

# Environmental Limits and Swiss Footprints Based on Planetary Boundaries

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A study commissioned by the Swiss Federal Office for the Environment (FOEN)

## Summary



### Authors

Hy Dao  
Pascal Peduzzi  
Bruno Chatenoux  
Andrea De Bono  
Stefan Schwarzer  
(UNEP/GRID-Geneva and the  
University of Geneva)  
&  
Damien Friot  
(Shaping Environmental Action)

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## Advisory group

Andreas Hauser (lead), Adrian Aeschlimann, Andreas Bachmann, Loa Buchli, Paul Filliger, Peter Gerber, Hans Gujer, Klaus Kammer, Anik Kohli, Nicolas Merky, Silvia Rauch, Ruedi Stähli, Gaston Theis, Markus Wüest (all Federal Office for the Environment FOEN), Anne-Marie Mayerat (Federal Statistical Office FSO)

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## Context

The present study is conducted in the context of the Action Plan for a Green Economy adopted by the Swiss government in 2013. The Swiss government has officially expressed the necessity to respect the Planetary Boundaries in its “Swiss Position on a Framework for Sustainable Development Post-2015” (2013, 2014, 2015).

This report was commissioned in November 2013 by the Swiss Federal Office for the Environment to the Global Resource Information Database (UNEP/GRID-Geneva) and the Institute of Environmental Sciences (University of Geneva). It has been written in collaboration with the NGO Shaping Environmental Action.

## The concept of Planetary Boundaries

The Planetary Boundaries (Rockström et al., 2009b; Steffen et al., 2015) are a set of nine bio-physical limits of the Earth system that should be respected in order to maintain conditions favourable to further human development. Crossing the suggested limits would lead to a drastic change in human societies by disrupting some of the ecological bases underlying the current socio-economic system.

The most known global limit is Climate Change but other global limits have been identified: Ocean Acidification, Stratospheric Ozone Depletion, Nitrogen and Phosphorus Losses, Atmospheric Aerosol Loading, Freshwater Use, Land Cover Anthropisation, Biodiversity Loss and Chemical Pollution.

## Application of the Planetary Boundaries to a national context

As a contribution to the international discussion, this exploratory study proposes new indicators for some of the limits and explores the possibility to apply the Planetary Boundaries to Switzerland. The production of indicators adapted to the national context is the second attempt of this kind after Sweden (Nykvist et al., 2013).

The proposed indicators (limits and footprints) provide an indication of the ecological sustainability of the impacts induced by the Swiss consumption in a long-term global perspective, assuming that past, current and future populations on Earth have, by definition, similar rights to the resources. The results from this study contribute to the scientific knowledge that could be needed for setting policy targets and measures at a later stage. The proposed limits are thus not to be understood as (policy) targets.

## The approach

### A comparison of limits and footprints, for the world and for Switzerland

A three-stage approach applied in order to a) better characterise the Planetary Boundaries and to understand which limits can effectively be currently quantified, b) to compute global and national limits as well as footprints, and c) to suggest priorities for action (Figure 1):

a) Preliminary analysis	1. Identification of Planetary Boundaries recognised as global
	2. Selection of indicators
b) Computation	3. Limits (global & national)
	4. Footprints (global & national)
	5. Performance (global and national)
c) Priority assessment	6. Priority areas

Figure 1. Overview of the approach

The global limit computed per Planetary Boundary is first downscaled at the country scale. Global and national limits are then compared to the size of the current footprints. Environmental footprints - also known as consumption-based or demand-based indicators - provide a complementary perspective to the classical territorial indicators. Territorial indicators consider emissions or impacts occurring on the territory of a country, e.g. the domestic greenhouse gases emissions reported under the Kyoto Protocol. Footprints aggregate environmental impacts and/or resource uses along global production-consumption chains according to a life cycle perspective. They allow quantifying the environmental impacts induced by the consumption of the inhabitants of a country wherever these impacts occur on Earth (Figure 2).

