WBGU

German Advisory Council on Global Change

Policy Paper

Human Progress within Planetary Guard Rails

A Contribution to the SDG Debate

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Summary

The year 2015 has special importance for the transformation towards sustainable development. New Sustainable Development Goals (SDGs) are then supposed to replace the Millennium Development Goals (MDGs). The aim is to offer a new orientation for political action in the coming decades. The WBGU recommends orienting the new catalogue of goals towards the key message of the 1992 Earth Summit: that development and environmental protection must be considered together and do not contradict each other. The SDGs should not be reduced to poverty eradication, but must address all dimensions of sustainable development. In particular, global environmental change must be incorporated, otherwise even poverty eradication will become impossible. Up to now, too little attention has been paid to this link in the ongoing discourse on SDGs. Although many reports mention the concept of planetary guard rails or planetary boundaries, they do not back this up with specific targets. The WBGU presents recommendations on how guard rails for global environmental problems should be incorporated in the SDG catalogue and operationalized by means of corresponding targets.

The political context

There are currently three obstacles to an international agreement on ambitious SDGs that also integrate the guard rail approach: (1) Many players misunderstand the guard rails as restrictions on future development. (2) An 'unholy alliance' of many OECD and newly industrializing countries would like to prevent goals being agreed that go beyond direct poverty eradication and also impose obligations on them. (3) International cooperation to preserve the global commons is currently stagnating. Against this background, the WBGU argues as follows: (1) Guard rails do not restrict development for the poorest. (2) Rather, compliance with the guard rails is a necessary prerequisite for poverty eradication and development. (3) The consumption decisions and lifestyles of the middle and upper classes are currently making the biggest contribution to the causes of global environmental problems. Their consumption decisions and lifestyles should be transformed in a sustainable direction. (4) Furthermore, guard rails highlight the need for international cooperation and coordination by means of global governance to protect global common goods. Humanity must therefore find ways to achieve human progress within the planetary guard rails. The WBGU sees this as a learning process for civilization.

Global environmental change

The scale of human-induced global environmental problems such as climate change, loss of biodiversity and land degradation threatens to cause intolerable and irreversible damage, which could profoundly interfere with the structure and identity of societies as well as undermine the livelihood of future generations. Global society must therefore limit the anthropogenic changes to the Earth system for the sake of its own future. For this reason, the SDGs are not an agenda 'exclusively for developing countries'; rather, they should apply to all states. Only in this way can curbing global environmental change become a joint task for humankind.

A neutrality concept for safeguarding Earth system services

The WBGU has developed the concept of 'planetary guard rails' to limit global environmental change. Guard rails are defined as damage thresholds whose transgression would have intolerable consequences either today or in the future. When guard rails are transgressed, the maintenance of natural life-support systems is put at risk, and with it poverty eradication and sustainable development. The development progress that has been made in the context of the MDGs would also be jeopardized. The WBGU counters this threat with its neutrality concept for safeguarding Earth system services: the development paths should be diverted in a way that prevents the planetary guard rails from being transgressed. This neutrality vis-à-vis the guard rails is a necessary condition for sustainable development and poverty eradication. Vice versa, however, the guard rails in no way hinder the implementation of the development goals that state that all people should be given access to food, safe water and sustainable energy. This neutrality concept can only be implemented if global disparities are reduced, the ecological footprint of the global middle and upper classes is reduced, and the economic elites gear their capital-investment decisions more towards compliance with the guard rails.

Guard rails as targets for the SDGs

Sustainable development must be oriented in such a way that it is neutral in relation to the guard rails and does not jeopardize Earth system services. To achieve this, the anthropogenic drivers of global environmental change must be stopped. The WBGU recommends adding an SDG concerning the planetary guard rails entitled 'safeguarding Earth system services'. Global, long-term targets should be allocated to this SDG for the following six global environmental problems. They involve stopping the anthropogenic drivers in order to keep the Earth system changes within tolerable limits. The WBGU recommends the following global long-term SDG targets for the 'guard-rail SDG':

1. *Climate change:* The warming of the climate system should be limited to 2°C. Global CO_2 emissions from fossil energy sources should therefore be stopped completely by about 2070.
2. *Ocean acidification:* In order to protect the oceans, the pH level of the uppermost ocean layer should not fall by more than 0.2 units compared to pre-industrial figures in any major ocean region. CO_2 emissions from fossil energy sources should therefore be stopped completely by about 2070 (congruent with Target 1).
3. *Loss of biological diversity and ecosystem services:* The human-induced loss of biodiversity and ecosystem services must be halted. Its direct anthropogenic drivers, e.g. the conversion of natural ecosystems, should be stopped by 2050 at the latest.
4. *Land and soil degradation:* Anthropogenic land and soil degradation must be halted. Net land degradation should be stopped by 2030 – worldwide and in all countries.
5. *Risks posed by long-lived and harmful anthropogenic substances:* The substitutable use of mercury and anthropogenic mercury emissions should be stopped by 2050. The release of plastic waste into the environment should be stopped worldwide by 2050. The production of nuclear fuels for nuclear weapons and nuclear reactors should be stopped by 2070.
6. *Loss of phosphorus:* Phosphorus is an essential resource for agriculture and therefore also for food security. The release of non-recoverable phosphorus into the environment should be stopped worldwide by 2050, so that its global recycling can be achieved.

National implementation

The aim of halting a global environmental problem by a specific date means that all countries, regions and sectors in society must stop their contributions to the respective anthropogenic driver. The WBGU proposes entrusting the specific UN environmental conventions with the detailed negotiations on implementing the guard-rail SDG to avoid duplication of structures and parallel negotiations. Under the conventions, all parties should develop transformation plans for implementing the SDG targets showing how the corresponding national target can be reached, what intermediate objectives would be involved, and what international transfer payments would be required. Taken together, the countries' contributions must suffice to comply with the corresponding planetary guard rail. The monitoring and review of the national formulation and implementation of these targets are therefore indispensable components of the SDG process.

The political context

"In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it."
Principle 4 of the 1992 Rio Declaration on Environment and Development

On the road to Sustainable Development Goals

In 2015 the foundations will be laid for the environmental and development policies of the next decades. At the UN Conference on Sustainable Development (UNCSD, the 'Rio+20 Conference') in 2012 it was decided to prepare Sustainable Development Goals (SDGs). The SDGs should be oriented toward the Agenda 21, the Johannesburg Plan of Action and the Rio Principles and guide future measures of sustainable development (UNCSD, 2012). The SDGs are political objectives of the international community, and as such they are of key, orientating importance for future global development in the direction of economic, social and environmental sustainability.

In 2015 a new development agenda is supposed to replace the Millennium Development Goals (MDGs). The MDGs are eight development goals to which the international community committed itself in 2000. Their core purpose is to overcome poverty. The MDGs have dominated the international discourse on development and given a clear and understandable direction to development cooperation. Their focus was on poverty eradication and investing in the basis for human development, e.g. health and education. The post-2015 process to draft the future development agenda has been initiated to ensure that there are global development-policy guidelines after the MDGs expire.

After the Rio+20 Conference and parallel to the search for a follow-up agenda for the MDGs, work on drawing up a proposal for a SDG catalogue (the SDG process) began. Unlike the MDGs, the SDGs are supposed to take into account all dimensions of sustainable development and be applicable for all states. The SDGs are to have the formal structure of 'goals', 'targets' and 'indicators'

Taking into account the agreements signed at the UN Conference on Environment and Development in Rio de Janeiro in 1992 (UNCED, 'Rio Earth Summit'), and the Rio follow-up conferences, in the view of WBGU the following requirements derive for the future SDGs: *First*, the SDGs should provide orientation and a focal point for all the activities of states and the UN system relating to sustainable development. *Second*, the SDGs should endorse existing international obligations and agreements and strengthen their implementation. *Third*, they should generate new impetus for existing processes and negotiations. *Fourth*, the SDGs should point out emerging challenges and uncover institutional flaws and gaps in knowledge.

Since 2013 an Open Working Group (OWG) has been negotiating a proposal for a SDG catalogue to be submitted to the UN General Assembly in September 2014. It is becoming clear both within the OWG and in the international debate that the majority of the states want the SDGs to focus on the eradication of poverty. This would mean that environmental objectives, especially with a view to global environmental change, are under-represented or omitted entirely. In spring 2014, key themes were proposed in the OWG as a basis for further discussion, but only few of them relate to global environmental problems (UN, 2014).

At the Special Event on the Post-2015 Development Agenda held in September 2013, the UN General Assembly cleared the way for a convergence of the initially separate post-MDG and SDG processes. The aim is to combine the two processes in a shared catalogue of goals. However, it is currently still uncertain whether and how this can be achieved. A report by the UN Secretary-General is expected in autumn 2014 containing all the official UN contributions to the post-2015 development agenda, including the OWG's report on the SDGs. The outcome document of the Special Event schedules the beginning of intergovernmental negotiations on the converged post-2015 development agenda for September 2014. In September 2015 the post-2015 development agenda, including the SDGs, is supposed to be passed by the UN General Assembly.

SDGs and planetary guard rails

In the WBGU's view, the only meaningful way forward is a single catalogue of goals on sustainable development that is equally valid for all states. Poverty eradication remains indispensable and should definitely be included in the catalogue of goals. However, long-term poverty eradication will be made more difficult unless the SDGs also cover environmental problems.

The Rio Earth Summit in 1992 already gave out the clear message that protecting the environment is the prerequisite for sustainable development and essential for poverty eradication (UNCED, 1992). The scientific findings of the last two decades make it even more urgently clear that, in view of the risks of the globally observable, advancing danger to the natural human life-support systems, the integration of environmental protection and development is indispensable. Even so, environmental problems have played a subordinate role within the framework of the MDGs that are valid up until 2015. Now, the preparation of the post-2015 development agenda offers an opportunity to take up the message of the Rio Earth Summit again and to agree worldwide on integrated objectives for sustainable development with the SDGs.

From the WBGU's point of view, it is therefore essential not only that the primarily local and regional environmental problems (e.g. air pollution) are included in the SDGs, but also that global environmental problems (e.g. climate change, land degradation) are taken into account in the form of guard rails. Guard rails are quantitatively definable threshold levels of damage beyond which human-induced global environmental problems have changed the Earth system to an extent that the consequences are intolerable (WBGU, 2011). It no longer makes sense to lay down global goals for sustainable development without taking planetary guard rails into account, since the scientific evidence shows that global environmental change involves considerable risks to the conservation of humankind's natural life-support systems. The concept of 'planetary boundaries' proposed by Rockström et al. (2009a, b) is very similar to the WBGU's concept of guard rails, and the same challenges to global governance can be deduced from them for the SDGs.

Development must remain within the guard rails. This is a precondition for maintaining the basis of human development in the long term and for the SDGs as a whole to be a success.

Guard rails in the SDG discussion

Several important reports and papers that have been submitted in the preparation of the SDGs and the post-2015 development agenda refer, at least in their introductions or preambles, to global environmental change or planetary boundaries (UNGSP, 2012; EU Council of Ministers, 2013; EU Commission, 2013; UN, 2013; Rockström et al., 2013; German Federal Government, 2014). However, there are very few substantive discussions of their importance for the SDGs. There are no concrete proposals systematically developing the guard rail approach in the context of the SDGs.

The Sustainable Development Solutions Network (SDSN) emphasizes that all countries have a right to a form of development that respects the planetary boundaries (UN SDSN, 2013a) and proposes ten priorities for SDGs. Although the SDG 'Development in the Context of Planetary Boundaries' proposed by the SDSN explicitly refers to the concept in the title, it does not integrate it in a comprehensive way, nor does it suggest any quantitative, global targets. It only demands that countries report on how they influence global environmental problems. Another SDG in the SDSN's proposal mentions the 2 °C guard rail for climate change, and two others relate to global environmental problems – implicitly in the context of agriculture and biodiversity. But the corresponding guard rails are neither explicitly mentioned nor operationalized. Ocean acidification is mentioned, but not defined as a guard rail. Griggs et al. (2013) propose six SDGs, and in this context they also refer to the 2 °C guard rail for climate protection and a guard rail for biodiversity.

One positive element of the discourse is that global environmental problems such as climate change, biodiversity loss, and land and soil degradation in particular are mentioned, in some cases even with the related guard rails. By contrast, other global environmental problems – for example ocean acidification, the risks posed by long-lived and harmful anthropogenic substances and products, and the finiteness of phosphorus – are only mentioned in a cursory fashion or not at all. To date, therefore, there are no proposals for the SDG catalogue that comprehensively incorporate and operationalize the guard rail approach.

Against this background, the WBGU proposes integrating six guard rails as SDG targets for the most urgent global environmental problems into the catalogue of SDGs under the title 'safeguarding Earth system services' (Table 1, p. 20):

1. Limit climate change to 2 °C,
2. Limit ocean acidification to 0.2 pH,
3. Halt the loss of biodiversity and ecosystem services,
4. Halt land and soil degradation,
5. Limit the risks posed by long-lived and harmful anthropogenic substances,
6. Halt the loss of phosphorus.

In its paper 'Key Positions of the German Government' on the post-2015 development agenda, the German government advocates an agenda for sustainable development that takes planetary boundaries into account and proposes thirteen exemplary policy goals; they refer inter alia to the 2 °C guard rail and the Aichi Targets of the Biodiversity Convention (German Federal Government, 2014). In the present paper, the WBGU develops this approach further and presents a neutrality concept for safeguarding Earth system services with the aim of preventing a transgression of the planetary guard rails.

Obstacles to, and prospects of, ambitious and universal SDGs

Three obstacles can currently be identified on the road to an international agreement on ambitious and universal SDGs that systematically incorporate the guard rail approach:

- *Resistance to restrictions:* Despite frequent rhetorical recourse to the guard rail approach, many state and non-state players reject the quantification and operationalization of guard rails, since they ultimately misinterpret them as restrictions on future development opportunities.
- *'Unholy alliance' against goals that go beyond direct poverty eradication:* The OECD countries and newly industrializing countries focus their future development goals primarily on the less and least developed countries. Highly commendable as ambitious action to fight poverty is, this focus means that the OECD and newly industrializing countries do not want to agree any goals that apply to all countries and also impose obligations on themselves. The less developed countries are also satisfied with a focus on poverty eradication, because they hope this will lead to financial inflows. At the same time, developing and newly industrializing countries are resisting a 'greener' development agenda and insisting on separate agendas for development – in the sense of poverty eradication – and environmental protection.
- *Political barriers to global cooperation:* Little progress is currently being made in global politics. For example, the global climate negotiations and the current round of world trade talks are stagnating. Many observers see the eastward and southward shift of power from the transatlantic axis as one of the major hurdles for global cooperation. The old powers of the West and the up-and-coming newly industrializing countries are getting caught up in power games instead of facing the global challenges together. Pessimists fear that, given the global power vacuum and the decline in the importance of old hegemonic powers, the global power shift is leading to a situation in which fewer and fewer states feel responsible for the global commons. The concern is that another multilateral process – the post-2015 development agenda – might fail.

Against this background, the WBGU advocates an international agreement on ambitious and universal SDGs:

1. Taking planetary guard rails into account does not mean any restriction on the future development of the poorest. Development and guard rails are not contradictory. Rather, the goals of human development for the poorest approx. 2 billion people – in the form of targets for education, health, and access to food, energy and housing – can be achieved with a form of global development that complies with the guard rails. Guard rails are normative 'road signs' or 'boundary conditions' of development.
2. All states must comply with guard rails as a prerequisite for poverty eradication and development. Human activity can have far-reaching consequences for the Earth system, which in turn can have serious consequences for human societies. The prerequisite for future development is that humanity's supply of Earth system services is not jeopardized – i.e. that no planetary guard rails are transgressed. This implies two things. The first is that compliance with the guard rails, e.g. by climate protection, is necessary for successful poverty eradication. Global environmental problems, such as climate change or the loss of biodiversity, harm especially the vulnerable poor sections of the population in developing and newly industrializing countries (WBGU, 2005). If guard rails are transgressed, for example through the loss of fertile soils, some of the successes of poverty eradication could lapse and positive trends be reversed. The second aspect is that, if the guard rails were transgressed, the emerging middle and upper classes in developing and newly industrializing countries, as well as in OECD countries, would also be adversely affected by global environmental change, e.g. by climate impacts like rising sea levels or extreme weather events.
3. Consumer choices and lifestyles of the global middle and upper classes are currently contributing most to the transgression of the guard rails; this is undermining the basis for the future development of all people. In the past, the middle and upper classes were primarily to be found in the OECD countries, but now they are growing much faster in the emerging economies than in industrialized countries. Transformation makes the greatest demands on the global middle and upper classes, since they consume the most resources as a result of their high incomes; they also have the largest ecological footprint. Their current consumption patterns cannot be universalized for all people. In order to prevent the planetary guard rails from being transgressed, the effects of non-sustainable consumption by the global middle and upper classes in particular and the corresponding production patterns must be transformed and made more sustainable. There are already signs of

relative decoupling between economic growth and resource consumption in some areas, although this is often partly offset by increased consumption (rebound effect; WBGU, 2011: 175). Politicians have a responsibility here: to create adequate conditions that will encourage sustainable production and consumption patterns – by establishing governmental and intergovernmental frameworks and drafting suitable policies. A combination of regulative legislation and market-based instruments should be used to create incentives encouraging producers and consumers to take the guard rails into account. At the same time, there should be a greater critical focus on individual consumption choices to make individual action more likely to support such policies. Initial signs of more sustainable actions by the middle and upper classes should be taken up and reinforced by policy-makers.

