SCORE LCA

STUDY N° 2016-01

ENVIRONMENTAL ISSUES, HIERARCHIZATION AND STRATEGIC INTEGRATION: WHAT PLACE FOR LCA AND PLANETARY BOUNDARIES?

SUMMARY

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Scientific Authors

- Caroline Catalan, Guillaume Neveux
I Care & Consult, 28 rue du 4 Septembre, 75002 Paris

- Quentin Bézier, Quentin Baret, Hélène Teulon
Gingko 21, 8 rue du Conseil de l'Europe, 91300 Massy-Palaiseau

SCORE LCA is an association that has been created to financially support collaborative research on LCA and related topics. It aims to promote and organize cooperation between companies, institutional and scientists in order to support the evolution of LCA methods and its practical implementation at European and international level.

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The information and conclusions presented in this document were established on the basis of scientific and technical data and regulatory and normative framework in force at the date of the publication of documents.

Introduction

Environment is an important issue of the international debate, both in the public and private sectors. As such, companies are facing multiple and often complex environmental issues. In order to answer effectively to the need of integrating environmental issues into their activities, they put strategies in place, most often covering the entire value chain.

In order for the strategies defined to be effective, companies need tools for evaluating and monitoring their actions. Life Cycle Assessment (LCA), a multi-criteria environmental assessment methodology, is one of these tools but its role is sometimes unclear, which raises several questions:

- What is the current role of LCA in strategic thinking concerning environmental issues?
- What is its relevance in general and regarding each of the environmental issues?
- What are the contributions of LCA in defining corporate strategies and what are the limits?

In addition, considering the general consensus on the need to maintain activities within the Earth's biotic capacity, *Carrying Capacities* and *Environmental Boundaries* concepts are beginning to be proposed as a basis for weighting in LCA in order to provide a more concrete vision of environmental impact results and to facilitate their interpretation and integration into corporate strategies.

Thus, in this context, the study focuses on the following three issues:

(1) How to identify and articulate environmental issues;
(2) How to prioritize environmental issues;
(3) How to integrate these issues into corporate strategy.

For each of these identified issues, the study determines to what extent life cycle assessment methods and the concept of Planetary Boundaries may provide answers to these questions.

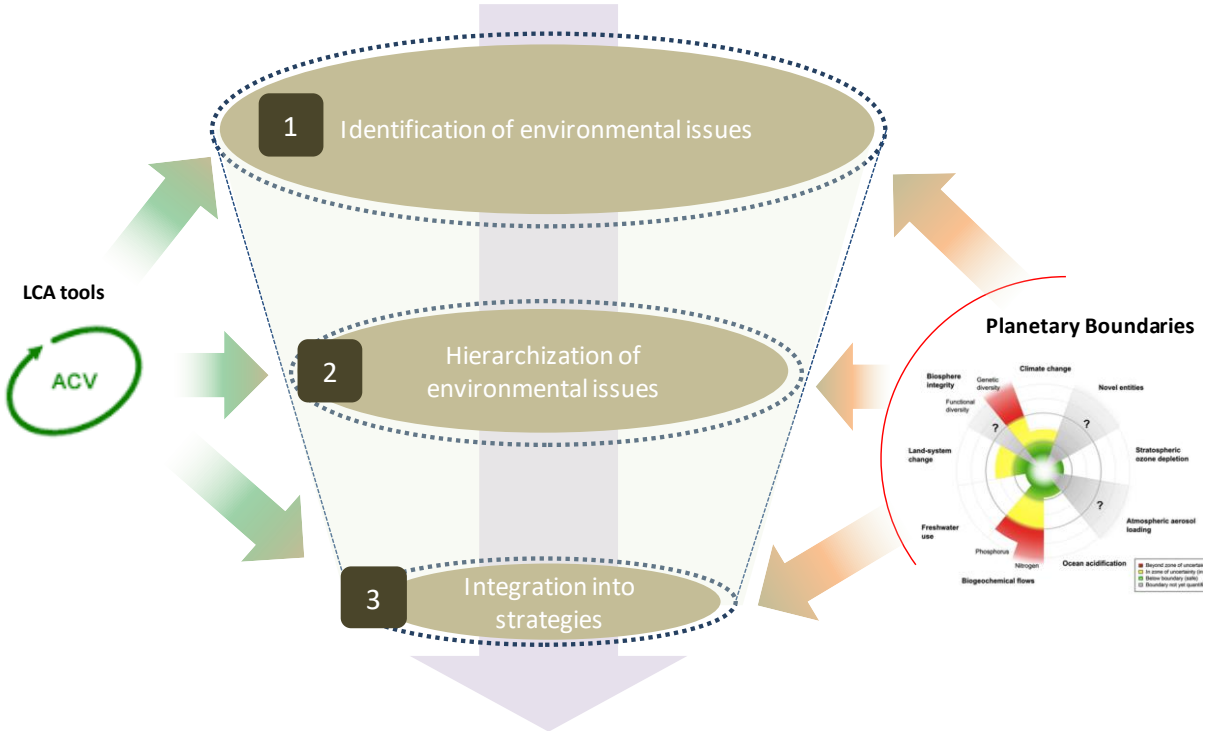


Figure 1 : Articulation between the different components and parts of this study

I. What environmental issues ?

An issue is a subject of particular importance to its stakeholders. The growing awareness of the degradation of our environment in many dimensions (soil, water, air, etc.), has automatically led to an increase in the number of environmental issues. How to understand these different environmental issues, how to classify and articulate them in a logical way is the question companies are facing.

Thus, identification and understanding of the issues is a prerequisite for their integration into corporate strategies (European Environment Agency, 2015b; OECD, 2016). Environmental issues are difficult to apprehend because they can be expressed through different forms:

- Elementary flows: CO_2 emissions in the air, nitrate emissions into water;
- Human activities or processes: agriculture, waste incineration;
- Impacts (or midpoint effect): climate change, eutrophication of water;
- Pressures: pollution, resource extraction;
- Damage (or endpoint effects): human health, ecosystems;
- Social issues: food, access to energy, mobility.

In this study, twelve main environmental issues were identified through the analysis of publications at national and international level, namely:

- Climate Change ;
- Air quality degradation;
- Degradation of water resources;
- Soil pollution;
- Land-use change;
- Depletion of energy resources;
- Depletion of non-energy resources;
- Waste;
- Industrial risks;
- Noise and odor pollution;
- Human health;
- Ecosystem degradation.

