From Planetary Boundaries to

Planetary Politics

CONCITO

From global to national boundaries

The planetary boundaries framework is increasingly used as a baseline for national policy making. Here, we examine insights from ten studies that apply and downscale the planetary boundaries from global to national levels.

So far, these downscaling efforts have been used to set national environmental targets and budgets, and for assessing environmental footprints with two main challenges: a) translating the global biophysical indicators into usable national ones, and b) choosing the allocation principle for determining national shares of global responsibility. Future work applying the framework in a national context should move beyond target setting and national environmental budgets, and instead focus on the interaction between boundaries for a more coherent policymaking.

Brief 2
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About "From Planetary Boundaries to Planetary Politics"

The project "From Planetary Boundaries to Planetary Politics" is carried out by the Danish green think tank CONCITO, with a scientific advisory board of researchers from University of Copenhagen, Stockholm Resilience Centre, and Potsdam Institute for Climate Impact Research. The aim of the project is to further, inspire, and support a more holistic approach to climate-, nature-, and environmental policy, using the Planetary Boundaries framework as a reference point.

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Introduction

With an increased focus on the interactions between climate and environment, countries are starting to look at how to address their environmental footprints reaching beyond greenhouse gas (GHG) emissions. One source of inspiration to do so, taken up by several countries, is the planetary boundaries (PB) framework.

The planetary boundaries framework, originally developed by Earth system scientists in 2009, shows the status of change to nine fundamental Earth system processes globally. Furthermore, the framework emphasizes the urgency regarding the importance of staying within the so-called "safe operating space for humanity", while highlighting boundaries that are already transgressed (Rockström et al., 2009). The PB framework and the boundaries are explained in further detail in our ***Brief 1: Planetary boundaries - A brief introduction***.

The PB framework was not originally intended to be used at any other scale than the global (planetary) (Steffen et al., 2015). However, most regulation and decision-making regarding the environment and climate takes place at a national level (Biermann & Kim, 2020). Recently, several studies have documented "downscaling" efforts, where the PBs have been translated and disaggregated to a national level as a way to evaluate overall environmental performance.

One of the first of these downscaling attempts used the original PB framework (Rockström et al., 2009) to assess the national environmental performance of Sweden (Nykvist et al., 2013). This study is notable as it intended to evaluate whether the PBs could be downscaled and used as a (at the time) new framework to assess national environmental impacts in a global context.

Since then, the PBs have been downscaled for a range of countries, including Australia, New Zealand, the Netherlands, Switzerland, Europe (European Environment Agency members), Taiwan, South Africa, Canada and Spain (Andersen et al., 2020; Climateworks Centre, 2022; Cole et al., 2014; Dao et al., 2015; European Environment Agency, 2020; Fanning & O'Neill, 2016; Huang et al., 2020; Keppner et al., 2020; Lucas & Wilting, 2018; Nykvist et al., 2013).

In this brief, we present an overview of existing national PB downscaling studies and highlight learnings and lessons from these cases that are important for other countries wanting to use the PB framework to define national environmental targets and budgets. As such, the brief is intended as a starting point for efforts to operationalize the PB framework in practical applications.

The planetary boundaries at the national level

With an increased focus on the environmental impacts caused by human activity, both on a national and global level, there is a need for a more holistic approach to assess multiple environmental impacts, going beyond greenhouse gas (GHG) emissions.

This broader focus on environmental impacts can be seen in both national goals and international commitments such as the 2030 Agenda for Sustainable Development (United Nations, 2015), or the 7th Environment Action Program of the EU "Living well, within the limits of our planet" (European Commission, 2014). As a reaction to this, countries have asked for science-based measures that can be used to evaluate their environmental impact and national performance. The planetary boundaries framework has by many been taken up as a quantitative assessment to assess a broader range of these impacts.

In this brief, we searched for studies using the planetary boundaries to set national budgets and assess national targets. We restricted our search to studies looking at ***countries*** or ***groups of countries***. To select the relevant downscaling literature, we used the following criteria to filter the search results:

- The study/report actively uses the planetary boundary framework and the PB framework is used as the main framework
- The study/report makes its own downscaling and assessment (i.e., does not just refer to other studies/reports)
- The study/report considers and downscales at least two of the PBs

With these criteria in mind, we identified ten different studies that have downscaled the planetary boundaries to a national scale and in one case at a European level (the 28 EU Member States and Iceland, Liechtenstein, Norway, Switzerland, and Turkey). Table 1 provides an overview.