4. Guard rails highlight the need to gear state protective measures towards global sustainability goals in order to permanently maintain Earth system services and global commons. Global commons, such as the atmosphere or the oceans, cannot be protected by national measures alone. In order to secure Earth system services, the international community must bear responsibility together. Guard rails therefore underline the need for global cooperation and coordination through global governance. The SDGs should serve as the international community's global goals for sustainable development. The protection of the Earth system by the global community is one of humankind's greatest challenges in the 21st century. Developing institutions to protect the Earth system – and the SDGs can contribute to this – represents a major challenge for cultural civilization.

Humanity must therefore find ways to achieve prosperity, democracy and security – and thus human progress – within the planetary guard rails. The WBGU regards this as a learning process for civilization.

Overall societal conditions for complying with the guard rails

If the guard rails are to be complied with and the neutrality concept implemented, certain overall societal conditions must be created and observed that are closely connected with the world's considerable socio-economic disparities and distribution problems. Absolute poverty must be eradicated. The necessary advances in development and income, and the increase in resource consumption by poorer sections of the population that this initially entails, can only be brought into line with the guard rails in the long term if, at the same time, the ecological footprint of the global middle and upper classes is considerably reduced and economic elites orient their investment decisions to the planetary guard rails.

In order to prevent the guard rails from being transgressed, the global middle and upper classes in particular, i.e. the better-earning half of the world's population and especially the wealthiest fifth of humanity, must take the requirements of sustainability more into account in their consumption choices. Otherwise, the scope for development will be rapidly eroded by the overuse of natural resources.

There are three approaches to transforming production and consumption patterns: *First,* the ecological footprint should be lessened by resource-friendly patterns of production and consumption and by improved resource efficiency. *Second,* new welfare models should be developed. The challenge here lies in developing a new, democratically legitimized welfare model that can be universalized within the guard rails for 9 billion people by 2050. *Third,* attention should focus more on the problematic, negative consequences of non-sustainable consumption in order to contribute towards the social recognition and promotion of sustainable lifestyles. Consumption according to the prevailing, non-sustainable patterns cannot be transferred to large sections of the world's population without undermining the basis for the future development of all people. At the same time, these consumption patterns are currently spreading among the growing global middle classes of the OECD and newly industrializing countries, and these are set to more than double in size from currently about 2 billion to almost 5 billion people by 2030 (Kharas, 2010).

The 85 richest people in the world own as much wealth (approx. US$1,700 billion) as the 3.5 billion poorest people; they also have enormous political and economic power, which is not democratically legitimized (Fuentes-Nieva and Galasso, 2014). This economic elite's power can limit humanity's chances of complying with the guard rails and implementing the neutrality concept. The challenge here is not so much the private consumption of these individuals and other members of the global upper class, as their power to direct investment decisions. These decisions have a huge effect on society, and if they were geared towards the guard rails they could make a decisive contribution to their adherence.

Reducing the disparities outlined here is the overall societal prerequisite for the long-term and robust implementation of the neutrality concept and can only be achieved if the wealthy global middle and upper classes embrace a more sustainable lifestyle, and if the living conditions of those living in absolute poverty can be improved. By focusing on poverty eradication, the current SDG discussion is one-sided in the way it reflects the problem of global disparities. It is therefore falling short of the mark in two respects: neither the ecological dimension of sustainability (and particularly the global environmental problems) nor global inequalities are properly integrated into the SDG discussion.

In the present policy paper, the WBGU highlights the global environmental problems and the impacts of human action on the global commons. It does not make recommendations for a full catalogue of SDGs that takes all environmental and development dimensions into account. Rather, it focuses on global environmental change, on a proposal for integrating and operationalizing the planetary guard rails into the SDGs, and on the decisive role of the guard rails in poverty eradication and development.

The aim in highlighting the planetary guard rails is to emphasize the global nature of many pressing environmental problems, to direct the attention of politicians and the public towards these environmental challenges, and to reveal possible solutions. The WBGU stresses that all countries need to transform in order to remain within the guard rails (WBGU, 2011). The SDGs should therefore be directed at all countries, irrespective of their level of development. Germany and the European Union also have considerable development needs with regard to ecological, economic and social sustainability.

A neutrality concept for safeguarding Earth system services

"States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem."
Principle 7 of the 1992 Rio Declaration on Environment and Development (1st sentence)

The Anthropocene and global environmental change

Humanity's impact on the natural environment has grown increasingly with the development of civilization, gradually reaching a global dimension since industrialization. About half of the Earth's land surface has been transformed and about a quarter of the biomass produced there is used by humans (IPCC, 2007). The oceans, too, are today in a much worse state than they were just a few decades ago – as a result of overfishing, coral-reef destruction and pollution (WBGU, 2013: 39ff.). In consequence of the large-scale transformation of nature, there is a threat of a man-made, global species extinction that could reach proportions comparable to the previous five major extinction events in the Earth's history, which were probably related to large-scale changes in the Earth system (e.g. volcanism, climate and sea-level changes, asteroid impacts; WBGU, 2001a: 3; Barnosky et al., 2011).

There are also profound changes in the Earth system's material flows. For instance, nitrogen turnover has approximately doubled in the course of the last century, mainly because of artificial fertilization with nitrogen (Galloway et al., 2004). This has serious, negative consequences for biodiversity and ecosystem services. Not least the anthropogenic emissions – mainly by the combustion of coal, mineral oil and natural gas – have increased the concentration of CO_2 in the atmosphere by 40% (IPCC, 2013). This has not only led to the acidification of the oceans – with acidity rising by almost a third, seriously threatening the marine ecosystems – it has also triggered global climate change which is threatening to overstrain the ability of humans and nature to adapt (WBGU, 2011: 35ff.).

Human beings have thus become a significant force for change within the Earth system (Vitousek et al., 1997; Ehlers, 2008). Paul Crutzen and Eugene Stoermer have proposed regarding this massive anthropogenic influence as the beginning of a new geological era, which they refer to as the Anthropocene (Crutzen and Stoermer, 2000).

The Earth system and human civilization have become a closely coupled system, with humanity using resources and services of the Earth system (Earth system services; Gifford et al., 2010; Steffen et al., 2013) that are indispensable for present and future sustainable development.

Much of the human-induced environmental change is not only having a formative influence on the Earth system; in the meantime it is also threatening to reach a dimension at which severe damage to ecosystems, Earth system services and societies is inevitable. The WBGU calls this *global environmental change*, "to refer to those changes that modify, sometimes irreversibly, the characteristics of the Earth as a system and that, therefore, have a noticeable effect, either direct or indirect, on the natural life-support systems for a major proportion of human beings" (WBGU, 1994:9).

The beginning of the Anthropocene also marks the beginning of a new era of responsibility (WBGU, 2011:31ff.). Global society must limit anthropogenic changes to the Earth system for the sake of its own future, if the damage to human societies is to remain tolerable. In the age of the Anthropocene, sustainable development is no longer possible without taking the impact of human activities on the Earth system into account. Ever since the Earth Summit in Rio de Janeiro in 1992, international environmental policy has been trying to do justice to this responsibility and to curb global environmental change.

To some extent, the scientific debate on the Anthropocene is already being reflected in political discourse. But although the term is adopted and the problem is addressed, the resulting consequences – i.e. changing the direction of societies and economic processes as described by the WBGU in its 2011 report 'A Social Contract for Sustainability' (WBGU, 2011) – have been largely ignored to date.

The WBGU's guard rail concept

The WBGU's concept of 'planetary guard rails' stems from the need to limit human-induced global environmental change. The WBGU has proposed the following definition: Guard rails are "quantitatively definable damage thresholds whose transgression either today or in future would have such intolerable consequences that even large-scale benefits in other areas could not compensate these" (WBGU, 2011: 32).

A transgression of the guard rails puts humanity's natural life-support systems at risk and should therefore be anticipated and prevented. Beyond the guard rails begins the area where anthropogenic global environmental change represents a risk that is no longer acceptable to society and would overburden the ability of societies to adapt. For example, unabated climate change would entail considerable risks, e.g. from extreme weather events, reduced food production or considerable sea-level rise. The target of limiting global warming to less than 2 °C (Annex A.1) was agreed as a 'decision' by the parties to the Framework Convention on Climate Change (UNFCCC).

The guard rails thus define the ecological framework within which sustainable development is possible. If a breach of one of the guard rails looks imminent, societies should react in time with a forward-looking sustainability policy to make sure the necessary change of course can be made without unacceptable breakdowns and costs (WBGU, 2011:32). If a guard rail has already been transgressed, measures must be taken to return 'in front of' it. The guard rail concept offers orientation for both cases.

Compliance with the guard rails is a necessary condition for sustainable development. But it is not a sufficient condition in itself, because global environmental change can cause considerable ecological damage and socio-economic ills even without transgressing guard rails. Furthermore, the guard rails remain subject to uncertainties, since our knowledge of global environmental problems and Earth system relationships is limited, so that misjudgements are possible. Advances in knowledge about the dynamics and tipping points of the Earth system and the impacts of global environmental change can make it necessary to adjust guard rails.

The WBGU quantified global guard rails first for anthropogenic climate change (WBGU, 1995b, 1997) and later also for other global environmental problems such as soil degradation (WBGU, 2005), biodiversity loss (WBGU, 2001a) and ocean acidification (WBGU, 2006).

Rockström et al. (2009a, b) have introduced a similar concept under the term 'planetary boundaries'. They postulate that human activities destabilize critical biophysical systems and can trigger abrupt or irreversible environmental change at the continental or global level which can have harmful or even catastrophic consequences for human beings. The core of the argument is that human civilization developed during the Holocene, i.e. approximately over the last 11,700 years (Walker et al., 2009), a geological phase with relatively stable environmental conditions. Leaving this environmental space would be tantamount to transgressing the planetary boundaries and involve unacceptable risks for humanity (Rockström et al., 2009b). It might lead to tipping points of the Earth system (e.g. instability of the Greenland ice sheet, monsoon transformation; Lenton et al., 2008; WBGU, 2009: 13) being reached, triggering non-linear, abrupt changes; or else gradual, continuous changes might lead – cumulatively over long periods – to damaging effects which are no longer acceptable beyond a certain dimension. Despite some differences in approach and certain details, the two concepts of WBGU and Rockström et al. (2009a, b) are similar, and the same challenges to global governance can be inferred from both.

Irrespective of the dynamics of environmental change, quantifying guard rails or boundaries constitutes setting a norm, since drawing the borderline between tolerable and intolerable changes is a decision based on value judgements. The scientific community should submit well-reasoned proposals for this purpose, but the actual fixing of the boundaries should then be carried out on this scientific basis by politicians in a democratic decision-making process (WBGU, 2011: 32).

The WBGU has illustrated the guard rail concept using an analogy with road traffic: "Guard rails have a function similar to that of speed limits, e.g. a limit permitting a maximum of 50 km per hour in built-up areas. The outcome of setting the limit at 40, 50 or 60 km per hour can be determined empirically, but in the final analysis the choice of figure is a normative decision, representing an expedient way to handle a risk collectively. Compliance with the speed limit cannot guarantee that no serious accidents will occur, but it can keep the risk within boundaries accepted by society" (WBGU, 2006:6).

The planetary guard rails can be divided into three types. The decisive criterion here is whether there is a direct or accumulating global effect that must be regarded as a danger to sustainable development.

1. *Guard rails for the use of global commons:* In this case, anthropogenic influences disrupt a globally relevant

part of the Earth system, so that indispensable Earth system services are put at risk. For example, emissions of greenhouse gases or CFCs change the composition of the atmosphere to such an extent that they lead to global environmental problems such as climate change or the depletion of the stratospheric ozone layer.

2. *Guard rails for accumulating regional environmental problems:* The totality of very differently distributed local and regional effects or forms of damage caused by anthropogenic influences (e.g. by land degradation, conversion of natural ecosystems, biodiversity loss) can have globally relevant effects on humanity. This also includes emissions of toxic substances such as persistent organic pollutants (POPs) or mercury, which in some cases spread globally and can have highly damaging effects on humans and nature by accumulation in organisms (Annex A.5).
3. *Guard rails for non-renewable and non-substitutable resources:* These guard rails are designed to ensure that the supply of humanity with non-renewable and non-substitutable, yet indispensable Earth system goods is maintained. Depletion of these resources poses a direct threat to the sustainable development of humanity. A useful example here is agriculture's supply of the essential plant nutrient phosphorus, which is indispensable for ensuring a sufficient production of biomass (Annex A.6). The known resources and reserves of phosphorus are limited and only present in concentrations worth mining in a small number of deposits.

The guard-rail approach offers policy an orientation and defines the framework within which political targets should be set. Without the guard-rail perspective, the full significance of global environmental issues (and the global dimension of local environmental problems) is not grasped or given enough weight in science and policies. It is therefore of great benefit for both national and global environmental policy to quantify the limits of the Earth system and to visualize the limits of adaptability (e.g. of ecosystems or infrastructures for agriculture, transport or housing). Furthermore, the guard-rail approach underlines the fact that certain forms of environmental damage can only be avoided with a global approach and by uniting the efforts of all those who cause the damage. Whenever local environmental effects develop a global reach, a solution becomes difficult without involving global governance.

Guard rails and sustainable development are by no means contradictory; on the contrary, they are mutually supportive (WBGU, 2011:34). Despite important successes in environmental protection, humanity is currently on a collision course with some of the planetary guard rails, and in some cases has already transgressed them. In its report 'A Social Contract for Sustainability', the WBGU argues that a fundamental change in the economy and society is therefore necessary in order to protect the natural life-support systems and the future prospects of humanity by keeping within the guard rails (WBGU, 2011:35). The WBGU has investigated this transformation by studying the example of anthropogenic climate change and comparing its extent and range with that of the Industrial Revolution. One conclusion is that the transformation means a paradigm shift from a fossil-based to a post-fossil society, which not least involves considerable challenges to global governance (WBGU, 2011:9).

Guard rails and poverty eradication

Transgressing guard rails jeopardizes poverty eradication

Transgressing guard rails and the related loss of Earth system services particularly hurts the poorer sections of the population in the newly industrializing and developing countries and hampers their development. The following three examples illustrate the impact of environmental change on absolute poverty (WBGU, 2005):

- *Land degradation:* Land and soil degradation mean lower soil fertility and a loss of agriculturally useful land, biodiversity and water resources. All this affects the natural conditions for local agricultural production, endangers livelihood security, and promotes food insecurity and absolute poverty.
- *Climate change:* Although the changing climate is a global phenomenon and problem, the negative impact on poor people, and developing and newly industrializing countries, is particularly severe, because they are the most vulnerable and more dependent on natural resources. Furthermore, for lack of available resources they are less able to adapt to climate fluctuations or extreme weather conditions (IPCC, 2014a; WBGU, 2005:65).
- *Loss of biodiversity and ecosystem services:* For many rural communities in developing and newly industrializing countries, natural ecosystems and their biological diversity are simultaneously a kind of the supermarket, DIY store, drugstore and pharmacy all in one (WBGU, 2005:80). In addition to food, safe drinking water, wood and fibres, natural ecosystems also offer genetic resources of plants and animals, traditional medicines, as well as jewellery and sacred objects.

Compliance with the guard rails does not hinder poverty eradication

Taking planetary guard rails into account does not impair poverty eradication. There is no contradiction at all between poverty eradication and environmental protection; rather, environmental protection is the precondition for fighting absolute poverty and for sustainable development (WBGU, 2005). Achieving the MDGs, or the SDGs developed from them – e.g. for education, health and participation, as well as for access to food, energy, housing, water supply and sanitation – does not collide with the planetary guard rails. This will be shown in the following analysis of the access targets for food and energy.

