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Planetary Boundaries and innovation:

What role for ICT in defining a safe operating space for humanity?

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1. Introduction

This aim of this paper is to discuss how ICT (information and communication technologies) can contribute to the challenge of not crossing PBs (planetary boundaries) [1], introduced in section 2, in order to enable a safe operating space for humanity. PBs define limits for nine key ecological equilibriums that should not be crossed, such as a maximum temperature increase of 2°C over the next 100 years for the climate PB. ICT (both hardware and software) play a dual role in this PB challenge.

At first, ICT can play a positive role by offering services to monitor the environment and to help solve other environmental problems. But ICT also generates its own ecological impacts that should be mitigated. In this paper, we discuss these two roles and then examine the extent to which the concept of PBs can help ICT firms to achieve greater environmental performances. Digital technologies have been praised by for-profit (GeSI (2008)) and non for profit actors (WWF (2002)) to be able to positively contribute to this PB challenge. Not only could this contribution decrease the negative ecological impacts of human societies, it could also foster a third industrial revolution introduced in the table below, with which current production and consumption systems would shift to more sustainable ones.

[1] "PBs". See Rockstrom et al. (2009) and Steffen et al. (2015) The limits set by PBs represent the most fragile elements of natural ecosystems. Therefore, if firms are to maximise their contribution to reducing the ecological impacts of human societies, they should target these PBs.

Table 1. From the first to the third Industrial Revolution

	1st Industrial Revolution: approx. 1780-	2nd Industrial Revolution: approx. 1890-	3rd Industrial Revolution: approx. 1990-
Dominant technology and raw material	steam engine, power loom, iron processing	electricity, chemistry, combustion engine, assembly line, synthetic materials	ICT, microelectronics, new materials, renewable raw materials, cleaner technology, biotechnology, recycling.
Dominant energy source	coal	coal, oil, nuclear power	renewable energies, energy efficiency
Transport/ communication	railway, telegraphy	car, airplane, radio, TV	high-speed railway systems, internet, mobile telecommunication
Society/ state	"bourgeoisie", freedom of trade, constitutional state	mass production, mass society, parliamentary democracy, welfare state	civil society, globalization, global governance
Core countries	UK, Belgium, Germany, France	USA, Japan, Germany	EU, USA?, China? Japan?

Source: Jänicke and Jacob (2009).

The dual relationships between ICT and the environment are summarised in the following table, which underlines that there are positive (ICT as a solution) and negative aspects (ICT as a problem) to these relationships. First order effects concern the direct positive and negative impacts of digital technologies on the environment, second order effects their indirect impacts, and systemic effects the society-wide impacts. It shows that ICT can both contribute to solve environmental problems, but that they can also make them worse. It also suggests that besides societal benefits, economic opportunities can be generated by using ICT to solve ecological problems, provided that they address their own negative ecological impacts.[2]

[2] See Hilty and Aebischer (2015).

Table 2. Conceptual framework of the relationships between ICT and the environment

<table>
<tr><th>Type of effect</th><th>Level of influence</th><th>ICT as a solution</th><th colspan="2">ICT as a problem</th></tr>
<tr><td rowspan="3">1st order
(direct effects)</td><td rowspan="3">ICTs themselves</td><td rowspan="3">Making more with less</td><td rowspan="3">Life cycle of ICT</td><td>Production</td></tr>
<tr><td>Use</td></tr>
<tr><td>End of life</td></tr>
<tr><td rowspan="3">2nd order
(indirect effects)</td><td rowspan="3">Application of ICT to other sectors</td><td>Optimisation</td><td colspan="2" rowspan="3">Induced negative effects</td></tr>
<tr><td>Substitution</td></tr>
<tr><td>Information collection/analysis/diffusion</td></tr>
<tr><td rowspan="2">3rd order
(systemic effects)</td><td rowspan="2">Societal changes</td><td rowspan="2">Deeps structural changes towards dematerialisation</td><td colspan="2">Rebound effects</td></tr>
<tr><td colspan="2">New digital infrastructures</td></tr>
</table>

Source: Adapted from Hilty (2008).

In this paper, we examine how the ICT sector might be able to respond to the PB challenge. All organisations are using ICTs, which are general purpose technologies and thus have a huge potential contribution to reduce the negative ecological impacts of human societies, in the form of "green ICT".[3] E.g. these technologies can connect heterogeneous actors and empower them so that they can achieve ambitious environmental objectives. Green ICT can also increase environmental awareness and ecoliteracy, and enable other socio-economic sectors to increase their efficiency and reduce their negative environmental impacts (e.g. smart grids, smart meters, smart traffic control systems, …). But digital technologies have their own ecological impacts, which they need to minimise so that they do not contribute to the crossing of planetary boundaries.

How can green ICTs face the dual challenge of helping other sectors reduce their negative ecological impacts while reducing their own impacts? E.g. how can those impacts be decreased across its complex supply chain? What types of innovations can emerge in this sector by taking up this challenge? What roles can play local, national and supranational institutions in helping this sector do so?

