70%)	SRC and scientific community	none, included in Climate change and ecosystem acidification control variables
STRATOSPHERIC OZONE DEPLETION	<5% reduction from pre-industrial level of 290 DU	Montréal Protocol	Emissions of ozone depletion potential units (tons of CFC-11 eq), per year
LAND SYSTEMS CHANGE, PER BIOME TYPE	**Global:** 75% (weighted average of biome boundaries) **Biome:** *Tropical:* 85% (85-60%) *Temperate:* 50% (50-30%) *Boreal:* 85% (85-60%)	SRC and scientific community	Surface area (hectares) occupied or degraded of potential forest area, per biome type
AEROSOL LOADING	0.20-0.50 AOD (with strong variation per region)	SRC and scientific community	PM emissions per year

Table 3. *Shows current limits defined for global boundaries, as well as the international institutions backing these boundaries. The last column names control variables that should be used for OPA purposes, with all variables listed as flows, instead of states.*

3.2.2 REGIONAL BOUNDARIES FOR BIOSPHERIC INTEGRITY AND SOCIAL ECOSYSTEM NEEDS

02 **IDENTIFYING THE UNDERLYING SYSTEM PROCESSES**

03 **MAPPING THE RELEVANT SYSTEM DYNAMICS**

For regional processes

Processes such as biodiversity loss, the biogeochemical flows of nitrogen and phosphorus, freshwater use, and the effects of novel entities operate primarily at regional scales. Moreover, aerosol loading and land systems change not only operate at global levels, but can also impact the Earth system at the regional level. For all these processes, the boundaries included in the PB framework are global averages that should not be used directly in a One Planet Approach. Instead, these boundaries need to be reevaluated on a case-by-case basis in accordance with local context. Additionally, they should be updated periodically to account for variation and changes over time. For companies with global supply-chains and / or geographically widespread markets this means that several local targets have to be managed.

In the PB framework, the boundaries on freshwater use and biogeochemical flows are already defined in flow units, so they only need to be reassessed at the adequate regional levels. All other boundaries have to be converted into flow units.

Biodiversity loss is currently measured through biodiversity intactness index and phylogenetic species variability, which serve as indicators but are impossible to convert to flow units for companies (or countries) to work with. We can't create a budget of "species loss per company" or "genetic variability loss per company". Moreover, the ideal state for this boundary is of no-net loss. Instead, OPAs must work with flow units for the drivers of biodiversity loss, such as: climate change, habitat loss, species extraction, ecotoxic emissions, nutrient emissions, etc. Some of these are already covered in the PBs; some others we have to include as new control variables for these programs.

We could subsume all the regional processes into the overarching objective of preserving biospheric integrity. Steffen et. al (2015) define it as a core boundary within the PB framework. Yet it is clear that in addition to the boundaries listed in the PBs, we require additional control variables to prevent the collapse of regional ecosystems. For example, we need a control variable on habitat loss, which can be defined as maximum amount of ecosystem space occupied by a company. In the same line of reasoning, we should also include a limit on wild biomass extraction, which can be defined in flow units and can be used to set targets based on maximum sustainable extraction for fisheries and forestry operations.

For these additional control variables, LCA databases include some additional impact categories that can be taken into account as a first step: terrestrial and freshwater acidification, photochemical smog formation, and ecotoxicity in different environments. In effect, an ideal OPA needs to strengthen regional boundary setting with additional control variables as relevant in each context.

Considering social demands on the environment

As a first step towards meeting social justice objectives, One Planet Approaches should define boundaries for biospheric integrity that also protect socioeconomic needs. There are at least four cases where society directly depends on ecosystems:

» The provision of certain consumptive (use) services, mainly access to freshwater for drinking and other basic needs, as well as access to food in subsistence-based production systems.

» The provision of local livelihoods, in cases where ecosystems are traditionally managed as local commons, for example in fisheries or pasturelands.

» The provision of non-use services to society, including the cultural, aesthetic, recreational, and spiritual services.

» The provision of resilience through protection services from floods, hurricanes, and other events, as in the case of coral reefs, seagrass beds, and mangroves that protect coastal communities.

At least in the first of these cases, a popular consultation process should define to what extent society currently demands these services. For issues that affect human health, such as aerosol loading and chemical pollution, OPAs should consider international and national health standards as part of the boundary setting process.

Figure 11: Systems Suitable for Regional Boundary Setting: Biospheric Integrity

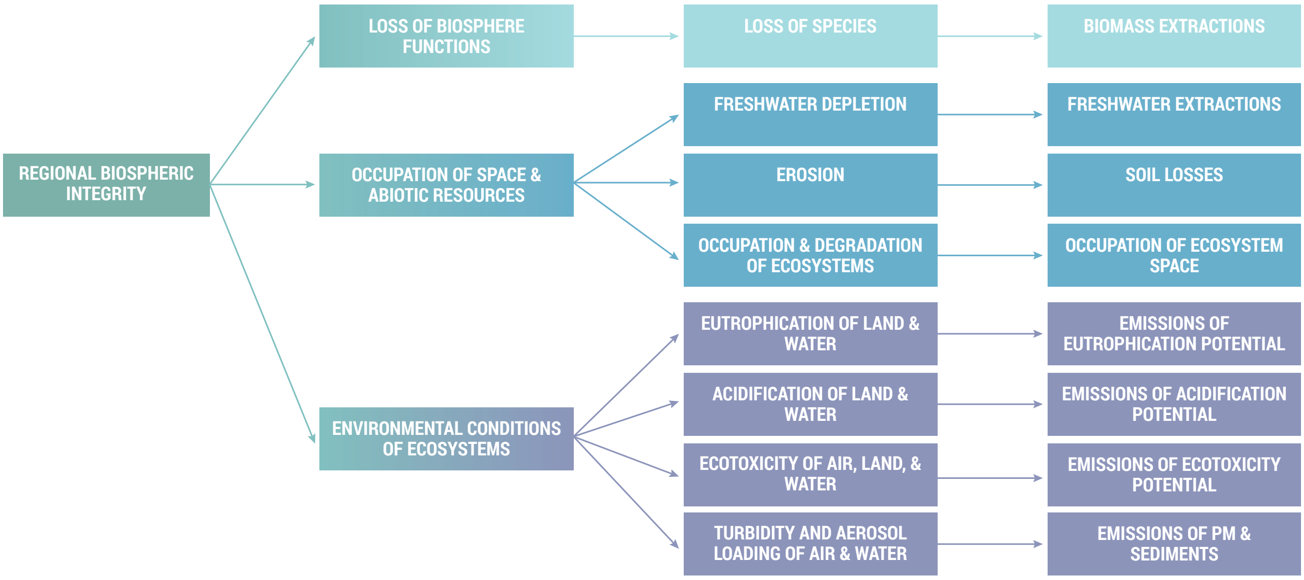


Figure 11. *An illustration of the causal relationships between biospheric integrity and the activities and impacts that can lead to its perturbation, including supporting processes and control variables that can be included in a One Planet Approach.*

A special consideration for habitat loss

The occupation of the operating space in terms of land use (in a broader sense, the occupation of ecosystems) happens through the conversion of natural ecosystems to anthropogenic uses, like agriculture, cities, and land, coastal, and marine infrastructure. While we inescapably need to occupy space to carry out all of our activities, there are powerful reconfigurations possible through urban densification, including new kinds of approaches to food production, which could theoretically leave much more space for ecosystems.

As with other changes, there are significant costs and technological limitations involved. For example, there are no landless solutions for growing most grains, starchy roots, and perennials. As for retreating the agricultural frontier, there are considerations on specific, positive services that agricultural systems provide to support biodiversity and the question of social justice and livelihoods for farmers and rural workers.

Nevertheless, we have not defined an adequate boundary for the occupation of terrestrial and water ecosystems, especially a boundary aimed at preserving the biodiversity and the ecosystems themselves. Currently this is, most likely, the worst transgressed of the planetary boundaries.

Much like how water and carbon can be used in more efficient ways, and how technological and institutional changes can mitigate pressure on all other Earth system processes, our occupation of ecosystem space can be minimized to a small fraction of the planet's area, but we need to address the question of burden sharing. How do we share the opportunity costs of halting - or even reversing - anthropogenic land uses?

Summary of regional boundaries for biospheric integrity

04

DEFINING BOUNDARIES OR OPERATING SPACE

For regional processes

In Table 3, we provide an overview of the processes that should ideally be subject to boundary setting on a regional scale. In Table 4, we recommend specific methodologies and databases that can be used in the process of defining these boundaries.

To note, the boundary-setting process is more advanced in some regions of the world than in others. For example, information on freshwater availability is more accurate where environmental flows have been assessed. Carrying capacity for other processes has been assessed in specific areas, such as the assessment of nitrogen and phosphorus cycling in the Baltic Sea region (Kahiluoto, 2015) and the sustainable extraction models used for fisheries and forestry activities.

Where boundaries have not been defined, existing indexes and datasets can be used in a rough way to understand some regional limits. These can be used directly by companies setting targets relative to planetary capacity, and, moreover, they should serve as first step to define boundaries (see table 5). The SETAC Life Cycle Initiative is currently advancing approaches to standardize impact assessment methods for a variety of impact categories.

Table 4: Regional Boundaries and Additional Control Variables for Regional Biospheric Integrity

PROCESS	RECOMMENDED CONTROL VARIABLES	CONTROL VARIABLE FOR OPACOMPANIES (FLOW UNITS)
BIODIVERSITY LOSS	Wild biomass extraction	Wild biomass extraction, per species or population, measured in mass or energy units
	Habitat loss and degradation (for all ecosystems, land and water) *(related to, but different than, the land systems change variable)*	Area of land and water ecosystems occupied or degraded by company activities, per ecosystem type, measured in hectares
	Acidification of land and water *(partially related to biogeochemical flows, but including other elements like Sulfur)*	Emissions of acidification potential (SO2-eq)
	Water turbidity *(similar to aerosol loading, the equivalent for water systems)*	*To be defined*
BIOGEOCHEMICAL FLOWS (EUTROPHICATION)	Emissions of N and P	Emissions of N and P measured in total eutrophication potential (PO4-eq)
FRESHWATER USE	Freshwater Use	Volume (m3) of consumptive blue freshwater extraction
AEROSOL LOADING (ALSO DISCUSSED IN GLOBAL SECTION)	Aerosol Loading	Emissions of PM, per year Emissions of photochemical smog formation potential, per year
NOVEL ENTITIES	Ecotoxicity of air, land, and water	Emissions of ecotoxic potential (14DCB-eq)
	Other potential effects, especially abiotic, to be defined as new research becomes available	*To be defined*

Table 4. *Identifies additional control variables that should be used to comprehensively define boundaries for these regional systems. Many of the control variables are relevant to more than one of the Planetary Boundaries, and can be considered multiple times.*

Table 5: Selected Boundary-Setting Methodologies for Preservation of Biospheric Integrity

DRIVER	SCOPE	METHODOLOGY	OBSERVATIONS
NUTRIENT EMISSIONS - NITROGEN AND PHOSPHORUS	Watershed, water bodies	Use UNECE critical load models for nitrogen/ phosphorus either based on 1) empirical data, 2) dynamic ecosystem models or 3) steady state modelling. Combine deposition maps with critical load maps a divide the deposition rate (mol/ha/yr) by the critical load (mol/ha/yr) per grid to calculate the % level of exceedance. (EEA, 2010)	* Critical load map should be cross-checked with ecosystem specific deposition rates, standard grid (50km x 50km) can only be considered a rough estimate. * Maps on critical levels and deposition rates are currently not available in some regions. * Not accounting for downstream impact * Not accounting for watershed
FRESHWATER EXTRACTION	Watershed / water basin, nested	The Water Stewardship Standard focuses on a broad range of relevant global freshwater criteria, these criteria are nested within the model The "Replenish" program provides methods to quantify freshwater balances in local watersheds; mainly uses the Soil & Water Assessment (SWAT) model for land and watershed model simulations , and "TCCC Rainwater Harvesting Model" for rain and aquifer related calculations (Rozza et al., 2013) NOAA's Watershed Database and Mapping Projects; focused on quality and quantity of coastal watersheds	*Quantification means are not available for all criteria in the Water Stewardship Standard *NOAA doesn't cover all regions *No databases/maps found with data on all watersheds *Combination SWAT and TCCC could yield a completer model by bridging land-use and aquifer
ECOSYSTEM OCCUPATION AND DEGRADATION	Per ecosystem type	Newbold et al (2016) combines global pressure on local biodiversity data with global land-use data. Chaudhary et al (2016) combines land occupation characterization factors (CFs) per ecoregion with maps of land-use (agriculture, pasture, forest) to calculate biodiversity impact.	Improving either or both methods via: * WOCAT sustainable land database (although does not account for biodiversity loss) * Globio to map biodiversity loss (induced by humans) * ReCiPe database to further specify the impact on biodiversity loss using LCIA * Both approaches have a strong emphasis on land-based ecosystem
WILD BIOMASS EXTRACTION	Per species, per biome	Fisheries: Use the FAO target reference points to determine a maximum sustainable yield (MSY) per specie in a specific region. Forestry: Use the FAO forest valuation database and the sustainable forest management standards (SFM) to determine the maximum sustainable yield for specific regions/forests	* Model does not account for food chain dynamics, but rather singles out the relation between fisheries and population levels.

Table 5. *Includes a list of recommended methodologies that can be used to define boundaries for selected impact categories at the regional level.*

3.2.3 OVERLAPPING REGIONAL AND GLOBAL BOUNDARIES

04 DEFINING BOUNDARIES OR OPERATING SPACE

Combining regional and global processes

In some cases, a single process might be relevant for more than one sustainability objective. For example, there can be a global boundary on remaining forest cover defined to protect the climate system, a second boundary defined to protect local biodiversity (the biospheric integrity), and there can be yet a third boundary to meet social demands on these ecosystems (such as the aesthetics of landscape areas). In these cases, the lowest boundary - the one with the lowest threshold or that constrains the operating space to the greatest extent - needs to be taken as the actual limit of the operating space, as this will guarantee meeting all three objectives. This idea is illustrated in Figure 12.

