

# Bringing EU policy into line with the Planetary Boundaries

## Introduction

Today, there is widespread acceptance that collective human activity already has significant impacts on the Earth system that, if continued, could have serious repercussions for human well-being and sustainable development. Far less settled are questions of how to determine individual countries' fair contribution towards mitigating those impacts and how to account for global environmental challenges in existing policy processes.

The Planetary Boundaries framework proposes quantitative limits for human perturbation of critical Earth system processes (Rockström et al. 2009; Steffen et al. 2015). In this regard, the Planetary Boundaries can be seen as defining a global "safe operating space" for human activity. The concept highlights the globally systemic interactions and impacts of the different Earth system processes. Crossing any of the boundaries at the global scale increases the risk of large-scale, possibly abrupt or irreversible environmental change. In addition to boundaries for climate change and biodiversity loss, already cornerstone issues in global sustainability policy, the Planetary Boundaries framework includes stratospheric ozone depletion, chemical pollution and the release of novel entities, ocean acidification, freshwater consumption and the global hydrological cycle, land system change, biogeochemical flows (altered nitrogen and phosphorus cycles) and atmospheric aerosol loading.

Since its publication in 2009, the framework has generated significant interest beyond the scientific community. The concept was prominent in the drafting of the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs). In fact, all the nine planetary processes are addressed either as goals or in targets. Furthermore, the European Union's 7th Environment Action Programme (EAP) sets out the EU-wide ambition of "Living well, within the limits of our planet" (EC 2013). The Planetary Boundaries framework was central to the design of the 7th EAP. However, for both the SDGs and the 7th EAP, the operational implications of remaining within the safe operating space have not yet been spelled out. Nor have they been integrated systematically into policy-making at EU or member state level.

In order to apply the Earth system perspective of the Planetary Boundaries into EU policy- and decision-making, the Planetary Boundaries need to be translated to that sub-global scale. As this downscaling process essentially divides up the global safe operating space, operationalizing the Planetary Boundaries can help to ensure that policy goals are coherent between scales. Furthermore, due to the multidimensional systemic character of the Planetary Boundaries their operationalization can also support horizontal coherence between governance systems, sectors and policies.

This brief takes some first steps in operationalizing the Planetary Boundaries for the EU. It translates the Planetary Boundaries to the EU level, using an equal-per-capita allocation approach, to exemplify what the EU's "fair share" of the global safe operating space might look like. It further uses them as benchmarks

## Key messages:

1. The Planetary Boundaries framework can help in formulating policies and targets to operationalize the global environmental dimension of the 7th Environment Action Programme and the Sustainable Development Goals (SDGs) in the EU.
2. Applying the Planetary Boundaries to EU policy-making involves normative (political) decisions about common but differentiated responsibilities and fair allocations of the global safe operating space. This requires an iterative dialogue and deeper cooperation between scientists and policy-makers.
3. Based on equal-per-capita allocation of the global safe operating space, the EU does not appear to be "living within the limits of our planet". The EU significantly exceeds its per capita "fair share" with respect to the climate change and biogeochemical flows (nitrogen and phosphorus flows) boundaries.
4. For the climate change, land use, biogeochemical flows and water use Planetary Boundaries, consumption per EU citizen exerts higher pressure on the Planetary Boundaries than the global average.
5. Existing EU policy instruments provide numerous potential entry points for mainstreaming the Planetary Boundaries. However, they do not sufficiently address interactions between Planetary Boundary processes, nor the EU's international environmental "footprint".

for EU environmental performance – both within and beyond the territory of the EU. Finally, building on these results, the brief discusses entry points for integrating or "mainstreaming" the Planetary Boundaries framework into EU policy-making.

## Translating the Planetary Boundaries to policy- and decision-making levels

Translating the Planetary Boundaries into targets that are relevant at policy- and decision-making scales requires addressing their biophysical, socio-economic and ethical dimensions (Häyhä et al. 2016). The *biophysical dimension* deals with the geographical scales of Planetary Boundary processes (e.g. the global level for climate change and watershed level for water scarcity) and their interactions.