Selected environmental issues are related to **different stakeholders and can be of different nature**. It is possible to distinguish the different stakeholders related to the different environmental issues: animal and plant populations or human populations whether they are close to the impacting activity or distant from it, or the "Earth system" as a whole. Nature of these issues can also be distinguished: "environmental type" if they modify the living environment, i.e. life on Earth as we know it, or "economic type" if they modify the economic framework of life on Earth:

- Whereas the two endpoint "ecosystem degradation" and "human health" issues are defined mainly in relation to their respective stakeholders, most of the other issues concern the different types of stakeholders, with the exception of resource depletion issues which concern only human populations. It should be noted that there is a difference between local and global stakeholders: resource depletion or climate change are global issues, whereas nuisance or degradation of water resources, air quality or ecosystems are local issues (at different scales) even though their cumulative effect may make them global issues.
- Most environmental issues are both environmental and economic in nature, as environmental impacts represent a cost or value for societies that can be monetized or valued as an externality. It should also be noted here that there is an exception to the issues of resource depletion, which are inherently economic.

1. Lifecycle assessment contributions to environmental issues analysis

Since the 1990s, Life Cycle Assessment (LCA) principles and methodologies have been developed to assess the environmental impacts of a product on many environmental issues and over its entire life cycle. As such, LCA enables to provide tools and solutions that are generally effective in analysing issues, although the relevance of LCA contribution has to be qualified depending on the environmental issues studied. Standardised at international level (ISO 14040-44 standard series), LCA is now widely recognized and used worldwide. Initially focused on Europe, methodologies currently being developed tend to become global methods (e.g. Impact World+), with a worldwide geographical perimeter. These methodologies are supported by international databases (e.g. ecoinvent).

In order to study the contribution of LCA to the identified environmental issues, a systematic analysis describing how LCA methodologies can be used to assess environmental issues and sub-issues was conducted. In summary, as shown in the following figure, LCA methodologies have a high degree of coverage of all the identified issues (70% on average). This indicates that the LCA scientific community has made significant efforts to address a wide range of environmental issues. However, the adequacy of LCA methodologies to properly assess these different issues can vary significantly from one issue to another and depend on different parameters.

For each of the sub-issues identified, the level of response provided by LCA was characterized as:

- **Completed** for certain sub-issues related to well-identified flows (total energy consumption, GHG emissions, ozone layer destruction);
- **Partial** for sub-issues related to poorly defined flows (waste generation) or incomplete characterization models (water quality, resource depletion);
- **To be developed** for certain sub-issues that cannot be integrated into existing flows (invasive species) or for which characterization models are under development (noise pollution);
- **Not suitable** for the industrial risk issue.

Issue	Sub-issue 1	Sub-issue 2	Sub-issue 3	Sub-issue 4	Sub-issue 5	Sub-issue 6
Climate change	Reduction of GHG emissions	Storage of GHG emissions	Adaptation to climate change			
Air quality degradation	Acidification	Photochemical ozone	Ozone layer destruction	Respiratory problems	Other health issues	
Nuisance	Odor pollution	Noise pollution				
Soil pollution	Pollution	Soil decontamination				
Industrial risks	Release of toxic substances	Explosion	Fire			
Depletion of energy resources	Total energy consumption	Non-renewable energy consumption	Renewable energy production			
Depletion of non-energy resources	Total raw material consumption	Zoom on critical raw materials	Non-energy renewable resources	Recycled resources		
Waste production	Total waste production	Zoom on hazardous waste	Energy recovery and waste recycling			
Degradation of water resources	Water scarcity	Water pollution	Competition between uses			
Land use change	Deforestation	Soil fertility depletion	Erosion	Soil artificialization		
Ecosystem degradation (endpoint damage)	Change or degradation of habitats	Invasive species	Pollution of habitats	Over-exploitation of resources	Climate Change	
Human health (endpoint damage)	Nutrition	Exposure to radioactive substances	Respiratory effects	Exposure to toxic substances	Access to drinking water	Climate change

Figure 2 : Coverage of issue by LCA

Legend : Level of LCA coverage to assess sub-issues:

Completed	Partial	To be developed	Not suitable

2. Contribution of Planetary Boundaries to the analysis of environmental issues

Planetary Boundaries concept is recent but is nowadays the subject of important research and operational transposition work, whether in LCA methodologies or more generally in the understanding of environmental issues for companies.

2.1. Description of Planetary Boundaries

The Planetary Boundaries concept was proposed in 2009 by an international team of 28 researchers, led by Johan Rockström, (Rockström, Steffen, Noone, Persson, Chapin Iii, et al., 2009). It consists of identifying limits that must not be exceeded in order to guarantee staying within the Holocene, Earth current state for about 10,000 years. Exceeding these limits could lead to sudden and irreversible environmental changes with unpredictable consequences, endangering socio-economic stability in the world. These limits are used to define a safe operating space for Humans. Planetary Boundaries have recently been updated (Steffen et al., 2015), confirming the initial set of limits, adapting some of them and proposing new and more robust values.

The study also includes an assessment of the current state of the planet, compared to the Planetary Boundaries defined before. It appears that four of the thresholds have already been exceeded (climate change, biosphere integrity, land use and biochemical cycles) due to massive human intervention, thus endangering the world's socio-economic well-being. As a result, the Planetary Boundaries Thinking Framework could be a practical solution to establish global governance and policy for sustainable development.

Among the nine Planetary Boundaries identified, two core boundaries are considered key limits, climate change and the integrity of the biosphere, which are each likely to cause the planet shifting into a new state. Exceeding one of the other limits could affect human well-being and affect one of the two core limits but without leading to a change in the state of the known Earth's system.

Each Planetary Boundary is characterized by one or several "control variable(s)" and their measurements enable to evaluate the state of the Earth system regarding the limit considered. The full report specifies the definition of each Planetary Boundary and the associated control variables:

- Climate change;
- Biosphere integrity;
- Novel entities;
- Stratospheric ozone depletion;
- Atmospheric aerosol loading;
- Ocean acidification;
- Biogeochemical flows;
- Freshwater use;
- Land-system change.

The figure below shows the nine Planetary Boundaries and their estimated state.