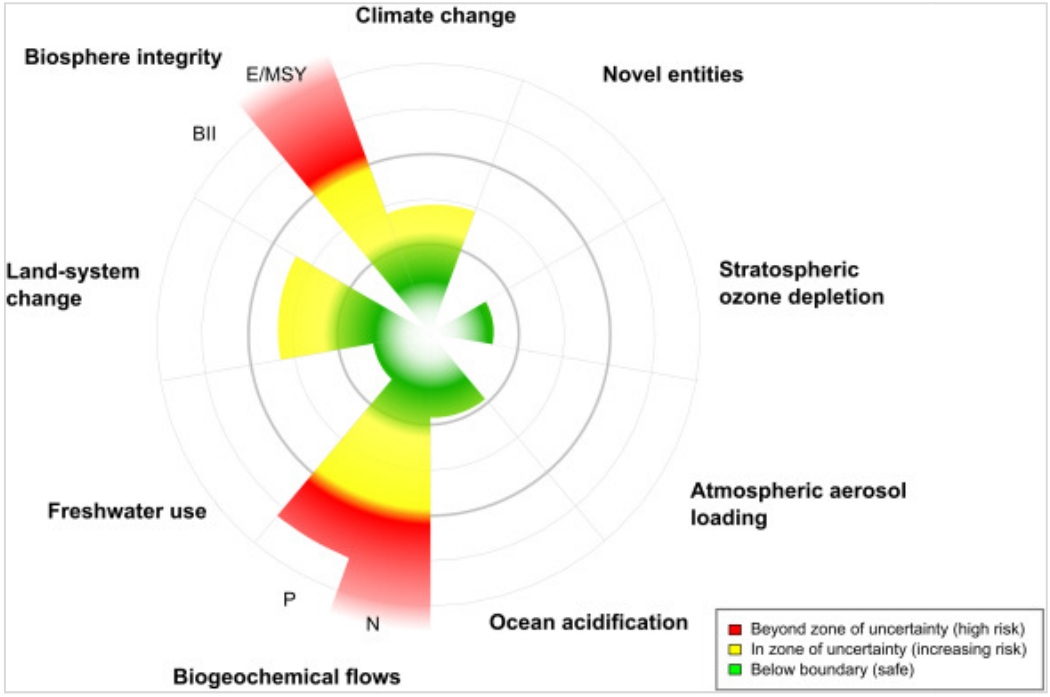
[3] About green ICT, see our paper Cecere et al. (2014).

The paper starts by explaining what PBs are and what they imply for businesses. It then explains the positive and negative contributions of ICT to the PB challenge, before discussing whether or not it might be useful for ICT firms to integrate PBs in their environmental policies and strategies, as some have already started to do.

2. Planetary boundaries and businesses

In order to help policy makers and other stakeholders reduce the negative ecological impacts of human societies, Rockstrom et al. (2009), and more recently Steffen et al. (2015), have proposed the planetary boundaries framework to define "a safe operating space for humanity based on the intrinsic biophysical processes that regulate the stability of the Earth System". Human activity has caused the crossing of four of nine planetary boundaries (climate change, loss of biosphere integrity, land-system change, and altered phosphorus and nitrogen cycles). Climate change and biosphere integrity are defined as "core boundaries". Crossing them would "drive the Earth System into a new state", a much less hospitable state for all human societies, be they rich or poor. The following figure shows the current status of PBs.

Figure 1. The current status of the control variables for seven of the nine planetary boundaries



Source: http://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries-data.html.

An increasing number of initiatives and research projects have sought to find ways to guide human societies on a trajectory that would not exceed planetary boundaries. For example, at the macro-political level, Biermann (2012) argues that the concept of planetary boundaries defines the overall goals of the governance of the Earth system. At firm level, Whiteman et al. (2013) argue that planetary boundaries can be used as ecological foundations for corporate sustainability. But they also stress that there is a lack of understanding about the linkages between social and ecological systems, especially regarding for profit agents like industrial firms, in order to "enhance the resilience of dynamic social-ecological systems" (p. 313). So far, management literature has focused on societal implications of ecological crises, "in isolation from quantitative indicators of ecosystem functioning" (p. 308). Besides, it has tended to focus on micro and meso-levels thinking and has lacked systemic thinking, which is required when dealing with non-linear systems such as natural ecosystems (ibid.). Therefore, there is a need for more research about how to "link business processes to macro ecological processes and boundary conditions" (ibid.). This leads Whiteman et al. (2013) to formulate the following question, which pleads for the emergence of a new PB research agenda in management sciences:

"How could management scholars integrate measures of ecosystem functioning into their studies on corporate sustainability?"

In this paper, we investigate ways to do so in the case of the ICT sector. The authors underline that "businesses often ignore scientific discourse on Earth systems", and that "many corporate reports describe 'sustainability' as a 'journey' with no explicit destination or quantifiable boundaries" (p. 311).

What could be the impacts on firms of integrating planetary boundaries in their strategies? According to the Stockholm Resilience Centre (SRC), business plays a vital role in responding to ecological challenges (the SRC has published a report explaining what planetary boundaries mean for business).[4] If business will be affected by ecological crises, the SRC report also underlines that business has played an important role in the positive evolution of several boundaries, such as freshwater abstraction or the loss of stratospheric ozone. We argue that there is a business case

[4] See http://www.stockholmresilience.org/download/18.6d8f5d4d14b32b2493577/1422535795423/SOS+for+Business+2015.pdf.

for innovative organisations to take up the challenge of not crossing planetary boundaries. The advantages for businesses to take up the PB challenge are threefold:

1) PBs help businesses focus on urgent environmental objectives.
2) PBs help firms focus on relevant environmental goals.
3) PBs help firms set long term environmental priorities.