The *socio-economic dimension* addresses differences in natural resource use, emissions and environmental impacts between countries. An important aspect is the relationship between production and consumption through international trade, pointing at potential externalization of environmental impacts beyond national borders. Finally, the *ethical dimension* takes

into account the differences between countries' and individuals' rights, abilities and responsibilities with respect to resource use and environmental impacts.

Translating the Planetary Boundaries to operational levels can best be done in two consecutive steps: i) downscaling of the boundaries to the regional or national level, and ii) using the downscaled boundaries as benchmarks for regional or national environmental performance.

### Downscaling of the Planetary Boundaries

In general terms, downscaling a Planetary Boundary requires converting its biophysical control variable into a global budget that then can be allocated, for example, to regions or individual countries. This allocation inevitably has ethical implications, as it directly relates to questions of fairness, including equality, (historic) responsibility, capacity to act, right to development, and anticipated future requirements such as for land, water and energy. Some of the possible factors to apply these normative criteria into actual allocation include a country's share in the global population, land area or economic output, its resource efficiency compared to other countries, or the country's historical share in global resource use, emissions or environmental impacts.

A broad range of allocation criteria and their implications for countries or regions have been thoroughly debated in the context of international climate negotiations. For the other Planetary Boundaries, most downscaling efforts so far have applied the equal-per-capita criterion, which has the advantage of conceptual simplicity. This criterion implicitly views the Earth system as a "global commons", with every person having equal rights to use or pollute it.

For some Planetary Boundaries, simply dividing up a global budget is not sufficient or may even be inappropriate. In cases where the effects of the relevant processes on Earth system functioning depend on the place where change is happening, it is important to make a spatially explicit assessment of their sub-global drivers or impacts, and integrate this with top-down allocations of the global budget.

Furthermore, for some boundaries, the temporal trajectory matters, and should be factored in when downscaling. For example, in the case of the climate boundary, the rate of emission reductions has an effect on the remaining carbon emissions budget and on the level of global warming. To remain within a safe operating space for climate change, carbon emissions have to go to zero by about mid-century, and if the global carbon emissions budget is exceeded, "negative emissions" (i.e. removing CO<sub>2</sub> from the atmosphere and storing it on land, underground or in the oceans) would be required to offset excess emissions. This means that for the downscaling of the climate change boundary, not only the cumulative carbon emission budget needs to be taken into account, but also the emission reductions pathway over time.

### Benchmarking environmental performance

The downscaled Planetary Boundaries can serve as benchmarks for environmental performance, either for production-based performance (i.e. the pressures related to production exerted within a country's territory) or consumption-based performance (i.e. the pressures related to the goods and services consumed in the territory, including external pressures associated with imports). Figure 1 provides an overview of how the two relate.

For the EU, production-based environmental performance data is generally available from institutions such as the European Environment Agency (EEA), Eurostat, the European Forest Institute (EFI) or the UN Food and Agriculture Organization (FAO).

Consumption-based performance data is more difficult to obtain and requires extra calculations. It demands a thorough and quantitative assessment of the supply chains from primary production to final consumption, and the associated environmental pressures all along these chains. Initial consumption-based performance measures, using multi-regional input-output or physical flow analyses, are available at EU level related to some of the Planetary Boundaries, including CO<sub>2</sub> emissions, land use, anthropogenic nitrogen fixation, phosphorus release into the environment, and freshwater use.