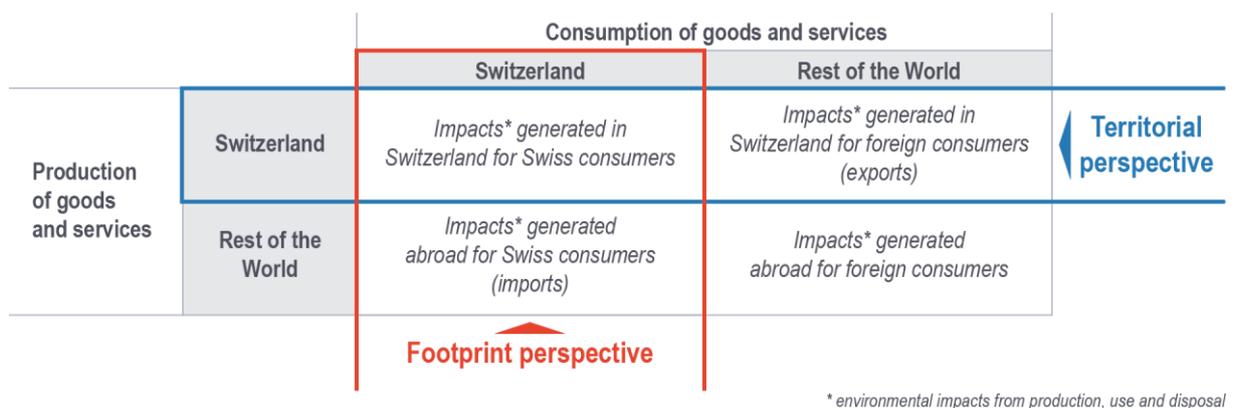


Figure 2. Swiss environmental impacts: territorial and footprint simplified perspectives

A footprint perspective is increasingly relevant in our interlinked global economy (Friot, 2009) since a rising part of the impacts on a territory is generated to satisfy consumers in other countries. This is especially the case for small, open and service-oriented economies such as Switzerland. More than half of the Swiss environmental impacts occur abroad (Jungbluth et al. 2011; Frischknecht et al. 2014).

## Downscaling the global limits to the national scale

### Global limits

Before being downscaled to the national level, global limits are first quantified for each studied Planetary Boundary. Two types of indicators are considered:

- *Yearly budgets*, available year after year (e.g. land for agriculture and urbanisation): The global yearly limit is the same every year and the global yearly limit per capita evolves each year, according to the global population.
- *Budgets over time*, available once for a given period of time (e.g. carbon emissions until 2100): The global budget over time is divided by the cumulated sum of the yearly population in the period considered. The global yearly per capita limit is thus identical each year. Conversely, the global yearly limit varies each year according to the global population.

In both cases, the global yearly per capita limits correspond to an “equal share” principle. It is assumed that every person on Earth may use the same amount of a given natural resource, i.e. an equal share per capita.

### National limits

Then, to compute national limits, a so-called “hybrid-allocation” approach is applied. Resources are allocated to countries first and then to people, the final beneficiaries, in order to represent the role of countries in the indirect allocation of resources.

The share of a Planetary Boundary per country is defined as the share of the country population relatively to the global population at a reference date. The share of the resources available per country is fixed from this date. When justified - by past knowledge, rights or responsibilities - a reference date is selected in the past (e.g. 1990 for Climate Change). For budgets over time, the current budget is computed by subtracting the national budget already used since the reference date.

Then, the per capita national limits are computed by dividing the national limit by the population in the period considered, i.e. yearly or over time according to the type of the indicator.

Since the national limits are set at a given reference date, the national yearly per capita limits evolve in subsequent years differently for each country, according to national demographics. The national yearly per capita limits differ thus from the global (equal share) yearly per capita limits.