- *Food security:* The WBGU studied the amount of agricultural land needed for food production to cover the global demand for food in its 'Future Bioenergy and Sustainable Land Use' report (WBGU, 2010). In order to determine global, sustainable bioenergy potential, a vegetation model was used to calculate the amount of land that was potentially available. The sustainability criteria used in the report included both the guard rails on climate protection, biodiversity conservation and soil protection, and – on the socio-economic side – the access targets on food, energy and health. To indicate uncertainties in relation to future dietary habits and food needs, a stable or rising demand for land for food production was assumed. All the resulting scenarios revealed potential areas of land for sustainable bioenergy generation, albeit small ones in some cases. It follows that covering the global demand for food can be fundamentally consistent with global guard rails. Further taking into account the fact that around 70% of the world's agricultural land is currently used for livestock farming (Steinfeld et al., 2006), it follows that if there were a transition to a diet that is less based on meat and other animal products, additional land would become available for a plant-based diet. Approximately a third of the food produced worldwide spoils, is lost or discarded (FAO, 2011). Further land could be released if this very high rate could be reduced. As is already the case today, in the future the greatest challenges also appear to lie not in the area of production, but in the field of equity in distribution and the use of produced biomass.
- *Energy:* Securing access to sustainable energy services for all people in accordance with the initiative of the UN Secretary-General Ban Ki-moon (Sustainable Energy for All: SE4All, 2014), and the increases in emissions this involves, is compatible with long-term compliance with the 2°C guard rail if it is embedded in comprehensive climate protection (Rogelj et al., 2013). The provision of modern energy services primarily means access to electricity and to modern, clean fuels for cooking and heating. The Global Energy Assessment (GEA, 2012) and Pachauri et al. (2012) come to the conclusion that the effects on the climate of safeguarding access to energy for all people are negligible or even negative. This even applies if access is achieved completely with fossil fuels, because the energy sources would for the most part replace traditional uses of biomass, which involves considerable emissions of greenhouse gases and radiatively-active substances.

A neutrality concept: from guard rails to targets

Incorporate planetary guard rails into the SDG list of targets

Compliance with planetary guard rails requires global cooperation between states, because the cause, effect and solution of global environmental problems take place on different scales. Although global environmental problems have local causes, they have global reach and can affect all people, albeit to different degrees. Furthermore, all states contribute to global environmental change to a greater or lesser extent, so all countries must make a contribution to solving these problems. For example, in order to limit climate change, all states must switch to a CO_2-emission-free economy in the medium term, because otherwise the climate-protection guard rail would be transgressed by the further accumulation of CO_2 in the atmosphere. This can only succeed if burdens are shared worldwide, so global governance has a crucial role to play.

Against this background the WBGU recommends embedding the guard rail concept into the SDG catalogue of targets. First, this would highlight the existential importance of global environmental problems for sustainable development. Second, it would draw the attention of politicians and the public to the need for action. And third, it would open up solution paths. The WBGU recommends including a separate SDG with the title 'safeguarding Earth system services'. The aim of this 'guard-rail SDG' would be to define a framework within which the other SDGs, especially those on poverty eradication and human development, can unfold.

Take the neutrality concept into account in the SDGs

The challenge of a sustainability policy that is oriented towards planetary guard rails lies in designing development processes in a way that will preserve humanity's natural life-support systems. Sustainable development for a future total of 9 billion people can only take place within the framework defined by the guard rails (Box 1). For operationalizing purposes, the WBGU recommends a 'neutrality concept for securing Earth system services'

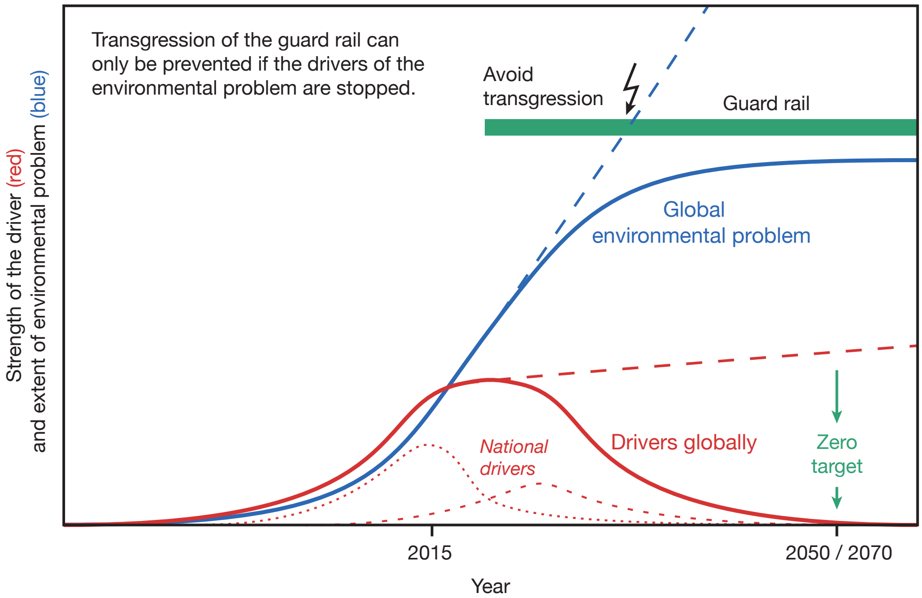


Figure 1
Schematic diagram of the relationship between drivers and the extent of global environmental problems (such as CO_2-driven climate change or anthropogenic biodiversity loss), in which the effects of the drivers accumulate over time. In order to stop such a global environmental problem (e.g. climate change or biodiversity loss; blue curve), so that the guard rail is not breached, it is necessary to globally reduce the drivers (e.g. CO_2 emissions or the anthropogenic extinction rate; red curve) to zero. This means that the drivers must also be reduced to zero in the individual countries (red dotted curves as examples of the development paths of two countries) – at the latest by the year in which the global drivers are supposed to have fallen to zero (2050 or 2070; SDG target). If the drivers are not reduced to zero worldwide, the global environmental problem continues to rise and the guard rail is crossed (dashed curves).
Source: WBGU

– to avoid the transgression of the planetary guard rails and to divert the paths of development accordingly. The idea behind this neutrality is to stop the anthropogenic drivers of global environmental change early enough to avoid the guard rail being transgressed (Figure 1). This concept therefore aims not to achieve a certain desired Earth system status, but rather to avoid non-tolerable Earth system statuses.

Two general strategies might be used for the political implementation of the neutrality concept:

1. *End the emission or production of persistent and toxic substances:* The anthropogenic release of persistent substances and products into the environment, the accumulation or decomposition of which puts people's health or the environment at risk, must be stopped in the long term. For example, decarbonization (i.e. the long-term phasing-out of CO_2 emissions from the use of fossil fuels) is indispensable for climate protection and for limiting ocean acidification, because CO_2 accumulates in the atmosphere.
2. *Protect natural resources and use them sustainably – the recycling economy:* When dealing with scarce, vital natural resources (e.g. soil, water, biodiversity, phosphorus), the focus should be on their role as life support for humanity. Handling these resources in a sustainable and wise way at all levels should become the maxim of human action. In the long term, the transformation towards a sustainable society also means a transition to a global recycling economy in which the required resources and materials are reused wherever possible.

For each guard rail, therefore, global, long-term targets should be introduced which include stopping the anthropogenic drivers of the respective form of global environmental change. For example, for climate and ocean protection there is a consensus among scientists that net CO_2 emissions from fossil sources must cease completely in the long term in order to comply with the 2 °C guard rail and limit ocean acidification (Annex A.1, A.2). In the field of biosphere protection there is already a scientific and political consensus that the loss of biodiversity must be stopped (Annex A.3); a comparable political objective is currently under discussion for net land degradation (Annex A.5). In the WBGU's view, emissions of persistent, anthropogenic substances that accumulate in the environment and have considerable hazardous effects on health or the environment should also be reduced to zero (Section A.4). With regard to phosphorus as a strategic resource, the WBGU proposes that the release of non-recoverable phosphorus should be stopped by 2050 (Annex A.6). Such 'zero targets' are also discussed in the context of development policy. For example, there are proposals to include targets in the catalogue of SDGs on reducing extreme poverty, hunger, infant and maternal mortality to, or close to, zero (UN SDSN, 2013a).

The WBGU recommends including a global long-term SDG target for each of the six guard rails (climate protection, biodiversity protection, etc.) under the title 'safeguarding Earth system services'.

National targets

All states should convert the global, long-term SDG targets into national targets. Neutrality towards a guard rail means that the corresponding anthropogenic driver of the global environmental change is stopped by the date specified in the SDG target. To achieve this, it follows that all countries, cities, regions and societal sectors without exception must stop contributing to the anthropogenic driver. The responsibility for this corresponds to the 'common' side of Principle 7 of the Rio Declaration on Environment and Development at the Earth Summit of Rio de Janeiro, according to which all states have "common, but differentiated responsibilities" towards the Earth's ecosystem (UNCED, 1992).

One key problem lies in the fact that the anthropogenic drivers of many global environmental problems are currently increasing worldwide, e.g. greenhouse-gas emissions, plastic-waste production and biodiversity loss. Along the road to the global, long-term SDG target, therefore, different national intermediate objectives are a sensible idea; they make it possible to achieve first a trend reversal and then reductions in the driver:

- *Trend-reversal target:* When global damage to the environment is still increasing, the first step must be a reversal of the trend. For example, both globally and nationally a reversal of the trend in greenhouse-gas emissions and in biodiversity loss must be achieved soon (WBGU, 2001a, 2009).
- *Reduction target:* After the trend reversal, the emissions and loss rates must be halved and subsequently reduced further, in order for the SDG target to be reached within the agreed time frame (e.g. a halving of emissions or loss rates).

These national intermediate targets must be reached on the future development path of the respective anthropogenic disturbance until the SDG target of zero is reached (Figure 1).

In the case of some guard rails, e.g. on CFCs or POPs (Annex A.5), emissions can be stopped with comparatively limited effort by substituting the pollutants in question or by spreading specialized technologies. Usually, however, the SDG targets relating to the guard rails imply phasing out the corresponding industrial processes or practices; these might be the use of emissions-intensive fossil energy sources, the conversion of natural ecosystems, or erosion-intensive industrial agriculture.

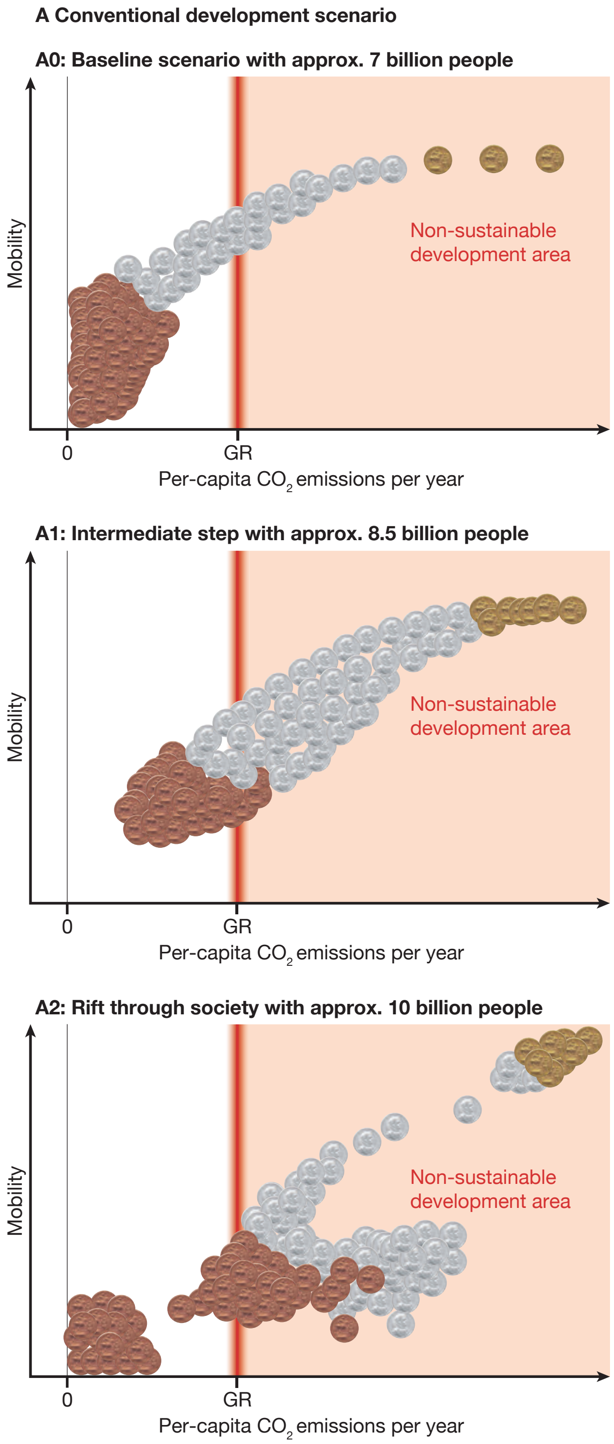
This interferes with deep-rooted, globally prevalent production and economic practices, which can only be modified with great effort and against a large amount of resistance. In order to change these production and business practices, long-term, strategically organized transformation processes are needed (WBGU, 2011) to design and create the global and national development paths on the road to the SDG target. Monitoring and reporting systems are of great importance for pursuing these development paths, in order, first, to make it possible to appraise the present situation, and then to scale the necessary changes according to requirements. National reporting obligations in the context of the review process of the post-2015 development agenda are therefore an important supplement to targets.

According to Principle 7 of the Rio Declaration, protection of the "health and integrity of the Earth's ecosystem" should, among other things, take into account the contribution of each country to global environmental degradation and its stage of development (UNCED, 1992). Depending on the characteristics of the underlying global environmental problem, it can therefore be useful to either lay down the national targets for all countries at the outset, or to differentiate them by groups of countries or individual countries.

This represents a considerable challenge for the SDG process, because negotiating country-specific targets takes time and requires extensive diplomatic efforts. In addition, it does not seem very efficient to hold detailed negotiations on national targets in the SDG process or the post-2015 process on environmental problems for which specialized UN conventions already exist. The WBGU considers it more sensible to find an appropriate framework for these global environmental problems within the SDG process in the form of the guard-rail goal entitled 'safeguarding Earth system services' and the longer-term, global SDG targets. Differentiation into national targets and their implementation should be left to the specialized UN environmental conventions or comparable international institutions.

Under the 'specialized' environmental conventions, the states parties should submit plans – in accordance with the respective global long-term SDG target – on how the respective national development path towards the common SDG target should be designed. There is thus more at stake than individual targets; rather, every country should develop a transformation roadmap that

Box 1
Schematic development scenarios



One coin represents 100 million people with a low, medium, or high income

GR: climate-compatible per-capita emissions (average between 2010 and 2050) in line with the planetary guard rail

Poverty eradication can only have a lasting impact within the planetary guard rails. The SDG entitled 'safeguarding Earth system services' aims to drive a transformation of development dynamics, in order to protect the natural life-support systems and with them the foundations of human progress. The charts compare a conventional (A) with a transformative development dynamic (B). In the transformative scenario, the dynamics of development unfold within the planetary guard rails. Mobility is used as an indicator of development, since access to transport also enables social mobility and stands indirectly for the availability of resources. Both scenarios make the same assumptions on population growth. The global distribution of gross domestic product is reflected in terms of purchasing power parity (PPP), as indicated by the different values of the coins.

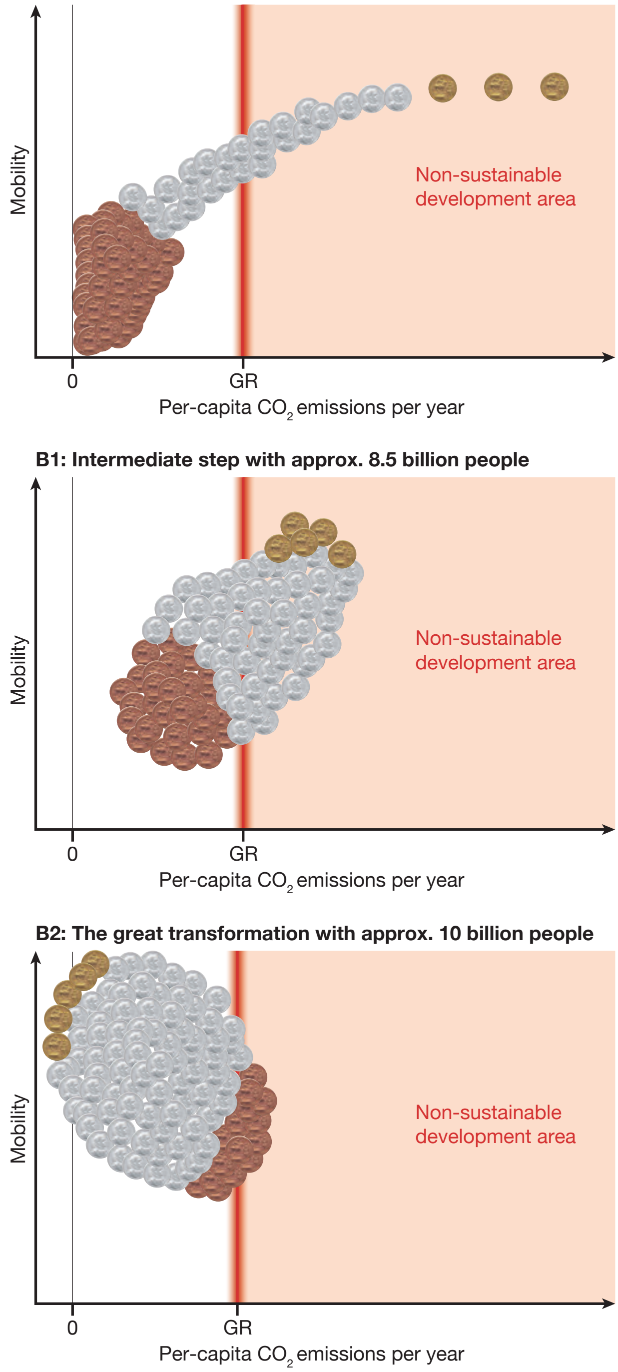
The initial state (A0, B0) is the present situation in each case. A relatively small number of people have a high level of development, are very mobile, and cause high emissions. Wealth, too, is very unevenly distributed among the world's population (20 % of GDP in PPP belongs to approx. 4.2 billion people, 60 % to approx. 2.5 billion, and 20 % to approx. 300 million; updated data from Grübler et al., 2012, and Nakicenovic et al., 1998). For example, the highly mobile population groups who cause high CO_2 emissions also own the most capital. The lower part of the figure symbolizes the bottom billion of the population, who hardly cause any emissions, are not very mobile and own no capital.