Whiteman et al. (2013) provide in a tabled form an "Overview of studies on corporate sustainability related to Planetary Boundary processes" (Table III, p. 318). Only for two PBs do publications provide evidence of a good understanding of firm or industry-level impacts (Chemical pollution, Climate change). For the Climate change PB, there is a fragmented understanding of disaggregated emission reductions. Knowledge is also fragmented for the Fresh water use PB, and although there are an increasing number of studies on this PB, many of them rely on simulation techniques. For the six other PBs, there is either no empirical understanding of the negative role played by firms (Global nitrogen and phosphorus cycles, Atmospheric aerosol loading, Ocean acidification), or only a very limited one.

The SRC published a document explaining how PBs might be used by businesses[5]. This document states that "To measure true progress toward sustainability, businesses need to benchmark collective performance against the physical and ecological limits of the planet. While science can't always predict catastrophic changes, it can identify likely risk scenarios." The following table shows example of the implications of PBs for business.

[5] WBCSD, Planetary Boundaries for Business. http://www.wbcsdservers.org/web/wbcsdfiles/GlobalPolicy/SOSforBusiness2015SRC-WBCSD.pdf.

Table 3. The implications of PBs for business

What are the planetary boundaries?		*What does this mean for business?*
Climate change Global temperature has risen by nearly 0.7°C since 1950[2], mostly due to CO_2 emissions from fossil fuel use.	**Boundary:** atmospheric concentration no higher than 350 ppm CO_2 **Current:** 400 ppm CO_2 ***and rising***	CO_2 emissions must decrease, soon and sharply. Climate change, energy security and economic stability are tightly linked. Assets and business activity will be affected by rising temperatures, more frequent weather extremes, and sea-level rise.
Loss of biosphere integrity Wild animal populations have roughly halved since 1970, and ecosystems worldwide have been impacted by human activities.[3]	**Boundary:** no more than 10 extinctions per million species-years **Current:** ~1000 E/MSY ***and rising*** (plus regionally determined boundaries for ecosystem function)	Business cannot function if ecosystems are degraded or out of balance. Nature provides directly beneficial services – food, fibre, fuel. It also provides many invisible but essential services, such as regulation of climate and the water cycle, air quality improvements, flood protection. It also contributes to cultural and individual wellbeing.
Changes to biogeochemical flows – nitrogen and phosphorus N and P are essential nutrients for all life. Exponential rises in N and P emissions from industry and intensive agriculture kill lake and marine life, cause severe air pollution and affect climate patterns.[4]	**P Boundary:** no more than 6.2 million tons P applied to land per year **Current:** ~14 Mt yr^{-1} ***and rising*** **N Boundary:** no more than 62 million tons N applied to land per year **Current:** ~150 Mt yr^{-1} ***and rising***	Humanity faces a global challenge to produce more food and energy without eroding its ecological life-support systems. Global disparities in food and energy security are severe. The environmental release of N and P is becoming an unaffordable waste of natural resources.
Land use change (forest conversion to croplands, roads and cities) As well as killing wildlife, deforestation and urbanization affect climate by changing CO_2 flows.[1,2]	**Boundary:** no less than 75% biome intactness **Current:** 62% ***and shrinking***	Business has caused a significant part of the world's large-scale land degradation and deforestation. It can make a major difference by adopting and promoting sustainable land management practices and policies.

This document focuses on how business might be impacted by the crossing of PBs, but little is said about how to integrate PBs into firms' strategies. In the social science literature on PBs we have not found any specific study on the ICT sector, despite the capacity of the latter to use its own technologies to monitor its ecological impacts and the ones of other sectors.

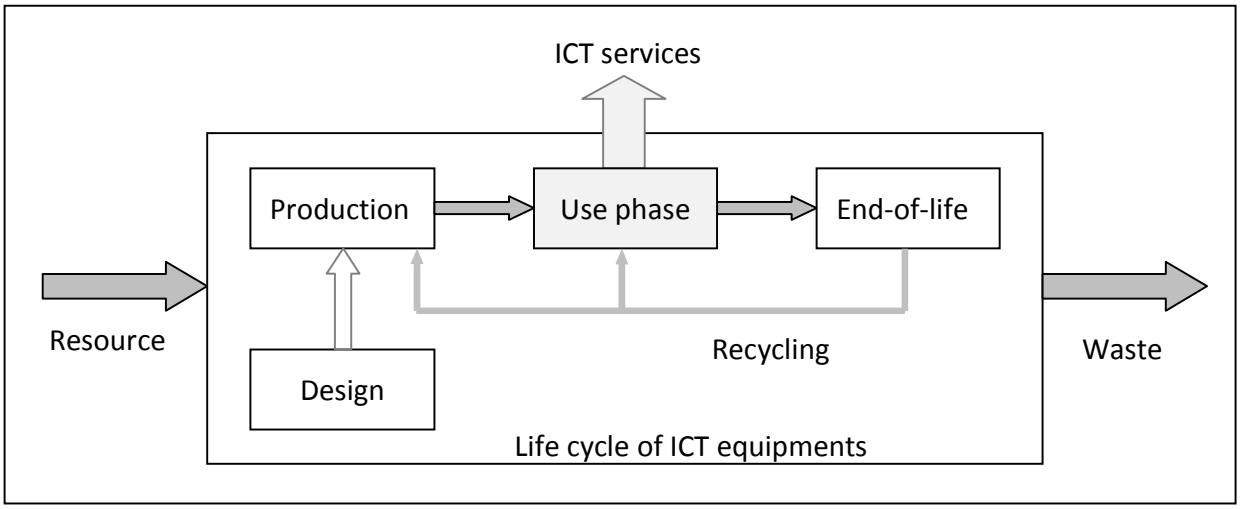
3. The contributions of ICT to the PB challenge