Do note that the studies use slightly different terminology for the boundaries, even if they use the same version of the PB framework (Table 1).

This brief can be seen as a snapshot of downscaling efforts at the national level. Other studies have taken inspiration from the planetary boundaries, for example using it to downscale to the regional levels (Hossain et al. 2017), the city level (Bai et al., 2024) or using it to guide businesses like the Science Based Targets Network (SBTN), building and developing on the existing climate change focus of the Science Based Targets initiative (SBTi) (Global Commons Alliance, 2020). WWF have also used parts of the PB framework to investigate environmental footprints of Norway and the UK (Esposito et al., 2022; Jennings et al., 2021). We excluded the WWF-studies from this brief since they divert from the active use of the PB framework and instead apply their own footprint framework.

Table 1. Downscaling the PBs – overview of country reports.

Country (Authors)	Year published (Version of PB-framework)	Purpose of assessment/Focus of downscaling	Number of boundaries assessed
Australia (Climateworks Centre, 2022)	2022 (2015)	To assess Australian environmental impacts with a focus on how to define a sustainable land use sector.	5. Climate change, freshwater use, land-system change, biosphere integrity, and biochemical flows.
New Zealand (Andersen et al., 2020)	2020 (2015)	To advise policymakers on how environment, well-being and economic development can be seen in a global systemic framework, and how national environmental goals can be set.	5. Climate change, freshwater use, land-system change, biosphere integrity and biochemical flows.
Europe (European Environment Agency, 2020)[2]	2020 (2015)	To define an environmentally safe operating space for Europe. Explores different allocation principles and assesses European performance.	3. Freshwater use, land-system change and biogeochemical flows.
Taiwan (Huang et al., 2020)	2020 (2015)	To establish environmentally sustainable indicators, using Taiwan as a case.	5. Climate change, freshwater use, land-system change, biogeochemical flows, and ocean acidification.
Germany and EU (Keppner et al., 2019)	2019 (2015)	To operationalize the downscaling process and explore how the PB framework can be implemented in a political aspect, including what role politics, science, civil society, and business could play in doing so.	3. Climate change, land use change, and nitrogen.
Netherlands (Lucas & Wilting, 2018)	2018 (2015)	To explore the normative assumptions needed to allocate boundaries and how national policy targets can be set in terms of reaching sustainability goals.	4. Climate change, land-system change, biogeochemical flows, and biosphere integrity.
Canada and Spain (Fanning & O'Neill, 2016)	2016 (2015)	To define both national and regional boundaries using a top-down approach. Uses Canada and Spain as a case of how environmental performance compares to a "steady-state economy".	4. Climate change, freshwater use, land-system change and biogeochemical flows.

[2] Europe has also been assessed previously by Hoff et al. (2014), Hoff et al. (2017) and (Häyhä et al., 2018), the latest downscaling builds on these, while including a bigger range of allocation principles.

Table 1. Downscaling the PBs – overview of country reports.

Country (Authors)	Year published (Version of PB-framework)	Purpose of assessment/Focus of downscaling	Number of boundaries assessed
Switzerland[3] (Dao et al., 2015)	2015 (2009)	To identify environmental limits and how that corresponds to a Green Economy in Switzerland.	5. Climate change, land cover anthropisation[4] , nitrogen and phosphorus losses, biodiversity loss, ocean acidification.
South Africa (Cole et al., 2014)	2014 (2009)	To assess whether the PB framework can be used at the national level, using SA as a test case. Focuses on a decision-based method with a focus on national environmental indicators and a bottom-up approach.	8. Climate change, freshwater use, arable land use, biodiversity loss, marine harvesting[5], nutrient cycles, air pollution, and ozone depletion.
Sweden Nykvist et al., 2013)	2013 (2009)	To assess whether PBs can be used to understand the dynamics between Swedish and global environmental pressures and to assess national performance.	4. Climate change, freshwater use, land-use change, and nitrogen cycle.

[3] Switzerland also assessed in 2018 (Dao et al., 2018), but the scientific article builds on the same assumptions and has the same downscaling values as the Swiss report.
[4] Refers to land-use/land-system change in the PB framework.
[5] Replaces ocean acidification in this study. Refers to the stock status of commercial fisheries.

As seen in Table 1, most of the studies assess 4-5 boundaries, while none assess all nine. The most studied boundaries are climate change, freshwater use, land system change, and biochemical flows. Conversely, the boundaries for stratospheric ozone depletion and atmospheric aerosol loading are much less studied, and the boundary novel entities is not assessed in any of the identified studies.