## Computing the footprint indicators

Global footprint indicators are computed, similarly to the global limits, on the basis of geospatial data and figures from the literature. The Swiss footprint indicators computed in this study are based on a FOEN proprietary environmental database based on official Swiss territorial data and modelled data for imports and exports. Life Cycle Impact Assessment approaches are then used to convert this inventory into values which are compatible with the computed limits when required.

### Assessing the global and national performances

In order to assess the sustainability of the footprints, four categories of performance were defined. For each Planetary Boundary, global and Swiss quantitative scores are computed as the ratio of the footprint over the limit. Then, taking into account the uncertainty and the trend of the footprint, the score is classified into one of the four following categories:

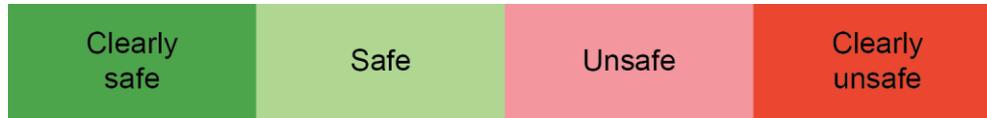


Figure 3. Categories of performance

### The five Planetary Boundaries assessed in this study

Five Planetary Boundaries are assessed in this study: Climate Change, Ocean Acidification, Nitrogen and Phosphorus Losses (with two indicators), Land Cover Anthropisation, and Biodiversity Loss. The limits are not calculated for: Stratospheric Ozone Depletion (since it is currently phased-out), Atmospheric Aerosol Loading and Chemical Pollution (rationales are lacking for setting a potential limit), and for Freshwater Use (considered by the experts consulted as a regional issue with a regional limit only).

#### Climate Change

This Planetary Boundary is set to avoid regional modifications at global scale including, among others: climate disruptions; reduction of land glaciers mass and related threat to water supply; complete loss of arctic sea ice, and weakening of carbon sinks; increased impacts from extreme events; changes in temperatures and precipitation patterns; shift in biodiversity and agriculture, as well as sea level rise and related coastal erosion.

Climate Change is a global issue since GHG emissions are accumulating in the atmosphere whatever their location of origin. The global limit for Climate Change is set with an indicator expressed in terms of *the remaining cumulative GHG emissions (including land cover changes) for a 50% chance to stay below a 2°C increase by 2100 compared with pre-industrial level.*

#### Ocean Acidification

This Planetary Boundary is set to avoid the “conversion of coral reefs to algal-dominated systems, the regional elimination of some aragonite - and high-magnesium calcite - forming marine biota” (Rockström et al., 2009a), as well as the negative effect on marine carbon sink.

Ocean Acidification is caused by CO<sub>2</sub> emissions, which are also the main cause of Climate Change. Ocean Acidification is a global issue since CO<sub>2</sub> emissions are accumulating in the oceans whatever their location of origin. Its effects are also global, albeit with regional variations.

The global limit for Ocean Acidification is set with an indicator expressed in terms of the remaining cumulative emissions of carbon dioxide (CO<sub>2</sub>) *from human activities to maintain an acceptable calcium carbonate saturation state  $\Omega$ .*

#### Nitrogen and Phosphorus Losses

The objective of the Nitrogen Losses Planetary Boundary is to reduce the impacts of reactive nitrogen losses to the environment leading to eutrophication and acidification of terrestrial,

freshwater and coastal ecosystems, to the loss of biodiversity, to climate change, and to the formation of high ozone concentrations in the lower atmosphere.

The Phosphorus Planetary Boundary is defined more narrowly by Rockström et al. (2009). The objective is to avoid a major oceanic anoxic event, with impacts on marine ecosystems. Phosphorus (P) inflow to the oceans has been suggested as the key driver behind global-scale ocean anoxic events, potentially explaining past mass extinctions of marine life (Handoh & Lenton, 2003).