In some cases, meeting the regional requirements can be more than enough to meet the global average requirements. This would mean that some regions might be overprotected, with unnecessary restrictions on the operating space (at an economic cost for society). The requirement for the global boundary can be loosened for these regions, so long as the global average is still met, and so long as the stricter regional boundaries are effectively kept (as illustrated in Figure 12).

3.2.4 DYNAMIC SYSTEMS CALL FOR DYNAMIC BOUNDARIES

All of these processes are dynamic and therefore the operating space needs to be recalculated and updated periodically to account for possible changes in the system's carrying capacity and stability. Complex systems, like the biosphere, respond to many more forces than can be modeled and accounted for in terms of flows. For instance, a species decline can signal the need for an urgent restriction of operating space in that region (in addition to other immediate measures to protect the species). Hysteresis and similar signs of instability should lead to constraining the operating space until ecosystems recover.

Human action can also affect the carrying capacity of ecosystems by increasing or reducing the operating space. Nevertheless, population and economic growth, while they may imply higher social demands, cannot be reasons to loosen boundaries defined for regional or global system stability.

Figure 12: Combining Global, Regional, Social, and Biophysical Objectives

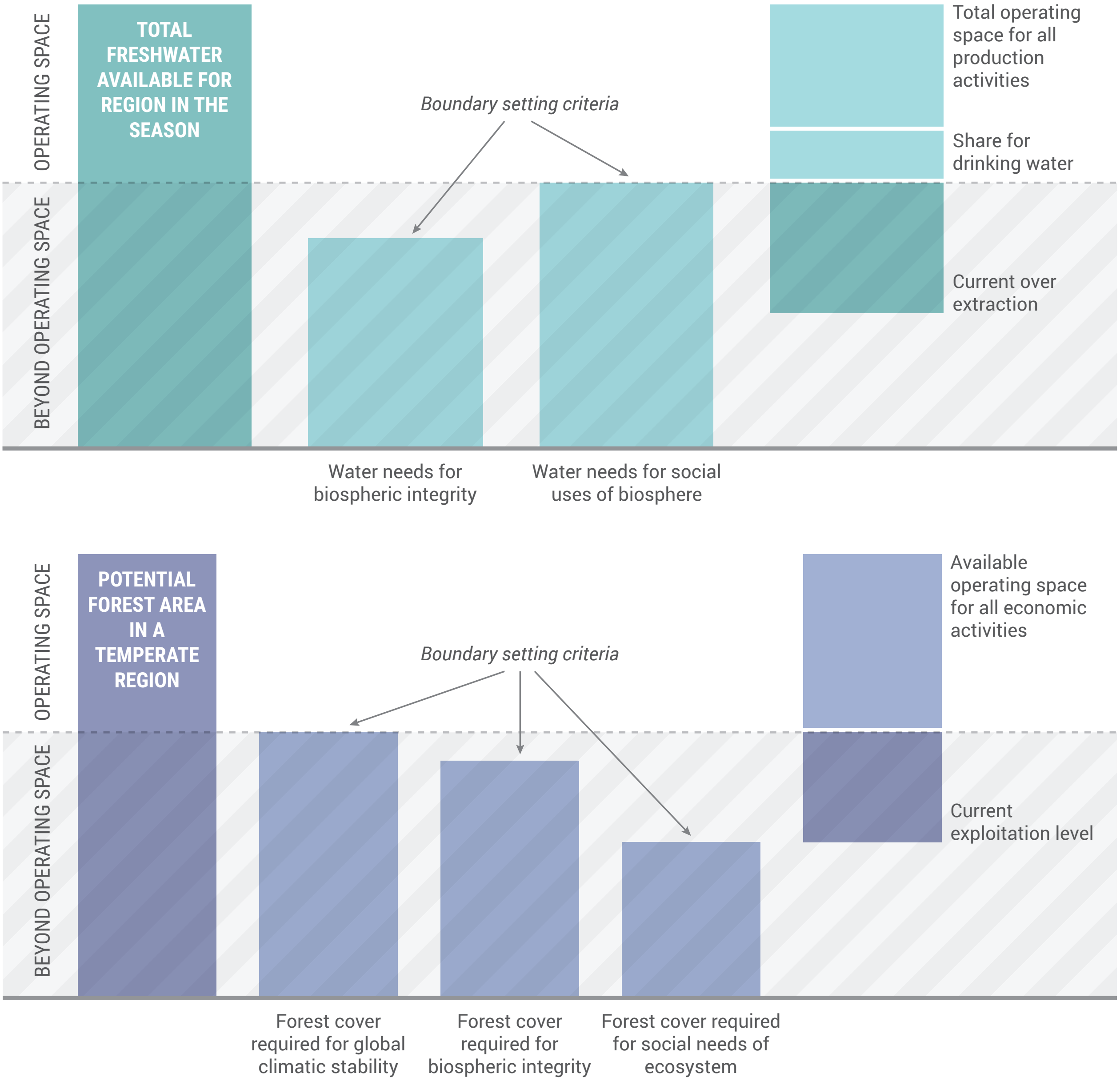


Figure 12. *A schematic illustration of the ways in which multiple demands for global stability, regional sustainability, and social as well as biophysical needs should be combined in defining a safe operating space.*

Figure 13: Control Variables for Boundary Setting in a One Planet Approach

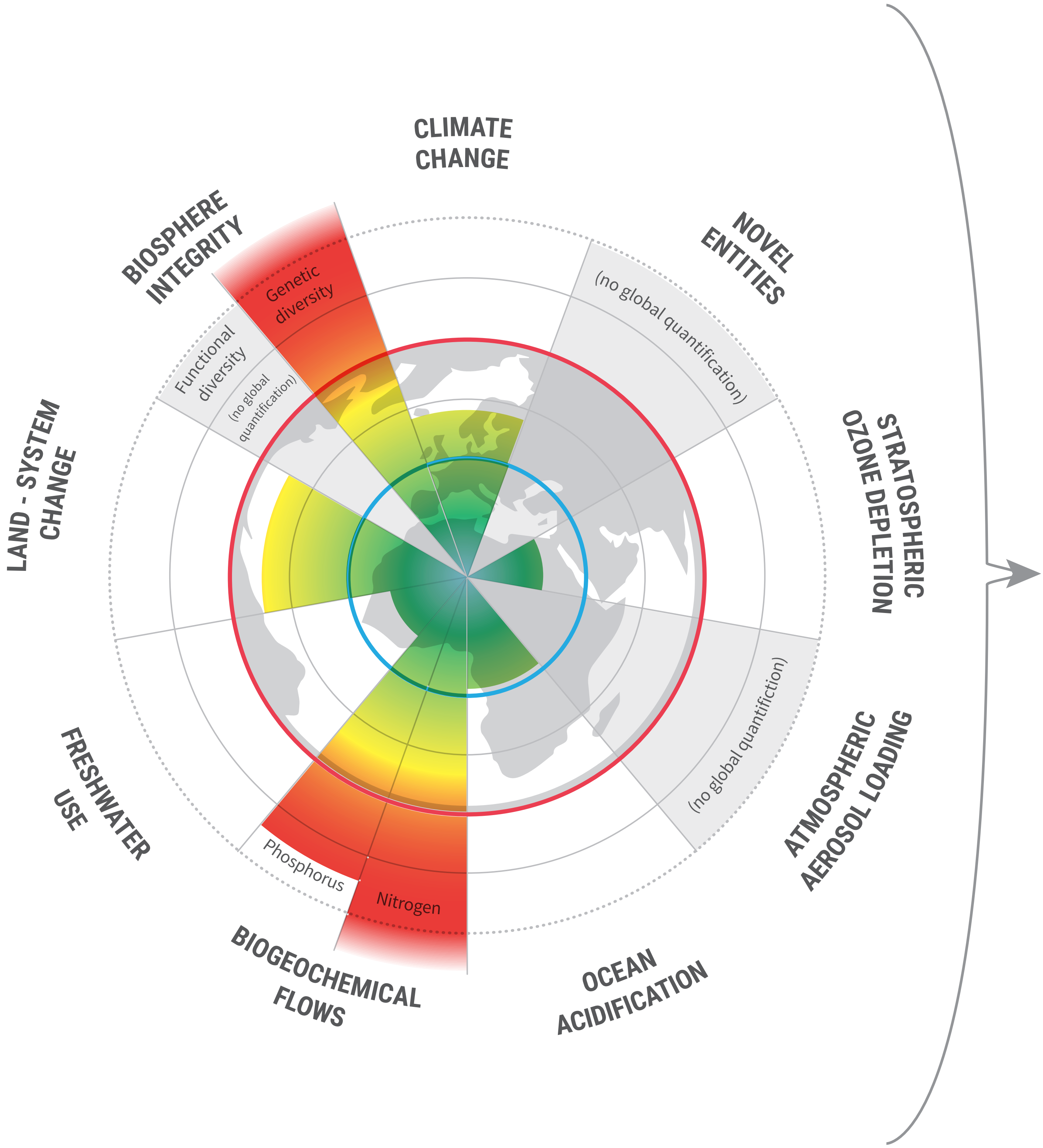


Figure 13. *Control variables recommended to include in the operationalization of the Planetary Boundaries as a One Planet Approach. These variables include the original processes of the framework, redefined as flow units, and additional variables to account for different processes that affect regional biospheric integrity.*

PLANETARY BOUNDARIES	CONTROL VARIABLES FOR OPA
NOVEL ENTITIES	EMISSIONS OF ECOTOXIC POTENTIAL
BIOGEOCHEMICAL FLOWS	EMISSIONS OF EUTROPHICATION POTENTIAL (ALL ECOSYSTEMS)
FRESHWATER USE	FRESHWATER EXTRACTION
BIODIVERSITY LOSS	WILD BIOMASS EXTRACTION, PER EXTRACTED SPECIES
LAND SYSTEMS CHANGE	HABITAT LOSS, OCCUPATION AND DEGRADATION, ALL ECOSYSTEMS
CLIMATE CHANGE	GREENHOUSE GAS EMISSIONS
OCEAN ACIDIFICATION	EMISSIONS OF ACIDIFICATION POTENTIAL (INCL. LAND AND FRESHWATER)
AEROSOL LOADING	EMISSIONS OF PM, SEDIMENTS, AND SMOG FORMATION POTENTIAL
OZONE DEPLETION	EMISSIONS OF OZONE DEPLETION POTENTIAL

3.3 INFORMATION FEEDBACK AND DECISION-MAKING

Impact assessment is not strictly necessary to create targets or budgets, but it is essential to evaluate how agents are impacting certain boundaries and ultimately to guide decision-making.

In Chapter 2 we introduced two ways to scope the extent of an agent's activities: an economic focus (through supply chains) and a territorial focus. While territorial approaches might be useful in some contexts, particularly for drafting some aspects of public policy, an economic approach is essential for companies, especially when their impact might extend across the world through various value chains. Companies performing OPA impact assessments need to provide or estimate supply chain information, including to the final point of sale, and ideally also throughout the expected use phase of a product. Estimations for end-of-life processing, though not fully accurate, are also required. These can be based, for example, on the most likely end of life processing for the product (incineration, recycling, etc).

3.3.1 ASSESSING IMPACT

05 DETERMINING THE EXTENT OF THE AGENT'S ACTIVITIES

LCA based impact assessment and footprinting methodologies based on Ecological Footprint Accounting (and its family of approaches) are similar methodologies and both applicable for assessing and implementing PB-based targets. Out of the two, we note that Ecological Footprint is already an OPA Methodology, as it compares total planetary capacity to individual impact. However, LCA-based implementations are a better approach for the purposes of implementing OPA-based targets for companies. Operationalizing through LCA has these advantages over other impact assessment methods:

- Wider selection of impact categories and drivers
- Availability of open-access databases
- Modular design, which permits continuous update through normalization factors and eventual extension to new impact categories
- Ongoing efforts to integrate LCA-based impact assessment to the context of OPA
- Existing efforts to regionalize databases
- Possibility to create impact assessments at the level of product, company, and sector

The integration of LCA into OPA is still in its infancy, but recent work has focused on identifying challenges in this regard (Ryberg, 2016) and proposed ways to define LCA-based allowances of planetary capacity (Doka, 2016) (See Text Box 7: LCA and the Planetary Boundaries).

3.3.2 NORMALIZATION AND REGIONALIZATION TO PLANETARY CAPACITY

06 QUANTIFYING THE FLOWS ATTRIBUTED TO THE AGENT'S ACTIVITIES

07 ASSESSING THE IMPACT ON THE OPERATING SPACE

Despite its relative advantages, LCA methods need to be refined before they can be successfully applied in OPA. There are three major areas that need refinement:

- Regionalization
- Normalization against PBs
- Inclusion of additional impact categories

All the processes that operate at the regional level are dependent on local contextual factors. For example, the capacity of ecosystems to absorb different types of pollutants will vary across the world. To obtain meaningful information on an agent's impacts, LCA databases should provide a differentiated assessment depending on regional factors. We note that regionalization is already a major trend in LCA research and development, especially in combination with GIS databases (see Mutel, 2009; Liu, 2014).

Similarly, it's possible to incorporate, into the impact normalization of LCA, a factor to account for carrying capacity. This basically would transform LCA into an OPA methodology. Several publications by A. Bjorn (2014a, 2015a, 2015b, 2016b) have discussed and explored this process. The nascent LCAbsolute network intends to develop methodologies and databases to adapt LCA to carrying capacity (see Text Box 7: LCA and the Planetary Boundaries). However, this normalization is not required to implement an OPA as we have defined it, so long as the impact assessment is paired with the boundary setting techniques and databases we discussed before.