While all the ten selected studies set national budgets and assess performance for at least three boundaries, the studies differ in terms of what they focus on. The studies on the Netherlands and Europe focus largely on allocation principles – i.e. how to determine a national share of the global responsibility – and showcase the differences between them, whereas the studies on Germany, Taiwan, and South Africa focus more on operationalizing the downscaling process, testing it on the countries in question. Finally, the studies on Australia, New Zealand, and Switzerland focus less on the downscaling process and more on assessing country performance and linking it to future policy development.

Researchers have also tried to give an overview of the transgression of planetary boundaries across different countries. One such project is Leeds University's "A good life for all within planetary boundaries" (O'Neill et al., 2018a). This project looks at data from more than 140 countries from 1992 to 2015 and assesses how the countries preform in terms of staying within both biophysical and social indicators, termed a "safe and just operating space" (see Raworth 2012).

The project concludes that the number of countries transgressing the boundaries are increasing; that no country is currently moving towards a safe and just operating space; and that the number of countries transgressing the land-system change, ecological footprint and material footprint is projected to continue to increase in the future, under a business-as-usual scenario (Fanning et al., 2022; O'Neill et al., 2018a).

Downscaling the Planetary Boundaries

Translating and downscaling the boundaries from a global to a national/regional level is a challenging process requiring multiple assumptions and approximations. This translation can be done either with a top-down approach (scaling global indicators to national levels) or a bottom-up approach (starting from a regional/national environmental issue and identifying indicators to measure change from there).

In this section, we describe one process for downscaling the PBs in details, outlines the key analytical decisions to be taken, and provides examples of how it has been done in the different country studies described in the previous chapter.

The downscaling process when using a top-down approach is often split into three main steps:

- Translating the boundaries to measurements of human influence (drivers or pressures).
- Choosing an allocation principle to determine national share of global responsibility.
- Assessing national environmental impacts/footprints.

The steps are described in further detail in the following.

Step 1: Translating the Planetary Boundaries to measures of human influence

As previously mentioned, the PB framework was originally intended solely for scientific purposes and only at the global (planetary) scale. Many of the boundaries are therefore set as a threshold for Earth system process or function using control variables that do not translate well into national policymaking contexts. Furthermore, some of the boundaries are highly geographically distributed (e.g. freshwater use) and are therefore not necessarily relevant everywhere (Lade et al. 2019).

Thus, the first step in downscaling the PBs requires a translation of the global control variables into indicators that are relevant in a national context and from which national performance can be assessed.

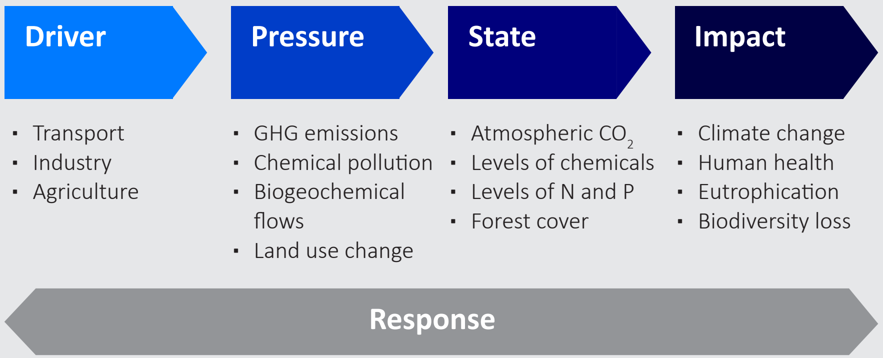
In the cases of Sweden, Switzerland, and the Netherlands, the "Driver-Pressure-State-Impact-Response"-framework (DPSIR) was used to understand and translate the boundaries (Dao et al., 2015; Lucas & Wilting, 2018; Nykvist et al., 2013).

Figure 1. The downscaling process in a top-down approach, illustrated.

The framework, developed by the European Environment Agency (EEA), can be viewed as a chain of causal links of *driving forces* (human activities) leading to *pressures* (e.g. GHG emissions and land use change), which changes the *state* of the Earth system (e.g. GHG concentrations in the atmosphere), which leads to *impacts* (e.g. climate change and biodiversity loss). Lastly this causes a societal *response* for example in terms of setting in to minimize the negative environmental impacts (Smeets et al., 1999). Figure 2 shows the DSPIR framework with examples of each level.