In scenario A1 an attempt is made to increase the mobility of successively more prosperous people and the lower income groups by means of conventional development and mobility concepts based on the combustion of fossil fuels. As a result, a growing proportion of the world's population would be pushed beyond the planetary guard rails. The higher the emissions of the prosperous sections of the world's population are, the less scope there is for the poorer sections of the world's population for a form of development intrinsically tied to emissions from fossil fuels within the planetary guard rails. A continuation of the present form of development dynamics (A1) without reacting to the resulting environmental damage would thus initially push ever larger proportions of the world's population beyond the guard rail, so that the CO_2 budget for global emissions would soon be exceeded (WBGU, 2009).

The massive transgression of the planetary guard rails caused by the emissions of the upper and middle income groups makes this development concept highly unstable, since the lower income groups in particular have no chance to adapt to changes in the Earth system. As a result, the economic disparities would be exacerbated in the

B Transformative development scenario

B0: Baseline scenario with approx. 7 billion people



One coin represents 100 million people with a low, medium, or high income

GR: climate-compatible per-capita emissions (average between 2010 and 2050) in line with the planetary guard rail

long term. In the second phase of this development (A2 with 10 billion people), therefore, there is a risk not only of falling back to the previous level of development, but also of a deeper rift between rich and poor. The conventional development dynamic (A1) is unable to maintain the growth of the global middle classes and simultaneously cope with challenges such as growing weather extremes or ocean acidification. The previous growth of the middle classes would thus be eroded by the concentration of incomes and capital in the upper income groups and growing poverty among the bottom billion people. The rift would run straight through the middle of society.

Scenario B shows a sustainable development within the planetary guard rails. Scenario B1: The lifestyles of the middle and high income groups are transformed and become sustainable, e.g. by electromobility. Furthermore, a change develops in the distribution of income between the countries as a result of financial transfers and the transfer of sustainable technologies. This enables the low income groups to gain access to development with lower emissions by leapfrogging non-sustainable energy technologies. In total, more people are mobile in scenario B than would be possible in scenario A in the long term. At the same time, neutrality towards the planetary guard rails enables the bottom billion to develop just as independently as the middle classes, since development is not slowed down by negative externalities of climate change.

In scenario B2 the upper income groups become more efficient in their mobility, since they have the broadest access to transformative technologies. They become pioneers of the transformation. This illustrates the fact that the groups with access to resources have a responsibility for the progress of a global transformation and for securing the Earth system services.

The aim is to promote a development scenario B by formulating and implementing the SDGs. To achieve this it is necessary to meet people's basic needs, such as mobility, food and housing, with sustainable development options. These must thus be more easily accessible for the bottom billion than the non-sustainable options. The chart shows that the SDG debate is also directed at the industrialized countries and the global middle and upper classes. They must transform their development paths towards sustainability to even make it possible for the world's population to move within planetary guard rails. Furthermore, by inventing and implementing sustainable paths of development, and by transferring finance and technology, they can help enable the poorer sections of the population to leapfrog non-sustainable development paths.

Source of charts: WBGU

is tailored to its national circumstances and potential. These plans should contain development paths as well as national trend-reversal or reduction targets. Furthermore, depending on the stage of development, the plans should transparently show what additional international financial and technology transfers will be made or are necessary for the country to achieve the transformation plan.

This would be equivalent to the 'differentiated' side of Principle 7 of the Rio Declaration, according to which all the states have 'common, but differentiated responsibilities' towards the Earth's ecosystem (UNCED, 1992). The development paths of the individual countries or groups of countries on the road to the SDG target will vary depending on their historical responsibility and capacity. However, it remains essential that all groups of countries, all countries, cities, regions and sectors of society must stop the anthropogenic drivers of global environmental problems within the envisaged timeframe.

The first message of the global SDG targets is thus that effective action is ultimately necessary and inevitable for all states. The second clear message that should come from the SDG process is that appropriate national targets should be negotiated within the framework of the specialized UN environmental conventions. If comparable targets have already been agreed there, they should be taken up in the catalogue of SDGs.

In cases where no specialized, competent international convention yet exists, a uniform national target should be set for all countries within the SDG process. An explicit call on countries to close this gap in governance could also be formulated under the mandate of the SDG process.

Monitoring, reporting and review

A thorough review of compliance with national transformation plans and targets should be agreed by the international community regarding the guard-rail SDG and the global, long-term SDG targets. The countries' contributions, taken together, must be sufficient to comply with the corresponding planetary guard rail. The global total of the solutions should thus follow a path that is consistent with the respective global SDG target and not have any technological or political inconsistencies. In order to match the national contributions with the respective global SDG target and to assess the effects at the global level, the reporting, review and verification of national contributions are essential. On a certain date, or on several predetermined dates, there should therefore be a review of national contributions and development paths within the framework of the SDG process. The reports should be scientifically evaluated using recognized standards and a transparent methodology in order to draw conclusions on global target achievement. The WBGU considers corresponding accompanying research to be very useful in this context. Should this review conclude that individual contributions, or the total contributions, are not sufficient, the diplomatic pressure on the countries to increase their contributions should be strengthened in the context of the SDG process.

Co-benefits among SDGs

The WBGU defines co-benefits as additional (positive) synergy effects, which are not actually part of the objective, that emerge when a political objective is achieved. If – as is the case with SDGs – a list of objectives is pursued, many co-benefits can arise which can mutually reinforce each other. Synergies can occur both between the different dimensions of global environmental change and between compliance with planetary boundaries and poverty eradication, e.g. the goals of access to food or safe water ('access goals'). For example, the 2 °C guard rail on climate protection is synergistic with the 0.2 pH guard rail on ocean acidification. These different objectives are discussed in the context of different time horizons (e.g. the connection between air pollution and health in the short term, and climate change in the medium to long term). For this reason they often 'compete' with each other for public or political attention (McCollum et al., 2013). Furthermore, different institutions are often responsible for individual objectives, both internationally and nationally. For this reason, synergies are often not well understood or even overlooked, with the result that the necessary costs and efforts are overestimated. An integrated approach is therefore essential, and the SDGs offer a suitable platform for this purpose.

One example of co-benefits is the aim of transforming the energy sector, which can be justified both by compliance with the 2 °C climate-protection guard rail and with the access goals for providing sustainable energy. Both objectives are mutually compatible to a certain extent, and each objective is supported by the measures taken to achieve the other. For example, Rogelj et al. (2013) come to the conclusion that implementing the objectives of UN Secretary-General Ban Ki-moon's 'Sustainable Energy For All' initiative (SE4all, 2014) is compatible with long-term compliance with the 2 °C guard rail, if the aims are embedded in a comprehensive system of climate protection.

Furthermore, compliance with the 2 °C climate-protection guard rail has positive effects on compliance with the guard rail for soil protection, since it prevents desertification, which can occur as a climatic effect due to reduced rainfall in arid areas. In addition, the energy sector is intricately interlinked with land use and the water cycle, e.g. in the production of bioenergy (WBGU,

2010) and the use of cooling water by thermal power plants. Another example is reducing the use of fossil fuels for reasons of climate protection, which has the added benefit of reducing air pollution and, in turn, health hazards. Even if the transformation of the energy sector doubtless not only has positive effects for other SDGs, an inclusive, multi-sectoral approach nevertheless offers a chance to recognize and exploit synergies.

Recommendations

SDGs and the message from Rio

At the UN Conference on Sustainable Development ('Rio+20-Conference'; UNCSD, 2012), the international community agreed that the SDGs should build on the 1992 UN Conference on Environment and Development in Rio de Janeiro ('Rio Earth Summit'). According to the Rio Declaration, environmental protection "shall constitute an integral part of the development process and cannot be considered in isolation from it" (UNCED, 1992: Principle 4). This central message was not sufficiently taken into account in the MDGs, and environmental problems were given a low priority.

The post-2015 process offers an opportunity to formulate an integrative strategy for sustainable development with the SDGs. The WBGU believes it is essential that the SDG catalogue takes into account not only poverty eradication and human development, but also local and global environmental change.

In accordance with the WBGU's neutrality concept for securing Earth system services, any transgressing of the planetary guard rails should be avoided and the development paths should be redirected accordingly. This helps to sustain humanity's natural life-support systems and is therefore a prerequisite for an environmentally responsible future for all people, for sustainable development, and for poverty eradication. There is no danger of transgressing the guard rails if goals of human development for the poor sections of the population in the developing and newly industrializing countries are sought and achieved.

The biggest contributions to the causes of global environmental problems currently result from the consumption decisions and lifestyles of the OECD countries and the growing middle and upper classes in all countries. The SDGs should therefore also include targets aimed at redirecting non-sustainable and non-universalizable production and consumption patterns towards sustainability. After all, taken together the SDGs should circumscribe a developmental corridor and welfare concept that can be reached by a future 9 billion people within the boundaries of the Earth system. This would make the SDGs a target system for comprehensive human development and for a transformation of the national economies and the world economy towards sustainability within the boundaries of the Earth system. Yet these links have been largely neglected in the political discourse on the SDGs to date. The focus is primarily on poverty eradication and development for the poorest sections of society, without also looking at the global environmental dimension in the sense of the concept of planetary guard rails. In particular, there are no proposals for a catalogue of SDGs that fully engages the guard-rail approach. For this reason, the WBGU focuses in this Policy Paper on the framework conditions in the Earth system within which a sustainable development must move. Against this background, the WBGU develops recommendations on how the guard-rail concept can be systematically integrated into the catalogue of SDGs and operationalized.

An SDG with targets related to the planetary guard rails

The WBGU recommends that, in the negotiations, the federal government should advocate the agreement of a separate guard-rail SDG entitled 'safeguarding Earth system services'. This SDG defines the framework within which the other SDGs on environment, development and poverty eradication can be implemented. The following six planetary guard rails proposed by the WBGU for the SDG process should be operationalized under this guard-rail SDG in the form of global, long-term SDG targets (Table 1). In-depth explanations and justifications of the six guard rails can be found in the Annex.

Limit climate change to 2 °C

The WBGU has proposed the prevention of an increase in the global mean surface temperature by more than 2 °C above pre-industrial levels as a guard rail for climate change. In order to have a realistic chance of keeping to this guard rail, the WBGU proposes, as an SDG target, completely ceasing global CO_2 emissions from fossil sources by about 2070, i.e. including every country and every sector of society (Annex A.1). This target is congruent with the target on ocean acidification. Within the framework of the SDG process, the parties to the Framework Convention on Climate Change (UNFCCC) should be called upon to agree national transformation plans, intermediate targets and transfers of finance, know-how and technology in accordance with this target. These 'decarbonization roadmaps' should clarify how the respective national CO_2 emissions path should be designed to move it towards the agreed SDG target.

Table 1
Recommendations of the WBGU for the post-2015 development agenda. An SDG entitled 'safeguarding Earth system services' should be set up with six guard rails as SDG targets. Red: no (or inadequate) global institutions exist; orange: no target exists; yellow: target(s) exist, but it is unclear whether they suffice for compliance with the guard rail.
Source: WBGU

Planetary guard rail	Recommendation for SDG targets	Recommendations for global institutions
Limit climate change to 2 °C	› Global CO_2 emissions from fossil energy sources should be ceased completely by about 2070.	› UNFCCC: 2 °C limit is recognized by COP decision › UNFCCC should agree reductions in CO_2 emissions with national trajectories, targets and transfers of finance, know-how and technology › Adopt the targets of the 'Sustainable Energy For All' initiative
Limit ocean acidification to 0.2 pH units	› Global CO_2 emissions from fossil energy sources should be ceased completely by about 2070. This target is congruent with the target for anthropogenic climate change.	› No global institution › Recognize acidification guard rail in the UNFCCC › UNFCCC should agree reductions in CO_2 emissions with national trajectories, targets and transfer payments
Halt the loss of biodiversity and ecosystem services	› The direct anthropogenic drivers of the loss of biological diversity should be stopped by 2050 at the latest.	› Support for the Aichi Targets and implementation by CBD member states › CBD should agree country strategies with national trajectories, targets and transfers of finance, know-how and technology
Halt land and soil degradation	› Net land degradation should be stopped worldwide by 2030 – globally and in all countries.	› Inadequate competence of the UNCCD › UNCCD should recognize SDG target and agree country strategies with national trajectories, targets and transfers of finance, know-how and technology › Set up an Intergovernmental Panel on Land and Soils or extend the FAO ITPS to include land degradation
Limit the risks posed by long-lived and harmful anthropogenic substances		
Mercury	› The substitutable use of mercury and anthropogenic mercury emissions should be stopped by 2050.	› Mercury is regulated by the Minamata Convention › If it proves to be inadequate for implementing the target, it should be tightened up to reach the target by country strategies with national trajectories, targets and transfers of finance, know-how and technology
Plastic	› The release of plastic waste into the environment should be stopped worldwide by 2050.	› Inadequate global and regional institutions › Strengthen and interlink existing conventions on plastic-waste emissions and on marine conservation › If the implementation of the targets proves to be inadequate, a specific international instrument should be set up
Fissile material	› The production of nuclear fuel for use in nuclear weapons and civilian nuclear reactors should be stopped by 2070.	› Inadequate global institutions › Agree the Fissile Material Cut-off Treaty › International monitoring of fissile materials and nuclear fuel cycle by IAEA
Halt the loss of phosphorus	› The release of non-recoverable phosphorus into the environment should be stopped worldwide by 2050, so that its global recycling can be achieved.	› No global institution › Call for a phosphorus assessment › If the implementation of the targets proves to be inadequate, a specific international instrument should be set up

Limit ocean acidification to 0.2 pH units

It is necessary to limit the rise in atmospheric CO_2 concentration in order to avoid the risks of major changes in the marine ecosystems as a result of the fall in the pH value of seawater. The direct and indirect effects of acidification are a great challenge not only for marine biodiversity and ecosystem services, but also for fisheries and aquaculture. In order to protect the oceans, the pH level of the uppermost ocean layer should not fall by more than 0.2 units compared to pre-industrial figures in any major ocean region (WBGU, 2006: 3; Annex A.2). The WBGU's proposal for a long-term SDG target is to completely cease global CO_2 emissions from fossil sources by about 2070, i.e. including every country and every sector of society. This target is congruent with that on climate change. An anthropogenic change in the Earth's radiation balance by geoengineering measures could affect the trend towards warming, but it would not reduce acidification. Ocean acidification is currently neglected by international environmental policy. There is no environmental convention that provides for agreeing the necessary CO_2 mitigation measures with the stated objective of limiting ocean acidification. Since, as in the case of climate change, anthropogenic CO_2 emissions play the decisive role, the WBGU reaffirms its recommendation of agreeing the CO_2-reduction targets and measures needed to limit ocean acidification and protect the climate within the framework of the UNFCCC (WBGU, 2006). A corresponding request should be made to the UNFCCC in the context of the SDG process.

Stop the loss of biodiversity and ecosystem services

Humans are dependent in many respects on biodiversity and the associated ecosystem services. A political consensus has therefore become established in the context of the Convention on Biodiversity (CBD) that the loss of biodiversity and ecosystem services must be stopped. As a global, long-term SDG target, the WBGU recommends that the anthropogenic drivers of biodiversity loss – e.g. the conversion of natural ecosystems – should be halted by 2050 at the latest (Annex A.3). As medium-term targets, the CBD's Aichi Targets should be supported within the framework of the SDG process and states called upon to implement them quickly. In the context of the post-2015 process, the CBD should also be called upon to agree national transformation plans with interim targets and transfers of finance, know-how and technology for all parties with the aim of achieving the SDG target by 2050.

Stop land and soil degradation

Protecting soils and land against overuse and degradation is a key prerequisite for ensuring the long-term supply of a growing world population with food and biomass. Human-induced land and soil degradation must therefore be stopped. As a global SDG target, the WBGU proposes that net land degradation should be halted by 2030 – globally and in all countries (Annex A.4). The reversal of the trend in land and soil degradation by 2020 should be recommended as a national intermediate target in the spirit of the decisions of the Rio+20 Conference.