Finally, the possibility for LCA to assess impacts such as habitat loss or wildlife extraction, needs further exploration. In this report, we refer to some LCA-based databases that incorporate biodiversity loss assessments, such as ReCiPe, but these are still very rough generalizations that don't account for different habitats and species with the necessary level of detail.

Table 6: LCA Databases Useful for Evaluating Drivers for OPA Impact Categories

DRIVER	LCA DATABASES TO USEFUL TO ASSESS IMPACTS	SOURCES
Climate change	LCA - using the ecoinvent 3.3 database	Weidema et al, 2013
Ocean acidification	LCA - using the ecoinvent 3.3 database	Weidema et al, 2013
Stratospheric ozone depletion	LCA - using the ecoinvent 3.3 database	Weidema et al, 2013
Aerosol loading	LCA - using the ecoinvent 3.3 database	Weidema et al, 2013
Eutrophication of land and water	LCA - using the ecoinvent 3.3 database	Weidema et al, 2013
Acidification of land and water	LCA - using the ecoinvent 3.3 database	Weidema et al, 2013
Ecotoxicity of air, land, and water	LCA - using the ecoinvent 3.3 database	Weidema et al, 2013
Freshwater depletion	LCIA - using ReCiPe database	ReCiPe, 2008
Occupation and degradation of land and water ecosystems	LCIA - using ReCiPe database	ReCiPe, 2008
Loss of species and populations	LCIA - using ReCiPe database	ReCiPe, 2008

Table 6. *Lists some available LCA databases to evaluate impact for different OPA impact categories.*

3.4 ALLOCATION: SETTING REFERENCES FOR OPA AGENTS

08 SELECTING AN ALLOCATION PRINCIPLE

Once operating spaces have been defined (after Step 4), it is theoretically possible to translate them to the agent level, or to allocate them. To do this, it is necessary to answer how much of the total operating space should be claimed by each agent.

In Section 2.8 we reviewed the main principles used to allocate operating space to different agents (egalitarian allocation, using economic values as proxies, continuing or upending historic patterns, and economic optimizations). We included some observations on their immediate strengths and weaknesses, particularly on whether they would result in fair resource distributions for the agents in question. We now discuss broader questions regarding allocation exercises that are not frequently addressed in the methodologies we reviewed, namely that of the legitimacy of the exercises themselves. Finally, we recommend viable ways forward considering that no principle yields universally satisfactory results.

3.4.1 THE LEGITIMACY OF ALLOCATION EXERCISES

In a world of abundance, it would be relatively straightforward to think of ways to use resources more efficiently without overburdening the planet with our waste and emissions. Reframing (and indeed, acknowledging) the Earth's capacity as fundamentally limited signifies moving to and managing a world of scarcity. In such a world, we need to think not only of how much the Earth can yield or absorb, but also of the opportunity costs of every action. The question of allocating resources becomes not one of environmental concerns, but fundamentally one of social justice.

Allocations of finite resources present opportunity costs; in favoring one possible use, they deny all others. They also reflect the values and principles of the actors prioritizing one use over the other. Determining what sector or product is more essential or valuable than another, and thus more deserving of operating space, cannot be determined by actors unilaterally. Currently, the economic system addresses these questions in a decentralized manner through market mechanisms and the related regulations and interventions.

Historically, society has followed an adequate process to allocate carbon and ozone emissions, as well as freshwater extraction, at their respective scales (global and basin levels), via extensive negotiation processes and consideration of natural resource economics. Carbon budgets and voluntary reduction commitments were set up by legitimate actors - governments - and through extensive stakeholder consultation. Water use rights are also carefully allocated by governments; in the case of international water basins, there are international water sharing agreements.

Land merits a separate discussion, and an important reframing, because in the case of land use, the flow that we are concerned about is, in practice, that of space. Land allocation systems have been in place for millennia. Traditional use rights, land markets, territorial planning, and agrarian reforms, among many policies and regulations, have historically determined land use allocation for all producing agents. Land markets and private property are the basis for budgeting land systems.

This due process of social consultation, consideration of the strategic role of resources and the opportunity costs of allocation, and the development of automatic allocation and correction systems (e.g., markets or cost internalization interventions) has been largely absent from other processes in the PBs (like nitrogen emissions). Nevertheless, it would be incorrect for any One Planet Approach to address the question of allocation through some quick set of guidelines, rules, or similar mechanisms that ignore the complex socioeconomic realities affected by allocation.

Governments, by virtue of having the social mandate to govern and determine development programs, are the only agents that can legitimately make centralized decisions about the (re-)allocation of operating space. Any allocation mechanism that does not involve governments should in principle be as decentralized, transparent, and democratic as possible to remain legitimate. In other words, producers, civil society, and scientists can't determine on their own, unilaterally or without general and explicit social endorsement, how much operating space is fair for them to use, at the expense of competing uses.

There are some decentralized mechanisms to allocate operating space in the absence of direct governmental arbitration: transparent and corrected markets, fully inclusive multi-stakeholder negotiations, and the use of proxies to determine needs for operating space. Besides these, which can be used in combination, there are some options to set references without reallocating the operating space.

The different allocation approaches, including the choice of direct recipients and the principles to reallocate operating space between competing uses, all have different shortcomings on the social, political, economic, or technical planes. In Figure 14, we provide an overview of the different pathways that can theoretically be used to set references or allocate budgets, the principles and mechanisms that can be applied in the process, and the primary drawbacks associated with each approach. There is no perfect option, though any one of these pathways can be applied if provisions are made to increase their individual feasibility or to reduce associated drawbacks.

Budgeting starts from the available operating space and then proceeds to allocate it among users, while defining ceilings is in itself a form of budgeting that provides maximum allowances. User rights, market mechanisms, and other similar measures all rely on absolute measures of impact and thus can limit the total allocation to the available operating space.

Relative measures such as impact intensity or resource efficiency targets are useful to provide a context of realism to sustainability targets, especially when an agent's performance is compared to best practices, but they don't de facto account for available space. Strictly speaking, unless resource efficiency targets are linked specifically to a total maximum impact or resource withdrawal rate, which is in turn connected to boundaries set at a global or regional level, they do not fall under the category of One Planet Approaches.

Figure 14: Reference Setting Approaches and their Primary Drawbacks

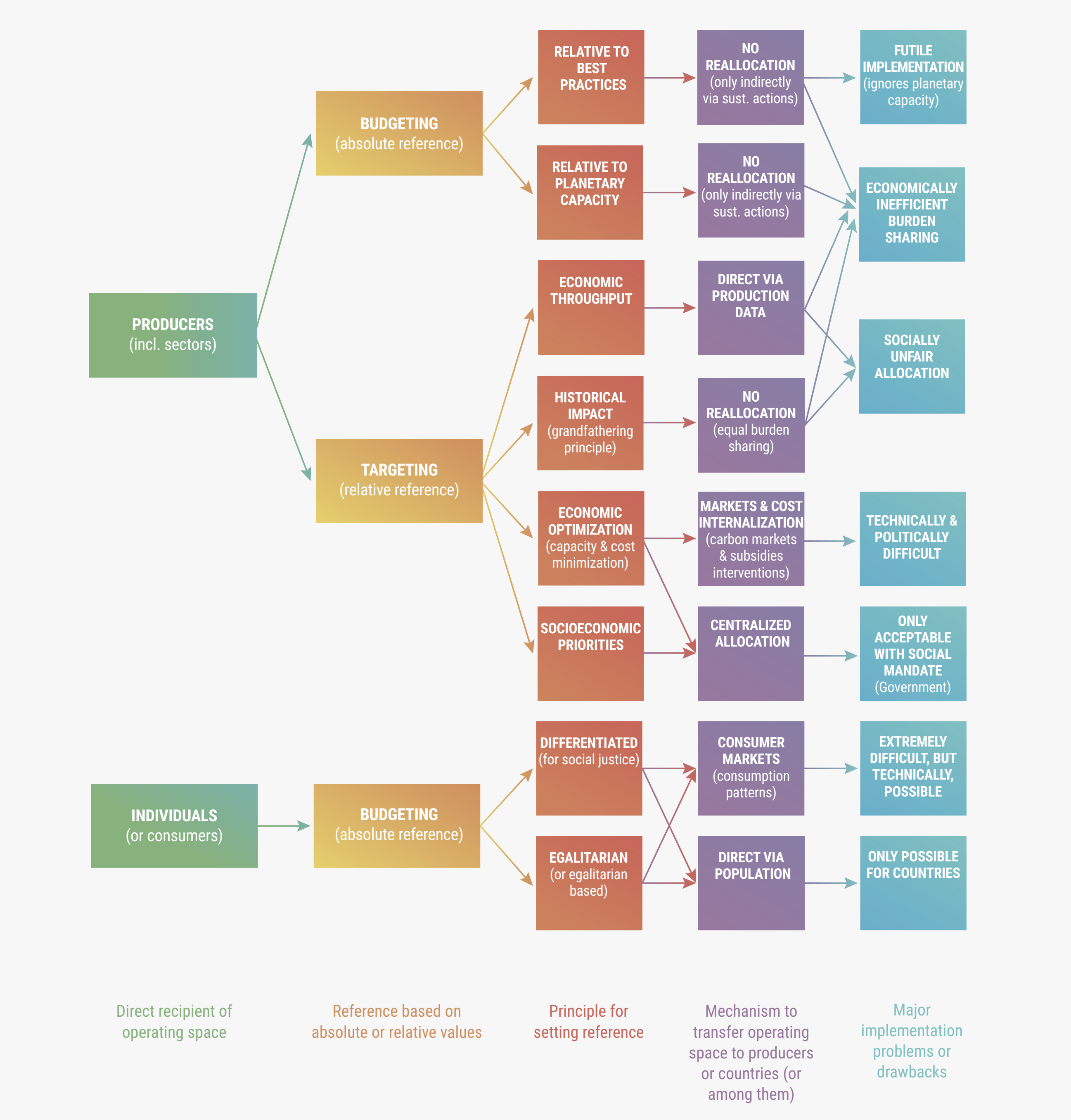


Figure 14. *This figure illustrates the different pathways that are available for setting reference values (for impact levels) to either individuals or organizations. Though most pathways are technically implementable, they all present significant challenges.*

3.4.2 THE EGALITARIAN APPROACH TO BUDGETING

Among the allocation principles we reviewed, the division of the emissions budget in terms of a fair per capita allocation seems to be an acceptable distributive pattern, though there are many debates when it comes to the details of fair distribution (different models of per capita allocation have been explored based on egalitarian, prioritarian, or sufficientarian ethical principles in Grasso 2012).

In a purely theoretical context, we would recommend an Equal Access egalitarian principle for per capita emissions distributions, as described by Grasso (2012). This principle allocates impact rights according to national population, corrected by an "access to services" factor that reduces the burden of impact-corrective measures in developing countries to the necessary extent for them to acquire the necessary access to the goods and services typically associated with the impacts.

Several publications (Nykvist, 2013; Hoff, 2014; Dao, 2015; Doka, 2016), use a direct, per capita allocation, as it is straightforward and easy, and can be calculated for a single country or region. While these approaches are useful to create country budgets, it would be extremely challenging to put them into practice in the context of business, for reasons we'll now discuss.

OPAs can calculate egalitarian allocations as an indication of a person's impact on the planet (as footprinting techniques do), but these indications can't be readily translated into company budgets. In other words, we can use an egalitarian allocation to determine a person's share of the planetary capacity and then posit using market shares as proxies to transfer these allocations to companies. However, market transactions have no inherent mechanism to cap the consumption of goods after a person has exceeded their fair share of operating space; a person's consumption and impact are limited only by their wealth. This means that if we used existing market share as a proxy to allocate company budgets, especially in Western countries, we would base our allocation on consumption patterns that actually transgress the planetary boundaries. In other words, we would be defining insufficient targets that surpass the planetary boundaries - not to mention that they would also fall short of satisfying basic human needs for large sections of society.

To remediate the problem of developing unfair and insufficient targets, we would require two parallel accounting systems: on the supply side, complete information of every supply chain in the world and product-level measures of impact on operating space; on the demand side, a system to keep track of every person's budget expenditure and limit consumption to their corresponding share. The work of a project like LCAbsolute could eventually provide the supply-side system, but there are no projects in place (even in a speculative stage) that would address the demand-side of the system. Moreover, all economic transactions would have to be accounted for, not only those in the formal and monetized economy.

To complicate matters, this idealized approach fails to acknowledge existing ownership structures; only some of the systems in question are global public or commons goods that can be freely reallocated. Most are currently under private or public (national) property systems, or else managed under traditional usage rights agreements, and ultimately fall under national sovereignty. While utopic, in practice it serves no purpose to state that every person has the same right to planetary capacity and to define budgets on this basis if we can't actually implement systems that meet these objectives.

3.4.3 ALLOCATING OPERATING SPACE TO COMPANIES

Since translating personal budgets into company budgets would be extremely challenging in both technical and practical terms, we need to resort to allocating budgets directly to producers (in other words, the economic actors who make direct use of planetary resources for the production of goods and delivery of services). All the approaches in the literature use a principle (discussed in section 2.8) as the basis for deciding how to allocate between sectors. As discussed, none of these are perfect and implementing them straight across the board would result in severe economic inefficiencies. To recapitulate on issues discussed in Section 2.8, taking GDP or value added as a proxy, which seems to be the most straightforward solution, would grant more operating space to diamond mining than to crop production, because these measures are a very distorted indicator of real social value.