Most of the indicators in the planetary boundaries are set as a state, e.g. concentration of CO_2 in the atmosphere (ppm CO_2); the rest can be categorized as either pressures or impacts (Nykvist et al., 2013). Neither states, nor impacts are easy to disaggregate. Moreover, human activities mainly influence drivers and pressures directly, and these components are therefore the most interesting in a national policy making context. Thus, the first step of the downscaling process is finding driver or pressure indicators to replace the state/impact indicators present in the PB framework.

Figure 2. DPSIR framework and example of indicators in each level in a planetary boundary context.



A good example of the conversion of a PB defined as state to a pressure is the PB for climate change. In the PB framework, the control variable for the climate change boundary is set as a concentration of CO_2 in the atmosphere (350 ppm CO_2). Many of the studies translate this state to a pressure of CO_2 emissions. When converting to this new (pressure) indicator and thus setting a global "budget", the studies refer to the Paris Agreement and sets the budget based on emission pathways corresponding to a 1.5 or 2 °C warming. The global budget is set to between 400-550 Gt CO_2 to stay below 1.5 °C and around 1000 Gt CO_2 for 2 °C (Lucas & Wilting, 2018)[6].

The DPSIR Framework generally takes a top-down approach in terms of downscaling the boundaries from global to local (national). For some of the boundaries it is however argued that local differences play a role in how the boundary should be downscaled and assessed. A more bottom-up approach can thus also be considered to include regional environmental issues and local differences for example in terms of land-system change, freshwater use, and biosphere integrity (Keppner et al., 2020).

An example of the use of a bottom-up approach is found in the downscaling of South African boundaries, focusing on local impacts of for example biodiversity loss, air pollution and nutrient cycles. In this case the boundary for biodiversity loss was set based on ecosystem threat status in the National Biodiversity Assessment. They argue that no ecosystem should have a status of being endangered or critically endangered, and the boundary would therefore be transgressed by the amount of endangered and critically endangered ecosystems (Cole et al., 2014).

[6] This is a political agreed on target, when comparing with the 350 ppm in the PB it is argued that that would equal a lower budget over time than the 1.5 °C target (Dao et al., 2018). This is however argued to be an unlikely target to reach (O'Neill et al., 2018b)

Step 2: Choosing an allocation principle to determine national share of global responsibility

The second step in a top-down approach to downscaling PBs relates to the need to determine national shares of a chosen indicator (driver or pressure). Since many of the Earth system processes described by the PBs are highly spatially distributed, and humanity's contribution to the pressure on most boundaries are also very diverse (e.g. greenhouse gas emission) (Hossain et al. 2017), there is no scientifically correct way to allocate national responsibility for the planetary boundaries. Thus, it is a political/normative process of deciding on the principle, invoking notions of fairness and justice.

Different allocation principles have been taken into consideration in the country studies. The most commonly used principle in the assessed studies is an equal share per capita allocation (e.g. Nykvist et al., 2013; Wood et al., 2020; see Table 2). This principle uses population size as a proportion of the global population or the country's land area to establish the share of resources or pollution allocated for a country. The method has been viewed as a straightforward approach building on the notion that the worlds inhabitants should have an equal share of resources, etc. and it is therefore also often referred to as the "fair share".

There are, however, also other important aspects to consider such as different needs of citizens in different geographies, the question of historical emissions, and the rights to economic and social development (Dao et al., 2018; European Environment Agency, 2020; Lucas & Wilting, 2018).

Table 2. Applied allocation principles in country assessments

Study	Allocation principle
Australia, 2022	Equal share per capita, and equal share per land area
New Zealand, 2020	Equal share per capita, and equal share per land area
Europe, 2020	Uses a range of equity principles including equality, needs, rights to develop, sovereignty, and capability
Taiwan, 2020	Global share of GHG in 2016, and allocation based on local conditions (bottom-up approach).
Germany, 2019	Equal share per capita, and equal share per land area
The Netherlands, 2018	Uses a range of equity principles including equality, capability, and efficiency
Canada and Spain, 2016	Equal share per capita, and equal share per land area
Switzerland, 2015	Equal share per capita, and "hybrid-allocation" that fixes the share per country and then divides per capita. Also introduces a temporal dimension in terms of recognizing the share of historic and future resource use/need
South Africa, 2014	Bottom-up allocation. Allocates boundaries for South Africa based on local conditions
Sweden, 2013	Equal share per capita