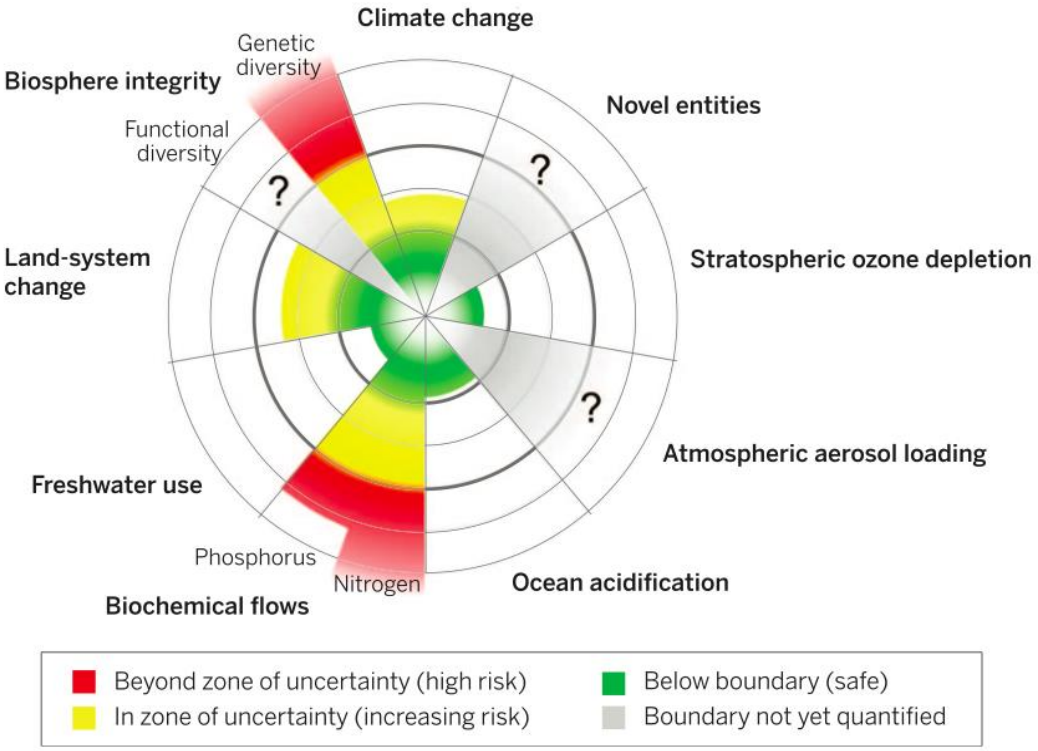


Figure 3 : Planetary Boundaries (Steffen et al., 2015)

Note: Green defines "safe operating", yellow presents an exceeding in an area of uncertainty, and red defines a certain exceeding. Choice of colours is misleading: scientists clearly identify an exceeding on 4 issues, including two key domains.

2.2. Limitations and controversies

There are still many uncertainties regarding the definition and quantification of Planetary Boundaries. The 2015 version shows an evolution from the original 2009 version, and it is very likely that improvements will be made in the coming years.

Doubts expressed by the authors themselves, as well as the criticisms raised by other researchers, underline that Planetary Boundaries are still a very recent concept, whose robustness is not considered sufficient for political application. However, the concept is still sufficiently interesting to be studied by major research institutions and to structure business or international organization approaches.

2.3. Planetary Boundaries vs. LCA : a change of perspective on environmental issues and problems of compatibility

Possible integration of Planetary Boundaries into LCA was quickly perceived by the LCA community as particularly interesting, since it would enable to improve the interpretation of results considering an absolute and no longer relative reference, and by evaluating the extent to which the product or service analysed contributes to exceed (or not exceed) the established thresholds.

Comparison of LCA and Planetary Boundaries methodologies requires a matching grid, as shown in the Figure below.

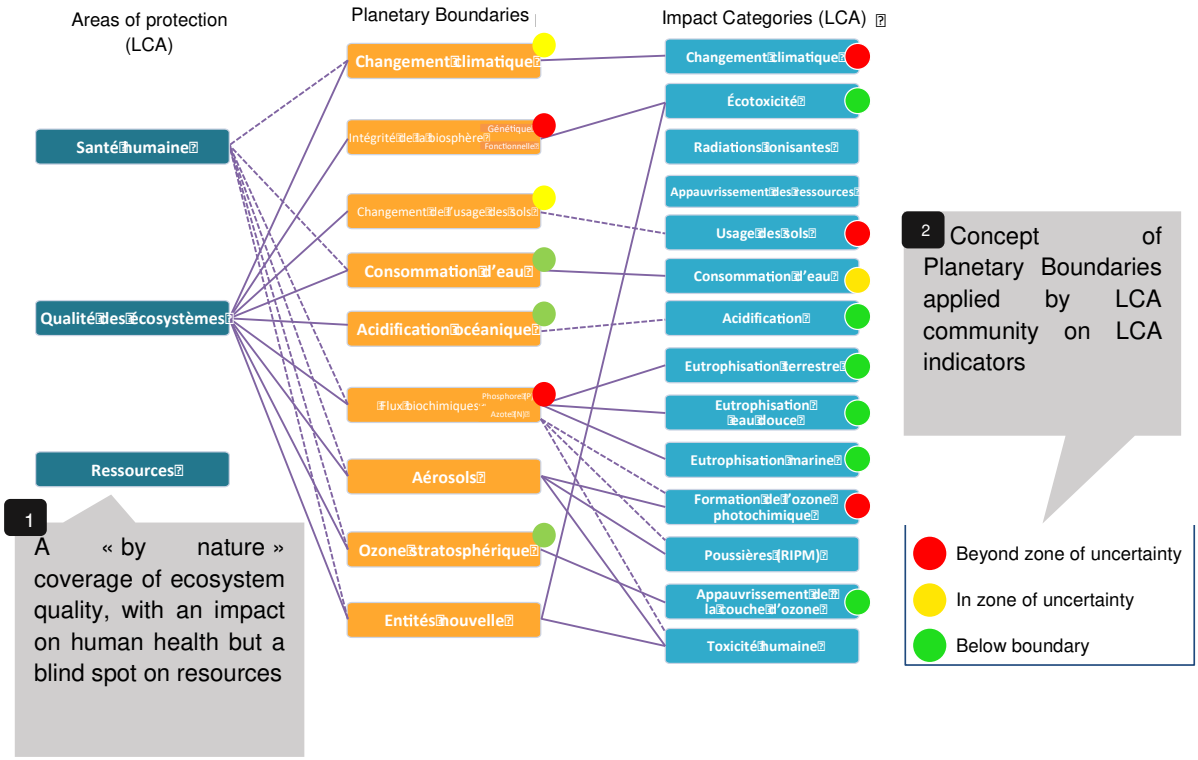


Figure 4 : Matching between LCA impact categories and Planetary Boundaries

The levels of exceedance are not consistent between the two columns because they come from different sources (Steffen et al. vs. Bjoern et al.).

While three Areas of protection are traditionally considered in LCA, there is only one area in the Planetary Boundaries perspective, namely the Earth system - the analysis does not address resource issues or human health. However, proposals have been made by some researchers to extend the conceptual framework of Planetary Boundaries to these two impact categories.