Figure 15: Differentiated versus Equal Burden Sharing

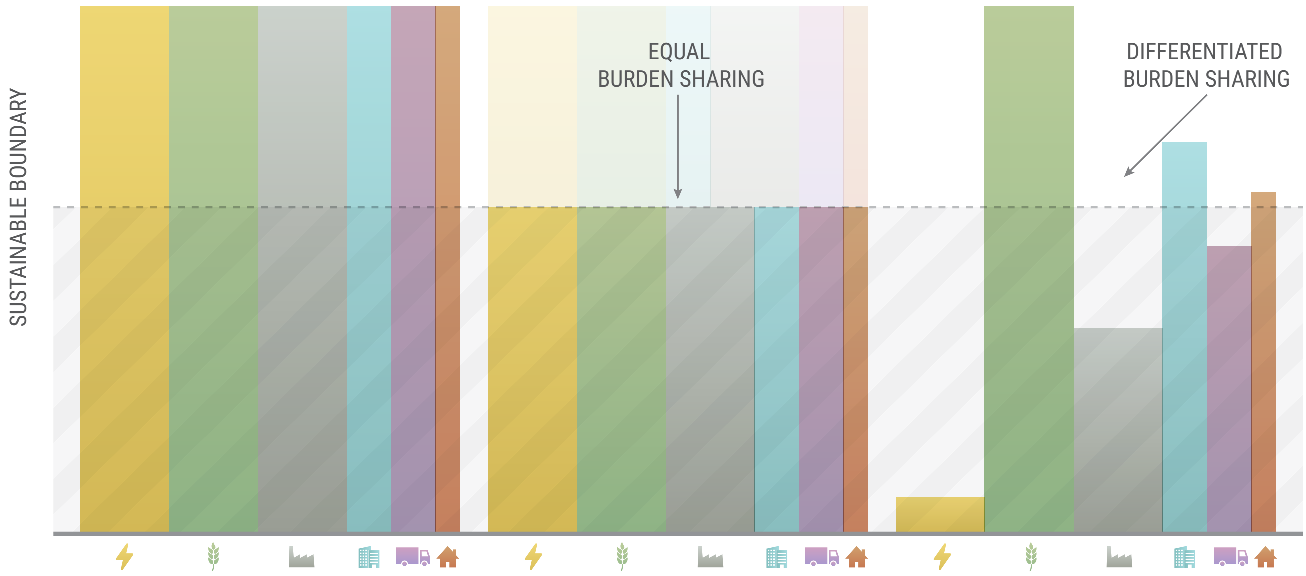


Figure 15. *This diagram illustrates the basic concept of differentiated versus equal burden sharing for the abatement and mitigation of impacts. Different sectors are represented by icons at the bottom of the graph.*

While these approaches are used in the literature because they are good thought experiments, they may face potential resistance if they don't have governmental support (in the form of policy programs or instruments) or gain wide business and societal consensus. For example, many groups determine water use rights via negotiation processes, sometimes internationally. In other cases, communities determine themselves how to manage commons, sometimes in effective and sustainable ways, when certain social conditions and organization is present (see for example Ostrom, 2009). Governments also regularly intervene on markets to direct resources to strategic sectors - for example, to address food security or protect employment or nascent industries. The success story of the Science Based Targets Initiative is partly owed to the selection of a seemingly fair allocation principle: optimizing total reduction costs and considering responsibility for historic impacts.

However, without consensus on an allocation principle, and instead offering each company the possibility to determine themselves what is a fair principle, we risk having each business and sector individually opting for different principles, possibly choosing the one that benefits their interests the most. Labor-intensive sectors would advocate to use labor as proxy for allocation, and high value-added sectors would advocate to use GDP, while others, such as agriculture or key industries, would appeal to their importance for strategic reasons (food security, industrial policy, etc). The result of this lack of consensus on the principle will be an allocation that exceeds the operating space. Unilaterally recommending one of these proxies risks raising resistance from disfavored sectors and would illegitimately impose economic costs on society.

A possibility is then not to reallocate operating space, but rather to keep the existing distribution while encouraging all agents to take an equal share of the reduction burden. However, in international negotiations on climate change, this type of approach was rejected by all developing countries, since it failed to differentiate responsibility according to historical contribution to the impact.

Alternatively, sectoral reduction strategies (like the one used in the Science Based Targets) can be used to guide reduction by optimizing burden sharing to minimize total social costs. It can be argued that if this is a trans-sectoral approach to minimize total costs, then it is a shared effort where costs should be at least partially borne by all agents, possibly in the measure of their capacity to invest. This offers possibilities, and a reasonable justification, to partially fund these measures with governmental support.

3.4.4 BENCHMARKING & PERFORMANCE BASED TARGETS

A practical solution is to define company targets based on existing performance. The idea is to compare the impact intensity of a company's production with that of best practices in the same sector. Companies implementing OPAs can then commit to reduce their impact intensity to at least that of best performers. The shortcoming of this approach is that it does not, in principle, consider available planetary capacity. Indeed, all companies can improve to best practices and the planetary boundaries can be trespassed all the same.

The approach of LCAbsolute (see Text Box 7: LCA and the Planetary Boundaries) attempts to solve this issue by determining impact intensity in relation to capacity. In essence, the project uses an additional factor to render how impactful a product is in relation to planetary capacity. Given the general trends to regionalize LCA databases, the results will eventually relate to the available capacity at the exact region where the environmental pressure occurs. A company can then identify the places where its activities present a larger burden on the planet, and either redistribute the pressure or mitigate impacts through changes in operations.

Both of these performance-based approaches can help companies to mitigate their impacts. However, the performance information obtained (share of operating space per unit of production and/or impact intensity per unit of production) reveals nothing about whether or not additional pressures exist in the same area or whether this company's use of resources is preferable over another's. In other words, neither of these relative targets can provide insight on the prioritization between one sector and the other.

We can consider the case of a power-generating company with a small but significant pressure on the nitrogen system via air emissions of NOx, in the Netherlands. In this situation, the air emissions are deposited in a region where the nitrogen cycle boundary is already heavily transgressed due to non-point agricultural emissions from manure and fertilizers. The electricity company can assess its current impact and learn that it's both performing below best practices and contributing to trespassing a regional boundary - although it's not the main party responsible. The immediate conclusion would be to ask the electricity company to at least mitigate its nitrogen emissions to meet best practices so that it stops exacerbating the problem. The same investment, however, would have a much larger impact if it was used to deploy technologies to close the nitrogen cycle in the agricultural sector in that same region.

3.4.5 CONSIDERING ZERO-IMPACT TARGETS

In principle, most of the flows we deal with are fully avoidable in terms of environmental pressures and zero-impact targets could be implemented. Nevertheless, there are important economic constraints to consider and some solutions might require some burden shifting between Earth system processes. For example, substituting substances with ozone depleting potential for others with global warming potential. Take the case of nitrogen emissions from agriculture, the main driver of the trespassing of the nitrogen boundary - emissions come from manure and fertilizers, but with proper technology and management, these can be mitigated to near-zero levels. NOx emissions from fossil fuel combustion in transportation and power generation activities can also be prevented with the use of emissions-capturing technology or through the transition to alternative, non-carbon energy sources. A similar situation applies with most emissions of phosphorus, novel entities, aerosols, and other substances that drive acidification and smog-formation.

The main barriers to minimizing these flows to near-zero value are mainly economic and, in some cases, institutional, but not in any way insurmountable. It is difficult to justify granting impact allocation budgets (to companies, countries, or even to people) when most of these impacts are preventable and we have financial mechanisms to facilitate some of the required investments. The conversation can not lose perspective of what is affordable, especially given the prohibitive costs that some technology changes imply, nor we should forget that the current price system is no indication of real costs, due to the pervasive externalization of social and environmental damage. However, zero-impact targets (or net-positive impact targets) should be seriously considered in all sectors and impact categories where they are viable. Where economic and technological barriers are significant, we need to start broader process with governments and financial institutions to bring targeted funds and investments into the game. A clear benefit of choosing zero-impact targets is that it obviates the need for complex discussions around impact allocation.

3.5 BEYOND IMPACT ALLOCATION

Providing quantitative references (budgets, targets, ceilings) to companies on what is a sufficient or reasonable sustainability effort for a company is an attractive prospect because these metrics are straightforward to monitor and evaluate progress. In some cases, though, solutions require more than quantitative metrics, and ideally include qualitative ambitions and system-wide transformation.

There are a couple of shortcomings that we might face if we define quantitative targets alone and fail to encourage collaboration and action beyond the walls of the company.

Providing an acceptable impact target (absolute, relative, in relation to planetary capacity, or in other ways) is an implicit validation a company's occupation of operating space. This gives a clear message that the current use is indeed preferable over all others, almost certainly leading to economic inefficiencies.

Furthermore, if we consider the root causes and systemic structures that ultimately engender the transgression of the planetary boundaries, we can see that there is only so much that a company can achieve by acting internally. For example, until our entire energy system is based on clean, renewable, carbon-free sources of energy, all companies will still be dependent, to a greater or lesser extent, on a polluting power grid and transport infrastructure, regardless of the efficiency gains they deploy within their direct scope of influence. Moreover, there is no way to create budgets in the case of the complex emergent systems of biospheric integrity (and social justice). We can only define indicators of progress and create budgets for the underlying drivers.

In short, there are some structural limitations to this approach. A possible solution to address these issues is to develop a Code of Behavior and Systemic Visions and Strategies of Sustainability to guide decision-making to best systemic results (see more on these concepts in Chapter 4).

3.5.1 CREATING MARKETS FOR OPERATING SPACE

One of the more sensible approaches for allocating operating space, one that avoids many of the pitfalls of a top-down process for defining and distributing impact budgets, targets, or ceilings, is to create instead a bottom-up distribution mechanism by establishing an exchange market. Markets are the existing allocation mechanism par excellence of our economy. They decentralize economic decision-making by distributing allocation decisions to every economic agent. Existing markets are indisputably very dysfunctional due to a number of design and information failures. Particularly relevant to sustainability problems is the externalization of social and environmental costs and, in the case of hard sustainability approaches like the Planetary Boundaries, the fact that existing currencies facilitate trade-offs and burden shifting between different impact categories by measuring all value under a single metric (money). Moreover, markets don't address social justice questions, and need to paired with stronger redistribution systems to achieve fairer allocations - an issue that lies beyond the scope of OPAs and this project, but that cannot simply be ignored.

Properly designed, however, markets could theoretically address the issue of allocating operating space. Needless to say, these systems would only put into availability the operating space within the previously defined boundaries. This means, in the case of economic valuations and property systems, that effectively the area beyond a boundary has an infinite value and is owned by society as a whole - thus it cannot be bought.

Trading mechanisms for impact reduction (like the carbon markets) can offer some options to encourage economic efficiency through reallocation of burden sharing. As with carbon markets, we would have to create markets for other impact categories, noting that in this context water rights cannot be converted into land rights, and water rights in one region cannot be claimed as water rights in a different basin (however, they can be traded as two commodities are traded, between different agents). Just as each impact category is assessed separately and is bound to its scope of operation (water in water basins, etc), so these systems need to mirror these limits. This is not unheard of, not only the case of carbon markets, but land markets have existed for ages.

As we have learnt with the experience with carbon markets, creating these mechanisms is a difficult task and one that requires extensive stakeholder support. Due to these reasons, we don't recommend proceeding in this direction in the short term, but do encourage exploring this through pilot projects and highly recommend this as the best long-term allocation mechanism.

In our assessment, market-based systems could be the best solutions for allocating operating space in terms of their robustness and fairness, provided the system in place is well-designed and properly enforced and that redistribution-type mechanisms are included to ensure fair access to resources.

04 NEXT STEPS AND PRACTICAL APPLICATIONS

NEXT STEPS AND PRACTICAL APPLICATIONS

Through the review and discussion in this report, we have described the general anatomy of One Planet Approaches and focused primarily on exploring the remaining uncertainties, challenges, and potential pitfalls of operationalizing OPAs. Despite these difficulties, the overarching fact remains that OPAs could represent an enormous and essential leap forward in terms of the available tools for halting anthropogenic planetary impacts. As discussed in Chapter 1, current approaches to eco-economic decoupling are falling far short of their targets. Tools like OPAs, that can consistently and accurately relate human impacts to planetary limits, can help achieve absolute decoupling. Furthermore, if properly and more holistically developed, OPAs can be tools for succeeding at the broader sustainability objectives expressed in the SDGs and the original call put forth in Our Common Future (Brundtland, 1987).

It is clear that a great deal of work still remains in order to operationalize One Planet Approaches on a broad scale. That said, there is a significant body of research, methodologies, and tools that can already be used, individually or in combination, to begin applying One Planet Approaches. In Chapter 3, we discussed some of the most urgent gaps and dilemmas to address in the current design of OPAs. In this Chapter, we provide a summary of our primary recommendations for how One Planet Approaches should be further developed. We then discuss what the primary groups of stakeholders (companies, governments, the research community, and civil society) can do to further the implementation of OPAs. We discuss some of the highest priority development and research pathways for advancing this field and provide some recommendations for strengthening the One Planet Thinking program in particular.

4.1 TOWARDS AN IDEAL ONE PLANET APPROACH FOR COMPANIES

Our recommendations for an ideal One Planet Approach relative to existing methodologies and considering the review and discussion presented so far in this report, can be summarized as follows:

1. Select a more holistic set of objectives

The fundamental rationale behind the setting of planetary boundaries should be strengthened from the current minimum viable objective of planetary habitability used in the PB framework. Ideally, it should include:

» Regional biospheric stability and social justice factors as an additional, unique set of goals

» Socioeconomic factors (i.e., reserving operating space for human access to freshwater, food, ecosystem access for livelihood provision, considerations of intergenerational equity, etc.),

» A recognition of biospheric integrity as of inherent rather than utilitarian value, striving for zero biodiversity loss,

» System resilience objectives

Including these additional criteria as part of the rationale for the boundaries will undoubtedly make them more stringent and potentially more challenging to apply, but the resulting program will be less likely to lead to insufficient action or new externalities down the line.

2. Define operating space in terms of flows rather than states

For application by companies, the system boundaries set in an OPA should be defined in terms of flows rather than states (as they currently are in many of the PBs). In other words, they should be translated into measurable quantities of resource extraction or emissions that can be easily linked to economic activities.