Nitrogen and phosphorus are usually considered regional rather than global issues since effects occur at a local or regional scale. A global perspective **can** however be adopted if nitrogen and phosphorus losses to the environment affect the earth system. Due to the spatial variability of the impacts, the existence of a global threshold is however difficult to prove with certainty (Rockström et al., 2009b; de Vries et al., 2013).

The Nitrogen and Phosphorus Losses Planetary Boundary is thus conceptually conceived as an aggregation of regional thresholds. The global limit for Nitrogen is set with an indicator expressed in terms of *agricultural N losses from N-fertilisers and manure*. The global limit for Phosphorus is set with an indicator expressed in terms of *the consumption of P-fertilisers*.

### Land Cover Anthropisation

The objective of the Planetary Boundary Land Cover Anthropisation is to avoid irreversible and widespread conversion of biomes (such as tropical forests) to undesired states by limiting the expansion of anthropised areas. Anthropisation of land (through cultivation and sealing) acts as a slow variable affecting several environmental aspects such as soil, landscape, water, biodiversity and climate.

Land cover is usually considered a regional issue rather than a global issue since changes occur at a local or regional scale. A global perspective can however be adopted when considering how land cover changes affect the global Earth system, in particular through their impacts on climate change (UNEP, 2012) as well as on global biodiversity.

The global limit for Land Cover Anthropisation is set with an indicator expressed in terms of *the surface of anthropised land, i.e. agricultural and urbanised (sealed) land, as percentage of ice-free land (water bodies excluded)*.

### Biodiversity Loss

The objective of the Planetary Boundary Biodiversity Loss is to avoid a level of biodiversity loss that would lead to irreversible and widespread undesired states of ecosystems. Biodiversity acts as a slow variable affecting the resilience of ecosystems, hence the services they provide, e.g. carbon storage, pollination or freshwater.

Biodiversity is usually considered a regional issue rather than a global issue since changes occur at a local or regional scale. A global perspective can however be adopted by considering that evidence for the important role of biodiversity for ecosystem functioning and human well-being is considerable (Cardinale et al., 2012; Hooper et al., 2005; Estes et al., 2011).

The global limit for Biodiversity Loss is set with an indicator expressed in terms of *the potential damages to biodiversity per land cover types accounting for the level of biodiversity per biome*

## Main findings

### Global limits, current footprints and performances

From a *global* perspective three of the six computed performances show a Clearly Unsafe situation either because of a large overshoot (Climate Change and Ocean Acidification) or because of an overshoot combined with a rapidly deteriorating trend (Biodiversity Loss). One performance is qualified as Unsafe because there is an overshoot combined with a slowly evolving situation (Nitrogen Losses) and two performances are considered as Safe (Land Cover Anthropisation and Phosphorus Losses).

The performance was not computed for four Planetary Boundaries. While further research is needed to assess their performance, there is no evidence in the literature that the limits of these Planetary Boundaries are currently crossed.

As a result, we conclude that the *global* limits are crossed for four out of nine Planetary Boundaries, with a Clearly Unsafe situation for three of them (Climate Change, Ocean Acidification and Biodiversity Loss), as shown in Table 1:

Performance	Planetary Boundary	Units	Limit	Current footprint	Confidence	Trend
Clearly unsafe						
Clearly unsafe	Climate Change	GtCO <sub>2</sub> eq	12.3	50.8	high	rapidly deteriorating
	Ocean Acidification	GtCO <sub>2</sub>	7.6	38.6	high	rapidly deteriorating
	Biodiversity Loss	no units	0.16	0.2	low	rapidly deteriorating
Unsafe						
Unsafe	Nitrogen Losses	Tg	47.6	55.6	low	slow evolution
Safe						
Safe	Land Cover Anthropisation	km <sup>2</sup>	19 362 000	16 669 000	medium	slow evolution
	Phosphorus Losses	Tg	38.5	31	low	slow evolution

**Table 1. Summary table of global performances, limits and footprints.**

A comparison with Rockström et al. (2009) as well as Steffen et al. (2015) could lead to the impression that their assessments differ from ours. However there is no contradiction between our analysis and theirs: While Rockström et al. (2009) and Steffen et al. (2015) assessed which boundaries are crossed at the current point in time, the indicators selected in this study consider also the trends as well as past and future use of the resources to assess if current footprints are within an ecologically sustainable level.

