WBGU

German Advisory Council on Global Change

Special Report

Development and justice through transformation: The Four Big ‘I’s

A contribution to Germany’s G20 Presidency in 2017

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Summary

2015 saw a historic double success for sustainability and climate policy. The 2030 Agenda for Sustainable Development, with its Sustainable Development Goals (SDGs), and the Paris Agreement on climate protection establish a system of ambitious policy goals for the world. The group of twenty major industrialized and emerging economies (G20) now needs to resolutely advance implementation of both agreements, seizing the opportunity of this 'Great Transformation' to sustainability as a unique modernization project that offers substantial economic development opportunities. Complete decarbonization of the world economy by 2070 at the latest can only be achieved by profoundly transforming energy systems and other high-emissions infrastructures. This transformation could inspire *Innovation* and channel *Investment* into sustainability and climate protection, e.g. into sustainable *Infrastructures* that need to be established and expanded. At the same time, the transformation could combat inequality and promote *Inclusion* within societies and globally, thus becoming an equity project. The G20, as a central global actor, should specifically promote the Four Big 'I's of sustainability and climate policy to ensure that conflicts over resources and their distribution are defused and international crises avoided. Sustainable development, and in particular global climate protection, is currently the only ambitious undertaking that involves all the world's nations and resulted in a global consensus. Achievements in this enormous, complex policy field enable countries to establish mutual trust, making the 'Great Transformation' to sustainability also a peace project. Germany's G20 presidency can set a decisive course for this future programme.

A double breakthrough: the political context

In 2015 two global conferences reached a double breakthrough. (1) The 2030 Agenda for Sustainable Development, with its 17 SDGs agreed upon at the UN in New York, outlines the complex challenges of a transformation towards sustainability that should also help overcome global poverty. The SDGs are at once shared goals and a challenging programme of action for the global community. (2) The Paris Agreement under the auspices of the UN Framework Convention on Climate Change (UNFCCC) for the first time establishes legally binding goals to keep man-made global warming well below 2°C and pursue efforts to limit warming to 1.5°C. These goals are an appropriate global political reaction to threats that can no longer be denied.

However, our current political context is also characterized by various dangerous tensions: wars and civil wars, mass migration and terrorism, global financial market crises and growing inequality as well as the rise of an authoritarian, populist nationalism observed in many countries are major issues. Given this situation, the Paris Agreement and the 2030 Agenda must not be allowed to be relegated to the bottom of the international political agenda.

Implementing decarbonization strategies

Implementing the Paris Agreement will demand a uniquely strenuous effort from the global community. If emissions remain at current levels, the global CO_2 budget for limiting global warming to 2°C will be exhausted within 20 years. If we are to keep global warming below the 2°C guard rail, emissions will have to be reduced to zero by 2070 at the latest. To limit the increase in the global temperature to 1.5°C, we will need zero emissions by 2050. This will only be achieved by fundamentally transforming energy systems and other high-emissions infrastructures and substantially changing citizens' behaviour.

There is a risk that some countries – in order to avoid a rapid phase-out of fossil energies – will engage in a massive expansion of nuclear energy and large-scale deployment of untested technologies such as carbon dioxide capture and storage (CCS, also in combination with bioenergy – BECCS), possibly supplemented by

high-risk geoengineering measures, e.g. manipulation of the global radiation budget.

The WBGU is proposing a much lower-risk alternative for preventing the global temperature from rising by more than 2°C. It recommends rapidly decarbonizing energy infrastructure, greatly accelerating the expansion and development of renewable energies, and effectively curtailing energy consumption. To bring about such a transformation, the WBGU is presenting a *decadal carbon roadmap* to plot the profound changes that will be necessary in coming decades. Its proposals range from effective CO_2 pricing and an end to fossil fuel subsidies (by 2020), denying licences for new vehicles with combustion engines (by 2030) and large-scale deployment of renewable energy technologies as well as energy storage and transport (by 2040), to complete decarbonization of the G20 economies (by 2050).

The G20's leadership role

G20 countries are responsible for 82% of CO_2 emissions from fossil fuels, so the G20, with its formative influence on the world's economy and politics, must play a leading role in implementing the 2030 Agenda and the Paris Agreement. The G20 countries should, for example, increase the reductions they announced within the framework of the UNFCCC to reconcile them with the goals agreed on in Paris. The WBGU also recommends that the G20 adopt the decadal carbon roadmap. Based on this roadmap, G20 countries should develop comprehensive and verifiable national *decarbonization strategies* for, inter alia, phasing out the use of fossil fuels by 2050 and preserving natural ecosystems, with their carbon stocks und sink functions.

The Four Big 'I's: Innovation, Infrastructure, Investment, Inclusion

If we are to pursue this challenging path, the Four Big 'I's must become part of the G20 programme: a reorientation of *Innovation* to make it possible to develop economies and prosperity within the guard rails of the Earth system; a rapid, climate-friendly and resource-efficient modification of the global economy's central *Infrastructures*; the creation of framework conditions for stimulating more *Investment* in the transformation towards sustainability; and linking these goals with the principle of social *Inclusion*, i.e. equity and participation, which should guide all these actions and is both a precondition and a goal of the societal transformation towards sustainability. G20 governments should advocate for the Four Big 'I's of transformation. To achieve all these goals, the WBGU believes that the *proactive state* – one that actively sets priorities, publicizes them explicitly, and gives its citizens greater opportunities to raise their voices, to participate in decision-making and to be actively engaged in their societies – must be strengthened.