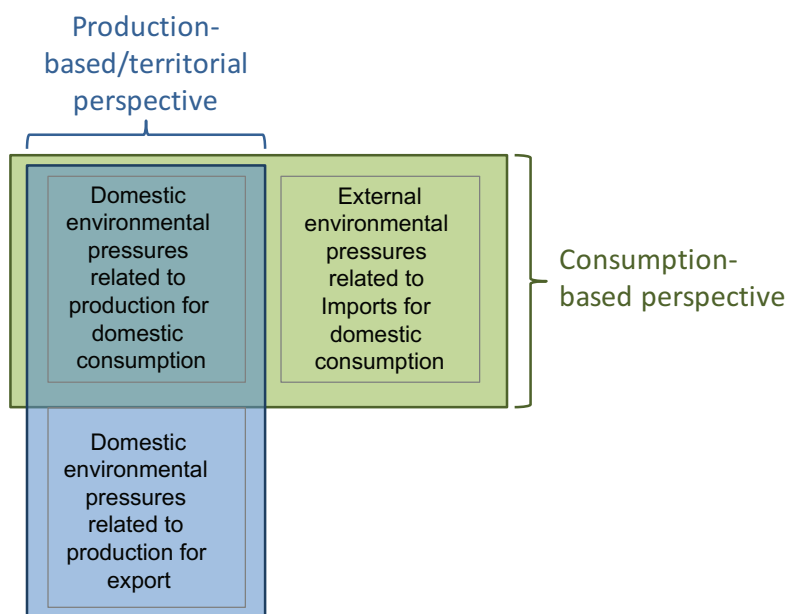


Figure 1: Comparison of production-based and consumption-based perspectives in environmental accounting

## Is Europe’s environmental performance “within the limits of our planet”?

Benchmarking the EU’s environmental performance against the downscaled Planetary Boundaries for the region (see Figure 2) provides a clear answer to the question of whether the EU lives within the limits of the planet: it does not, for most of the boundaries analysed, whether from a production-based or consumption-based perspective.

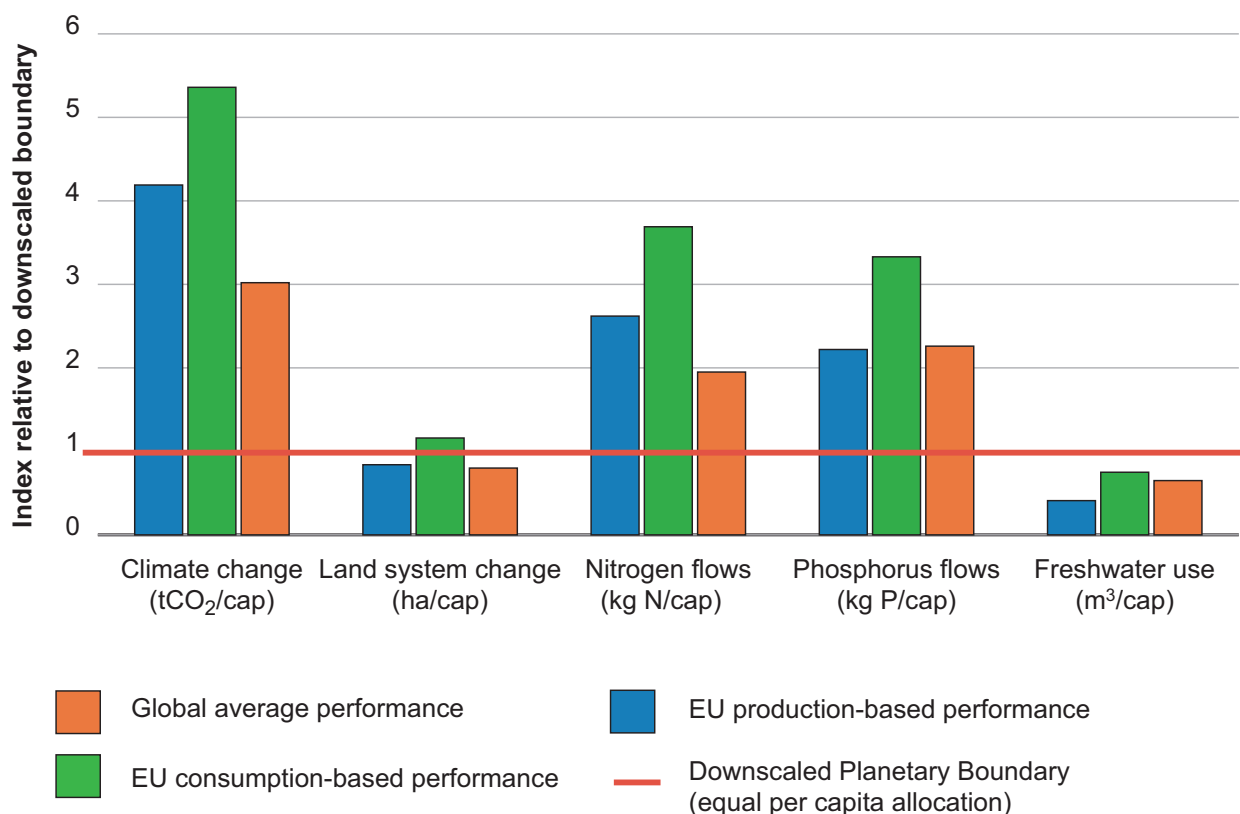
For this study, five of the nine Planetary Boundaries were analysed: climate change, land system change, biogeochemical flows (nitrogen and phosphorus), freshwater use and biosphere integrity. The remaining boundaries either have not yet been transgressed at the global level (stratospheric ozone, ocean acidification) or do not yet have quantified control variables, making them impossible to measure (aerosol loading, novel entities/chemical pollution).