ICT can contribute in three ways to the PB challenge: by ensuring the ecodesign of their own products and services, and by providing environmental services.

3.1. Greening ICT

ICT generate ecological impacts that affect PBs throughout each phase of their lifecycle. The figure below shows a simplified version of the life cycle of ICT.

Figure 2. Life cycle of ICT



Source: Lorenz M. Hilty (2008), *Information Technology and Sustainability: Essays on the Relationship between Information Technology and Sustainable Development*, Books on Demand, Figure 6-1, p. 124.

Reducing the negative ecological impacts of ICT implies to "green" ICT, which leads to produce ecodesigned ICT, and to use and dispose of them in a responsible manner. Ecodesigning a product or service means to substantially reduce its ecological impacts throughout its whole lifecycle. It usually implies to carry out a life cycle assessment of the ICT product or service, and requires a good understanding of its entire life cycle. Therefore, ecodesigning ICT implies for each life cycle phase to minimise all ecological impacts: pollutions, exhaustion of natural resources, and global environmental changes.[6] Some call the ICT which are doing that "green IT".[7] For example, the Fairphone is an ecodesigned mobile phone which guarantees that it does not contain any metal coming from conflict zones.[8] Also, there are datacentres which are designed to consume less energy, including for cooling. Finally for green IT examples, some computers are also ecodesigned to last longer, to save energy, and to ease their dismantling and thus their recycling (limited number of screws, easy access to the battery, etc.).

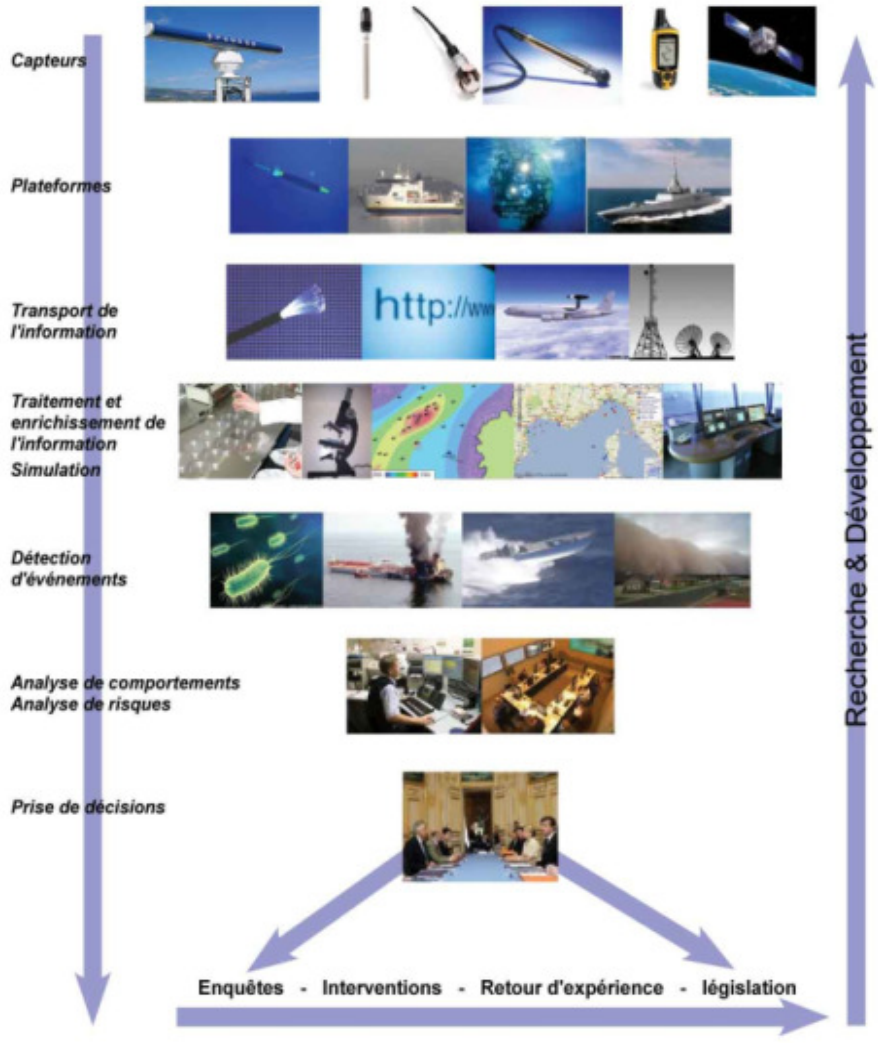
[6] For a review of the literature (in French) of the ecological impacts of ICT, see ÉcoInfo (2012).
[7] See Cecere et al. (2012).
[8] See https://www.fairphone.com.