### Swiss limits, current footprints and performances

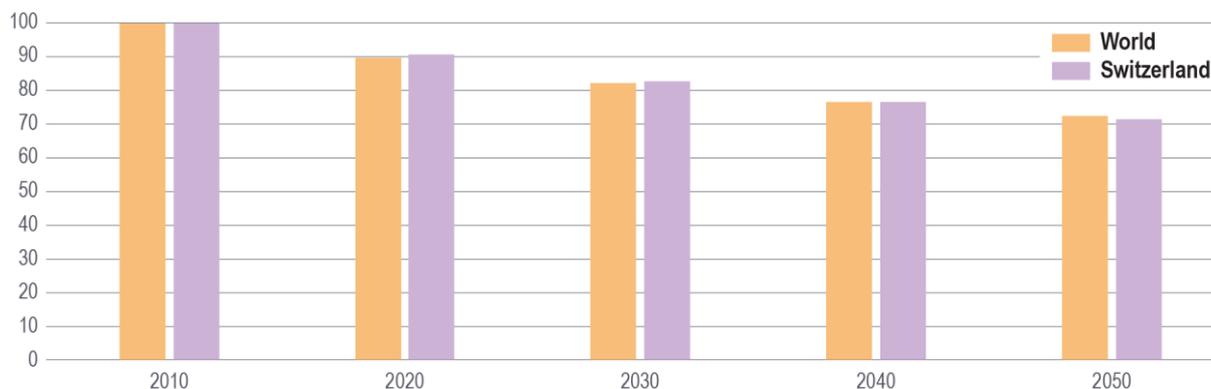
The situation for Switzerland is very similar to the global situation for three Planetary Boundaries while two are worse and one is unknown: the situation is worse for Nitrogen Losses (large overshoot), i.e. a Clearly Unsafe situation, as well as for Land Cover Anthropisation, i.e. Unsafe, because of a rapidly evolving footprint, as shown in Table 2:

Performance	Planetary Boundary	Units	Limit	Current footprint	Confidence	Trend
Clearly unsafe						
Clearly unsafe	Climate Change	MtCO <sub>2</sub> eq	4.8	109	high	rapidly deteriorating
	Ocean Acidification	MtCO <sub>2</sub>	5.7	82.8	high	rapidly deteriorating
	Biodiversity Loss	<i>no units</i>	0.16	0.3	low	rapidly deteriorating
	Nitrogen Losses	Kt	53.8	108.6	low	slow evolution
Unsafe						
Unsafe	Land Cover Anthropisation	km <sup>2</sup>	21 900	17 600	medium	rapidly deteriorating
Missing data						
Missing data	Phosphorus Losses	kt	43.6	<i>no data</i>	low	slow evolution

**Table 2. Summary table of Swiss performances, limits and footprints.**

### Thinking ahead with Business As Usual scenarios

Considering the projections of the future Swiss and global populations, the evolution of the global and Swiss per capita limits for the Planetary Boundaries based on a yearly budget (Nitrogen and Phosphorus Losses, Land Cover Anthropisation and Biodiversity Loss) are shown in Figure 4.



**Figure 4. Evolution of the global and Swiss per capita limits based on population projections for 2010-2050 (Index 100 = 2010).**

For Planetary Boundaries with indicators considered as yearly budgets, the global and Swiss per capita limits evolve similarly, resulting in a reduction of the limits per capita of around 10% in 2020, 18% in 2030 and 29% in 2050. Since the yearly limits are similar every year, maintaining the same global and Swiss performances in the future requires thus reducing over time the per capita footprints. The required reduction is, for example, of 10% in 2020 compared to 2010 values. Assuming a Business as Usual scenario, i.e. a constant per capita footprint, the limit will be attained for all Planetary Boundaries before 20 years, due to population growth.