The downscaling was done on the basis of equal per-capita allocation. As the EU is home to about 7% of the global population, 7% of the respective Planetary Boundary value was allocated to the EU. For the EU’s consumption-based performance, only the most recent data source was used for each Planetary Boundary.

Figure 2 compares EU and global per-capita performance on the four downscaled Planetary Boundaries. It is clear that the EU significantly exceeds its equal-per-capita “fair share” of the global safe operating space for climate change and biogeochemical (nitrogen and phosphorus) flows. For land system change, the boundary is only (slightly) transgressed in terms

of consumption-based performance. For freshwater use, the EU remains within the calculated fair share for both consumption- and production-based performance. In both cases, this is mainly a result of the EU’s much higher resource-use efficiency for land and water, compared to the global average.<sup>1</sup> Figure 3 also shows that in every case, EU consumption puts more pressure on the respective boundary per capita than the global average.

For the *climate change* boundary there is internationally agreed policy commitment to holding the increase in global average temperature to well below 2°C above pre-industrial levels and preferably below 1.5°C. To have a 66% chance of staying well below a global mean temperature increase of 2°C means a remaining global budget of roughly 1000 Gt CO<sub>2</sub> (IPCC 2014). The EU’s relative transgression of its downscaled share (70 Gt CO<sub>2</sub> equally allocated between the remaining years of the 21st century: 1.6 t CO<sub>2</sub> per capita per year) is currently more pronounced than for any of the other Planetary Boundaries. Moreover, at current CO<sub>2</sub> emission levels, the EU’s net CO<sub>2</sub> emissions have to go to zero within a couple of decades in order to stay within its allocated budget of 70 Gt CO<sub>2</sub>. Studies discussing regional emissions-reduction pathways in line with a global carbon budget, applying a range of equity and fairness principles, have concluded that by 2030 the EU will need to reduce its total greenhouse gas emissions by between 35% and 76% below 1990 levels (van Vuuren et al. 2016). For comparison, the current EU targets for 2030 and 2050 are 40% and 80–95% reduction in total greenhouse gas emissions below 1990 levels, respectively.



**Figure 2: The EU’s production- and consumption-based performance (2007–2013) and global average performance on five Planetary Boundaries, benchmarked against downscaled values**

Note: All values are EU-wide, except the performance for nitrogen flows, which has been calculated for Germany only due to limited data availability.

<sup>1</sup> For land see FAO yield statistics and for water see Gerten et al. (2013).

For *land system change*, a significant fraction of the pressure linked to EU consumption is exerted outside the EU's borders, since the EU is a large net importer of agricultural products.<sup>2</sup> The EU's consumption and associated imports are responsible for about 10% of global trade-related deforestation (Cuypers et al. 2013; EC 2013), while there is no net deforestation within the EU itself. Since drivers and impacts of land system change are very context-specific (it is not only the land use – cropland or forest – that matters, but also land-use intensity and land management), the downscaled land system change Planetary Boundary needs to be further integrated with local or regional sustainability criteria.