3. Set both global and regional boundaries

Different kinds of boundaries need to be defined for the different kinds of Earth system processes that are impacted - particularly in terms of time and space. Quintessentially global systems should indeed have boundaries set at the global scale (i.e., those concerned with preserving the stability of atmospheric and oceanic systems), but all other boundaries need to be additionally defined on at regional level through appropriate multi-stakeholder consultations. Periodic revisions of the boundaries is recommended to account for changes in the Earth system. For an overview of recommended boundary setting criteria and methodologies, see Tables 2, 3, 4, 5, and 6.

4. Use additional control variables for boundaries at the regional level

We recommend setting regional limits on several additional processes beyond those selected in the PBs. Additional impact areas roughly in line with the categories selected in current Life Cycle Assessment frameworks are particularly relevant to regional system stability (e.g., biomass extraction, soil acidification, ecotoxicity). Policy directives and social demands should be taken into consideration as legitimate mechanisms for defining boundaries next to scientifically led processes.

5. Take into account the dynamic and overlapping nature of boundaries

If multiple boundaries are set for one system (a global and a regional boundary), then the stricter of the two boundaries should generally be applied. Finally, the dynamic nature of the boundaries should be taken into account, with some boundaries requiring reassessment at more frequent intervals than others. For example, regional water boundaries may need to be reassessed multiple times per year to account for shifts in local rainfall and water demand. Ideally, we should develop a central database to monitor the state of all system boundaries across the world, to put an agent's impact in the context of carrying capacity.

6. Assess impacts using dynamic, geospatial tools

Impacts should ideally be assessed in a regionally contextualized and dynamic manner. The development of regionalized LCA frameworks can be an important tool in this regard but, in an ideal state, companies would have access to the equivalent of a dynamic impact dashboard that would show close-to-real-time transgression of boundaries in different geographic contexts along their supply chains. Until these tools are available in their ideal form, companies should put continuous effort into getting high-resolution data about their supply chains with as much geospatial information as is available.

7. Define aspirational impact ceilings per sector

Allocating a safe operating space to different actors remains one of the more technically and ethically challenging steps. In the short term, the practical solution is to define relevant, sector-based, aspirational impact targets for companies. These targets should take into account current and future demands for resources and be defined evaluating current sectoral performance, best practice levels, and costs of impact abatement (as has been done with GHG emissions in the SBT methodology).

For non-global impacts, we would also need to translate each of these targets to a regional level. These impact targets can be presented as reference ceilings that each sector should stick within. Developing these kinds of impact ceilings is likely to be complex, contentious, and inaccurate, but may be one of the more practical and immediate approaches available.

For companies, we recommend:

1. Starting with those environmental issues that are the most relevant along the product life cycle of the company's products (hotspots)
2. Defining a long term scenario of the business / market that can be regarded as compatible with planetary and local boundaries
3. Setting intermediate targets towards this scenario
4. Discussing targets with stakeholders such as peer companies, NGOs, or environmental agencies

8. Work towards a market-based mechanism for allocation of operating space

In the long term, a more ideal approach to allocation, though challenging to implement, is the development of a market mechanism for trading allowances of operating space (or products that embody these allowances) both within and across regions. This includes developing new markets and trading schemes as well as using the existing market and price system with cost internalization measures. This approach is complex and contentious but, in our assessment, it could be one of the best long-term solutions for fair and robust allocations of operating space, provided the market system in place is well-designed and its regulations properly enforced.

9. Strive for net positive (or no-net loss) impact where technically possible

For many impacts (e.g., biodiversity loss, nitrogen emissions, the emissions of novel entities), we should ultimately be striving for net positive or no-net loss impact rather than setting targets for allowable impact. In many cases, technological advancements and alternative system designs should feasibly allow for a near complete elimination of impact (as has occurred to a large extent with Ozone Depleting Substances), though the cost of technological development and switching will certainly play a significant role in the speed of these potential transitions.

10. Strive for systems change beyond company walls

It should be taken into account, that unless all companies globally are implementing an OPA strategy, a single company will not necessarily contribute to ideal sustainability outcomes on its own, even if it has adopted an OPA approach. Efficiency gains can lead to rebound effects and unsustainable market behaviors can continue to proliferate in parts of the world where One Planet Approaches are not implemented, effectively leading to burden shifting through supply chains (as has been the case with other sustainability efforts). For this reason, we also recommend developing a Code of Behavior for One Planet Companies, which would provide decision-making guidance for creating structural shifts towards sustainability (e.g., engaging with underperforming suppliers to encourage improvement rather than simply switching to lower-impact options).

4.2 AN AGENDA FOR ADVANCING THE IMPLEMENTATION OF OPAS

Since it may take quite some time to successfully define boundaries at the regional scale, develop systems for the dynamic impact tracking, or establish the necessary infrastructure for a global impact-trading market, we must also consider what companies, governments, and the scientific research community can do immediately to advance the development of One Planet Approaches.

There are a number of actions and knowledge gaps that need to be taken care of by multiple stakeholders to implement OPAs at the necessary scale. There are some approaches that are more advanced and can already be implemented, like the Science Based Targets Initiative. Moreover, there are a number of frameworks and initiatives that can support moving towards the sustainability goals of OPAs, while not necessarily being part of the family of One Planet Approaches.

In this section we first make recommendations for companies wishing to start moving today in the direction of OPAs and then list the research gaps and tasks needed to advance actual full OPA implementation by other key groups of stakeholders: the scientific research community, governments, and civil society groups. Finally, we include some design and tooling recommendations for OPT in particular.

We have organized some of the most important actions going forward in a general timeline (See Figure 16) noting what actors are required to take leading roles for each action. In this effort, civil society needs to take the role of central coordinator, vision keeper, and agenda setter - basically a linking party between all others and the main driver of the effort. Companies have already available tools and programs that they can start implementing, and already join in the OPA philosophy, setting targets based on local context and in consideration of holistic sustainability strategies. Governments need to take both a supporting role towards other actors while taking initiatives on their own to replicate this process nationally and develop market instruments as long-term solutions. Finally, the scientific community should continue the massive efforts to develop our understanding of the Earth system and to improve tools to monitor the system dynamics and our impacts on it.

While some actions are possible now, for example adopting the SBTs, fully and accurately implementing OPA requires addressing several impact categories regionally, which means that a great amount of data needs to be put together. To speed up this process, priorities should be set (a process where civil society needs to take the lead, as discussed later in this section) in terms of impact categories, geographical areas of action, and sectors and industries.

We consider that among the 10 impact categories we recommended as control variables in Chapter 3, the following should take priority due to their effect on planetary habitability and regional biospheric integrity: climate change, ecosystem occupation and degradation (i.e., habitat loss), wildlife extraction, freshwater depletion, ecosystem eutrophication, and ecosystem acidification. We also note that climate change can be addressed through the SBTs for a number of industrial and energy sectors.

Boundary setting will be an iterative process as we gather information on the state of the Earth, and the boundaries will necessarily change over time, hence it's appropriate to start with available information and databases, and to make corrections over time. Next to the boundary setting process, impact assessment tools (databases, frameworks, etc.) need to be developed. As a practical solution to allocation, we need sectoral studies to define impact mitigation targets, but we also recommend to start researching and testing the use of market-based solutions to this end. Meanwhile, the process to develop OPAs for companies should be mirrored by one for countries, where governments need to take the lead with civil society.

At the later stages of the timeline we have included the construction of particular tools (boundaries database, dynamic impact dashboard, code of behavior), that we recommend for OPT in particular to adopt (See Section 4.3).

Figure 16: Recommended Activity Timeline for the Implementation and Development of OPAs

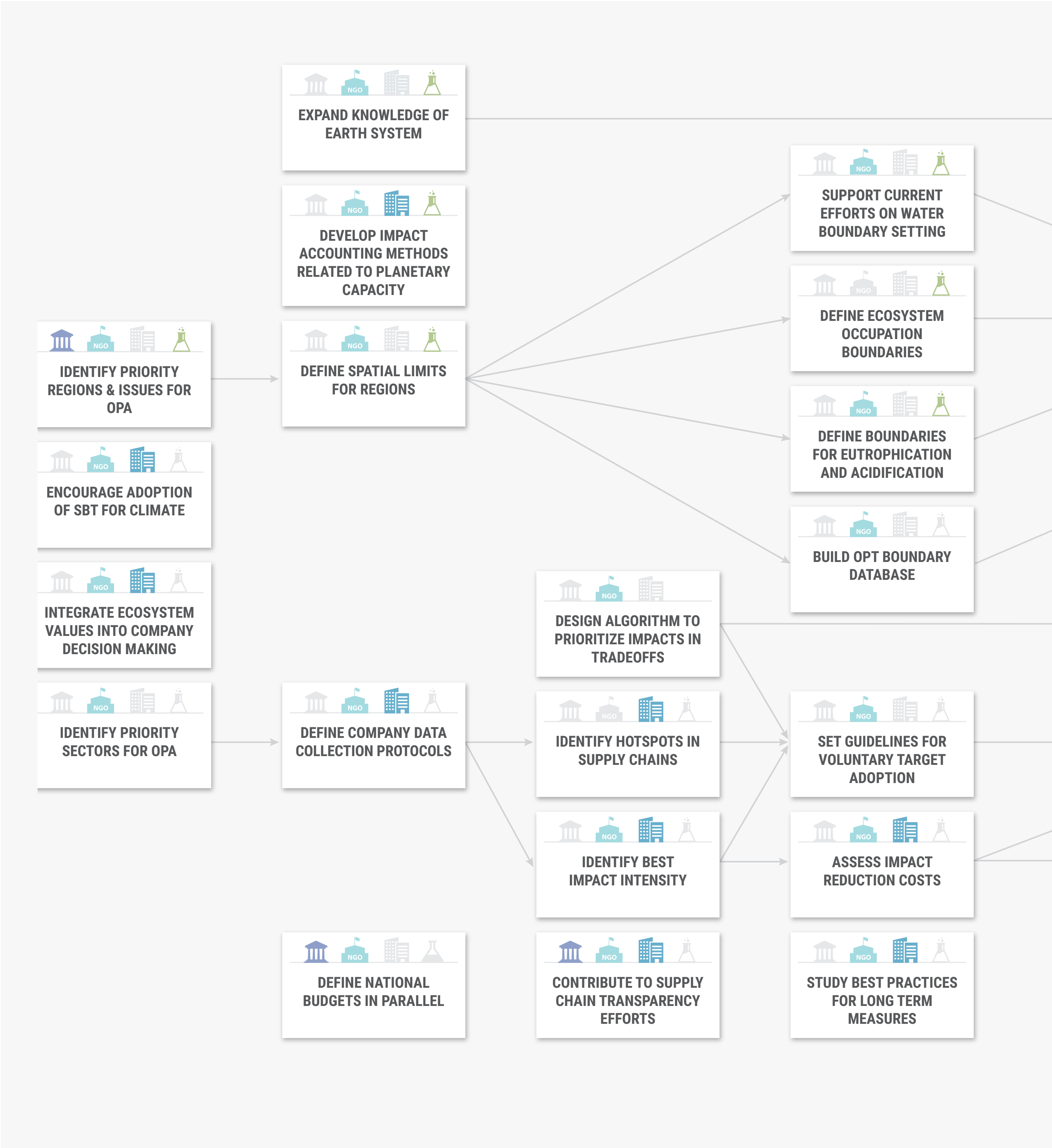
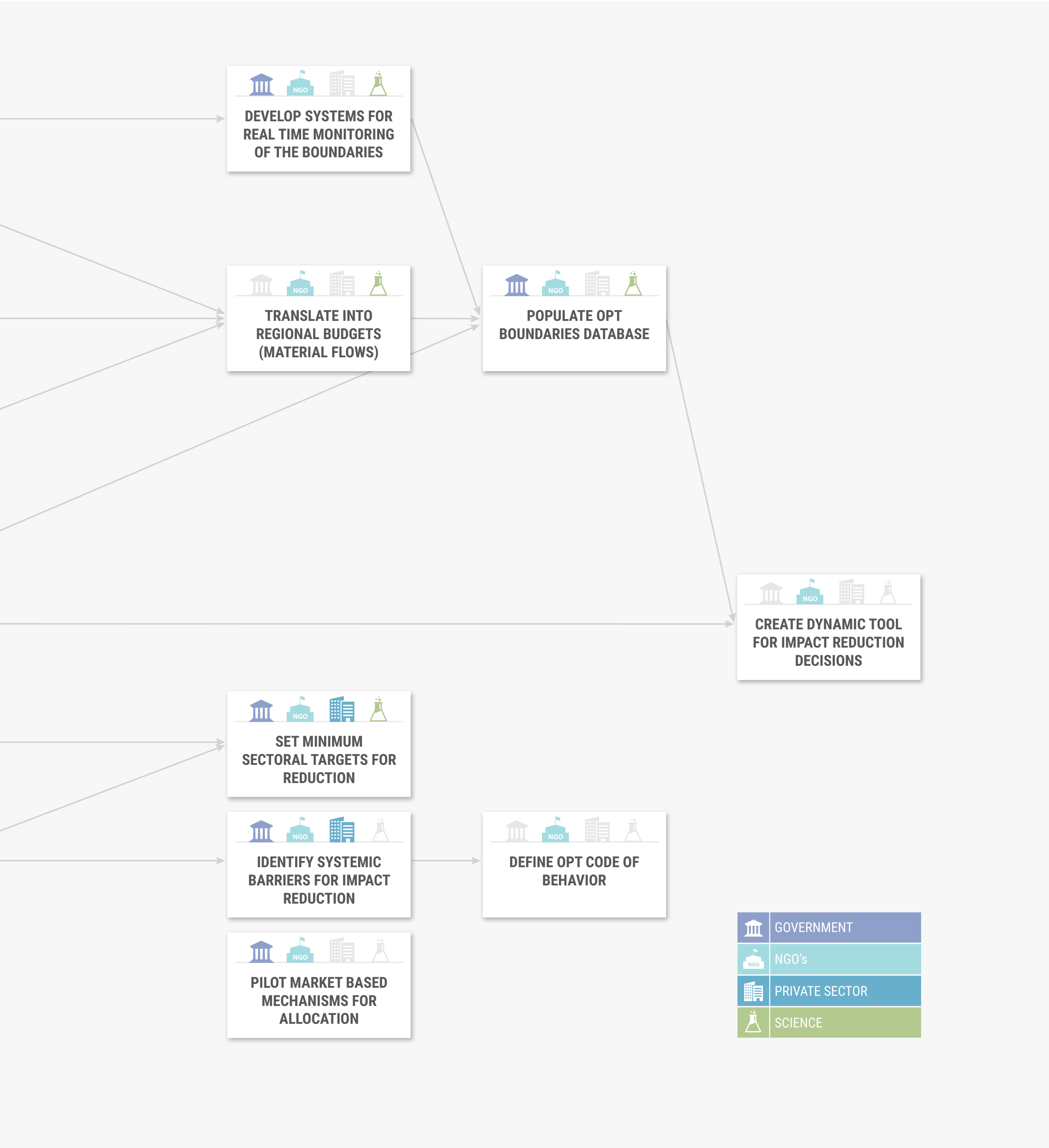