For Planetary Boundaries with indicators considered as budgets over time, the evolution of the future population is already accounted for in the indicator. Assuming a Business as Usual scenario, i.e. a constant per capita footprint, the limit will be attained for Climate Change in 4.8 years (Switzerland) and 26 years (globally). For Switzerland, a sustainable pathway would require an ongoing yearly reduction of 17.5%. For Ocean Acidification, the limit will be attained in 6 years (Switzerland) and 20 years (globally). For Switzerland, a sustainable pathway would require an ongoing yearly reduction of 15%.

### Potential use of the limits and footprint indicators

The three potential uses of the limits and footprint indicators proposed in this report are to:

- a) Raise awareness
- b) Set priorities among the Planetary Boundaries,
- c) Identify large overshoots and analyse long-term trends, i.e. relative differences over 5-10 years periods, of aggregated values.

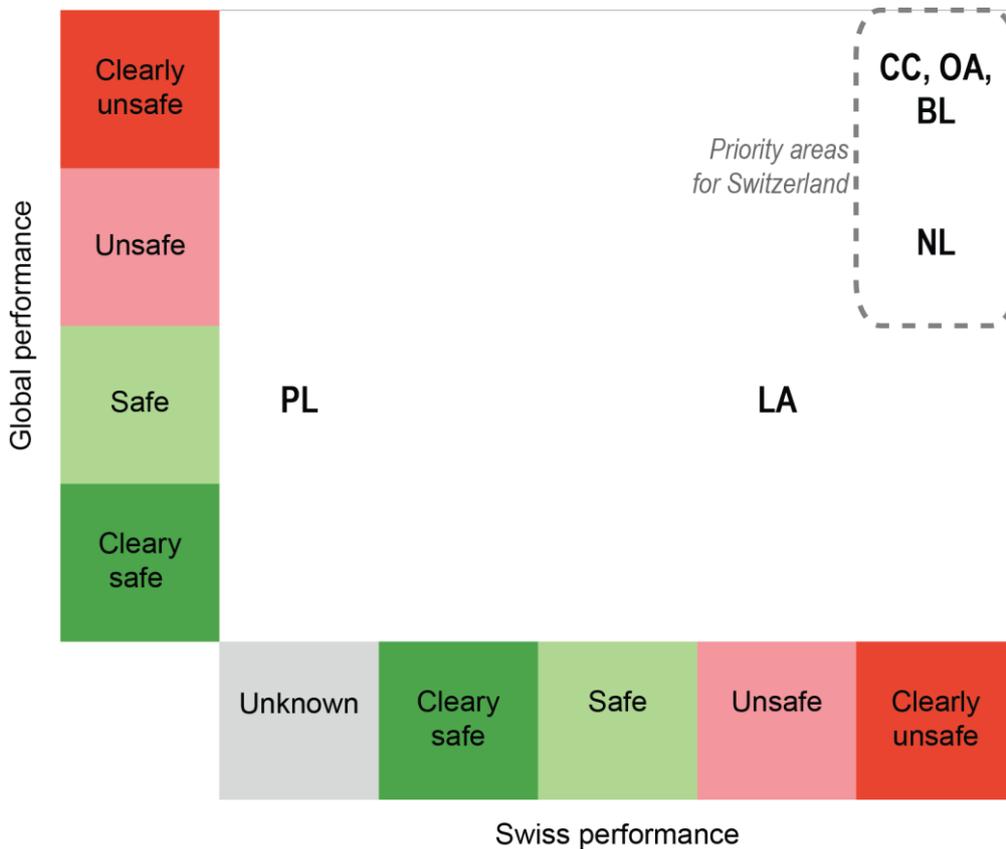
The generated indicators and values are *not* adequate to:

- d) Monitor precise values,
- e) Identify small overshoots, and monitor small variations (e.g. 10%) over short periods (e.g. yearly variations).