The Planetary Boundary for *nitrogen (biogeochemical flows)* is globally exceeded by a factor of 2. Generalizing from German figures (for reasons of data availability), we find that the downscaled Planetary Boundary is exceeded nationally by more than a factor of 2 from a production-based perspective and more than a factor of 3 from a consumption-based perspective. Furthermore, the improvement anticipated under existing and planned German and European nitrogen regulations is not sufficient to bring Germany back into its equal-per-capita share of the safe operating space, not even from a production-based perspective (Hoff et al. 2017). Also, similar to the land system change boundary, this initial downscaling and benchmarking of the global boundary needs to be integrated with context-specific local or regional sustainability criteria for nitrogen fixation and release into the environment.

The Planetary Boundary for *phosphorus (biogeochemical flows)* is exceeded globally by more than a factor of 2 and by roughly the same in the EU's territorial production. As for nitrogen, the EU's consumption-based pressures exceed the downscaled boundary by about a factor of 3. As in the case of the other context-specific boundaries, operationalization of the phosphorus boundary also needs to account for local and regional sustainability criteria, including for example the vulnerability of receiving ecosystems such as lakes and coastal zones. It is worth noting that while the phosphorus boundary is defined in terms of negative environmental impacts (such as eutrophication), phosphorus is both a non-renewable mineral resource and an essential plant nutrient for agriculture, meaning that its availability has major implications for global food security. Accordingly, addressing both hotspots of overuse such as Europe and deficit regions such as Africa will play a major role in meeting environment and development (food security) goals simultaneously.

The Planetary Boundary for *freshwater use* is currently not exceeded globally nor at the EU level. However, this boundary needs to be developed further in order to better integrate large-scale water-related sustainability issues with local-scale limitations on water withdrawals, such as the water requirements of aquatic ecosystems (so-called environmental flows) or local water scarcity problems, for example around the Mediterranean. Further integration of the freshwater Planetary Boundary with bottom-up sustainability criteria would also need to account for water quality constraints, and the water required by natural and rain-fed agricultural vegetation (“green water”),

as well as the interactions of the water boundary with other boundaries, in particular land system change.

The *biosphere integrity* boundary does not yet have a clear quantitative “budget” that can easily be scaled. An assessment of EU's fair share of the safe operating space is thus not yet possible. However, all across Europe, biodiversity intactness is severely compromised, both in terms of species richness (<80%) and species abundance (<90%), to levels beyond the precautionary Planetary Boundary value (Newbold et al. 2016). This is not surprising, given Europe's very long history of habitation, agriculture, and urbanization. There is also more information available for the EU's territorial (production-based) than for consumption-based and external threats to biodiversity, although several studies on consumption-based biodiversity indicators have been published recently (e.g. Wilting et al. 2017). In order to eventually arrive at a fair share for biosphere integrity for the EU, the knowledge base on both territorial and consumption-based performance needs to be advanced in line with further development of the control variables.

Given the immature state of some of the underlying downscaling and benchmarking methods and data, as well as the continued scientific development of some of the Planetary Boundaries themselves, these findings should be treated as initial results that need further refinement. To better assist policy-makers in operationalizing the Planetary Boundaries, the boundaries require further research and development. This includes improved quantification of each boundary and of their respective control variables, in particular development of robust control variables for the freshwater and biosphere integrity boundaries and for the four boundaries not examined here.

In the area of downscaling, more diverse fairness and equity criteria should be explored and tested. Here insights gained from applying different criteria to the climate change boundary, as well as from the science-policy debate on climate change mitigation, could be instructive for the other boundaries. For several Planetary Boundaries – including biogeochemical cycles, land use, water use and biosphere integrity – top-down allocation of the global safe operating space needs to be further integrated with local and regional sustainability criteria. Finally, consumption-based environmental footprinting and underlying trade and supply chain data generally need to be improved.