3.2. Providing environmental services

3.2.1. Monitoring natural ecosystems

Environmental monitoring involves the collection of environmental information, its storage, analysis, and diffusion to end users in accessible formats. The following figure shows the chain of environmental information processing from sensors to decision makers. This chain applies to data collected for each PB, and given the fast rate of innovation can generate big environmental data requiring specific algorithms to be processed.[9]

Figure 3. The environmental monitoring chain



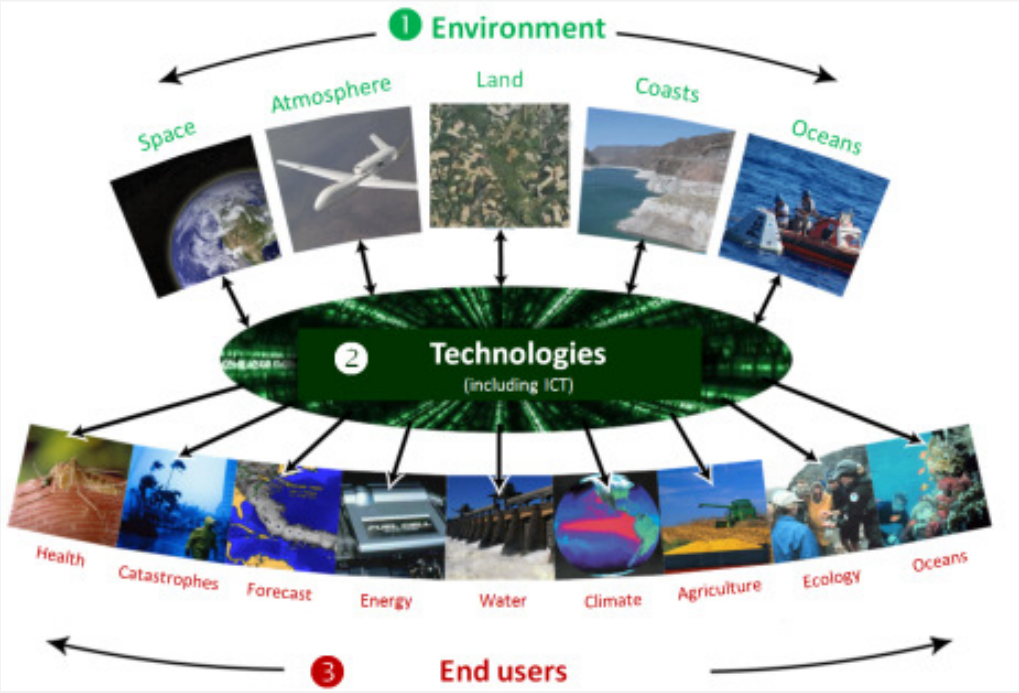
[9] About big environmental data, see Cirac Claveras and Gossart (2015), https://terminal.revues.org/1034.

This chain provides environmental information to all kinds of actors, be they politicians, scientists, or citizens whose environmental awareness can be raised by using ICT. Since it uses ICT to reduce ecological impacts in other sectors than the ICT one, some call it "IT for green". [10] For example, climate monitoring technologies contribute to avoid crossing the climate PB.[11]

3.2.2. Other environmental ICT services

There are many other green IT solutions that can contribute to avoid crossing PBs. Indeed, as exemplified in the following figure, many end-users can benefit from the services that ICT can offer to avoid crossing PBs. In this figure, the first level comprises the five main natural ecosystems with which human beings co-evolve. The second level contains the technologies used to observe, monitor and analyse these ecosystems, and eventually to diffuse information about them to human actors, included in the third level of end-users.

Figure 4. A three-level perspective on the relationships between ICT and the environment



Source: Adapted from GEOSS (Global Earth Observation System of Systems), http://www.earthobservations.org/geoss.shtml.

[10] See Cecere et al. (2012).
[11] For other examples, see Gossart and Garello (2015).

The last level provides examples of the variety of services that ICT can provide to help avoid crossing PBs. For example, drones can be used to measure the content of nitrates in agricultural soil and limit the use of fertilisers. Sensors can be used to monitor the state and evolution of oceans or watersheds. GPS trackers can help protect endangered species, etc.

4. Planetary boundaries and ICTs

The International Telecommunications Union (ITU) conducts multi-stakeholders projects for the ICT sector, including about environmental issues. However, the term "planetary boundaries" appears only once in the whole ITU website, in a keynote presentation given by Pr. Jeffrey Sachs.[12] In this presentation, the author grants six roles to ICT for contributing to sustainable development goals (their contribution to improved health, education, sustainable agriculture, smart energy, smart urban networks, SDGs implementation), but he does not mention anything specific regarding PBs. The UN World Summit on the Information Society (WSIS) sometimes addresses societal issues, and its 2016 edition reinforces commitment to harnessing ICTs to meet the SDGs.[13] It simply mentions six ICT applications for realizing the SDGs (E-government, E-business, E-learning, E-health, E-employment, E-environment, E-agriculture, E-science), but does not mention PBs.