Up to now, negotiations on land and soil degradation have taken place in the context of the Convention to Combat Desertification (UNCCD); however, no negotiations are currently taking place aimed at obliging states parties to make specific reductions in land degradation or to take action in areas other than arid regions. The UNCCD should therefore be called upon in the context of the SDG negotiations to create an international protocol on the fight against land and soil degradation that is not restricted on arid regions. The guard rail on land and soil degradation should be recognized in the context of this protocol. Furthermore, all countries should develop national strategies and identify the transfers of finance, know-how and technology necessary in order to reach this target. In order to improve the scientific advice available to politicians, the WBGU recommends, within the framework of the SDG process, proposing to the UN General Assembly the idea of setting up an 'Intergovernmental Panel on Land and Soils' along the lines of the IPCC (WBGU, 2001b), or extending the 'Intergovernmental Technical Panel on Soils' (ITPS), established at the FAO in 2013, by adding the issues of land degradation and livelihood security.

Limit the risks posed by long-lived and harmful anthropogenic substances

Anthropogenic emissions of long-lived and harmful substances that accumulate in the environment and represent serious hazards to human health and the environment have also increased sharply since the beginning of industrialization. Persistent organic pollutants (POPs; e.g. pesticides such as DDT) are already regulated under the Stockholm Convention, which includes prohibitions and gradual reductions of production to zero. Chlorofluorocarbons (CFCs) are reduced to protect the stratospheric ozone layer; the Montreal Protocol covering this is regarded as an outstanding success of international environmental policy. The agreements on these two groups of substances seem to be moving in the right direction, so that the WBGU sees no need for SDG targets in this field. The WBGU does see a need for action on the following three substances or substance groups:

Mercury

Mercury is a highly toxic heavy metal that is fatal in high doses. In view of mercury's toxicity, the WBGU recommends, as an SDG target, that its substitutable use and anthropogenic emissions into air, water and soil should be stopped by 2050 (Annex A.5.1).

The reduction of mercury emissions is regulated by the Minamata Convention, which was agreed upon in 2013. The Minamata Convention is a young, international environmental agreement. It is unclear when it will come into force. In its current form, the Convention is probably not sufficiently stringent to completely stop mercury emissions in the long term. This absence of quantitative emission-reduction targets for the biggest sources of mercury emissions is a serious shortcoming in the WBGU's view. At the same time it cannot be ruled out that the states might reduce mercury emissions completely, as they did in the case of the heavy metal lead.

Plastic

Every year, large, difficult-to-quantify amounts of plastic waste enter marine ecosystems for lack of safe disposal or recycling strategies. Animals can eat the plastics and either die themselves or feed their young with it. Microplastics are also absorbed by marine organisms and are suspected of accumulating in the food chain and transporting pollutants. The amount of plastic in the oceans will accumulate further if no action is taken. Negative effects on marine ecosystems are already verifiable, but it is currently difficult to foresee the full extent of possible negative effects on humanity's natural life-support systems or how likely serious socio-economic consequences might be. Neither can be ruled out, however, and marine plastic waste could prove to be a considerable risk. In view of the growing amount of plastic entering the oceans, the known and impending environmental effects, and the global distribution of plastic, the WBGU believes that the following SDG target should be included: the release of plastic waste into the environment should be stopped worldwide by 2050. Strategies to support prevention, introduce reusable packaging systems and develop biodegradable plastic should go hand in hand in this context (Annex A.5.2).

So far there is no a global institution that recognizes plastic waste as a serious global environmental problem and supports and coordinates states' efforts to reduce and dispose of plastic and develop recycling systems. Existing conventions are either not very specific when it comes to inputs of plastic waste from the land, or else they only regulate emissions at sea or are regionally limited. Similarly, there is no international scientific body publishing regular reports on the latest state of knowledge, nor comprehensive data collections on the sources and effects of plastic waste. For these reasons, the WBGU recommends, in addition to laying down an SDG target, tightening up the existing international conventions on waste dumping at sea and ship-generated waste and, in addition, agreeing regulations to prevent or at least to minimize emissions of plastic waste from the land. It also reiterates its recommendations to strengthen and better interlink regional ocean conservation agreements, and to strengthen and extend the UNEP Regional Seas Programme (WBGU, 2013). Should it transpire in the course of the review on the SDGs that the measures taken by the states are not leading to any significant reduction in plastic waste, then a new international convention should coordinate a more ambitious approach by the states.

Fissile material

When it comes to nuclear fuel, a distinction must be made between stocks and flows and between low-enriched and highly enriched material. The WBGU rejects all further proliferation of nuclear weapons, and advocates stopping the use of nuclear technology for energy generation. As an SDG target, the WBGU proposes stopping the production of nuclear fuels for use both in nuclear weapons and in civilian nuclear reactors by 2070 (Annex A.5.3). Extensive security precautions are needed wherever the production of fissile material is continued or weapons-grade stocks are maintained. All uses and stockpiles of fissile material, as well as the sensitive steps in the nuclear fuel cycle, should be subjected to strict and permanent international control.

The Nuclear Non-Proliferation Treaty is an international agreement that prohibits dissemination and commits signatory states to nuclear disarmament. Compliance with the treaty is monitored by the International Atomic Energy Agency (IAEA). The Fissile Material Cut-off Treaty is an international agreement discussed within the framework of the UN on banning the production of highly enriched material that can be used for the production of nuclear weapons. If such an international agreement were to be set up, it would help, as recommended by the WBGU, to reduce the annual production of radioactive fissile material to zero by 2070. The WBGU therefore recommends the conclusion of such a treaty. Compliance should be monitored by the IAEA. International plants for the provision, enrichment and processing of fissile material should also be set up under the supervision of the IAEA. The WBGU recommends placing the fissile material, as well as the nuclear fuel cycle, under the IAEA's international control.

Stop the loss of phosphorus

Phosphorus is an essential strategic resource for agriculture and therefore of great importance for food security and the production of bio-based products. Highly concentrated, extractable phosphate rock is a scarce, finite resource (WBGU, 2011:43). Phosphorus cannot be replaced by other substances, or be manufactured artificially. As an SDG target, the WBGU proposes that the release of non-recoverable phosphorus into the environment should be stopped worldwide by 2050 to make it possible to set up recycling systems worldwide (Annex A.6).

At present there is no global institution addressing the issue of fair access to phosphorus and how best to conserve this resource. Should the review of the SDGs show that the state measures seeking to achieve these objectives are inadequate, the use of phosphorus should be regulated under its own convention. A global phosphorus assessment could help improve fertilizer use, waste management and recycling. It should also include information on phosphorus resources, relevant technologies and practices, infrastructure and political measures.

National implementation

The negotiations within the framework of the SDG process would be overburdened if attempts were made to translate the global, long-term SDG targets into national targets that are differentiated according to countries or groups of countries complete with suitable intermediate targets. The WBGU therefore proposes that the detailed negotiations on the national implementation of SDG targets be carried out under the UN environmental conventions responsible for the respective issues. All national objectives should reflect the global SDG targets; i.e. all countries should develop plans on how the corresponding national target can be achieved, and what intermediate objectives and transfers of finance, know-how and technology would be involved.

The WBGU recommends the following division of labour between the SDG process and the UN environmental conventions in order to avoid duplication of structures and parallel negotiations:

- *Two R's:* The SDG process should be responsible for a *regulatory framework* (of the guard-rail SDG and the global SDG targets) within which sustainable development can take place. The SDG process should *review* the national design and implementation.
- *Three T's:* The existing global environmental conventions should, within the framework of the SDG process, be mandated to use their intergovernmental negotiations to find the best ways to design the state parties' obligations to implement national *transformation plans, targets* (including intermediate targets) and *transfers* of finance, know-how and technology.

If there are no specialized, competent institutions, the international community should set a uniform national target for all countries within the SDG process, or an explicit call should be formulated to close this gap in governance. The conservation of common goods is only possible with much more intense global governance (long-term cooperation and formal, legally binding rules) on laying down guard rails, global and national targets and their verification.

Role of research

Successful national and international implementation of the SDG targets as proposed by the WBGU is an iterative process that also requires scientific support. For example, research is needed to determine national targets and to design and implement national and cross-border regional transformational development paths to achieve the SDG targets proposed by the WBGU for the six guard rails. There are direct links here to national application-oriented research programmes – such as the German programmes 'Research for Sustainability' (FONA) and 'Social-Ecological Research' (SÖF) supported by the Federal Ministry of Education and Research – but also to international research programmes such as Future Earth. With regard to the role of research on the post-2015 development agenda, the WBGU recommends the following:

- *Monitoring and review:* The monitoring and review process of the SDGs should be carried out on the basis of independent science. The WBGU considers such accompanying research to be very useful in this context. An appropriate amount of basic data is the prerequisite for assessing SDG implementation.
- *Knowledge gaps on planetary guard rails:* Several gaps in knowledge have become evident in the run-up to the negotiations on the post-2015 development agenda. The complexity of global environmental problems in the context of the Earth system is greater than in the case of local environmental problems, and thus also increases scientific uncertainty. More research should be conducted on knowledge deficits or uncertainties relating to planetary guard rails to further improve their knowledge base: in order to quantify them more reliably and make it easier to operationalize them. A close international scientific division of labour is important due to the complexity of the Earth system, the dynamics of global environmental change – and to ensure the legitimacy of the results. Advances in knowledge could then have repercussions on the assessment of the guard rails and thus also on the international community's efforts to eradicate the causes.

- *Implementation of the post-2015 development agenda:* The process of the post-2015 development agenda offers not only an opportunity to choose a new orientation for international environmental and development policy, but also a chance to integrate this with national and international research. In the context of the post-2015 development agenda, therefore, recommendations should be issued and research agendas outlined which could be directed towards the research community, e.g. in the framework of the international science and research institutions and networks (e.g. ICSU or Future Earth), in order to support the implementation of the development agenda. To do this, international research institutions and international research collaborations in particular should be strengthened.
- *Science/policy interface:* The science/policy interface should also be strengthened for the guard rails proposed by the WBGU. The Intergovernmental Panel on Climate Change (IPCC) is doing excellent work to scientifically support the achievement of the targets on climate protection and ocean acidification. The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) is being developed to cover the loss of biodiversity and ecosystem services. There are no comparable global assessments for land and soil degradation, plastic waste or phosphorus. For this reason the WBGU proposes the establishment of similar assessments.

Annex: Rationale for the guard rails

A.1 Limit anthropogenic climate change to 2 °C

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) leaves us in no doubt: the warming of the climate system is unequivocal (IPCC, 2013). The temperatures of the atmosphere and the ocean are rising, the amount of snow and ice on Earth is decreasing, sea levels are rising, and the concentration of greenhouse gases in the atmosphere is increasing. The human influence on the climate system is clear (IPCC, 2013), and the impact of climate change on natural and human systems is already noticeable and measurable in all parts of the world (IPCC, 2014a). The extent of the possible future impacts will essentially depend on how much and how quickly climate protection is implemented worldwide.

Unabated climate change endangers the natural life-support systems for humankind. One example is food production. An increase of more than 1 °C in the global mean surface temperature will already lead to lower harvests of the most important food cereals in many regions; if the temperature rises by more than 4 °C, far-reaching negative effects on agriculture are to be expected worldwide. (Unless otherwise stated, all the temperatures quoted in this Annex A.1 relate to the reference period 1986–2005 used in the IPCC (2014a); to determine the temperature rise relative to the pre-industrial level, please add approx. 0.6 °C to the figures). Climate change also has a considerable impact on the global water cycle, with dry regions tending to become drier and wet regions wetter. If the temperature were to increase by more than 2 °C, climate change could become a dominant factor for water availability in some regions.

The IPCC (2014a) identifies a number of key risks of climate change for the world's population; they are summarized in five reasons for concern.

1. *Unique and threatened systems:* Some unique ecosystems and cultures are already at risk. They increase in number when temperatures rise by approx. 1 °C. Above 2 °C the risks to many species and ecosystems with limited adaptive capacity rises considerably.
2. *Extreme weather events:* Climate-change-related risks from extreme weather events such as heat waves, extreme precipitation and coastal flooding must already be regarded as high if temperatures rise by 1 °C. Risks associated with some types of extreme events (e.g. extreme heat) increase further at higher temperatures.
3. *Distribution of impacts:* Risks are unevenly distributed and are generally greater for disadvantaged people and communities. Risks relating to decreases in regional crop yields and water availability become high for some countries when temperatures rise by more than 2 °C.
4. *Global aggregate impacts:* There are already risks to the world economy and biodiversity if temperatures rise by between 1 and 2 °C. Extensive biodiversity loss with associated loss of ecosystem goods and services results in high risks if temperatures rise by approximately 3 °C.
5. *Large-scale singular events*: With increasing warming, some physical systems or ecosystems may be at risk of abrupt and irreversible changes. Warm-water coral reefs and Arctic ecosystems are already experiencing irreversible regime shifts. Risks associated with such tipping points increase disproportionately with 1 to 2 °C of warming and become high above 3 °C, due to the potential for a large and irreversible rise in sea levels from ice sheet loss. In the event of sustained warming greater than a certain threshold (estimates range between 1 °C and 4 °C), near-complete loss of the Greenland ice sheet would occur over a millennium or more, contributing up to 7m of global mean sea-level rise.

As a guard rail for climate change, the WBGU has proposed preventing the global mean surface temperature from increasing by more than 2 °C compared to pre-industrial levels (WBGU, 1995b, 1997, 2003, 2009). This was also the target set by the international community at the UN Climate Change Conference 2010 in Cancún. In its report, 'The Future Oceans – Warming Up, Rising High, Turning Sour', the WBGU proposed a further guard rail: absolute sea-level rise should not exceed 1m in the long term (WBGU, 2006). The global mean surface temperature has increased by almost 0.9 °C to date, the sea level by just under 0.2 m. This means that the guard rails for climate change proposed by the WBGU have not yet been transgressed, but all the current trends are moving in the direction of surpassing them.

Rockström et al. (2009b) have also proposed a planetary boundary for climate change, but using different metrics. Their proposal is that the concentration of CO_2 in the atmosphere should not rise above 350 ppm, and radiative forcing should be no more than 1 W per m^2 compared to the pre-industrial level. CO_2 concentration is now already well above 390 ppm (Le Quéré et al., 2013), and human-induced radiative forcing is at more than 2 W per m^2 compared to the pre-industrial level (IPCC, 2013). The planetary boundary for climate change proposed by Rockström et al. (2009b) has thus already been significantly exceeded, and even the most ambitious climate-protection scenarios of the new IPCC report show no development that might be able to undo this in the foreseeable future.

Continuing greenhouse-gas emissions will lead to further warming and changes in all parts of the climate system. Anthropogenic climate change can only be stopped by reducing net emissions of CO_2 to zero. However, the climate change caused by CO_2 emissions is irreversible over centuries: the surface temperatures will remain approximately constant at the elevated level for several centuries, even after CO_2 emissions have stopped completely. The extent of the rise in temperature will be largely determined by the cumulative CO_2 emissions. Other greenhouse gases also contribute to climate change, and their emissions should be reduced, but it will not be possible to limit anthropogenic climate change without a cessation of CO_2 emissions. Science shows that at the current point in time it is still possible to prevent a temperature rise of more than 2 °C compared to the pre-industrial level (IPCC, 2014b).

In the IPCC's climate scenarios that allow compliance with the 2 °C guard rail, CO_2 emissions from fossil fuels are at or below zero in the second half of the 21st century (Figure 2). The earlier the CO_2 emissions are lowered, the less 'negative emissions' will be necessary, i.e. the active absorption of CO_2 from the atmosphere and its storage, a process that has not yet been commercially proven. As an SDG target, the WBGU therefore recommends stopping global CO_2 emissions from fossil sources completely by about 2070 in order to have a realistic chance of limiting global warming to 2 °C compared to the pre-industrial level. This requires reducing fossil CO_2 emissions to zero in every country, every region and every sector of society by about 2070.

Under the United Nations Framework Convention on Climate Change (UNFCCC), which enjoys almost universal membership with 195 countries and the EU, the parties already agreed in 1992 to stabilize the concentration of greenhouse gases in the atmosphere to avoid a "dangerous anthropogenic interference with the climate system". Since 2010 a limitation of temperature rise to less than 2 °C compared to the pre-industrial level has been accepted in several decisions by the Conference of the Parties. Up to now, however, the states have not even formally accepted the scientifically deducible necessities regarding the development of global emissions, let alone agree on national targets that might make such a development of global emissions possible. In the WBGU's view, the UNFCCC is the right forum for reaching a consensus on this matter that is fair and sufficiently ambitious.