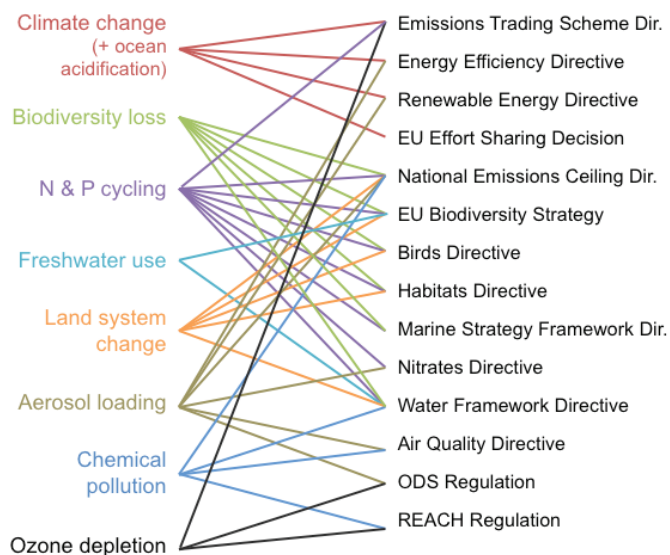
### Linking the Planetary Boundaries to EU policy

The next step in applying the Planetary Boundaries framework in EU policy-making, building on the initial results presented in the previous section, is to see how each of the boundaries is represented in existing or planned policies. This kind of policy mapping can help to identify entry points.

Numerous short-term and long-term policies and associated targets (up to 2050) have been developed in line with the vision of the 7th EAP, all of which can serve as entry points for mainstreaming the Planetary Boundaries. They include the “Roadmap for moving to a competitive low-carbon economy” (EC 2011a), the long-term 2050 target for biodiversity and ecosystem services (natural capital protected, valued and appropriately restored) as part of the EU Biodiversity Strategy to 2020 (EC 2011b), and the goal of zero land take by 2050 as part of the “Roadmap to a resource-efficient Europe” (EC 2011c),

<sup>2</sup> This assessment was done using the original cropland-based definition of this boundary (Rockström et al. 2009). For the newly defined forest-based land boundary (Steffen et al. 2015) no fully quantitative assessment of the externalization of pressures through trade is yet available.





**Figure 3: Planetary boundaries and related key policy levers in EU policy instruments**

and other policy frameworks such as the Water Framework Directive (Directive 2000/60/EC) and the Emissions Ceiling Directive (2001/81/EC) for nitrogen.

Figure 3 sketches some links between the individual Planetary Boundaries and major EU Directives and Regulations. Although this is far from being a comprehensive policy mapping, it shows that the EU already has policy instruments related to most of the processes underlying the Planetary Boundaries. While no fully quantitative global control variables have yet been proposed for aerosol loading and chemical pollution, there are already several Directives and Regulations in place to prevent these issues from becoming large-scale problems.

However, these policy instruments only refer to one or other of the processes; none addresses their interlinkages – for example between air quality (aerosols), nutrient cycling and management, climate change and biodiversity. Also, while most of these environmental processes and impacts are relatively well addressed within the EU territory, there are still major policy gaps related to the EU’s environmental impact outside its territory.

In addition to the existing EU-level policies, Europe is fully committed to implementing the 2030 Agenda for Sustainable Development and the SDGs within the EU and in its development cooperation partner countries. This implementation builds on existing EU policies and actions, for further developing a longer-term vision for the EU (EC 2016; Lucas et al. 2016). Downscaled Planetary Boundaries and environmental footprint measures can support this process, as well as the monitoring, reporting and reviewing of its implementation from a global environmental perspective.

### The way forward

Despite the current methodological and data limitations, insights from our analysis could already be used for integrating a global environmental and Earth system perspective into EU policy-making.

The key message from our initial analysis is that Europe is currently not “living within the limits of our planet”. The EU exceeds its equal-per-capita fair share of the global safe operating space for several Planetary Boundary processes. This analysis is based on the EU’s documented past and current performance. A priority for research would be developing scenarios of Europe’s future performance and changing role, using approaches such as foresight and pathway analysis see (van Vuuren et al. 2015). This would require new data integration, modelling approaches and participatory scenario development capable of dealing with multiple boundaries and clusters of issues and integrated policies.