Current research topics:

- Spatial Differentiation: relevant for all non-global planetary boundaries;
- Allocation: how to allocate the defined capacity for a planetary boundary to a sector or product;
- Planetary boundaries and normalization in LCA: use of planetary boundaries as weighting and normalization values;
- Planetary boundaries and impact methodologies: definition of a new area of protection and a set of impact indicators derived from the planetary boundaries.

II. Hierarchization of environmental issues

The question of hierarchization of issues arises whenever a company has to make choices regarding its environmental strategy, i.e. whether there are already priority issues or in case of performance objective to be achieved. For a business company, the main available hierarchization methodologies are:

- Method of relative impact: assessment of a company contribution to the overall impact of human activities;
- Method of global impact: assessment with a common unit of all the environmental impacts of a human activity;
- Method of materiality: assessment of the extent to which an environment issue may have an impact on company activities.

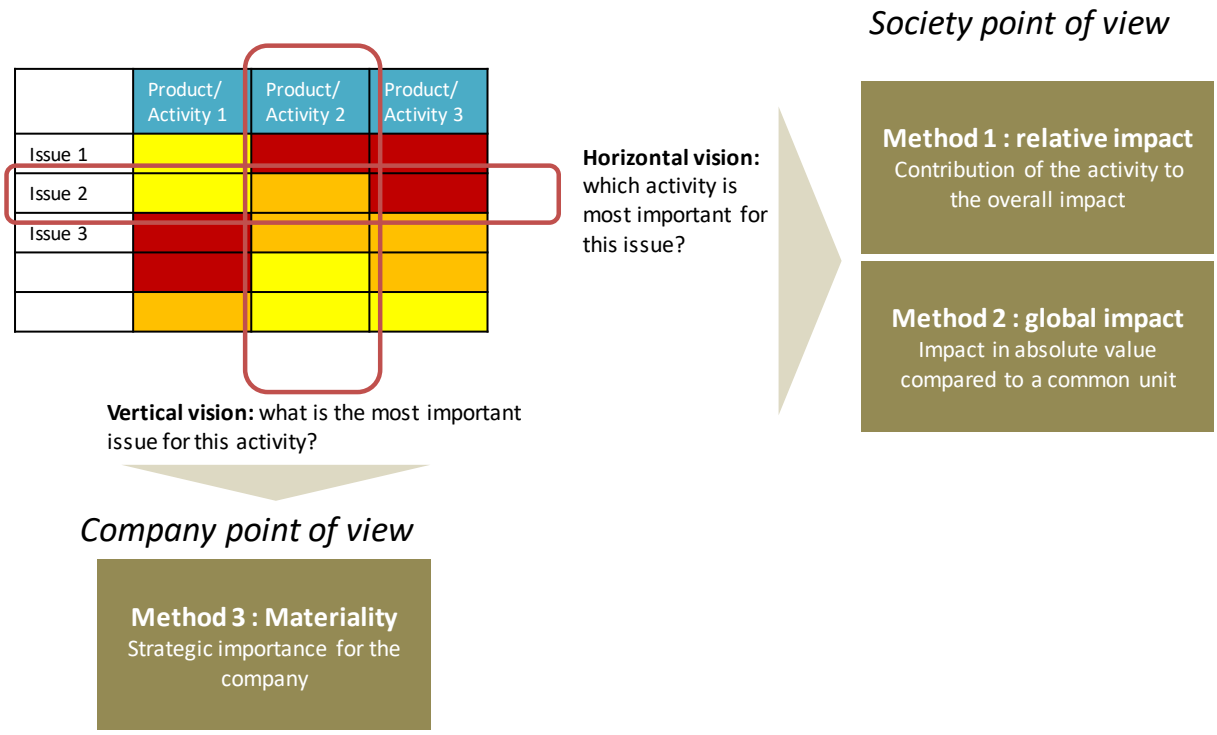


Figure 5 : Main approaches for the hierarchization on environmental issues

1. LCA contribution to the hierarchization of issues

LCA has the advantage of enabling to "automatically" quantify the environmental impacts of a product over the main environmental issues. However, LCA has the defect of its quality, i.e. to provide the user with very (too) rich information through very numerous impact indicators, each representing a different environmental issue, making the interpretation of a LCA result complex, or even very difficult for a non-expert.

For example, to facilitate the interpretation of LCA results and enable a hierarchy between environmental issues, it is possible to compare the LCA results of a product to total pollution on a geographical area. This phase, called **normalization**, evaluates each indicator result by dividing it by a reference value, for example the value of total pollution per capita according to the same indicator. This makes it possible to identify, for each product, the environmental issues for which the product has a more or less significant contribution compared to all the activities and products of the concerned area.

2. Contribution of Planetary Boundaries to the hierarchization of issues: a change in the order of priority?

The ranking elements traditionally brought by LCA (through normalization in particular) do not enable today to provide answers regarding the absolute durability of a product, i.e. with respect to the physical thresholds of the planet. In this context, the definition of the Planetary Boundaries concept seems to provide new areas for reflection on the assessment of environmental impacts and may potentially change the ranking of issues at the corporate strategy level.

The perspective of the Planetary Boundaries differs radically from the classical approach of damage assessment in LCA. Indeed, while it is possible to subjectively weight the preservation of human health compared to biotic or abiotic ecosystems, the point of view proposed by the Planetary Boundaries is objective: the aim being to preserve the Earth ecosystem in a state similar to the Holocene, the various dimensions of evolution of the Earth ecosystem are ordered according to their exceedance or distance from the threshold value, with the risk of change the Earth state.

However, the hierarchy of the Planetary Boundaries is not as simple as that: if the study of threshold exceedance makes it possible to identify which limits have been exceeded and by how much, and at what distance from the threshold the Earth ecosystem is for the others, the translation of this information into a ranking for the various limits, or even a weighting system, leaves still subjectivity: all the exceeded limits have the same weight? Should the boundaries be linearly weighted by their distance to the threshold? Or exponential? Or any other function? The nuances introduced by Steffen et al. (2015) that define climate change and the evolution of the integrity of the biosphere as two key limits - "core boundaries" - suggest that not all limits would be as important. Within this framework, the ranking of boundaries could be defined according to their distance to the threshold and their potential contribution to core boundaries.

3. Case study : comparison between thermal vehicle (Vth) versus electric vehicle (VE)

In order to compare the different hierarchy methods of environmental issues at product level and to test the influence of Planetary Boundaries on this hierarchization, we compared, in particular, for a thermal vehicle and an electric vehicle:

- LCA results normalized by the overall impact;
- LCA results normalized by the Planetary Boundaries.