In the context of the SDGs, the states should commit to transform their economies so that ultimately no CO_2 from fossil sources is emitted. Within the framework of the SDG process, the UNFCCC should be called upon to agree that all parties, in accordance with this global SDG target, prepare and submit decarbonization roadmaps showing how the respective national CO_2 emissions path is to be designed to move it towards the agreed SDG target. In addition, regulations should be found within the UNFCCC on technological and financial transfers that reflect a just assumption of responsibility by states for global climate protection (WBGU, 2009). The targets of the UN Secretary-General's 'Sustainable Energy For All' initiative (SE4All, 2014) on efficiency, renewable energy and access to modern energy services contribute to climate protection and should, also for this reason, be incorporated into the SDG process.

A.2
Limit ocean acidification to 0.2 pH units

The WBGU dealt with ocean acidification in its reports 'The Future Oceans – Warming Up, Rising High, Turning Sour' and 'Governing the Marine Heritage'. Much of the following section is quoted verbatim from these reports (WBGU, 2006:65ff.; WBGU, 2013:178ff.). The anthropogenic increase in CO_2 in the atmosphere, caused largely by burning fossil energy sources, has turned the ocean into a CO_2 sink: the oceans have so far absorbed about 30 % of the anthropogenic CO_2 emissions (IPCC, 2013). The CO_2 dissolves in the seawater, forming a weak acid, which can be measured via the pH value. The pH value of the surface water of the oceans has already dropped by 0.11 units since the beginning of industrialization (The Royal Society, 2005), corresponding to an almost 30 % increase in the acid content. On the geological timescale this corresponds to an extremely rapid increase in acidity within a few decades not seen for at least 300 million years (Hönisch et al., 2012).

The acidification is primarily a consequence of the rapid increase in the quantities of anthropogenic CO_2 in the ocean. When there is a slow input of CO_2, as has repeatedly occurred in the Earth's history, the CO_2 mixes down into the deep sea, where a slow dissolution of carbonate sediments counteracts the acidification

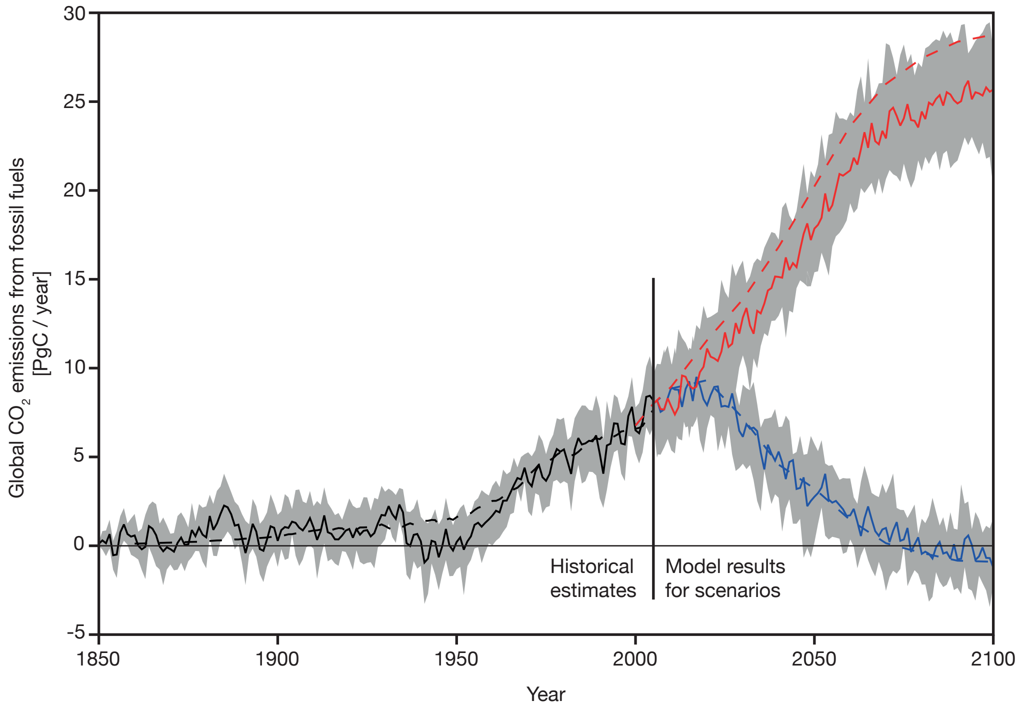


Figure 2
Global CO_2 emissions from fossil fuels according to historical estimates and for various future scenarios (1 Pg C corresponds to 3.67 Gt of CO_2). The dashed lines show the historical estimates and model results of integrated assessment models; the solid lines show the results of a model comparison of more complex Earth-system models and the related standard deviations (grey-shaded area). What is important is that the upper, red line shows emission pathways that lead to global warming of well over 4 °C by 2100; the lower, blue line shows emission pathways that are compatible with the 2 °C guard rail. The 2 °C-compatible developments show average emissions for 2050 that are 50 % below those of 1990. The cumulative global CO_2 emissions from fossil fuels between 2012 and 2100 for this scenario average about 990 Gt of CO_2.
Source: modified from IPCC, 2013

(WBGU, 2006:67). If rapid acidification were to continue unabated as a result of continued CO_2 emissions from fossil sources, the chemistry of the ocean would be changed for millennia to come, since it cannot be reversed by human intervention.

Hardest hit by ocean acidification in the marine ecosystems are the calcifying organisms (corals, molluscs, many species of microplankton; Turley and Gattuso, 2012), which find it increasingly difficult to build up their skeletal structures under conditions of acidification. Plankton species are responsible for about three-quarters of global marine calcification (WBGU, 2006). They not only play a role in the global carbon cycle by exporting calcium carbonate into the deep sea, but also provide food for other marine animals by forming huge plankton blooms, thus greatly influencing the marine food webs. Calcification is significantly reduced in mussels and Pacific oysters at the CO_2 concentrations that can be expected by the end of the century if emissions are not reduced (Gazeau et al., 2007). In some regions, acidification is already causing considerable problems for oyster larvae hatcheries (Service, 2012; Barton et al., 2012). Other species can tolerate acidification or adapt to it (Sunday et al., 2014). Some are even at an advantage for this reason, e.g. seagrass (IGBP et al., 2013), so that the structures of marine food webs will change. The direct and indirect effects of acidification are a great challenge not only for marine biodiversity and ecosystem services, but also for fisheries and aquaculture.

Coral reefs contribute indirectly to ensuring food security for about 500 million people, because they form the habitat for many species that are in turn important to fisheries (UNEP, 2010b). At the same time, however, they are particularly affected by acidification, because the reef structures consist of aragonite carbonate, which dissolves especially rapidly when pH values fall. Hardly any reef locations (including both hot- and cold-water corals) will be able to support coral growth by the middle of the century if CO_2 emissions continue unabated (Guinotte et al., 2006; Turley et al., 2007; Cao and Caldeira, 2008). The synergistic damage done by rising temperatures, acidification, pollution and overuse could increasingly drive reef ecosystems to functional collapse, with serious consequences for fisheries, tourism and people who live on the coasts (Hoegh-Guldberg et al., 2007). Uncontrolled acidification thus poses a considerable risk of far-reaching and irreversible changes to marine ecosystems; not least, this is likely to affect food security (WBGU, 2013).

Steinacher et al. (2009) conclude that limiting the atmospheric CO_2 concentration to a maximum of 450 ppm is the only way to avoid the risk of major changes to ocean ecosystems. The WBGU has proposed the following guard rail for ocean acidification: "The pH of near surface waters should not drop more than 0.2 units below the pre-industrial average value in any larger ocean region (nor in the global mean)" (WBGU, 2006:3). Rockström et al. (2009b) propose using aragonite saturation as an indicator, stating that it should not fall to less than 80% of its pre-industrial level. Irrespective of how the threshold level of damage is defined in detail, compliance with it can only be achieved by limiting the rise in atmospheric CO_2 concentration, thus reducing anthropogenic CO_2 emissions. Although anthropogenic alterations of the Earth's radiation balance (screening off solar irradiation) by geoengineering measures could affect the trend towards warming, it would not reduce acidification (IPCC, 2013).

The solution to this problem by reducing CO_2 emissions thus reveals a close synergy with anthropogenic climate change. If the long-term goal of completely stopping CO_2 emissions from fossil sources by about 2070 proposed in Annex A.1 to ensure compliance with the climate protection guard rail was achieved, this would simultaneously curb acidification to the extent that the guard rail proposed by the WBGU would not be transgressed (IPCC, 2013).

Ocean acidification is currently not being explicitly addressed by international environmental policy. There is no environmental convention explicitly aimed at limiting ocean acidification and agreeing the necessary CO_2-mitigation measures. In its 2006 report, the WBGU recommended that climate policy should consider all the effects of greenhouse-gas emissions on marine habitats, i.e. including the direct impact of CO_2 input on marine ecosystems. Furthermore, binding regulations on ocean acidification should be taken under the UNFCCC: "This presents an immediate need to limit acidification and adopt appropriate measures under the UNFCCC" (WBGU, 2006:75).

A quantitative limit on ocean acidification should therefore be agreed under the UNFCCC. Because of the above-mentioned synergies between the necessary global CO_2 reductions and climate protection, the national implementation of the SDG target on ocean acidification in accordance with the UNFCCC would be consistent with the SDG target for climate protection, namely national emissions roadmaps leading to the complete cessation of global CO_2 emissions from fossil fuels by about 2070.

A.3
Halt the loss of biodiversity and ecosystem services

Humans have dramatically changed the biosphere. The conversion of natural ecosystems into cropland, grassland, plantations and settlement infrastructure – as well as their degradation, the dispersal of invasive alien species to other continents, and the over-exploitation, pollution and destruction of forests, lakes, rivers, wetlands, coral reefs and other ecosystems – have, as 'anthropogenic drivers', triggered a massive loss of biodiversity which is taking place at a rate that is a hundred or a thousand times faster than the natural background rate (WBGU, 2011:37ff.). Climate change (Annex A.1), ocean acidification (Annex A.2) and environmental pollution (Annex A.5) are also key drivers of biodiversity loss. Human societies are dependent on biodiversity and the associated ecosystem services in many respects. For rural communities in newly industrializing and developing countries, natural ecosystems and their biodiversity are a kind of supermarket, DIY store, drugstore and pharmacy all in one. In addition to food, safe drinking water, wood and fibres, natural ecosystems also offer the genetic resources of plants and animals, traditional medicines, as well as jewellery and sacred objects (WBGU, 2005:76). Given the rapid loss of biodiversity, it can no longer be taken for granted that these life-support systems will be maintained for future generations (MA, 2005b).

Scientific knowledge is too fragmentary to define a clear-cut planetary guard rail beyond which biodiversity loss would have intolerable consequences for humanity. However, it can be regarded as a scientific consensus that the current very high loss rates are not sustainable (MA, 2005a). At the same time, the loss of biodiversity is linked with irreversibilities, because the restoration of ecosystems is only possible to a limited extent and with huge effort; the global extinction of a species is final. Following the precautionary approach (Principle 15 of the Rio Declaration, UNCED; Preamble to the Convention on Biodiversity), there is now a political consensus in international environmental policy that the human-induced loss of biodiversity must be slowed down as soon as possible and ultimately stopped. Following the 1992 Convention on Biodiversity (CBD), the WBGU regards halting the anthropogenic loss of biodiversity and ecosystem services to be an appropriate planetary guard rail: i.e. in the long term the rate of species extinction should not be much higher than the natural extinction rate. In line with the implicit message of the vision and the mission of the CBD's Strategic Plan, the WBGU recommends, as an SDG target, that the direct anthropogenic drivers of biodiversity loss (and especially the conversion of natural habitats into cropland, pasture or plantations) should be stopped by 2050 at the latest. This target must consequently apply to all countries, regions and sectors of society (in particular also to industrial agriculture and forestry). Furthermore, the WBGU considers it necessary to designate 10–20 % of the area of the world's terrestrial ecosystems, and 20–30 % of marine areas, as parts of a global, ecologically representative and effectively managed system of protected areas (WBGU, 2006, 2011, 2013). The EU's biodiversity strategy also aims to halt the loss of biodiversity and ecosystem services by 2020 (EU Commission, 2011). Rockström et al. (2009a, b) propose a planetary boundary for biodiversity loss that is formulated a little more conservatively; according to this, the extinction rate should not be more than ten times the natural rate. The authors also emphasize that the knowledge is still incomplete so that the boundary position is highly uncertain.

The CBD's first Strategic Plan already contained the objective of halting biodiversity loss (CBD, 2002), and the second, current Strategic Plan reaffirms this objective (CBD, 2010). There is also a longer-term timeline in the current Strategic Plan. Its vision is 'Living in Harmony with Nature', and its aim by 2050 is to achieve appreciation, conservation, restoration and wise use of biodiversity, and the maintenance of ecosystem services. The WBGU interprets the decisions in such a way that the CBD states that at least the anthropogenic drivers of a further loss of biodiversity must be stopped by 2050.

The Aichi Targets of the CBD's current Strategic Plan (CBD, 2010) are a set of 20 ambitious objectives to be achieved by 2020 (or as early as 2015 in the case of three of them). Because the statements of the Strategic Plan are always related to the global level, initially no specific national targets are defined; rather, the Aichi Targets are supposed to provide a flexible framework for the national targets and their implementation.

There is no longer any explicit statement on reversing the trend of biodiversity loss in the current, second Strategic Plan; this may be because such an objective in the CBD's first Strategic Plan – "... to achieve by 2010 a significant reduction of the current rate of biodiversity loss" – (CBD, 2002) was missed by a large margin.

With regard to ending biodiversity loss and the co-benefits of other SDG targets, the WBGU considers the following Aichi Targets to be especially important:

- *Habitat loss and land-use change:* Aichi Target 5 calls for the rate of loss of all natural habitats to be at least halved – and where feasible brought close to zero – by 2020. This target implies that the global trend reversal is to be achieved before 2020. Figure 3 shows that this trend reversal in the global loss rate would be necessary within just a few years. In certain ecosystem types (e.g. forests, wetlands or coral reefs), most of the losses occur in just a few countries, so that their actions largely determine the global loss rate. It follows that in these countries the national trend reversals must be achieved and considerable reductions implemented within a few years. This assessment is compatible with the recommendation of the International Resource Panel, according to which the conversion of grassland, savannas and forests into cropland should be stopped worldwide by 2020 (UNEP, 2014). Rockström et al. (2009a) propose as a planetary boundary the conversion of a maximum of 15 % of the global land area for agriculture; about 12 % has currently already been converted. As changes in land use are responsible for about 10 % of global anthropogenic CO_2 emissions (Le Quéré et al., 2013), this target also contributes to climate protection.
- *Agriculture, forestry and fisheries:* The Aichi Target 7 stipulates that all areas under agriculture, aquaculture and forestry should be managed sustainably by 2020. Aichi Target 6 states, among other things, that overfishing should be prevented and fisheries have no adverse impacts on threatened species and vulnerable ecosystems by 2020. This is formulated in a more general way in Aichi Target 4, which states that the impacts of the use of natural resources must be kept well within safe ecological limits by 2020. In terms of content, these targets are in line with the proposal made by experts from the UNCCD context to reduce land and forest degradation to zero by 2030 (Annex A.4). There are also co-benefits with climate protection, because land and forest degradation involves CO_2 emissions. Aichi Target 8 stipulates that by 2020 pollution, including excess nutrients, must be brought to levels that are not detrimental to ecosystem functions or biodiversity. This target is in line with the definition of a planetary boundary for nitrogen and phosphorus emissions, as proposed by Rockström et al. (2009b). Since a restriction of pollution caused by excess phosphate fertilization will be achieved mainly by means of reduced and more targeted fertilizing, there are co-benefits with the guard rail for preserving the strategic resource phosphorus (Annex A.6).
- *Ecosystem conservation and maintaining ecosystem services:* Aichi Target 11 provides for the conservation of at least 17 % of terrestrial areas and inland waterways, and 10 % of coastal and marine areas by 2020. Aichi Targets 14 and 15 call for essential ecosystem services (carbon stocks are mentioned explicitly) to be

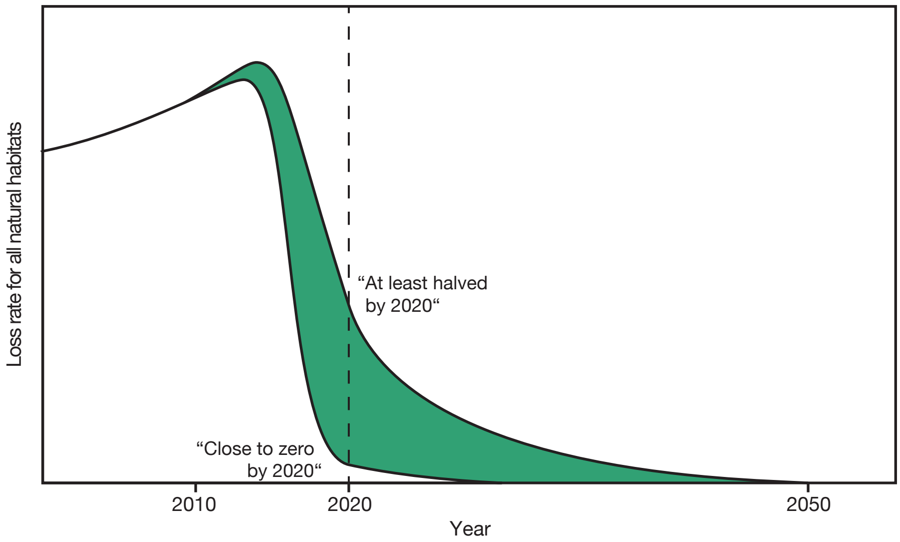


Figure 3
Schematic diagram showing global development paths of the rate of loss of natural habitats. Up to 2010 (when the Aichi Targets were agreed) the diagram schematically outlines the real observed rate of loss. The area shaded green is the area within which the path must move after 2010 if Aichi Target 5 is to be achieved. This target states that the rate of loss of all natural habitats should be "at least halved" – and where feasible brought "close to zero" – by 2020. The trend reversal must be achieved within a few years.
Source: WBGU

safeguarded and ecosystem resilience to be enhanced; at least 15% of degraded ecosystems should be restored by 2020. Aichi Target 10 calls for the reduction of anthropogenic pressures on ecosystems that are vulnerable to climate change and ocean acidification. Co-benefits for climate-change mitigation and combating desertification are explicitly mentioned in Aichi Target 15.