The indicators are thus not appropriate to set operational target values linked to the importation of a specific product, e.g. palm oil. More disaggregated data or models, a more narrow focus on specific products, and a focus on Driving-Forces, should be used for these purposes. However the Planetary Boundaries can be envisaged as an alternative to the Ecological Footprint.

## Recommendations

From the above assessment it can be recommended that **Climate Change, Ocean Acidification, Biodiversity Loss and Nitrogen Losses** are the first priorities (Figure 5): these Planetary Boundaries with a Clearly Unsafe or Unsafe performance at global scale should be managed. Current footprints are above an ecologically sustainable level, both globally and for Switzerland. International discussions and scientific developments on these issues should be promoted. National action should be taken, respectively intensified to reduce the Swiss footprints.



**BL:** Biodiversity Loss, **CC:** Climate Change, **LA:** Land Cover Anthropisation, **NL:** Nitrogen Losses, **OA:** Ocean Acidification, **PL:** Phosphorus Losses (Swiss performance unknown due to lack of data).

For the four other Planetary Boundaries - Stratospheric Ozone Depletion, Atmospheric Aerosol Loading, Freshwater Use and Chemical Pollution - there is no evidence of global overshoots, their global performances are considered in the green zones. The Swiss performances of these Planetary Boundaries have not been assessed.

**Figure 5. Priority Planetary Boundaries, based on Global and Swiss performances**

**Land Cover Anthropisation and Phosphorus Losses are priorities of second rank:** these Planetary Boundaries for which the performance of Switzerland is (potentially for Phosphorus) Unsafe, but with a Safe situation at global level should be better understood to identify potential risks of a future global overshoot. This report shows that the global situations are evolving slowly: currently the Planetary Boundaries framework does not provide a justification for the reduction of the national footprints. However the approach to allocate shares to countries shows that Switzerland is rapidly approaching its national limits. In the case it is assumed that national limits should be respected in all countries, Switzerland should then engage into reduction efforts.

**Atmospheric Aerosol Loading, Freshwater Use and Chemical Pollution are priorities of third rank:** these Planetary Boundaries for which a limit cannot be identified yet should be set on the research agenda.

### A new way of thinking environmental assessments and policies

This report confirms the already well-known importance of acting to manage Climate Change and Biodiversity Loss. This report adds Ocean Acidification and Nitrogen Losses to the list of the key topics.

The interest of the applied approach - combining Planetary Boundaries and footprinting as a *complementary* perspective to existing analyses - is in providing:

- a) A multi-criteria assessment going beyond the current focus on Climate Change.
- b) Global priorities that can be applied at various scales, e.g. countries, sub-countries or cities, as well as at the levels of corporations, products or technologies.
- c) Absolute limit values against which performances can be benchmarked.

Eventually, it should be emphasized that this report focuses only on global environmental processes. The regional nature of other environmental issues does not preclude that action is not required from a global policy perspective. Regional pollutants can travel or be transported (due to trade) over long distance and can be transboundary, i.e. requiring potentially a global approach. Some of these regional environmental issues are thus subject to international protocols like the Convention of 13 November 1979 on Long-Range Transboundary Air Pollution. In addition, issues not mentioned as first priority from this specific analysis may be of high priority for other reasons like being a key input for the agro-industrial system, e.g. phosphorus, or for local health, e.g. mercury.

The study hopes to open the path to establishing a new mindset based on the recognition of global environmental limits, the possibility to quantify these limits as well as the footprints of nations. It definitely has potential to change the way we practice environmental assessments and environmental policies both at the global and national levels.

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