Characterized LCA results data were provided by Renault. The avoided impacts method was chosen to assess the impact of the end-of-life. The following figure presents the normalized LCA results by the overall impact.

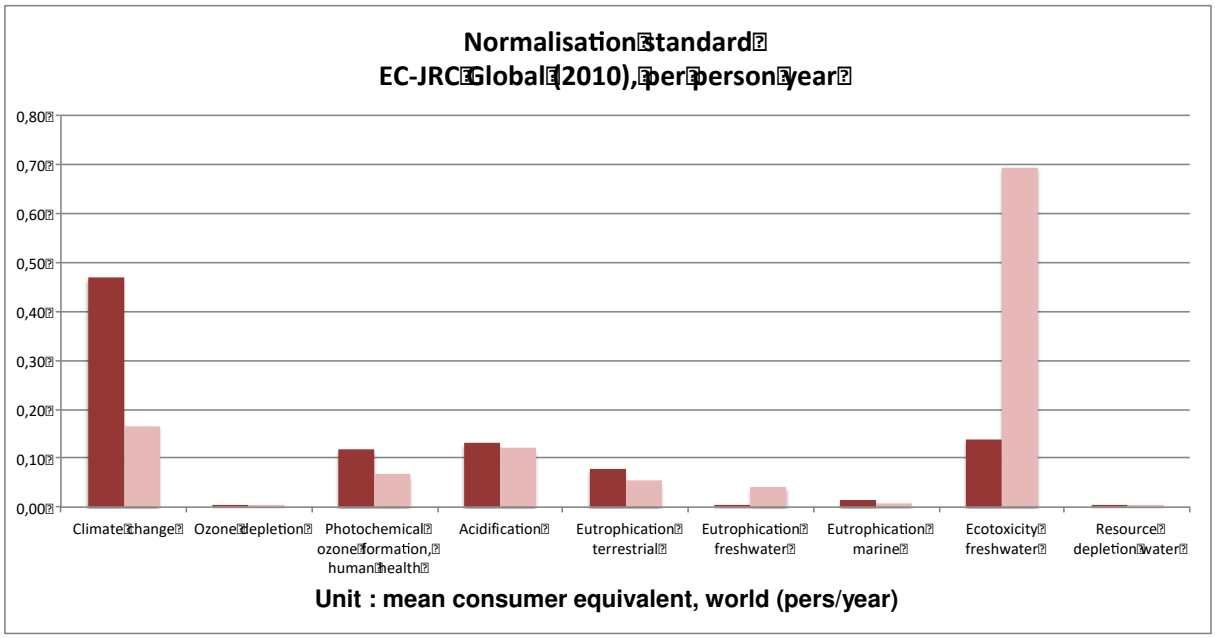


Figure 6 : Comparative LCA between a thermal vehicle (dark red) and an electric vehicle (light red), normalized results, Global, JRC data 2016, for 15,000 km driven (i.e. one year of use)

For the current normalization, the electric vehicle (light red) presents an advantage over most indicators, except for freshwater ecotoxicity and freshwater eutrophication. The impacts on the "Acidification" category are also comparable, as the difference is not significant.

In a second step, the LCA results were normalized with the Planetary Boundaries and the results are presented in the following figure.

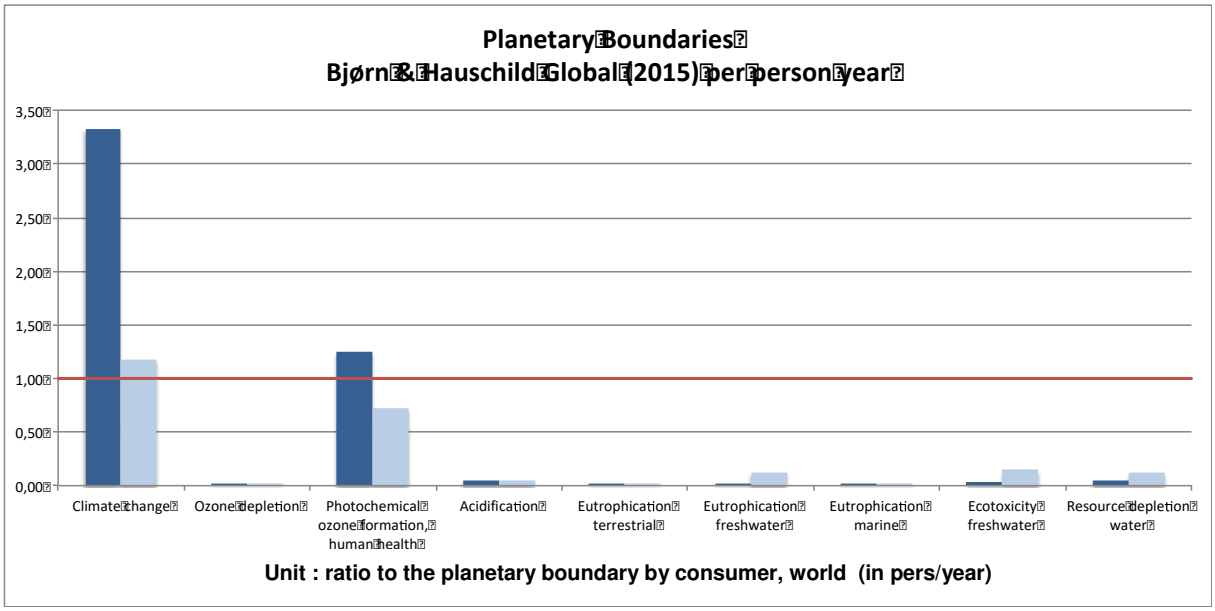


Figure 7 : Comparative LCA between a thermal vehicle (dark blue) and an electric vehicle (light blue), normalized results with Planetary Boundaries, Global, for 15,000 km driven (i.e. one year of use), the red line represents the threshold not to be exceeded within the planetary boundaries.

Here, the categories Climate Change and Photochemical Ozone Formation overwhelm the other categories. We present the results on the following graph by excluding these two categories, for a better readability.