The WBGU supports the CBD's Strategic Plan and the Aichi Targets, which represent meaningful global intermediate objectives for the periods up to 2015 and 2020. Since these targets reflect a very broad consensus of the international community negotiated within the CBD (the CBD has been ratified by 193 countries and the EU), the WBGU proposes supporting the CBD's Aichi Targets within the framework of the SDG process and calling on states to implement them quickly. Within the framework of the SDG process, the CBD should be called upon to ensure that all parties prepare and publish plans, in accordance with the provisions of the guard rail and SDG target, on how their respective national development paths towards the zero target are to be developed in the direction of the joint SDG target and in harmony with the Aichi Targets. These biodiversity plans should include development paths and trend-reversal or reduction targets and, where appropriate, give details of the transfer payments they require.

A.4
Halt land and soil degradation

As early as 1994 the WBGU stated that too little attention was being paid to the global environmental problem of soil degradation (WBGU, 1995a). This is only changing slowly, although this problem "will considerably limit the scope for action with regard to agricultural production, nature conservation, water catchment areas and forests, and not least climate change mitigation in the coming decades" (WBGU, 2011:41). Erosion and salinization in particular are serious problems that cause irreversible damage to soils. Protecting soils and land (and thus also vegetation cover and water resources) against overuse and degradation is therefore a key prerequisite for supplying a growing world population with food in the long term. Land degradation is more than soil degradation. Land degradation involves the degradation of soils, vegetation cover and water resources of a region, and thus the impairment of productive capacity as a whole (Eswaran et al., 2001). In the context of the 1994 UNCCD (UN Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa), particular importance is attached to this broad-based approach, because the livelihood systems do not depend on the soil alone.

As a guard rail for soil protection, the WBGU has recommended minimizing soil degradation by erosion and salinization to such an extent that the natural yield potential of the soils is not critically diminished over a period of 300 to 500 years (WBGU, 2005:73). In practice this guard-rail definition is very similar to the demand for a 'land-degradation neutral world', which was agreed at the Rio+20 Conference (UNCSD, 2012). The goal formulated there was to reverse the current trends of land degradation by urgent action and to restore degraded land. This was taken up by the UNCCD Secretariat, which has formulated the proposal for an SDG on land degradation based on a background paper by Lal et al. (2012): "Sustainable land use for all and by all (for agriculture, forestry, energy and urbanization)" (UNCCD Secretariat, 2012). This proposal includes the SDG target of reducing net land degradation to zero by 2030.

The proposals by Ehlers et al. (2013) build on the consensus of the Rio+20 Conference of a 'land-degradation neutral world'. Their suggestions on land degradation and restoration are (1) to reduce the annual rate of land degradation by 50 % by 2030, and (2) to restore an area of degraded land every year that corresponds to the annually degraded area by 2030. The German Council for Sustainable Development (RNE) also advocates reducing the annual rate of land degradation by 2030, but fixes the target date for zero net land degradation at 2050 (RNE, 2014).

In view of the indispensable nature of fertile soils and of maintaining the productive capacity of land as the basis for feeding the world's population, the WBGU recommends, as a planetary guard rail, that land and soil degradation must be halted. The corresponding global SDG target should be to stop net land degradation by 2030 – globally and in all countries. As a national interim target it might be expedient, in view of the resolutions passed by the Rio+20 Conference, to reach the trend-reversal stage in land and soil degradation by 2020 at the latest. This target would also be a prerequisite for achieving an SDG on food security.

In principle, a zero target for net land degradation could also be achieved if land continued to be degraded in some parts of the world, while land was being restored in other regions. However, this would not make much sense, since it is easier and more cost-efficient to reach the zero target if less restoration is needed overall, especially since the restoration of land can take several hundred years. In the interests of protecting national natural resources, the WBGU therefore proposes setting the zero target for net land degradation not only globally, but also individually for every country.

Up to now, negotiations on land and soil degradation have been held in the context of the UNCCD. However, no UNCCD negotiations are currently taking place on binding targets for reducing land degradation or on measures outside of arid regions. In order to implement the SDG target on land and soil degradation, a call to the UNCCD should be formulated in the context of the SDG negotiations to create a protocol on the reduction of land and soil degradation that is not restricted to arid regions (UNCCD Secretariat, 2012). This could be a new international treaty integrated into the institutional structures of the UNCCD (Ehlers und Ginzky, 2012). The guard rail on land and soil degradation should be recognized in the context of this protocol. Furthermore, all countries should develop national strategies and identify the transfer payments necessary in order to reach this target.

A useful instrument to back this up would be an improved scientific advice for policy-makers to support global governance on these issues. The WBGU (2001b) has recommended the establishment of an 'Intergovernmental Panel on Land and Soils' following the model of the IPCC. The creation of a 'Intergovernmental Panel on Land and Soil' is currently under discussion in the context of the UNCCD (UNCCD Secretariat, 2012). The WBGU recommends submitting, in the course of the SDG process, a proposal to the UN General Assembly to set up such a panel. Alternatively, the Intergovernmental Technical Panel on Soils (ITPS) established in 2013 by the FAO, which up to now has focused its attention on questions of soil science, could be extended by adding the issues of land degradation and livelihood security.

A.5
Limit the risks posed by long-lived and harmful anthropogenic substances

Anthropogenic emissions of long-lived pollutants that accumulate in the environment and have considerable hazardous effects on human health and the environment have also increased sharply since the beginning of industrialization (ECHA, 2014). The WBGU has an especially critical view of chlorofluorocarbons (CFCs), persistent organic pollutants (POPs), mercury, plastics and fissile materials.

The reduction of emissions of CFCs (to protect the stratospheric ozone layer) and a number of POPs such as DDT (to protect the environment and people's health) has already been regulated in separate international agreements (Boxes 2, 3). The WBGU underlines the need to completely stop the use of the above-mentioned pollutants as soon as possible. However, the WBGU does not see any need to include special targets for them in the list of future SDGs. The Montreal Protocol has been an outstanding success for international environmental policy (Box 3; WBGU, 2011).

The production of POPs, which is regulated by the

Box 2
Persistent organic pollutants

Persistent organic pollutants (POPs) comprise synthetic organic compounds whose properties include severe toxicity, mobility and persistence. The term is used, inter alia, for certain organochlorine insecticides, applied industrial chemicals and dioxins. Some of these substances are intentionally synthesized products e.g. pesticides; others are pollutants that come about unintentionally, e.g. dioxins in the unregulated combustion of household waste, which represent a major source of POPs in developing countries (WBGU, 2011:45).

POPs are a group of toxins that present a particular serious health hazard for people and the environment. Their number and volume has greatly increased, they are spreading globally, and they are particularly dangerous, not least because they accumulate in the food chain (UNEP, 2007; WBGU, 2011:45). The 2001 Stockholm Convention on Persistent Organic Pollutants, which came into force in 2004, restricts or bans the production, use and release of the so-called 'dirty dozen' in this class of compounds (nine pesticides, PCBs, dioxins and furans). Ten other POPs had been incorporated into the convention by 2011.

Box 3
Chlorofluorocarbons

Long-lived chlorofluorocarbons (CFCs) damage the stratospheric ozone layer. CFCs are very stable substances, which are only broken down in the middle and upper atmosphere, where their degradation products then lead to the destruction of the ozone layer. As a result of their use in aerosols, for example, they have built up in the atmosphere and regularly lead to the depletion of the ozone layer over the Antarctic and the Arctic, in each case with effects on the middle latitudes. The extreme thinning of the ozone layer over the Antarctic ('ozone hole') has been happening every year since the early 1980s.

The speedy establishment of an international legal framework in the form of the Vienna Convention for the Protection of the Ozone Layer in 1985, and the follow-up Montreal Protocol on Substances that Deplete the Ozone Layer (1987), succeeded in almost completely stopping the production and use of ozone-depleting substances worldwide (Parson, 2003; WBGU, 2011:101). As a result, the CFC content in the atmosphere has been greatly reduced. However, due to their persistence it will take several decades before the concentration of ozone-destroying substances will have returned to pre-1980s levels. For this reason, ozone depletion in the stratosphere will continue for several decades (WMO, 2010).

Stockholm Convention, has been falling for ten years, and the convention supports the development of substitutes. The objectives of the convention have not yet been fully achieved – for example, there are challenges relating to how to deal with existing stocks of POPs in developing countries – but with continuing commitment on the part of all the relevant actors, the convention offers a basis for further reductions in POPs (Weber et al., 2013).

The reduction of mercury emissions is already regulated in an international agreement. In the following, the WBGU explains why it nevertheless recommends the inclusion of a target for mercury among the SDGs. The WBGU also sees an urgent need for action in the case of plastics and fissile materials at the international level, and this is explained in the following.

A.5.1
Mercury

Mercury is a highly toxic heavy metal that is fatal in high doses. It enters the environment as a result of volcanic eruptions or coal seam fires and by human activities. Emissions into the atmosphere make up the largest anthropogenic contribution. According to estimates, anthropogenic sources account for 27 %, natural sources 13 % and reverse emissions from soils, surface waters and plants 60 % of mercury emissions into the atmosphere (UNEP, 2013; Amos et al., 2013).

Elementary mercury, e.g. in the form of mercury vapour, can spread over very wide areas in the atmosphere. It spreads regionally bound to particles, e.g. those formed during combustion processes. It can stay in the atmosphere for up to twelve months and subsequently finds its way, via deposits in soils and waterways, into flora, fauna and ultimately the human body.

Eating fish and seafood is generally the biggest hazard for the public because this is where mercury tends to accumulate. Direct exposure to mercury vapour, too, can lead to increased ingestion levels and poisoning in the human body (Drasch et al., 2001). Mercury is extracted from mines and used intentionally, among other things, in small-scale gold prospecting, in the chlorine-alkali industry, and as a component in electrical devices. Artisanal small-scale gold mining in sub-Saharan Africa and Latin America is by far the largest emission source of intentionally used mercury. Mercury is a (non-intentional) by-product of industrial processes e.g. in cement manufacture, the combustion of coal and biomass, and in the uncontrolled burning of waste. Coal-fired power plants are by far the largest anthropogenic source of non-intentional emissions (UNEP, 2013).

Historically, total anthropogenic emissions of mercury peaked during the North American Gold Rush towards the end of the 19th century. After that they declined until the 1950s, when they began rising fast again, mainly as a result of industrial coal combustion and small-scale gold mining (Streets et al., 2011).

Emission trends vary from sector to sector. According to research, industrial mercury emissions into the air peaked during the 1970s and have been falling since then. However, there are signs that they have been going up again since 2010. There are big regional differences here. For example, emissions are declining in the USA, but rising fast in Asia. Measured emissions from artisanal small-scale gold mining doubled between 2005 and 2010. There are alternatives to mercury for most consumer products and industrial processes, so that waste amounts here are decreasing (UNEP, 2013). Filters can reduce the mercury content of waste gases from coal-fired power plants by up to 95 %. Emissions generated by artisanal small-scale gold mining can also be reduced by taking simple measures (Selin, 2014a).

In 2013, 140 states agreed the Minamata Convention, which aims to reduce mercury emissions (Minamata Convention on Mercury, 2013). 97 states have signed it to date and one (the USA) has also ratified it. It will enter into force once it has been ratified by 50 countries. In total, the convention covers 96 % of all anthropogenic mercury emissions (Selin, 2014b).

The convention contains zero targets for some emission sources. For example, no new mercury mines are to be commissioned, and existing ones are to be closed no later than 15 years after the convention comes into force. The use of mercury in the production of chlorine-alkali is to expire by 2025 and in the case of acetaldehyde by 2018, although applications can be made for exceptions for two periods of five years. The use of dental amalgam is also to expire, although the convention has not set a fixed deadline in this case. The production of, and trading in, certain specific products containing mercury, such as batteries, cosmetics or pesticides, is to expire in 2020. There are some exceptions, such as military uses or the use of mercury as a preservative in vaccines (Minamata Convention, Art. 4 (1) in conjunction with Annex A).

As far as the remaining sources of mercury are concerned, the convention only provides for a reduction in emissions. For example, use in the manufacture of other controlled substances is only limited (e.g. vinyl chloride, sodium or potassium methylate or ethylate, and polyurethanes using mercury-containing catalysts). Under the Minamata Convention, new individual emission sources (coal-fired power stations, factories producing metals, gold or cement) must apply the 'best available techniques' and the 'best environmental practices' in order to 'control and, where feasible, reduce emissions'. Measures are to be taken to reduce emissions from existing industrial point sources no later than ten years after the date of entry into force of the convention, taking national circumstances into account and considering economic feasibility. Countries where the small-scale mining of gold takes place at a 'more than insignificant' level should develop and implement non-binding action plans to reduce emissions.

The date of ratification is not in sight. The USA, the only country to have ratified the convention, had already met the convention's requirements beforehand. For the EU, ratification would mean only a minor amendment to existing directives (Simon, 2013; Andresen et al., 2013; IPEN Heavy Metals Working Group, 2013). The biggest challenges lie in retrofitting existing industrial point sources in Asia and in small-scale gold mining in sub-Saharan Africa and Latin America (Selin, 2014b).

However, in both cases the convention contains comparatively unambitious targets: the demands on the application of emission-reduction technologies at industrial point sources are weak, and the action plans in the field of small-scale gold mining lack binding legal force. First model calculations on the effectiveness of the convention suggest that, even if it is fully implemented, the best result that can be expected is that future increases will be smaller, but that absolute emissions will not fall compared to today's levels (Selin, 2014a, b).

The Minamata Convention is a young, international environmental agreement. It is unclear when it will come into force. In its current form, the convention is probably not demanding enough to completely stop mercury emissions in the long term (Selin, 2014b). In the WBGU's view, the absence of binding targets for complete emission reduction for the biggest sources of mercury emissions is a serious flaw. At the same time it cannot be ruled out that the states might reduce mercury emissions completely, as they did in the case of the heavy metal lead.

In view of the toxicity of mercury, the WBGU recommends that the following SDG target should be included: the substitutable use of mercury and anthropogenic mercury emissions into the air, water and soils should be stopped by 2050. In this context the Minamata Convention should be ratified and implemented quickly. If the review of the SDGs shows it to be inadequate for implementing the SDGs, the Minamata Convention should be tightened up in order to reach the SDG target by country strategies with national development paths, targets and transfer payments.

A.5.2
Plastics

Synthetic materials, usually known as plastic, are carbon-containing polymers. Production of plastics has increased more than a hundredfold worldwide since the 1950s and today totals more than 280 million tonnes per year. About 20% of plastics are manufactured by companies in the EU (PlasticsEurope, 2012). Disposable packaging accounts for a large proportion of production – about 38% in Europe (UNEP, 2010a). In developing and newly industrializing countries, economic growth, as well as changing lifestyles and production methods, have caused a considerable increase in the use of plastic and thus also in plastic waste. The amount of plastic waste generated in developing countries with no waste-management systems can also be very large, and it will increase with economic development, growing urbanization in coastal cities, and population growth. This is in line with the observation that the concentration of plastic waste in the oceans is lower in the southern hemisphere than in the northern hemisphere (Lebreton et al., 2012).

Every year, large, difficult-to-quantify amounts of plastic waste enter the oceans for lack of reliable disposal and recycling strategies. 80% gets there through sewers, sewage treatment plants, industrial discharges, as runoff from waste disposal sites, as well as from agriculture or polluted beaches (Cole et al., 2011). The rest comes from ships, oil rigs, aquaculture installations and fishing operations. Plastics are estimated to make up 60–80% of the waste that collects in the oceans (UNEP, 2010a).