Figure 16. *This timeline shows recommended actions and sequencing for different actors - governments, civil society, private sector, and the scientific community - in order to advance the development and implementation of OPT. We discuss these activities in detail in the remainder of this chapter.*


DEVELOP SYSTEMS FOR REAL TIME MONITORING OF THE BOUNDARIES
TRANSLATE INTO REGIONAL BUDGETS (MATERIAL FLOWS)
POPULATE OPT BOUNDARIES DATABASE
CREATE DYNAMIC TOOL FOR IMPACT REDUCTION DECISIONS
SET MINIMUM SECTORAL TARGETS FOR REDUCTION
IDENTIFY SYSTEMIC BARRIERS FOR IMPACT REDUCTION
DEFINE OPT CODE OF BEHAVIOR
PILOT MARKET BASED MECHANISMS FOR ALLOCATION
NGO
GOVERNMENT
NGO's
PRIVATE SECTOR
SCIENCE

4.2.1 FOR COMPANIES WISHING TO ACT NOW

For companies wishing to begin implementing One Planet Approaches within their organizations, we recommend a number of practical first steps.

Join and support initiatives based on OPA philosophies

One of the most straightforward recommendations is to join the Science Based Targets Initiative, which is currently one of the farthest advanced corporate programs based on a One Planet model. Becoming part of such an initiative can provide important organizational learning opportunities and identify key barriers for the subsequent implementation of more comprehensive, multi-boundary OPAs, such as One Planet Thinking.

Currently in the making, WWF's Context-Based Water Stewardship program is inspired by the Science Based Targets, but applies this line of reasoning to water systems and the freshwater depletion impact category. Companies can support and follow this initiative, and join the program once it is rolled out.

In the realm of the biomass extraction impact category, companies can commit to using certified products, such as those with the Forest and Marine Stewardship Council labels (FSC & MSC), or backed by the Roundtables on Sustainable Palm Oil, Responsible Soy, and Sustainable Biomaterials (RSPO, RTRS, RSB), and to participate in these initiatives. While these kinds of certifications are not usually directly associated with One Planet approaches, they fall into the realm of OPAs as they consider maximum extraction rates (in other words, carrying capacity) and place caps on extraction (boundaries) for forestries and fisheries in their standard setting. We note that there is a broad range of certifications available for agricultural, forestry, aquaculture, and fisheries products, some of which better represent the OPA philosophy than others. It is beyond the scope of this report to evaluate or recommend specific ones, and we only mention these certifications and roundtables as examples.

Regarding impact assessment, companies can follow the workings of the LCAbsolute working group and, once these methodologies are available, use them to calculate the share of operating space of its products and/or activities – noting, though, that this protocol by itself doesn't answer the critical Step 8 of the OPA framework; it doesn't provide information on whether an individual's impact falls within a reasonable range considering other competing uses.

Develop data collection and management capacity

A second, more universal recommendation is to actively pursue the development of corporate data collection programs on the impact of services, products, and supply chains. An essential component of any One Planet Approach will be the detailed understanding of company- and product-level impacts – not just in aggregated form, but also including geospatial and temporal context. Most organizations currently collect Life Cycle inventory data on an ad hoc basis in the best of cases, and this data rarely includes detailed geospatial information. This is largely because the cost of such data collection can be high. However, since this is a prerequisite in the ultimate implementation of any OPA, it is worth investigating and investing in advanced data collection systems for the automated collection of supply chain impact data. Companies can also form and join collaborative initiatives to build supply chain clarity.

In recent years, many tools and services have emerged with the explicit goal of assisting companies in the process of supply chain mapping and risk assessment. As more companies begin to use these services, the pool of digital information on suppliers, the origin of raw materials, and the overall history of products in the global economy will grow. If this data is commonly accessible by all parties, it will reduce the effort and cost needed to understand where supply chain impacts are affecting planetary or regional boundaries. There is, however, a long way to go on this front and, with the number of different services assisting with supply chain mapping, there is also a risk that the information could become fragmented and siloed behind various paywalls. This could prevent the economy-of-sharing effect that could ultimately reduce the cost of supply chain data collection for all parties. We recommend exploring available tools for these purposes, while remaining cognizant of the long-term implications of specific partnerships and contracts with regards to future needs for open data.

Identify Impact Hotspots and Priority Actions

To reduce the total costs of this data collection approach, we also recommend conducting a systemic hotspot analysis of the company's activities (both upstream and downstream), to identify areas of particularly high impact. The highest impact areas are not necessarily tied to higher volumes of materials or units of goods or services sold: sometimes very high impacts can be hidden in deceptively small resource flows, particularly in the case of biobased material extraction or toxic material flows (both of which can have significant impacts on biospheric integrity, for instance). These areas of disproportionately high impact can then be the focal point for further data collection efforts, since they're likely to be the most important places to intervene in the future. This hotspot analysis can also be the basis for the materiality check in corporate sustainability reporting protocols, like GRI, and be the basis for target setting related to these hotspots.

Companies also need to incorporate multi-criteria decision-making frameworks into their impact assessments. Many of the impact mitigation decisions can result in burden shifting - relieving pressure in one impact category but increasing it another, or geographically displacing impact from one area to another. While this is often unavoidable, the net results of the action might be positive or negative depending on the context. In the case of OPAs, for example, it's preferable to shift impact into impact categories where there is less transgression of the boundaries or to impact categories that are reversible. For example, the Natural Capital Protocol can aid decision-making by incorporating environmental information about a variety of processes and impacts. In the long term, companies would ideally have access to a dynamic and comprehensive impact dashboard tool as described in section 4.2.3.

Explicitly incorporate a One Planet mindset in corporate goal-setting and communications

A small, but important measure that companies can already take is the adoption of the principles and philosophy of One Planet Approaches. Even if exact targets for all areas of impact are not yet fully developed, it is essential to frame the intention to set goals in line with a One Planet philosophy and to communicate this both inside and outside of the organization.

Participate in and support OPA Research and Lobbying Efforts

Companies can also initiate or participate in research efforts around furthering One Planet Approaches, and participate in political lobbying or discourse geared towards encouraging the establishment and enforcement of both global and local boundaries. Implementing practical allocation mechanisms, based on expected sector trends and costs of mitigation, requires research on challenges for each sector, including growth forecasts, studies of best practices, and evaluation of technologies and methods to reduce impact. The private sector can take the lead in carrying out these assessments, ideally through industry or sector collaboration, and attending to the particular context at the level of each country or region (i.e., European-level studies).

The private sector is also in a strategic position to contribute to allocation efforts (Step 8 of the framework) by conducting carrying out sectoral assessments on trends and barriers for impact reduction for priority impact categories (carbon emissions, water depletion, biomass extraction, habitat loss, eutrophication, and acidification). In particular, each sector would ideally identify:

» demand trends for its products/services
» best performances on impact intensity
» best practices to reduce impact intensity
» costs of impact abatement

To an extent, this effort has already started with the sectoral decarbonization approach, in the context of carbon emissions mitigation for several industrial and energy sectors (while it is missing for agriculture). We encourage industries and companies to work together on this effort through sector-specific and supply-chain specific collaborations, which should also form the organizational basis to find systemic solutions to the barriers preventing impact reductions.

4.2.2 FOR THE ADVANCEMENT OF FULL OPA IMPLEMENTATION

There are a number of knowledge gaps and developments that need to take place to actually implement One Planet Approaches. The main challenge ahead is setting up the knowledge base (definition of spatial limits, clear understanding of system dynamics, safe and fair boundaries, regionalized impact assessment) for the distinct regional processes. Ultimately, our ability to take action on these issues at the same level of clarity and robustness as has been undertaken in the area of greenhouse gas emissions and climate change is dependent on the rapid advancement of knowledge in these areas. Meeting this challenge will require joint participation from the scientific community, civil society, and governments.

From our research, it is clear that the state of knowledge differs greatly depending on the process in question (see Table 7) and that given their impact on biospheric integrity, we should prioritize our attention on some processes rather than others. Considering both of these factors, we emphasize the great urgency to strengthen our knowledge of the habitat loss impact category. In other words, we need to define the quantity of unoccupied and undegraded habitat, for each terrestrial and aquatic ecosystem type and in each geographic context, that would be needed to achieve net zero biodiversity losses.

In terms of implementation and process, we recommend start hotspot mapping to identify priority areas going forward (geographically, in terms of sector, and of supply chains). We note that the agricultural sector, in its broadest sense including not only farming but also animal husbandry, fisheries and aquaculture, and forestries, is the most important driver behind the trespassing of the planetary boundaries; OPAs need to quickly ideate strategies to engage the sector and bring it to planetary capacity. Other priority issues in terms of implementation include the formation of governing bodies to steer and coordinate OPA efforts, the strengthening of multi-stakeholder communication platforms, and carrying out sectoral studies to define impact mitigation strategies.

Table 7. State of Knowledge for Earth System Processes, Boundaries, and Impact Assessment

			Steps 2-3		Step 4	Step 7
	IMPACT CATEGORY	**CONTROL VARIABLE** (flow units)	**SPATIAL LIMITS MAPPED**	**SYSTEM DYNAMICS KNOWN**	**BOUNDARY DEFINED**	**REGIONALIZED IMPACT ASSESSMENT AVAILABLE**
GLOBAL PROCESSES	Climate system	Greenhouse gases	Not needed	✓	✓	Not needed
	Land systems change (climate effects)	Forest cover	Not needed	✓	✓	Not needed
	Ozone depletion	Ozone depletion potential	Not needed	✓	✓	Not needed
	Ocean acidification	CO_2	Not needed	✓	✓	Not needed
	Aerosol Loading	Aerosols	Not needed	✗	✗	✗
REGIONAL PROCESSES	Habitat loss	Area, per ecosystem	✓	✗	✗	✗
	Biomass extraction	Biomass, per species	✓	✓	✓	✗
	Eutrophication	Eutrophication potential	✗	✓	✗	✗
	(Land and freshwater) Acidification	Acidification potential	✗	✓	✗	✗
	Freshwater depletion	Cons. Blue Freshwater	✓	✓	✓	✗
	Aerosol loading	Aerosol, sediments and smog formation	✗	✓	✗	✗
	Ecotoxicity	Ecotoxic potential	✗	✓	✗	✗

Table 7. *Detailing the state of knowledge for different impact categories, check marks (✓) indicate areas where knowledge is more advanced while crosses (✗) indicate areas where knowledge is more lacking. The checks and crosses don't imply that knowledge is perfect or completely absent, as clearly this is never the case, but rather pinpoint where we need to place our attention. For this table, we have considered the control variables that we recommended in this report (See section 3.2), to complement additional categories for biospheric integrity and account for regional dynamics. OPAs can of course, include a different set of control variables depending of their objectives.*

4.2.3 RECOMMENDED ACTIONS FOR THE RESEARCH COMMUNITY

The research community has been at the forefront of both the continued development of the Planetary Boundaries as a framework and of proactively identifying and addressing the gaps for its implementation. Many of these recommendations come from members of the research community itself, who are well aware of the next steps in the field.

Expand our knowledge of the Earth System

First, it is necessary to continue advancing our knowledge of the Earth System, developing more accurate models with predictive force and flexible applicability, as well as to continue capturing data and developing geographically-referenced databases to monitor future changes in the operating space. A particular barrier currently preventing the full implementation of OPAs is the lack of maps to define the spatial limits in which all regional processes operate - in other words, to identify and map the equivalent of the water basins for all impact categories.

There is a recognized need from natural scientists to engage their counterparts in the social sciences, moving towards social-ecological systems, and considering the role of socioeconomic factors in position of system boundaries through improved modeling. This is not suggesting to include social issues as additional impact categories in OPAs but, rather, to consider the role of local social factors when defining the boundaries of the already defined impact categories. This is by itself important to the implementation of company-targeted OPAs (as it effectively changes the size of the available space), but moreover it's an important consideration for long-term agenda setting and policy making at the national and international levels. It will enable the modeling of different development pathways and high-level strategies that would allow humanity to prosper within the planetary boundaries.

We also need to improve our capacity to monitor the state of the planet, in real time, for all regions, and for all impact categories. This is a massive endeavor that goes beyond the needs of OPAs, but that would benefit all global sustainability efforts.

For OPT in particular, researchers and developers can focus on creating tools to keep track of available data, such as the System Boundaries Database discussed in Section 4.3.1.