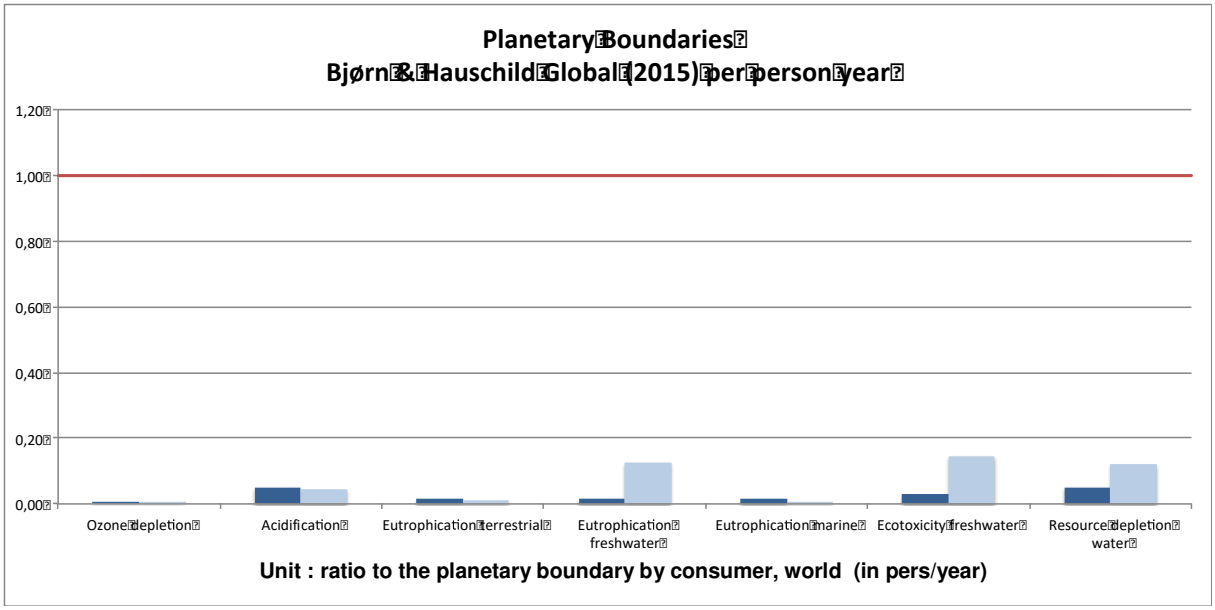


Figure 8 : Comparative LCA between a thermal vehicle (dark blue) and an electric vehicle (light blue), normalized results with Planetary Boundaries, Global (without Climate Change and Photochemical Ozone), for 15,000 km driven (i.e. one year of use), the red line represents the threshold not to be exceeded within the planetary boundaries.

Note : Human health and resources issues are not addressed in normalization by Bjoern and Hauschild.

By comparing the two normalization methods, the main difference is ecotoxicity, which dominates the first graph, and is almost not seen on the second graph. LCA experts consider that the normalization factors for toxicity and ecotoxicity categories are unreliable, which may explain this difference. If we disregard this indicator, the effect of normalization within Planetary Boundaries by Bjoern and Hauschild highlights essentially the categories "Climate change" and "Photochemical ozone formation". The change in normalization method, as far as the current state of knowledge is concerned, would therefore not reverse the hierarchy of environmental issues for VE and VTh, as the VE would show a benefit on these two indicators.

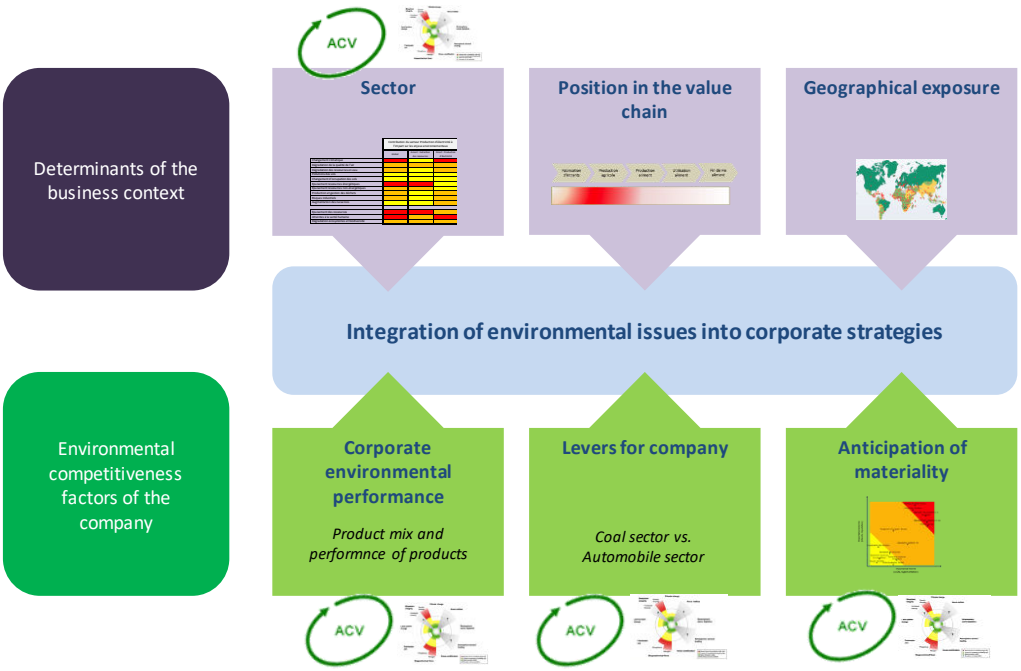
Without having the benefit of hindsight on recent methodological developments, it is still difficult to interpret such a result and therefore to know to what extent planetary boundaries can modify the hierarchy of issues. Nevertheless, the following points can be noted:

- An interesting ranking effect that highlights two issues that are exceeded according to Bjorn (climate, ozone formation) and two other issues (freshwater eutrophication and ecotoxicity) that are not completely consistent with the "original" Rockström Planetary Boundaries (Rockström, Steffen, Noone, Persson, Chapin Iii, et al., 2009)
- Other paper studies, using the same method, seem to rank the same issues in the same order.
- Further work is needed to strengthen, improve and stabilize these normalization and weighting factors.

III. Integration of environmental issues into corporate strategy

1. Strategic analysis framework

After the phases of identifying and prioritizing the issues, companies have then to integrate these issues into their strategy. In this respect, the feedback from the strategic analysis of environmental issues highlights 6 main factors which analysis helps to guide the company in integrating environmental issues into its corporate strategy:



3 determinants of the company's position:

- **Sector**: it is clear that the environmental issues for companies producing the same products are close. Thus, for a company, the knowledge of environmental issues carried out at sectoral level is an essential step in the analysis of its own issues (sectoral analysis by industry federations for example);
- **Position in the value chain**: for each environmental issue and each value chain, there is usually a stage in the chain that concentrates the intensity of the environmental impact. This positioning in relation to the key environmental impact is structuring in the integration of environmental issues (upstream or downstream of the impact phase; on the direct impact/impact phase);
- **Geographical exposure**: it plays a very important role in the strategic integration of environmental issues, whether through the impact generated by the product (impact on local biodiversity, conditions of use of an energy product according to the country's mix, etc.) or the materiality of the issue for the company (regulatory materiality differing from one zone to another for example).