Why isn't the ICT sector tackling the PB challenge? It could be that PBs is an irrelevant concept for business. This does not seem to be the case, since e.g. the World Business Council for Sustainable Development (WBCSD) has been collaborating since 2012 with the SRC to support solutions to achieve the PB challenge, and has aligned its long term strategy with the nine PBs.[14]

5. The transformative power of PBs for the ICT sector

Identifying the roles that digital technologies can play in helping human beings to avoid crossing PBs is important for the sector to set environmental priority strategies. Indeed, the PBs framework

[12] See https://www.itu.int/en/ITU-D/Statistics/Documents/events/wtis2013/017_E_doc.pdf.
[13] See https://www.itu.int/net4/wsis/forum/2016/Outcomes/#ft.
[14] See http://www.theguardian.com/sustainable-business/business-solutions-based-scientific-analysis.

functions the other way around compared to forecasting strategies, which state present times as the point of reference and future times as a projection of the evolution of the present situation. On the other hand, the PB framework follows a backcasting logic, according to which the point of reference is a boundary that cannot be crossed, and to which present times need to adapt. For example, in order to limit global warming under 2°C, all fossil fuel reserves not exploited yet should remain in the ground, which e.g. implies for financial actors to remove their investments from these sectors. Concerning the ICT sector, such backcasting exercise would e.g. lead to intensively invest in alternatives to the intensive use of rare earth elements and other precious metals in ICT.

In France, a quick search of the terms "planetary boundaries" and "frontières planétaires" in the website of the 40 largest French firms (listed in the CAC 40, which includes 6 ICT firms) gives no result. Only DANONE mentions it once and in very general terms in its Climate policy published on 18 May 2016.[15] This suggests that the concept has not yet filtered through in the French business world. Is it also the case in a sector that is more on the frontline of ecological critiques such as the petroleum industry?[16] Not really, since only Shell mentions PBs in its corporate website, to explain that the company takes a systemic approach at ecological problems: "Continuing to pursue an environmental policy centred on climate change will fail to preserve the planet's environmental stability unless the other defined boundaries are addressed with equal vigour."[17] Then what about multinational firms lobbies or think tanks? The World Business Council for Sustainable Development (WBCSD) has 22 web pages mentioning the term PBs.[18] Many pages are mere presentations of PBs, but one of them underlines that "a new mindset is needed with a deep understanding of how our planetary boundaries and the role of business interact."[19] The WBCSD also uses PBs to call for new members to join "the most ambitious business sustainability agenda

[15] See http://www.danone.com/fileadmin/user_upload/DANONE_Climate-Policy_Full_Version_EN_18052016.pdf, p. 5.
[16] The largest firms are listed in https://en.wikipedia.org/wiki/List_of_largest_oil_and_gas_companies_by_revenue.
[17] See "Shell Energy Scenarios to 2050", p. 48. http://www2.warwick.ac.uk/fac/soc/pais/research/researchcentres/csgr/green/foresight/energyenvironment/2011_shell_international_signals_and_signposts_-_shell_energy_scenarios_to_2050.pdf.
[18] Search carried out = site:http://www.wbcsd.org "planetary boundaries".
[19] Source: http://www.wbcsd.org/education-initiative.aspx. Page visited on 2 June 2016.

to build a future in which 9 billion people can live well within the planetary boundaries by 2050".[20] But it is not clearly explained how businesses might take up the PB challenge. In a page dedicated to agriculture, the WBCSD uses PBs to highlight "the importance to reduce nitrogen and keep phosphorus flows below safe thresholds in order to avert large scale irreversible damage".[21] But again, no recommendation is made about how firms might contribute to help humanity avoid crossing these thresholds. They seem to be working on it, since Gail Whiteman from ERIM, who has worked on PBs and businesses, was "Professor In Residence" at the WBCSD.

Another way to envisage how ICT companies might use PBs in their environmental policies, is to examine the extent to which the issues raised by PBs are dealt with by ICT firms. When examining the use of PBs by major ICT firms, we find that for the "Telecom equipment" area Ericsson is the only company to mention them, in particular to advocate in favour of the use of ICT to better monitor our environment. In this case, PBs are thus used as a source of business opportunities, not to reflect on the negative ecological impacts of the company: "A truly transformative and sustainable international development agenda that delivers for all, within planetary boundaries, will depend on the enabling role of ICT and broadband."[22]

The 2013 report prepared by the Task Force on Sustainable Development of the Broadband Commission for Digital Development puts forth ten goals to reach, the second one being to "Achieve development within planetary boundaries". Broadband is presented as a key solution to this achievement: "Broadband technologies can help countries quantify their contributions towards each planetary boundary and identify opportunities to reduce environmental impacts. They support data-gathering platforms for developing the science-based evidence on which sustainable development policy is built". But not a word is written on the energy consumption of servers e.g. and thus on their indirect contribution to ecological impacts, including to climate change if they are powered by fossil fuel-based energy sources.