One example of the use of multiple allocation principles is the joint report by the Federal Office for the Environment and the European Environment Agency that assesses Europe's environmental footprints in relation to the PBs, using five different allocation principles (European Environment Agency, 2020):

- Equality (equal share per capita)
- Needs (different resource needs)
- Right to development (allocating more resources to people in low-income countries)
- Sovereignty (territorial rights and allocation similar to current use of resources)
- Capability (based on countries ability to pay e.g. mitigation)

Table 3. Allocation principles and allocated share (based on EEA, 2020)

Allocation principle	Description	Median share
Fair share (Equality)	Equal share per capita	8.1%
Needs	Differentiated needs of resources	7.3%
Right to develop	The right to for low-income countries to develop to achieve a decent life	4.1%
Sovereignty	Countries have a right to their own territory	12.5%
Capability	High-income countries should contribute more to mitigating efforts	6.2%

Step 3: Assessing national environmental impacts

The last step of the downscaling process is assessing the national environmental impacts relative to the established national environmental budget. This requires choosing an approach that can measure all the different environmental impacts in the PBs.

Country examples: Europe and the Netherlands

Most country reports rely on the "equal share per capita/land area" principle when allocating national shares. However, the reports for Europe and the Netherlands included a variety of allocation principles, showing the large differences this creates. Table 3 shows the different results from the EEA-study on Europe. For example, depending on the allocation principles, the median European share varies from 6.2% to 12.5% of the global boundary. To illustrate, this means that the downscaled budget for Europe for the land system change boundary would range between 0.5 and 4.1 million km2 of land converted to cropland, infrastructure, and other human uses (European Environment Agency, 2020).

The study on the Netherlands also uses a range of allocation principles. These includes for example the "grandfathering (sovereignty)" approach, which is based on the idea that countries are entitled to a similar resource use as they have had previously and therefore favors countries that already have a high resource use. In contrast, a "development rights" approach allocates more resources to countries that have previously had a lower resource use. In the case from the Netherlands therefore the CO2 emissions ranged from-6.6 to 1.9 tCO2 per capita, where the development rights resulted in the negative emissions budget (-6.6 tCO2 per capita) and the grandfathering approach retained a higher budget (1.9 tCO2 per capita).
The chosen allocation principles can thus give quite different shares in terms of the individual national budgets.

Of the analyzed country reports all recognize the global interconnectedness of the world and the need of including consumption-based impacts, and therefore include both a production- and consumption-based approach.

Including consumption-based emissions/resource use is seen as a way of representing the entirety of a country's environmental footprint and can for example influence the land use change made in other countries in terms of import of agricultural products (Hoff et al., 2017). In terms of data availability, the production-based environmental impacts are usually easier to account for as they take place within the national borders, whereas data on all the PBs in a consumption-based approach can be harder to track.

Figure 3. Production- and consumption-based approaches. Cropland use in the Netherlands for the two approaches (Hoff et al. (2017)

Production based

Environmental pressures from production for domestic consumption and from export

Consumption based

Environmental pressures from production for domestic consumption and from foreign production related to imports

Country examples: Netherlands and New Zealand

Using production-based compared to consumption-based approaches can give quite different environmental footprints. This is illustrated in the CO_2 emissions in New Zealand and cropland use in the Netherlands where the consumption-based accounting gives a larger footprint.

One of the assessed boundaries in New Zealand was climate change. The CO_2 emissions were 7 tCO_2 per capita per year for production-based accounting and 9 tCO_2 per capita per year for consumption-based accounting. Both by far exceed the boundary range with a stringent boundary of 0.66 tCO_2 per capita per year.

Netherlands use both a production- and consumption-based approach, which showed large differences in terms of the size of environmental footprint when comparing the two approaches. In terms of the assessed cropland use, this results in a quite substantial difference in cropland use. The production-based approach results in the use of 0.05 ha per capita cropland use, compared to 0.38 ha per capita in the consumption-based approach (Figure 3). To further complicate things, the Dutch cropland use budget ranges between 0.1-0.5 ha per capita, depending on the allocation principle employed. In sum, where the production-based footprint stays within the boundary, the consumption-based footprint transgresses the boundary in the equal per capita approach, but not the grandfathering approach.