3 environmental competitiveness factors of the company:

- **Company's environmental performance**: product mix, a company's history and the environmental improvement actions already undertaken are all factors that make the company's environmental performance very different from its competitors;
- **Company's levers**: it is often strongly linked to the levers of all companies in the sector, as it depends on the technological solutions available to significantly reduce the impact of products;

- **Anticipation of materiality**: through the confrontation of the analysis of the environmental impact of a product and its materiality, the company can orientate its strategy and its axes of impact reduction and/or materiality (evolution of the regulation, awareness of stakeholders).

2. Consideration and role of LCA into strategic integration of environmental issues

As part of the reflection around the integration factors of environmental issues into corporate strategy, LCA provides a number of solutions and makes it possible to:

- Set benchmarks at sectoral level with "sector average" LCAs carried out by professional federations;
- Understand at what point in the value chain the most important impacts occur;
- Position the performance of the company's products in relation to other products on the market, but also evaluate the company's environmental performance through organizational LCA;
- Initiate eco-design actions to use the company's levers;
- Anticipate materiality by detecting significant environmental impacts that are not yet material.

3. Consideration and role of Planetary Boundaries into strategic integration of environmental issues

The use of LCA in integrating environmental issues into a corporate strategy regularly comes up against the difficulty of prioritizing multi-criteria results, each axis being independent of the others. In this context, the planetary boundaries propose a basis for a shared and coherent normalization for the various indicators. In this way, reading of LCA results could be easier.

However, the operational implementation of the concept of planetary boundaries requires:

- **The evaluation of the planet threshold**: this is what the initial work on Planetary Boundaries has established, by setting limit values for each control variable.
- **The evaluation of the limits of human activities impacts**: moving from the planetary boundaries to the limits of the impact of human activities implies being able to model the contribution of an annual flow to the control variable (often a state variable, not a flow variable), and to subtract the "natural" contribution, in order to deduce the human emissions that are admissible per year. This modelling enables to define a Planetary Capacity, i.e. the maximum emission not to be exceeded in order not to exceed the Planetary Boundary. This Planetary Capacity can be the subject of a **temporal trajectory** that allows us to better account for a possible and optimal transition between the current impact of human activity and the desired impact to be compatible with this Planetary Boundary.
- **The assessment of shared responsibility**: allocating the overall reduction of all actors to each sector or product is not a purely scientific process. It is based on both techno-economic modelling of each sector, macro-economic modelling of the transition, but also on governance and equity considerations (see Section 2.3) that make this a stage of negotiation between the parties rather than scientific modelling.

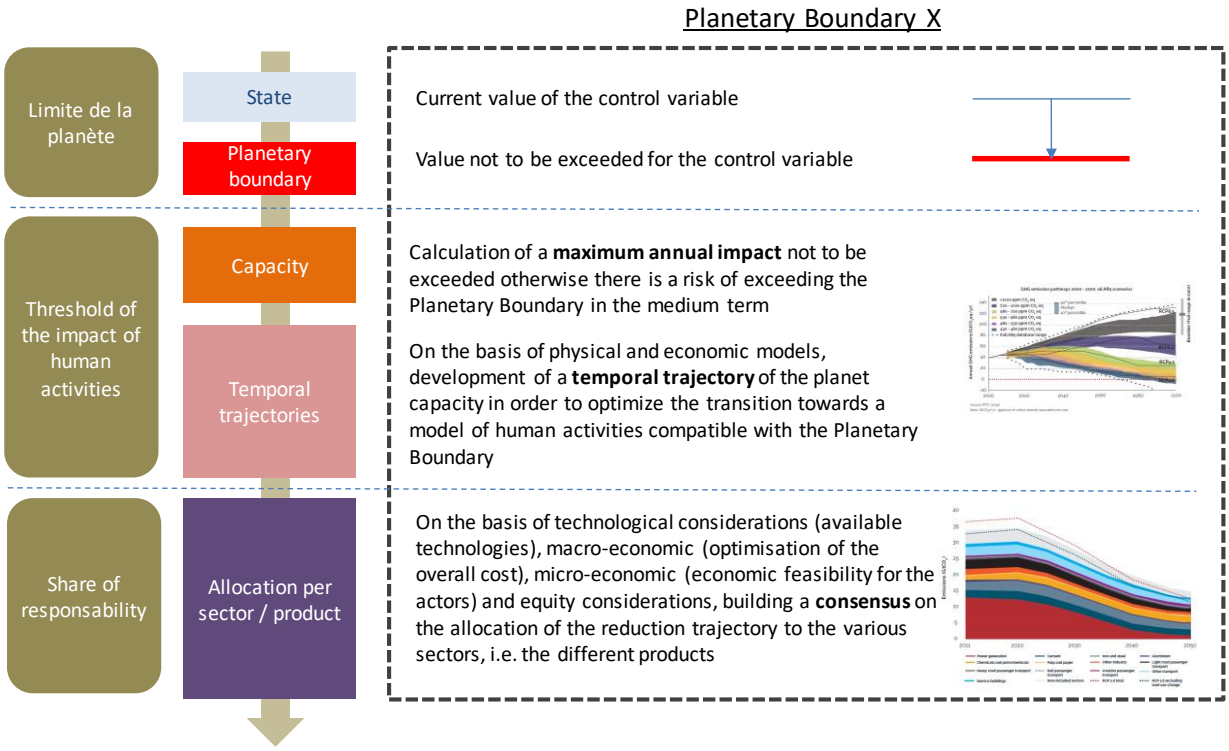


Figure 9 : Global Planetary Boundary implementation scheme (I Care & Consult, 2017)

The Planetary Boundary "Climate" has a special place in the general reflection on planetary boundaries. Indeed, it has been on the international agenda for more than twenty years and because of its global nature, it has brought out more advanced tools and methods than for the other planetary boundaries. Thus, it has to be noted that the various initiatives are now "linked" (IPCC/IEA/SDA/ACT) to propose to the actors a coherent set of tools to define and evaluate trajectories compatible with the Planetary Boundary "Climate", as shown in the figure below.