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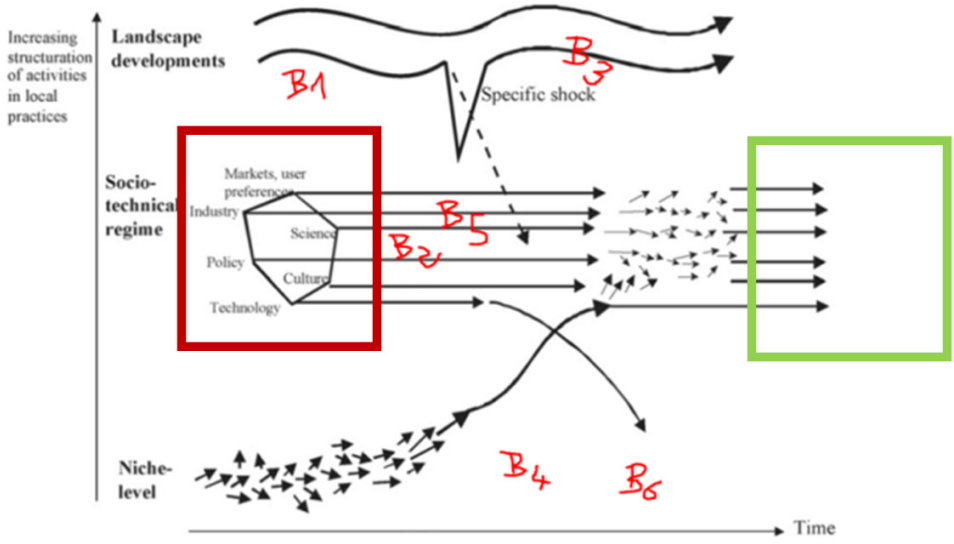
[20] Source: http://www.wbcsd.org/about/members/member-benefits.aspx. Page visited on 2 June 2016.
[21] Source : http://www.wbcsd.org/changing-pace/current-context/currentcontextagriculture.aspx. Page visited on 2 June 2016.
[22] Source: Broadband Commission for Digital Development (2013), Report of the Task Force on Sustainable Development, http://www.ericsson.com/res/docs/2014/means-of-transformation.pdf.

This suggests that the ICT sector has not taken up the task of responding to its own contributions to the PB challenge. We suggest below ways to make PB thinking filter through the environmental policies of ICT firms. For a start, this can be done by examining the environmental reports of ICT firms and by relating their content to PBs. We could then be able to examine whether it is possible to draw a PB graph for a single company. At worse we should be able to identify which PB issue is negatively affected by the activities of a company or sector. In this way, the PB framework could help support the ecological transition of the ICT sector.

The ecological transition of the ICT sector can be represented by using the multi-level perspective, as pictured in the figure below. The brown rectangle is placed on the old ICT sector that has not fully integrated PBs, and the green one of the future ICT sector which has transitioned to higher ecological performances by contributing to solutions to avoid crossing PBs.

Figure 5. Graphical representation of barriers to the ecological transition of the ICT sector



Source: based on Geels and Schot (2007).

Along the transition path that leads to this ecological transition are obstacles or barriers that need to be identified and circumvented, at all three levels of the transition and not only by means of technological innovations but also with social innovations for example or organisational innovations (new business models, ecodesign practices, …) or more systemic changes such as the

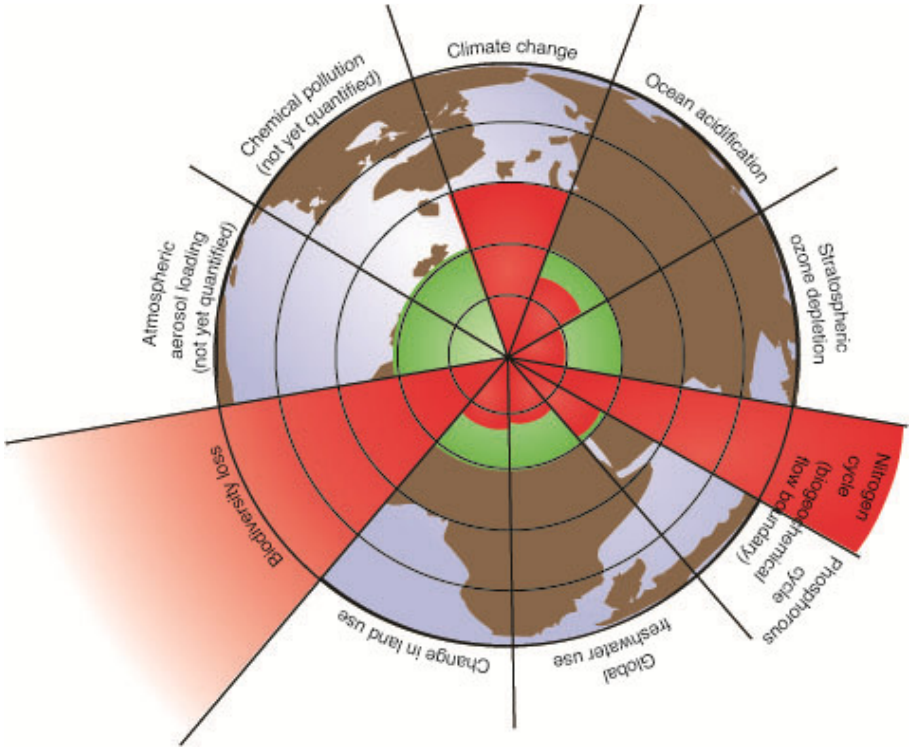
satisfaction of dematerialised human needs by non-for-profit organisations. In order to identify these barriers, a list of PB-related impacts of ICT across its life cycle stages would prove very useful to understand what it means for the ICT sector to integrate PBs.