Improve our impact assessment capacity

A second task for the research community is the continued improvement of impact assessment tools. We noted in Chapter 3 the necessary developments in this arena, most of which are already occurring and include regionalization, improvement of the databases for certain impact categories (like habitat loss and soil loss), and accounting for available planetary and regional capacity.

For impact categories that have traditionally been outside the scope of LCAs, namely those directly related with biospheric integrity, including land occupation, biomass extraction, and soil loss, we also need to define and select control variables that can be used to define the operating space in terms of flow units.

4.2.4 RECOMMENDED ACTIONS FOR GOVERNMENTS

Governments have a central role to play in facilitating the implementation of OPA and supporting the continued development of the foundation frameworks and knowledge that sustain these approaches.

Lay the foundations for inclusiveness and social justice in OPAs

As discussed in Chapter 3, allocation exercises are an extremely delicate matter that can mean the difference between truly sustainable OPAs (those that are socially and environmentally sustainable) and efforts that result in regressive outcomes in terms of social fairness (that would certainly not be considered sustainable). Part of the challenge is the current state of inequality in the world, mainly on the unequal allocation of resources (property, capital) and the lack of adequate institutional and financial mechanisms to repair these inequalities in a satisfactory manner.

Governments must act now, at the regional, national, and international levels, to lay down the institutional foundations necessary to overcome these issues. While an extensive research on the required measures was beyond the scope of this report, we strongly recommend a detailed study on this matter as part of the high-level implementation of OPAs (and indeed, to contribute to the global sustainability efforts marked by the SDGs).

For illustrative purposes of the research directions needed in this area, we would recommend for governments to study (and implement) the formalization of social access to commons and basic resources and quantifying these needs, so as to take them into account for boundary setting and resource allocation exercises.

Provide structural support to OPA development efforts

Governments have the capacity to structurally support OPA development, assisting and collaborating with actors from the civil society, research community, and private sector spheres to carry out different tasks going forward. For example, some European countries are already hosting science-policy dialogues to advance the implementation of the planetary boundaries in policy-making. This model should be replicated in more countries, and expanded to include considerations of OPAs (applying the boundaries in the form of shares at the national of company levels).

Given their position, governments should also represent their citizens, and carry out social consultation processes to determine social demands on the earth system processes - a process that can strengthen the boundary setting (Step 4) exercises.

Governments already collect statistical and territorial information that is very valuable to all steps of the framework, from understanding system dynamics to tracing supply chains. In light of this, we encourage governments to form solid partnerships with other stakeholders to make this data publicly available.

Governments can also actively encourage companies in the adoption of One Planet Approaches as a strategy to meet their own sustainability objectives, and, where possible, provide concrete incentives, like taxes or subsidies, to penalize or reward performance along these approaches. Governments should also work directly with key sectors to carry out sectoral studies (as discussed earlier) that build towards economically efficient impact abatement efforts.

Integrate OPA into national policy making

Governments can take a leadership position by implementing national-level OPAs - defining budgets or share of operating space for their countries. As with companies, it's important for countries doing this to consider an economic approach (Step 5 of the framework) in this process.

These exercises would give opportunities to further develop methodologies that can later be used by other sectors. Moreover, the assessment of existing impact should feed into the development and sustainability policies of the country (or region) in question.

Move towards decentralized allocation

Finally, governments have a critical role to play in the development of long-term, decentralized mechanisms for impact allocation. As discussed in Section 3.5, we recommend economic instruments as the ideal solution to the allocation problem, but emphasize that markets need to be corrected, with complete cost internalization and redistributive mechanisms, to guarantee equal access to life quality. Options to be assessed include trading schemes, alternative currencies, and green taxes.

4.2.5 RECOMMENDED ACTIONS FOR CIVIL SOCIETY

Civil society needs to take a spearheading role to develop OPAs. NGOs such as the WWF and IUCN have a strategic position to engage all other relevant stakeholder groups and steer OPAs in the correct direction.

Serve as vision keepers for OPA

OPAs should keep high ambitions and standards of what sustainability means, particularly because of the "one planet" premise that our efforts must be sufficient in light of the finite capacity of the planet. Insufficient action is incompatible with living in One Planet. We've highlighted in this report the importance of defining ambitious and holistic sustainability objectives (see Section 3.1) and, in particular, recommend civil society to actively define the objectives of OPAs to more-than-habitable levels and to keep humanitarian and social justice issues at the heart of these programs.

Moreover, civil society needs to remain the custodian and protector of the rights of the biosphere, future generations, and unrepresented minority groups. As discussed throughout this report, OPAs can actually result in the entrenchment and exacerbation of inequalities if measures aren't taken to prevent this.

Set the agenda and implementation priorities

Civil society should set the implementation priorities for OPAs, and thus also take the lead setting the development agenda. This includes identifying high impact hotspots in terms of sectors, supply chains, and regions, as well as priority areas for action, such as biodiversity hotspots or vulnerable regions.

s require a joint effort by many different actors and in many different regions. Civil society should take a central coordinating role, guiding research to lacking areas, overseeing the development of tools to implement OPAs at a large scale (see following section for our recommendations on this), lobbying governments to implement and support OPAs, and encouraging companies to join these initiatives.

Provide support to company and government decision-making

There is also a role for civil society to provide guidance on decision-making to companies and governments, in terms of defining impact reduction strategies. On one side, companies and governments need standardized data collection protocols, where shared data platforms and libraries of statistical information would be extremely useful, as well as multi-criteria impact assessment tools to evaluate their progress on impact mitigation efforts.

Considering that trade-offs will be unavoidable, we need to choose those that result in net positive effects for the world. In this regard, we need decision-making protocols that incorporate priorities between impact categories, level of transgression of the boundaries, and socioeconomic considerations (such as considering what other activities compete for the available operating space in a particular region, for each impact category). Existing frameworks, such as the NCP, can be developed further to include these issues, but we also present in the following section a list of tools to serve these purposes.

Develop systemic visions and strategies for sustainability

As discussed in Section 3.5, there are considerable limitations on what individual agents - companies or countries - can achieve with individual sustainability efforts because of structural barriers. A general solution to this issue is the proposed OPT Code of Behavior (see Section 4.3.3), but there is a need to create new production and consumption patterns based on a systemic understanding of sustainability.

General developments include visions for sustainable industries tied to existing models, as the case of the Ellen McArthur Foundation and its Vision for Growth within a Circular Economy. These visions need to be complemented with specific and groundbreaking solutions, including new organizational arrangements, business models, financial and institutional mechanisms, and resource ownership and management mechanisms, to name some.

Sustainable Development Goal 12 calls for work on this front. Meeting this challenge will require sector-specific initiatives and developments. All actors, including the private sector, governments, civil society, and researchers should contribute to this effort.

4.3 RECOMMENDATIONS FOR THE ONE PLANET THINKING PROGRAM

This report has focused on analyzing many initiatives, frameworks, and tools that are all part of the family of One Planet Approaches. These approaches share the common feature of considering the Earth's limited capacity to define sustainability targets and strategies, for example, translating the Planetary Boundaries to the level of countries and companies. Clearly, there are many ways to set up these approaches depending on the specific objectives of the program in question. For example, a program could create a decision-making framework for companies to take forward on their own, while another program could be centrally coordinated, plus many combinations; a program designed for country application will also be different from one designed for companies.

We now present a series of design features and tools that we would like to recommend for One Planet Thinking to take forward, as we believe they could make it one of the most meaningful and impactful OPAs in the long-term.

Given the complex dynamics and choices of the process described by the 8-step framework, we strongly recommend that all issues related to boundary setting and impact allocation mechanisms remain centrally coordinated by a governing body with scientific and civil society membership, and to a lesser extent with government and private sector participation. We note that these two steps of the framework (Step 4, the definition of boundaries, and Step 8, the selection of an allocation principle) are critical to the meaningful implementation of OPT and should remain under the management of expert and neutral parties.

OPT will need to manage a great amount of complex information, in particular the regional and dynamic variability of boundaries, the number of impact categories that need to be considered, the number of actors that will be implementing it, and the need for strategic decision making to break down systemic structures. We recommend for OPT to build three tools to manage this information: a System Boundaries Database, a Dynamic Impact Dashboard, and a Code of Behavior.

4.3.1 THE OPT SYSTEM BOUNDARIES DATABASE

To implement OPT effectively and at a large scale, we need a central platform that serves as a "system boundary" database. In keeping with the spirit of the Planetary Boundaries, this database would monitor and report boundary positions (and available operating space) in a geo-referenced and disaggregated manner for all impact categories, at the adequate regional levels.

This tool would be an online platform, of free access to all stakeholders, with modular design that permits a phased construction, and would be continuously updated by research institutions and government agencies. A first step towards building this platform would be geographically defining the regional boundaries for all impact categories, a process that is already underway for some systems. For example, information for water basins is readily available. Ecosystem maps with information on biodiversity concentration areas are also available. In the future, information can be complemented with satellite measurements and big data approaches. Site visits and locally-collected data can verify assumptions on the ground.

This tool would serve for more purposes than company-level OPA implementations; it can also help civil society, the research community, and governments to monitor the regional stability of ecosystems, sustainably manage water and biomass extraction rights, and monitor pollution. To connect this central tool with company-targets, a target setting and decision-making framework are required, as discussed in Section 3.3.3.

4.3.2 THE OPT DYNAMIC IMPACT DASHBOARD

We need to communicate information to the company on its current performance relative to planetary capacity. The planetary boundaries are built on a strong sustainability perspective (Sandin, 2015) where each boundary needs to be kept separate and transgressions in one system cannot be mitigated in another. Following this line, the impact categories and control variables we have recommended in this report need to be kept separate.

Companies (and other agents) implementing OPT, need a tool to aid their decision making towards the best sustainability actions and results - a dynamic impact dashboard. This tool should serve, in particular, to avoid burden shifting between different regions and/or impact categories.

We recommend building this as a software tool that can be readily accessed by companies to obtain real-time impact profiles of their activities as well as to model and forecast how their results would change under different scenarios. The dashboard should connect to the central OPT System Boundaries Database to contextualize the agent's impacts to the operating space available at each region of operation. As the boundaries have been defined in a region-specific way, the inputs into the dashboard also needs to be georeferenced.

The tool would show, at a glance, a company's contribution to each impact category, guiding attention to the most transgressed boundaries and comparing the company's impact intensity to that of best practices in the sector. This step is crucial for holistic CSR management, contributing directly to the materiality check according to GRI. Ideally, the tool would also provide the company with information on what are the other activities or uses of operating space occurring in the region where it operates.

Following on the strong sustainability principle, the dashboard would indicate in its main overview the worst transgression of all areas (not the average) for each affected impact category. For example, the freshwater extraction wedge would show the results for the one basin where the company has the largest impacts (even if all other areas are within the allocated operating space). When processes operate regionally, an impact heavily concentrated in one single area will lead to collapse there. The dashboard needs to communicate this so that companies can concentrate their actions in these areas at highest risk. Next to this overview, the tool would also present disaggregated information on performance across all categories and for every region.

When the company using these tools considers different scenarios for action, it will see how its performance is affected, or not, by changes in the wedges. For example, shifting livestock raising to areas where there is more abundant water can lower the impact on the freshwater boundary. We could assume that by shifting the operations, the same amount of manure would be produced (and handled in the same way). While the total pressure on the nitrogen and phosphorus cycles wouldn't change, if this new area has more competing use for that operating space, the company's performance would decrease.

Some type of impact trade-offs might be unavoidable, so the tool should also help to prioritize impacts. We would need to develop a proper and detailed protocol to help assess this on a case by case basis, taking into account different factors such as the reversibility of the impact, the biodiversity richness of the areas in question, the relative importance of the process for the area (for example, freshwater extraction might be more severe in an area with volatile climate than in an area where rains are more reliable), as well as the effects on human welfare and social justice indicators.