Further operationalizing the Planetary Boundaries requires more dialogue and deeper cooperation between scientists and policy-makers. This is because the scientific knowledge of global systemic risks to ecosystem resilience is evolving at the same time as human pressures are intensifying. Only through dialogue can the global boundary values be refined and translated into targeted information for EU and other sub-global policy- and decision-making contexts.

Applying the Planetary Boundaries also involves normative (political) decisions about how to apportion responsibility for responding to and mitigating environmental harms, and about fair allocations of the global safe operating space and natural resources. Such “co-operationalization” of the Planetary Boundaries by scientists and policy-makers together would increase both their legitimacy and the soundness of their scientific underpinning. Furthermore, improved knowledge about how the different Planetary Boundaries and different sustainability criteria interact across scales could help to strengthen policy coherence both horizontally (between sectors and disciplines) and vertically (between levels and scales).

The next step in such co-operationalization of the Planetary Boundaries for EU policy-making is systematic policy mapping to identify entry points for mainstreaming the Planetary Boundaries into relevant strategies and policies. This could be expanded into a gap analysis: “Do we have the right policies in place? What is missing?” Policy mapping also needs to go beyond first-order effects, such as climate policies impacting the climate boundary, and should also include indirect as well as external impacts of, for example, agricultural, trade, development or economic policies on the Planetary Boundaries.

The downscaled Planetary Boundaries could be used as benchmarks for new policies and regulatory regimes, for assessing their effectiveness in reducing pressure on critical Earth system processes. Related to this, new operational targets and key performance indicators could be proposed for each Planetary Boundary (e.g. with reference to EEA/EAP indicators) for monitoring national performance and for providing benchmarks within Europe. That could be a first step towards a European “dashboard” across different environmental goals.

Finally, the operationalization of the Planetary Boundaries can help to identify crucial issues where sustainability transformations are required, including in food systems, energy systems, transport and housing. This would frame the boundaries in terms of the safe operating space, and how to stay within it, pointing more directly to human activities and well-being, and thus connecting to the dual social-environmental challenge of the SDGs and the 7th EAP.