Figure 6. List of PB-related impacts of ICT

PB	Production phase	Use phase	EOL phase
Climate change			
Novel entities			
Stratospheric ozone depletion			
Atmospheric aerosol loading			
Ocean acidification			
Biogeochemical flows			
Freshwater use			
Land-system change			
Biosphere integrity			

An ICT firm XYZ could then use its environmental data to evaluate how strong its negative contributions to each of the nine PBs are.

Figure 7. The planetary boundaries contribution of firm XYZ



For example, in its 2015 CSR report, CISCO highlights two environmental priorities[23]: Energy and Greenhouse Gas and Product End of Life. For large ICT equipment, LCAs tell us that the use phase is the largest contributor to environmental impacts, because of the energy it consumes. Thus, as a supplier of large IT equipment (networks) it is logical for Cisco to focus on energy and GHGs. Its efforts focus on reducing the energy consumption of its equipments by ecodesigning them, and by supporting renewable energies where they can control their use i.e. in Cisco's HQ. The second focus is placed on the end-of-life of its equipment, which are hazardous materials that qualify as e-waste and thus which should be treated properly. Otherwise it generates chemical pollution. But the countries to which Cisco sells its products do not necessarily have SOA e-waste treatment facilities. This is why they have set the objective of 100% Product Return. The company does not mention the consumption of exhaustible resources during the production phase such as rare earths, or even water that is used in huge amounts by manufacturers of PCBs. The extraction of metals much needed in electronics, including gold, can also lead to changes in land use. We can see in the case of Cisco that ICT equipment contributes to get closer to some PBs. To what extent do their environmental strategies contribute to offset them? This is not demonstrated by the firm and casts serious doubts on the effectiveness of its environmental actions. Using PBs might help the firm provide more robust evidence of its negative environmental impacts and increase the legitimacy of the actions taken up to reduce them.

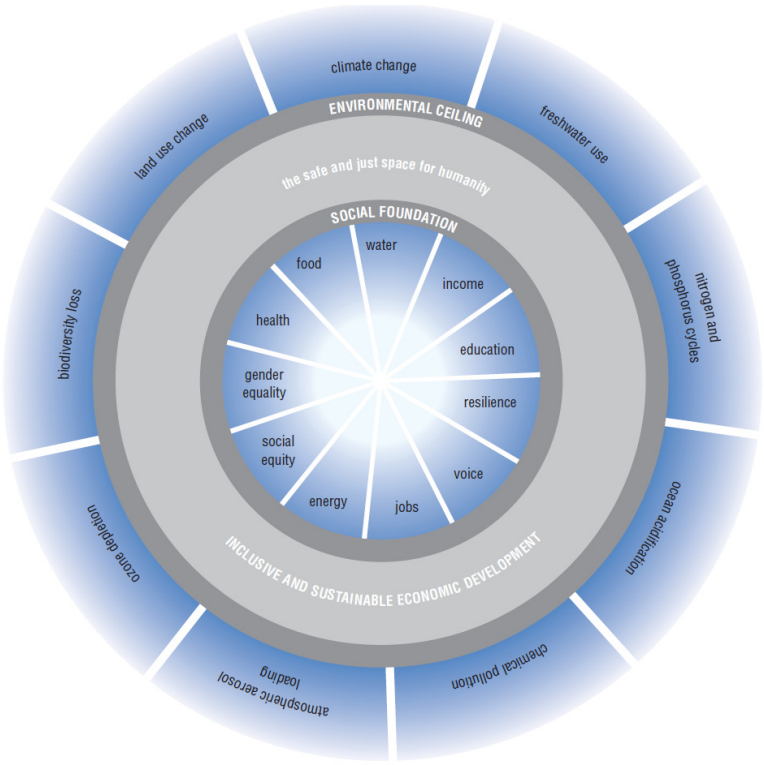
6. Conclusion

We have argued in this paper that PBs could help ICT firms better contribute to the ecological transition of human societies. ICT firms can do so in two ways: by ensuring the ecodesign of their own products and services, and by providing environmental services such as the ones allowing us to monitor our environment. In order to examine how ICT firms could use PBs in their environmental policies, a method has been suggested, which would require to analyse the PB-relevant aspects of the environmental reports of those firms. But current environmental management tools may not be adapted to integrate PBs. An attempt to translate PBs into firms'

[23] See http://csr.cisco.com/pages/csr-reports.

environmental management systems was done by Hörisch et al. (2015). They used variables on waste production (mass of waste produced in tons divided by net sales) and material consumption (mass of materials used in tons divided by net sales) as proxies for these dimensions of environmental pollution. This attempt suggests that it is possible to use PBs to strengthen the contribution of the ICT sector to planetary resilience, but that many challenges remain to do so. Last but not least, among the critics made to the PB concept, if PBs are important for the very survival of human beings, social boundaries are also important for our current well-being… on this aspect, Leach et al. (2012) have proposed the following figure worth discussing among management scholars.

Figure 8. Social and planetary boundaries



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