Figure 17: Mockup View of an Impact Dashboard for a Hypothetical Company

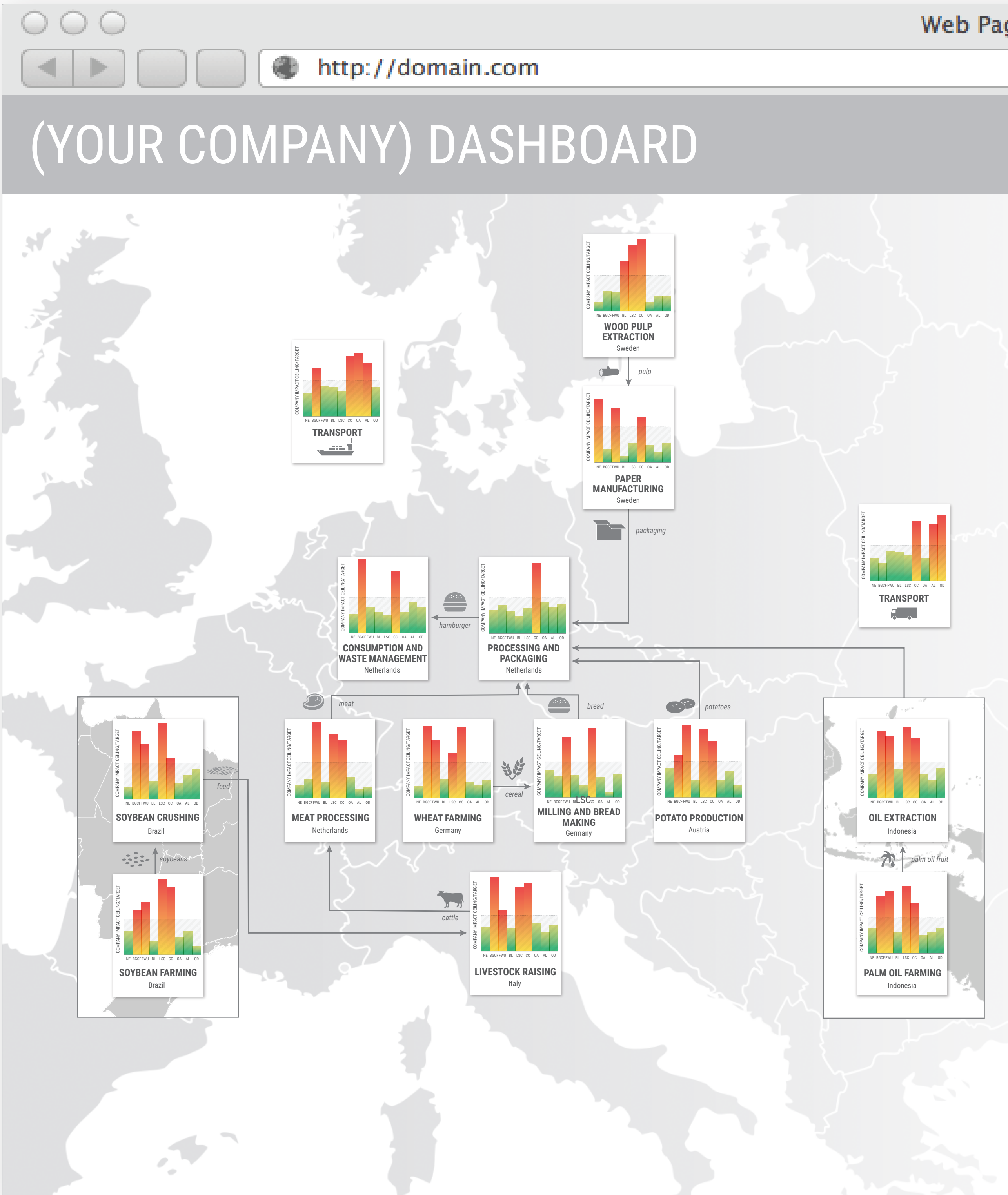
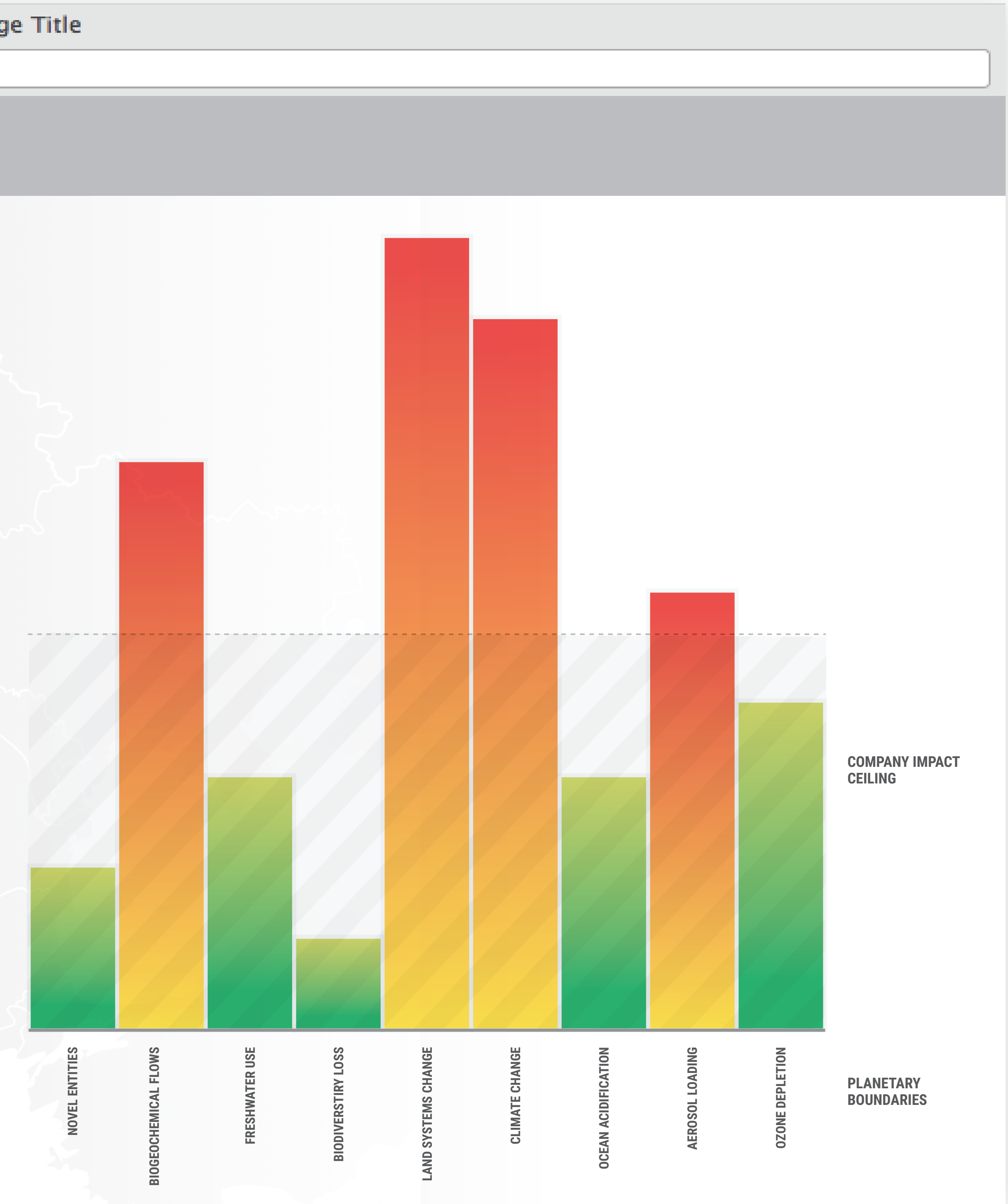


Figure 17. *This image shows a mock-up of a potential Planetary Boundaries dashboard screen for companies. This overview screen would illustrate at a glance how a company is performing across its areas of activity, indicating both the company's impacts on each planetary and regional boundary, with impact targets or ceilings defined based on a reasonable impact for the company. This dashboard would ideally aggregate detailed information on the company's regional impacts across its supply chains, and detail these impacts in a georeferenced manner.*


ge Title
NOVEL ENTITIES
BIOGEOCHEMICAL FLOWS
FRESHWATER USE
BIODIVERSTIRY LOSS
LAND SYSTEMS CHANGE
CLIMATE CHANGE
OCEAN ACIDIFICATION
AEROSOL LOADING
OZONE DEPLETION
COMPANY IMPACT CEILING
PLANETARY BOUNDARIES

4.3.3 THE OPT CODE OF BEHAVIOR

In order to meet the sustainability challenges imposed by the reality of the limited capacity of the Earth and the competition for scarce resources, we need to shift our thinking models. Solutions should not necessarily be about how to merely optimize flows for companies. Instead of just thinking about how to create budgets for impact, we should find ways to satisfy needs without impact. In short, companies committed to sustainability leadership and implementation of One Planet Thinking need to go far beyond the targets and commit to starting systemic change.

Sustainability leaders are not those who just reduce their impact, but those that trigger change in their spheres of influence (suppliers, partners, clients, etc.) to create structural change. Companies are encouraged to adopt a One Planet Thinking Code of Behavior to complement their quantitative targets and facilitate decision-making. We sketch here some of the principles that would ideally be included in such a Code.

Systemic solutions are preferable to isolated action. To have leverage over the entrenched systemic structures that usually prevent change, OPT companies should collaborate in sectors and supply chains in order to:

» Identify systemic technological, economic, and policy barriers to change
» Generate public or common access technology to face the challenges of their sector
» Participate in friendly competition with their peers regarding their OP target performance

Solutions might be beyond the walls of the company. OPT companies should commit to:

» Explore impact mitigation possibilities through collaboration with other agents, so long as the impacts are reduced for the same impact categories and regions
» Consider the wider social and environmental context as inspiration and guidance to solution-finding
» Pursue strategic sustainability reductions: avoiding burden shifting and prioritizing core boundaries
» Commit to repair historical damage and to build ever fairer relations with supply chain partners

In the interest of long-term resilience and the rights of future generations, solutions today should also aim at building socioenvironmental resilience into the Earth system and furthering the construction of public capital and the preservation of material resources. In this context, OP companies should:

» Include solutions that encompass decentralization of technology and resource provision
» Commit to eliminating material losses and dispersion, especially for critical and scarce materials
» Contribute to public research and open-access technologies

Agriculture and extractive activities in the primary sector (i.e., fisheries, forestry) are nowadays a major driver of the transgression of several planetary boundaries, including the critical habitat occupation impact category, as well as other such as climate change, biogeochemical flows, freshwater depletion, and biomass extraction. Unfortunately, the vast majority of actors in these sectors are dispersed, small and medium farm-holders that are unlikely to participate in an OPA. Companies working in the food, beverages, tobacco, textile, leather, wood, and paper sectors, or working with other biomaterials (e.g., bioplastics, construction materials from biomass), either in manufacturing, trading, or distribution, must take responsibility to engage their suppliers and commit to bringing their entire value chains within planetary capacity.

For companies in energy-intensive, industrial sectors, the adoption of Science Based Targets should be an essential part of the OPT strategy. Furthermore, these companies need to commit to, and lobby for, the shift towards sustainable, carbon-free energy.

LIST OF INTERVIEWEES

Naikoa Aguilar	WWF USA
Anders Bjørn	CIRAIG Polytechnique Montréal
Paul Chatterton	WWF Austria
Megan Cole	Oxford University
Sarah Cornell	Stockholm Resilience Center
Hy Dao	UNEP & University of Geneva
John Dearing	University of Southhampton
Pooran Desai	Bioregional
Alessandro Galli	Global Footprint Network
Ben Gill	Bioregional
Jaap Hanekamp	Roosevelt College
Tiina Häyhä	Stockholm Resilience Center
Holger Hoff	Stockholm Environment Institute & Potsdam Institute of Climate Impact Research
Paul Lucas	Netherlands Environmental Assessment Agency (PBL)
Georgina Mace	University College London
Mark McElroy	Center for Sustainable Organizations
Alexis Morgan	WWF Canada
Natasja Oerlemans	WWF Netherlands
Jasper Ohm	Arcadis

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GLOSSARY

Planetary boundaries	Nine essential Earth systems that need to be kept stable in order to keep the biosphere functioning.An attempt has been made to define “boundaries” that represent the amount of change each of these parameters can absorb without hitting an unsafe and destabilizing level. Out of the nine boundaries identified, SRC has estimated that we have already transgressed four: climate change, biodiversity loss, both phosphorus and nitrogen biogeochemical flows, and land system change.
Operating spaces	Processes and activities that take place at a safe distance from the thresholds that define the planetary boundaries.Determining a safe distance involves normative judgements of how societies choose to deal with risk and uncertainty (Rockstrom et al., 2009)
Holocene	Geological epoch that refers to the timeframe from11.700 years ago – present day. It encompasses all written history and the growth and impact of the human species. The last part of modern history (starting from the industrial revolution) is sometimes referred to as the Anthropocene, due to the human-induced climate change. The Anthropocene is not officially approved as a geological epoch.
Regime shift	A sudden, abrupt and persistent structural change in the functioning of a system.
Tipping point	A tipping point is a threshold for abrupt irreversible changes (regime shifts). A tipping point has been crossed when a system enters a significantly different state as the result of a small alteration. Well-known tipping elements in the climate system include the Greenland ice sheet and the Atlantic thermohaline circulation
One Planet Approaches	The complete family of tools, methodologies, frameworks, programs, and action plans, which recognize the need to measure and reduce human impact in relation to the absolute boundaries of the Earth system.
System processes	Natural processes on Earth that take interact on a global scale on which human activities have a negative influence. Processes that have been identified are: Climate change, Loss of biodiversity, Biogeochemical, Ocean acidification, Land use, Fresh water, Ozone depletion, Atmospheric aerosol and Chemical pollution.
System dynamics	The interactions in the Earth system, many of which are nonlinear and operate at different, overlapping scales.
Impact categories	Categories grouped on system process and impact through which impact is measured using a set of indicators related to the measured effect. Example are global warming (potential), water depletion and acid rain.
Anthropocentrism	The belief the human beings are the most significant entities in the universe. It evaluates the world in terms of human value and experience.
Biocentrism	The believe that extends the status of moral object to all living things in nature. It advocates animal rights, environmental preservation and biodiversity.
Ecocentrism	The believe in a nature-centered system of values.
Resilience	An emergent system property that describes the capacity of a system to deal with change and continue to develop without collapsing (Stockholm Resilience Centre, 2016). Resilience can be built into systems through intended human action, both at the biophysical and the social levels.
System structures	The patterns of interactions and relationships between different components of a system.

ABBREVIATIONS

BAU	Business as Usual
C-FACT	Corporate Finance Approach to Climate-Stabilizing Targets
CFP	Carbon Footprint
CSI	Carbon Stabilization Intensity
CSR	Corporate Social Responsible
EPA	Environmental Protection Agency
ESG-framework	Environment Social Governance – framework
EFP	Environmental Footprint
EWF	Environmental Water Flow
FSC	Forest Stewardship Council
FPF	Footprint Family
GEVA	Greenhouse emissions per value added
Gha	Global hectares
GHG	Greenhouse Gas
GRI	Global Reporting Institute
HANPP	Human Appropriation of Net Primary Production
INDC	Intended National Determined Contributions
IPPC	Integrated Pollution Prevention and Control
LCA	Life Cycle Assessment
MSY	Maximum Sustainable Yield
NCP	Natural Capital Protocol
OPA	One Planet Approach
OPT	One Planet Thinking
PB	Planetary Boundaries
SDG	Sustainable Development Goals
SRC	Stockholm Resilience center
SDA	Sectoral Decarbonization Approach
SFM	Sustainable Forest Management
SBT	Science Based Targets
UNEP	United Nations Environmental Program
UNGC	United Nations Global Compact
WFP	Water Footprint
WRI	World Resource Institute
WUE	Water Use efficiency
WSC	Water Stewardship Council

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