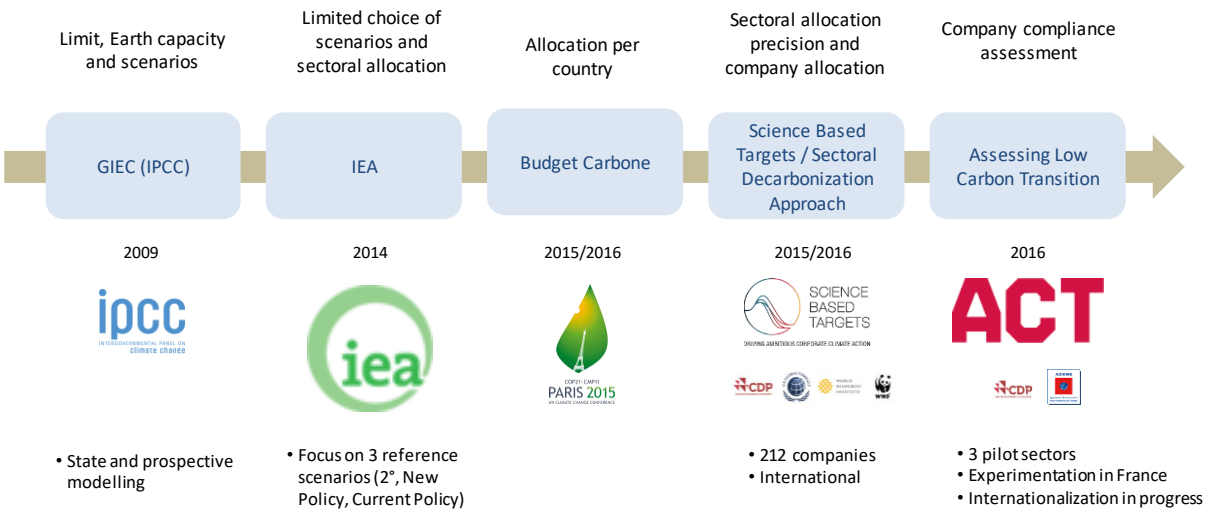


Figure 10 : Suite of tools on the Planetary Boundary "Climate" (I Care & Consult, 2017)

The operational implementation of the Planetary Boundaries is therefore a long process, requiring coordination bodies to ensure consistency and homogeneity of approaches. For a global impact, such as climate change, international coordination has proved possible through various bodies (IPCC for defining the climate limit, IEA for carbon reduction scenarios, COP for negotiations on the sharing of responsibility between States).

However, the application of the Planetary Boundaries concept for other environmental issues than climate does not yet seem to be operational (Häyhä, Lucas, Vuuren, Cornell, & Hoff, 2016): there is no consensus on the other issues in 2017, at the level of defining the control variable, capacity or coordination bodies.

This does not mean that work is not underway to move forward on the other boundaries. For example, a consortium of 31 researchers (Clift et al., 2017) recently published an article on the challenges of applying Planetary Boundaries in corporate strategies and public policies. Written in collaboration with Unilever, the article focuses on 4 Limits and explores ways to develop practical tools for the application of these Limits. Beyond the climate issue, Clift et al. (2017) present the way forward (up to international coordination) for 3 other issues: Freshwater use, Integrity of the biosphere and Chemicals/new entities. These Boundaries were chosen by the authors to illustrate all the problems raised by the Planetary Boundaries subject, namely the definition of scientifically robust metrics and capacities as well as governance issues, which remain essential for the assessment of shared responsibility. The two emerging Boundaries, which could become operational in the short to medium term after the Climate, are freshwater consumption and the integrity of the biosphere.

In the absence of scientifically defined planetary capacities, some companies have chosen to define objectives in connection with regional, national or local public policies, implicitly assuming that these public policies are linked to the planetary boundaries, which is not always the case. These voluntary and experimental approaches have the merit of being in line with the idea of the Planetary Boundaries and of testing scheme on available indicators and on the sectoral attribution that can be made on these other limits. Although it is not as robust as the tools for the climate limit, these feedback can, in our opinion, feed into a bottom-up approach the global "top-down" reflections that emerge to provide the theoretical background for a suite of tools for each limit.

Conclusion

A review of the evolution of corporate communication over the past ten years undeniably shows a clear increase in the place given to environmental issues into strategy, while noting for the most part the predominance of the climate issue over other environmental issues.

Life Cycle Assessment concept and tools have proven to be essential tools in this evolution. In particular, they have made it possible to articulate the issues (via impact chains and pollution transfer prevention), and above all to go beyond a "site" approach by providing an overall view of the company's impact (from the supply chain to the use of the product), which is essential for assessing the materiality of the environmental issues.

However, this coverage of the issues by Life Cycle Assessment is not complete and does not enable to analyse them with the necessary accuracy as robustness varies greatly depending on the issues. Various works are underway to improve this point in the coming years. However, the question of prioritising issues remains a weakness of Life Cycle Assessment methods.

More recently, the Planetary Boundaries are a promising new conceptual framework that could bring three main advances in the strategic integration of environmental issues:

- Hierarchization of issues (depending on the distance to the limit);
- Transition from a relative view of impact to an absolute view;
- Possibility of defining objectively ("science-based") impact reduction trajectories.

Concerning hierarchization, various works are underway to operationalise the concept, in particular by building bridges with LCA methods, but they are not sufficiently advanced at the beginning of 2017 to allow for an operational and unquestionable ranking of the issues at company level. This could evolve very rapidly over the next few years, which could lead to the Planetary Boundaries constituting a more relevant basis for the normalization of impacts in LCA practice.

Regarding the reduction trajectories and the "absolute" vision of impacts, it is clear that there is a significant gap between the operational suite of tools developed for the Climate limit and the work still to be done for the other limits. For the Climate limit, this operationalisation was only possible thanks to the combination of progress in four areas: scientific (IPCC), political (COP21,...), technical (IEA,...) and business (multi-stakeholder initiatives such as SBT,...). It is only by following the same process the operationalization of other boundaries can be as robust as it is for the climate. Significant progress can be expected in the next 5 years for two boundaries: water and biodiversity, although the latter is less mature.

Beyond the academic work, it is remarkable to note the numerous voluntary initiatives of companies that grasp the concept of Planetary Boundaries and experiment with a strategic and operational declination without stopping at the defects of robustness noted, as the concept of Planetary Boundaries is so attractive for companies because of the "additional meaning" it brings to environmental analysis. These "bottom-up" exploratory initiatives seem to us to be complementary to "top-down" academic work and allow to explore the Planetary Boundaries concept, as companies are confronted directly with the problems of data and the use of results to define a strategy. All these elements clearly make the Planetary Boundaries a field of innovation for the years to come.