Lessons learned

As the previous sections have shown, the PB framework has been used several times in a national context to help set national environmental budgets and guide policymaking. In this section, we aim to highlight some of the challenges of applying the PB framework in a national context and give some perspectives on opportunities for improvement in similar, future studies.

Challenges

Each downscaling step leads to several decisions and assumptions that should be taken into consideration. Here, we highlight two core challenges of the process:

Translating the global biophysical indicators into usable national indicators
This challenge is twofold. First, it includes identifying the appropriate drivers and pressures that adequately corresponds to the control variables for each global PBs. This includes identifying meaningful national indicators in the specific context of a study. These may vary from place to place, and challenges comparative studies at national level. Moreover, the more context-specific the national indicators are, the harder it becomes to link them to the PBs. Data accessibility is an additional issue. The best, national indicators might be theoretically sound, but lack of national data might impede their use. For some of the PBs, the existing studies provide helpful guidelines for translation, but especially novel entities, atmospheric aerosol loading, and ocean acidification have received less attention.

Second, downscaling involves a decision on whether to use a top-down or bottom-up approach (or a combination of the two) for choosing relevant, national measures. There are markedly more examples of the top-down approach in the existing literature, and more work needs to be done on when and how to apply the bottom-up approach.

Choosing the allocation principle
As shown, national shares of each boundary will vary widely depending on the allocation principle chosen, and this choice involves political and normative decisions. Countries can choose different allocation principles based on different political priorities or positions. Therefore, national assessments of PBs are not always comparable across countries – or sum up to the global thresholds set for each planetary boundary. To address this challenge, at the very least, countries that use the PB framework to set national, environmental budgets should provide transparency on which and why specific allocation principles have been chosen.

This also highlight the potential of rethinking the purpose of downscaling exercises. Instead of using the PB framework to assess absolute environmental performance relative to a normatively set budget, the framework could be employed to highlight areas for political action, focusing more on the relative performance on different indicators.

Opportunities

Our review in this brief also indicates the continued opportunities for improving the use of the framework when downscaling from global to national. Here we highlight four potentials meant as a starting point for further debate, rather than an exhaustive list:

Full country assessments of all nine planetary boundaries
With the updated 2023 version of the PB framework (Richardson et al. 2023), all boundaries are now assessed with set limits and with updated control variables for some boundaries (See Brief 1). This presents a foundation for new country level studies to assess all nine boundaries and find new ways of measuring limits and setting budgets.

Cooperation between scientists and politicians

To our knowledge, the previous assessments have been conducted by scientist/consultants/researchers from outside the political system – and with little or no political involvement. Considering that downscaling involves a choice of the allocation principle, which is fundamentally political, it would be beneficial to involve decisionmakers directly in the assessment process. Moreover, we see that closer cooperation is essential for translation of the biophysical variables from the PBs into (national) pressures that make sense in a political decision-making context.

More work on governing the PBs

While our review has shown some initial attempts at downscaling the PBs for use in national policy contexts, more work is needed on governing the PBs. Here it is important to highlight the difference between the boundaries in terms of translation and allocation.

As shown through the country case studies, some of the PBs are more easily translated as pressures on a national level, e.g. national GHG emissions as contributions to global climate change. Furthermore, for climate change there is already international regulatory frameworks such as the UNFCCC that guide the setting of boundaries, e.g. the 1.5-degree target in the Paris Agreement. The same goes for ozone depletion through the Montreal Protocol. Despite this there are continued international debates on allocating "fair shares" of for example GHG emissions.
For some of the other processes, the translation and allocation are less easy due to the geographical distribution of the pressures and resources, e.g. forests and freshwater, so that the global pressure on e.g. the land system boundary is aggregated from regional pressures. These might be governed more effectively in regional collaboration between countries. Recently, Rockström et al. (2024) have also suggested a new paradigm for safeguarding some of the most important global Earth-regulating systems, so-called "planetary commons". Overall, we identify a need for more attention to these governance aspects when using the PBs for national or regional assessment of environmental change and footprints.

Use the framework directly in policymaking

Finally, we see an opportunity for using the PB framework more explicitly when designing and evaluating environmental policy. Some studies touch upon this possibility, yet do not develop it further. We believe that the framework holds value beyond budget- and target-setting. For starters, the PB framework emphasizes the interlinkages between boundaries in a complex system, pointing towards a need for better environmental horizontal policy coherence where climate, nature, and environmental policy is addressed with a systemic perspective; where positive synergies are emphasized and pursued; and where negative, cascading effects are identified, mitigated, and/or nullified.

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