Generally, a distinction must be made between macro- and microplastics. Microplastics include industrially produced plastic pellets and plastic powders which are used, for instance, in peelings or toothpaste, and microfibre dust particles, which are formed by attrition when synthetic textiles are machine-washed. Plastic particles can find their way into the sea via production and transport, or through waste water, since they cannot be filtered out by sewage treatment plants. They measure between 1 µm and 5 mm (Cole et al., 2011). Another form of microplastics is small plastic pellets (<5 mm), which are formed when larger pieces of plastic are exposed to chemical (UV radiation, salt) and mechanical (friction, waves, wind, corrasion) effects, primarily on beaches (Derksen et al., 2012).

Plastic is distributed over huge distances by rivers and ocean currents and accumulates in oceans and lakes. It collects on the beaches, in remote regions of the seas, in the deep sea and in five major oceanic gyres. However, due to the prevailing patterns of winds and currents, there is very little exchange of plastic waste between the northern and the southern hemispheres, i.e. only in few coastal areas (UNEP, 2010a; Lebreton et al., 2012; van Cauwenberghe et al., 2013).

In coastal areas the concentrations of microplastics are higher if the region is densely populated and exposed to waste water (Browne et al., 2011). If the population of coastal towns rises in the future, an increase in microplastic contamination of the oceans can also be expected if there is no intervention. The amount of plastic waste circulating in the oceans is estimated at about 100 million tonnes in the meantime (UNEP, 2010a). Microplastics can now be found on all the beaches of the world, as well as in coastal sediments, and the concentrations that are measured in sea water vary considerably (Wright et al., 2013). Thompson et al. estimate that plastic accounts for 10% of the net weight of selected beaches. Little is known about the lifespan of plastics in marine environments. Estimates assume a period of several hundred years (UNEP, 2010a).

The environmental impacts of macro- and microplastics differ. The effects of larger pieces of plastic on marine organisms and the environment are well-studied. Fishing nets and plastic parts strangle and injure dolphins, seals, turtles, sharks and birds, among others. Above all, animals eat the plastic and die themselves or else feed their young with it. Another problem is the dispersal of non-native species into other marine ecosystems on pieces of plastic (Gregory, 2009), as a result of which they can cause ecosystem damage as invasive alien species. Pieces of plastic on the seabed can furthermore attract organisms dependent on hard substrate and thus lead to changes in benthic communities and the related ecosystems (Katsanevakis, 2008).

Less is known about the effect of microplastics in the marine environment and in marine organisms. Research findings in the last ten years show that microplastics emit plasticizers and other ingredients into the environment. Additives such as pigments, plasticizers or hardeners escape into the environment during the grinding process. At the same time, microplastics can be harmful to the endocrine system and bind carcinogenic substances such as POPs. These substances can possibly be spread by the transport of the plastic particles, find their way into organisms and accumulate in the food chain (Cole et al., 2011; Andrady, 2011; Ugolini et al., 2013).

Ingestion of microplastics has been proven in the case of algae, marine organisms that live close to the seabed such as sea cucumbers and langoustines, and several species of small fish that feed on plankton (Wright et al., 2013). Apart from a few exceptions, it remains unclear whether and which marine organisms are able to excrete microplastics. Possible damage is determined by factors such as whether excretion is (im)possible and how long microplastics remain within an organism. Damage can include inflammations, disrupted food intake, the transition of adhering contaminants from the digestive tract into the body, and the transfer of microplastics into food chains.

Microplastics have been found in the excrement of seals and sea lions, which is interpreted as their entry into the food web. In experiments, microplastics have also passed into the blood of mussels (Browne et al., 2008; Wright et al., 2013).

The most important strategy for reducing plastic waste is material reduction, particularly in one-way packaging. Reuse and recycling are also important solution approaches for reducing plastic waste. In addition, improved waste management should greatly reduce its unplanned release into the environment. Industrial microplastics can be substituted or filtered from waste water at great cost. The replacement of conventional plastics by biodegradable plastics should be the longer-term aim. 'Biodegradable' here means that the plastic can be decomposed by enzymes or microorganisms (aerobic or anaerobic decomposition in fermenters). The primary aim of research and development in the field of biodegradable plastic should be to facilitate and improve plastic recycling. In principle it would also be conceivable to only allow biodegradable plastic to enter the natural environment and to let it decompose by itself after a specified period of time. Since material reduction and recycling are the preferred strategies for solving the problem of waste from the perspective of resource conservation, uncontrolled self-decomposition should be a secondary objective of research and development.

Nationally and at the EU level, there are numerous private initiatives and political measures aimed at reducing waste. The final report of the Rio+20 Conference also points to the dangers of plastic waste and affirms the desire to solve the problem (UNCSD, 2012).

There are international conventions that focus on the pollution of the seas by ship-generated waste (International Convention for the Prevention of Pollution from Ships, MARPOL, 1973; Annex V in particular refers to plastic), and the targeted dumping of waste and other matter by ships, aircraft and other marine vessels (1996 London Protocol, which complements the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972). They also contain exceptions which allow the dumping of plastic waste in the seas. Most conventions covering the land-based dumping of waste into the sea, such as the Helsinki Convention (Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992), are regionally limited (Gold et al., 2013).

There is no global institution that commits states to reducing the land-based emission of plastics into waterways. Although Art. 207 (1) of the United Nations Convention on the Law of the Sea (UNCLOS, 1982) contains an obligation on the part of its 166 member states to prevent, reduce and monitor the land-based pollution of the seas, this framework regulation has still not yet been fleshed out and put into practice by a worldwide agreement. There is not yet any sign of an effective global approach to containing the problem of pollution with plastic (STAP 2011).

Plastic and microplastic are present in varying concentrations in many parts of the oceans. If no countermeasures are taken, the amounts of plastic will accumulate further. Negative effects on marine ecosystems are already apparent, but it is currently impossible to predict the full extent of possible adverse effects on humanity's natural life-support systems or how likely serious socio-economic consequences might be. However, neither of these can be excluded, and marine plastic waste could prove to be a considerable risk. In view of the ubiquity of plastic waste, its long lifespan and the medium-term irreversibility of the pollution, the precautionary principle should be followed and efforts to find a global solution to the problem intensified.

For these reasons, the WBGU believes that the following SDG target should be included: the release of plastic waste into the environment should be stopped worldwide by 2050. Prevention, reusable packaging systems and biodegradable plastic should go hand in hand. The international community should take measures to ensure that this objective is reached.

To date there is no global institution that recognizes plastic waste as a serious global environmental problem, obliges states to reduce plastic waste, dispose of plastic and develop recycling systems – and supports and coordinates their efforts in this regard. Similarly there is no international scientific institution that publishes regular reports on the current state of knowledge or collects comprehensive data on the sources and effects of marine plastic waste.

For these reasons, the WBGU recommends tightening up the existing international conventions on waste emissions at sea and ship-generated waste. It also reiterates its recommendations to strengthen and better interlink regional ocean conservation agreements, and to strengthen and extend the UNEP Regional Seas Programme (WBGU, 2013). Should it transpire in the course of the review on the SDGs that the measures taken by the states are not leading to any significant reduction in plastic waste, then further action by the states should be coordinated by a new specific international instrument.

A.5.3
Fissile material

Nuclear fuels – i.e. fissile material such as enriched uranium-235, plutonium-239 and other radioactive fission products with long half-lives – show certain parallels with carbon dioxide due to their persistence. In order to limit long-term effects – in the case of nuclear fuels a dangerous exposure to radiation, in the case of CO_2 dangerous climate change – their anthropogenic sources must be cut to zero. In both cases, the danger stems from the cumulative quantity. The cumulative amount of CO_2 in the atmosphere determines the extent of climate change; the cumulative stocks of radioactive material determine the scale of the danger from radiation and the potential for nuclear weapons production. Both the stocks and the flow values are therefore relevant in both cases.

In the case of fissile material, a distinction should be made between two different types of stocks: first the highly enriched stocks which are used in nuclear weapons, and, second, the lower-enriched stocks which essentially consist of spent reactor fuels and current inventories in the operating nuclear power plants; smaller amounts also exist in other civilian uses such as medical technology or drive systems. Both military and civilian uses of nuclear energy are dependent on the input of fissile material.

The International Panel on Fissile Materials (IPFM, 2011) estimates the global stockpiles of nuclear weapons at 19,000. These typically contain 90% uranium-235 (highly enriched from natural stocks with 0.7% concentration by isotope separation), which corresponds to about 1,440±125 tonnes of fissile material. Global stocks of weapons-grade plutonium are estimated at 495±10 tonnes. About half of it comes from military nuclear reactors for the production of weapons, while the other half is produced in civilian nuclear power plants. Stockpiles of weapons-grade plutonium are growing continuously as a result of production in countries that have not signed the 1968 Treaty on the Non-Proliferation of Nuclear Weapons. The five weapon states of the Non-Proliferation Treaty stopped producing weapons-grade plutonium decades ago, but they have not yet discarded excess stocks; China and France have not even declared the excess stocks. In addition, Japan has about 10 tonnes of weapons-grade plutonium from spent fuel. Approximately 98% of the world's weapons-grade uranium and plutonium belongs to the nuclear weapons powers, the largest stocks to Russia and the USA. There is no reliable information on stocks of low-enriched uranium in civilian use, since these data are not published by the operators of nuclear installations as a rule. Global stocks of civilian-produced plutonium are estimated at 260 tonnes (IPFM, 2013).

In the WBGU's view, the SDG target should be to stop the production of nuclear fuels for use in both nuclear weapons and civil nuclear reactors by 2070. Top priority should be given to destroying nuclear weapons and transferring stocks of radioactive material to places where it can be safely stored. The Fissile Material Cut-off Treaty is part of the negotiations within the UN Conference on Disarmament (UNIDIR, 2010), where the objective is to end the production of highly enriched uranium and plutonium by prohibiting the production of nuclear weapons. Such an international agreement would contribute to reducing the annual production of radioactive fission products to zero by 2070, as recommended by the WBGU. The WBGU also recommends the successful conclusion of the Fissile Material Cut-off Treaty.

The WBGU believes a nuclear moratorium is necessary. To the extent that the production of fissile material is continued and weapons-grade stocks are kept, special safeguards will be needed and maintained for decades or even thousands of years, depending on their radiation intensities and half-lives. Any use of nuclear energy involves the obvious risk of a proliferation of fissile material which is either used as reactor fuel (enriched uranium) or created in the processing of spent fuel (e.g. plutonium). Before the SDG target is reached, therefore, all uses and stocks of fissile material, as well as the sensitive steps in the nuclear fuel cycle, should be subjected to strict and permanent international control.

In response to this risk situation, a number of proposals have been developed on how the safety of nuclear-fuel processing and storage can be internationally guaranteed. Multilateral approaches, which would put the sensitive fuel-cycle steps under international control, could ensure more transparent safeguarding of these dangerous substances and more credible guarantees of their safe storage. The relevant literature (Yudin, 2009) discusses twelve of these proposals, which differ in vision, scope, targets and time required for implementation. Important elements of these proposals include, for example, a central store for nuclear fuels or an international centre for uranium enrichment under the supervision of the International Atomic Energy Agency (IAEA), as proposed by Germany, for example. The creation of international plants for the provision, enrichment and processing of fissile material should also be under the supervision of the IAEA. The WBGU recommends placing the fissile material, as well as the nuclear fuel cycle, under the IAEA's international control.

One possible way to reduce the stocks of highly enriched uranium is to use it as a fuel in civilian reactors, although this would generate new plutonium among the waste fuels. Another way to reduce stocks is transmutation, in which the more hazardous fissile material with long half-lives is converted into more benign, shorter-lived elements (Podlech, 2011). For example, irradiation with fast neutrons can convert transuranium elements such as plutonium into elements with a shorter half-life. A final, hitherto more or less theoretical possibility, is spallation, in which fissile material is converted into non-fissile or more benign fissile material.

A.6
Halt the loss of phosphorus

Alongside nitrogen and potassium, phosphorus in the form of phosphate is one of the three main components of artificial fertilizers. Highly concentrated, extractable phosphate rock is a scarce, finite resource (WBGU, 2011:43). Unlike crude oil, for example, phosphorus cannot be replaced by other substances; nor can it be manufactured artificially. Phosphorus is indispensable as a crop nutrient to ensure the required increase in productivity per crop area; its availability and accessibility are essential in order to maintain food security for the world's population and to meet the rising demand for bioenergy and bio-based products from land use (Bouwman et al., 2009; WBGU, 2011:43). Estimates on the size of phosphate rock reserves are very uncertain. Recent estimates put deposits in the region of 60 billion tonnes (van Kauwenbergh, 2010).

Phosphate production has been increasing since the 1960s. Studies suggest that the demand will continue to rise, especially in developing and newly industrializing countries. The demand is being driven primarily by the growing world population, rising consumption of meat and dairy products, the increasing production of non-food crops (e.g. for bioenergy or as a basis for the bio-based economy), the production of lithium iron phosphate batteries for electric vehicles, and the ongoing soil degradation in developing countries (Cordell and White, 2011).

Estimates on how long it will take until the reserves of phosphate rocks are completely depleted vary between 61 and 400 years, with the lowest estimates assuming the highest growth rates in demand; the highest estimates include no increases in demand. Estimates on when phosphorus production might peak also fluctuate. According to Cordell et al. (2009) it could be as early as 2030; Déry and Anderson (2007) say it was already exceeded in 1989. As with 'peak oil', the quality of the phosphate minerals will fall thereafter, while, ceteris paribus, there will be an increase both in environmental damage and in production costs (WBGU, 2011:43).

Irrespective of when precisely the deposits will be completely depleted, there is a whole list of reasons why the extraction of the deposits should be extended for as long as possible, and why fair access to phosphorus should be assured across the world.

The deposits of phosphate rocks are heavily concentrated in certain regions. An estimated 85 % of the deposits are in Morocco and Moroccan-occupied West Sahara, another 6 % in China, 3 % in the USA and 2 % in Jordan; 4 % are distributed across a further eleven countries (Cordell and White, 2011).

The use of phosphates, too, is very unevenly distributed across the world. In some regions the excessive use of phosphates causes phosphorus-related environmental problems, e.g. large-scale eutrophication; in other parts of the world, e.g. in large regions of sub-Saharan Africa, a lack of access to artificial fertilizers is preventing urgently needed improvements in agricultural productivity. A geographical redistribution from areas with a high rate of use to areas with low phosphorus use could protect the environment and increase agricultural productivity where necessary, without imposing any additional burden on phosphate stocks (Steffen and Smith, 2013).

Important strategies for achieving necessary long-term improvements in land productivity using phosphorus include using phosphate fertilizers more efficiently, closing nutrient cycles in agricultural production, further reducing phosphorus loss during extraction, preventing soil erosion, and recovering phosphorus from excreta and waste as well as from waste water via sewage sludge (Vaccari, 2009; Cordell, 2010; Craswell et al., 2010).

Even if phosphate deposits offered sufficient reserves for many decades, the risk of a shortage would still exist for the time thereafter. Scarcity of phosphate would drive prices up and make access more difficult for poorer sections of the population. More serious shortages could even make it difficult to maintain food production at the levels required. At present there is still time to take action to reduce the amounts of phosphate fertilizer being used and to boost phosphorus recycling.

Up to now there have been no international governance structures that are explicitly responsible for the long-term availability of phosphate and equitable access to it (Schröder et al., 2010). At the national level, political measures to encourage a more efficient use and more recycling of phosphorus are the exception, even though suitable technologies are available.

The European Commission has launched a consultation process on the question of how the supply of phosphorus can be secured in the long term and how recycling processes can be introduced. The European Parliament has asked the European Commission to develop criteria and pilot projects on sustainable phosphorus management; the aim is to be able to recycle all phosphorus by 2020 (EU Parliament, 2012). Griggs et al. (2013) suggest a 20% increase in the efficiency of nutrient use by 2020, limiting phosphorus runoff into the seas to 10 million tonnes by 2020, and cutting phosphorus runoff into lakes and rivers by half by 2030. The Global Partnership on Nutrient Management also proposes a 20% increase in nutrient efficiency by 2020 (Sutton et al., 2013). The Sustainable Development Solutions Network has proposed raising nutrient efficiency by 30% by 2030 (UN SDSN, 2013b). The Resource Panel of the UN Environment Programme has also proposed including a phosphorus efficiency target in the SDG list (IRP, 2014).

Given the strategic importance of phosphorus for the world's food supply, the WBGU believes it is of great importance to establish a guard rail via an appropriate target in the SDGs. The WBGU therefore proposes the site-specific optimization of global primary fertilization with phosphorus by 2030. The release of non-recoverable phosphorus into the environment should be stopped by 2050, so that its global recycling can be achieved.

At present there is no global institution addressing the issue how best to conserve phosphorus. Should the review of the SDGs show that the state measures seeking to achieve these objectives are inadequate, then the use of phosphorus should be regulated under its own convention. A global report on phosphorus use and deposits could contribute towards improving fertilizer use, waste management and recycling.

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