## References

- Cuyppers, D., Lust, A., Geerken, T., Gorissen, L., Peters, G., et al. (2013). *The Impact of EU Consumption on Deforestation: Comprehensive Analysis of the Impact of EU Consumption on Deforestation: Final Report*. Technical Report No. 2013-063. European Union, Luxembourg. <http://dx.publications.europa.eu/10.2779/82226>.
- EC (2016). *Next Steps for a Sustainable European Future: European Action for Sustainability*. COM(2016) 739 final. European Commission, Strasbourg. [http://ec.europa.eu/europeaid/commission-communication-next-steps-sustainable-european-future\\_en](http://ec.europa.eu/europeaid/commission-communication-next-steps-sustainable-european-future_en).
- EC (2013). *Living Well, Within the Limits of Our Planet: 7th EAP – the New General Union Environment Action Programme to 2020*. Decision No 1386/2013/EU. European Commission, Luxembourg. <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013D1386>.
- EC (2011a). *A Roadmap for Moving to a Competitive Low Carbon Economy in 2050*. COM(2011) 112 final. European Commission, Brussels. <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52011DC0112>.
- EC (2011b). *Our Life Insurance, Our Natural Capital: An EU Biodiversity Strategy to 2020*. COM(2011) 244 final. European Commission, Brussels. <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52011DC0244>.
- EC (2011c). *Roadmap to a Resource Efficient Europe*. COM(2011)571 final. European Commission, Brussels. <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52011DC0571>.
- Gerten, D., Hoff, H., Rockström, J., Jägermeyr, J., Kummu, M. and Pastor, A. V. (2013). Towards a revised planetary boundary for consumptive freshwater use: role of environmental flow requirements. *Current Opinion in Environmental Sustainability*, 5(6). 551–58. DOI:10.1016/j.cosust.2013.11.001.
- Häyhä, T., Lucas, P. L., van Vuuren, D. P., Cornell, S. E. and Hoff, H. (2016). From Planetary Boundaries to national fair shares of the global safe operating space — How can the scales be bridged? *Global Environmental Change*, 40. 60–72. DOI:10.1016/j.gloenvcha.2016.06.008.
- Hoff, H., Keppner, B. and Kahlenborn, W. (2017). Die planetare Stickstoff-Leitplanke als Bezugspunkt einer nationalen Stickstoffstrategie (*The planetary nitrogen boundary as reference for a national nitrogen strategy*). UBA Report. German Environment Agency, Dessau, Germany. In press.
- IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Core Writing Team, R. K. Pachauri, and L. A. Meyer (eds.). Intergovernmental Panel on Climate Change, Geneva. <http://www.ipcc.ch/report/ar5/syr/>.
- Lucas, P., Ludwig, K., Kok, M. and Kruitwagen, S. (2016). *Sustainable Development Goals in the Netherlands – Building Blocks for Environmental Policy for 2030*. PBL Netherlands Environment Assessment Agency, The Hague, Netherlands. <http://www.pbl.nl/en/news/newsitems/2016/un-sustainable-development-goals-also-require-policy-effort-in-the-netherlands>.
- Newbold, T., Hudson, L. N., Arnell, A. P., Contu, S., De Palma, A., et al. (2016). Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. *Science*, 353(6296). 288–91. DOI:10.1126/science.aaf2201.
- Rockström, J., Steffen, W. L., Noone, K., Persson, Å., Chapin III, F. S., et al. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology & Society*, 14(2). 32. <http://www.ecologyandsociety.org/vol14/iss2/art32/>.
- Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., et al. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, 347(6223). 1259855. DOI:10.1126/science.1259855.
- van Vuuren, D. P., Boot, P., Ros, J., Hof, A. and den Elzen, M. G. J. (2016). Wat betekent het Parijsakkoord voor het Nederlandse langetermijn-klimaatbeleid? (What does the Paris agreement mean for Dutch long-term climate policy?). PBL Netherlands Environmental Assessment Agency, The Hague. <http://www.pbl.nl/publicaties/wat-betekent-het-parijsakkoord-voor-het-nederlands-langetermijnklimaatbeleid>.
- van Vuuren, D. P., Kok, M., Lucas, P. L., Prins, A. G., Alkemade, R., van den Berg, M., Bouwman, L., van der Esch, S., Jeuken, M., Kram, T. and Stehfest, E. (2015). Pathways to achieve a set of ambitious global sustainability objectives by 2050: explorations using the IMAGE integrated assessment model. *Technological Forecasting and Social Change*, 98. 303–305. DOI:10.1016/j.techfore.2015.03.005.
- Wilting, H. C., Schipper, A. M., Bakkenes, M., Meijer, J. R. and Huijbregts, M. A. J. (2017). Quantifying biodiversity losses due to human consumption: a global-scale footprint analysis. *Environmental Science & Technology*, 51(6). 3298–3306. DOI:10.1021/acs.est.6b05296.



PBL Netherlands Environmental Assessment Agency

**Stockholm Resilience Centre**  
Sustainability Science for Biosphere Stewardship



**Stockholm University**

### Published by:

Stockholm Environment Institute  
Linnégatan 87D, Box 24218  
104 51 Stockholm  
Sweden  
Tel: +46 8 30 80 44

### Author contact:

Holger.hoff@sei-international.org

### Media contact:

Caspar Trimmer  
caspar.trimmer@sei-international.org

**sei-international.org**  
2017

Twitter: @SEIresearch, @SEIclimate

This brief was written by Holger Hoff (SEI), Tiina Häyhä and Sarah Cornell (Stockholm Resilience Centre), and Paul Lucas (PBL Netherlands Environmental Assessment Agency). It is based on an initial operationalization of the Planetary Boundaries at the EU level, carried out for the European Environment Agency.

TH and SC also gratefully acknowledge funding from the Swedish Research Council Formas (Grant Nr 2012-742).

Revised 24 April 2017.