Establish transformative sovereign wealth funds

The nations participating in the 2030 Agenda and the Paris Agreement will need to develop effective national policy instruments to implement the goals they have set. The WBGU recommends in particular that G20 countries establish *transformative sovereign wealth funds*, which we also call 'future funds'. These could enable G20 countries to be more active in financial markets as stakeholders, with the goal of promoting socially responsible structural change to create a sustainable economic and social system. These future funds should draw their revenues from CO_2 taxes and emissions trading as well as from a generational component levied on estates. The investments made by the transformative sovereign wealth funds should be oriented towards climate change targets and the SDGs; profits should be used to advance equity and the common good.

Using sustainability and climate policy to solve global political problems

G20 governments should become involved as pioneers in this area not only 'at home', but also at the international level, and help to strengthen cooperation and solve global problems. If correctly configured and strategically used, the Four Big 'I's of sustainability and climate policy could serve to leverage solutions to global political problems.

First: A far-seeing climate and sustainability policy could become a *modernization project* for the global economy. It could open up opportunities for economic development by inspiring innovation and creating sustainable investment and employment prospects, and it could help channel investments into technologies, companies and infrastructures that will secure a better future in the long term.

Second: Climate and sustainability policy could become an *equity project* at the national level and promote inclusion by making decarbonization strategies socially responsible, combating inequality and strengthening social cohesion.

Third: Tackling shared sustainability and climate policy challenges could become a *peace project*, enabling countries that otherwise do not cooperate, or are in open conflict with one another, to establish mutual trust. This would require inclusion at the global level to defuse conflicts over resources and their distribution and to counteract civil wars and mass migration.

Introduction

1

This report begins with a long overdue clarification and ends with a well-founded hope.

The clarification

In the first decades of the 21st century, the global economy has stalled and inequality increased further in many countries. It is by no means the detrimental interventions of a sustainability policy that are to blame for this development. On the contrary, political measures in this area have to date been so powerless that global warming and species extinction are now progressing at a terrifying speed.

This is occurring even though almost all the preconditions normally regarded as conducive to the flourishing of global markets (and their customers) have been met. Many nation states are vying with each other to deregulate their economies and offer companies tax reductions. Central banks are incessantly pumping cheap money into national economies, even though private liquidity has now reached historically high levels and the planet is veritably flooded with low-priced fossil fuels.

And yet the mature economies, as well as some emerging economies, are stagnating, the real interest rate has fallen to zero, investment activity is declining, in many countries essential infrastructure is deteriorating, and the youth unemployment rate is dramatically high, including in many areas of Europe. Broad segments of society are experiencing shrinking real incomes and feel that they are further lagging behind national and global elites. It must again be emphasized that the dynamics of these crises are not caused by what are still fairly timid environmental regulations, but by the internal logic of an industrial system, driven by fossil fuels, that can generate prosperity for the many only while in expansion mode and at the same time passes on most of the true costs of growth to vulnerable income earners and future generations – whether in the form of social debasement, spectacular levels of national debt or the destruction of natural life support systems. It is alarming that the traditional model of the global economy no longer works, even though the future costs are being ignored. It is therefore evident that a model of prosperity that no longer works, but causes major damage every day, must be questioned and restructured. This will take *transformation*, not repair.

This is not to say that the benchmarks of modern society – development in the sense of material and cultural progress and equity in the form of fair opportunities for individuals – have to be disregarded. Western democracy's most precious achievement in this context, namely the right to *self-determined personal development in an open society*, should by no means be impaired. However, the framework within which this development can take place must now be redefined, which is the inherent responsibility of politics in the service of the greater common good. Therefore, the mission of today must be the transformation to a sustainable global society and world economy! G20 countries must play a leading role in this transformation. Two observations should be made in this context.

Observation 1: Transformation to sustainability is possible

The transition to a sustainable economy will require *binding objectives* and a powerful *operative concept*. Despite substantial resistance and countless setbacks, multilateralism – cooperation between nations at the international level, namely in the UN system – achieved an important shared objective in 2015 with the proclamation of the Sustainable Development Goals (SDGs) goals compiled in the 2030 Agenda and the signing of the Paris Agreement for global climate protection under the auspices of the Framework Convention on Climate Change. This is rightly regarded as a historic success. The 2030 Agenda and the Paris Agreement are also currently the *only* ambitious initiatives involving all nations. These two projects for the benefit of mankind could bring together actors that otherwise do not cooperate or are engaged in serious conflicts. How can we breathe life into this ambitious vision? What steps should the G20 countries take to realise it?

Before answers can be given to these questions, the WBGU declares unequivocally that the now largely globalized project of modern society – the campaign against climate change – will fail if the global objectives painstakingly hammered out in multilateral processes and institutions in 2015 are not taken seriously. The climate crisis has grown dramatically worse in recent years, a development entirely in line with the best projections of international science. In contrast to the situation a few years ago, its existence is now rarely disputed among scientists and is now only denied by political actors who position themselves as 'post-factual' and operate explicitly outside the limits of truth and real-

ity. The Paris resolutions, and especially the agreement to limit anthropogenic global warming to 1.5–2°C, are an appropriate global political reaction to a threat that can no longer be denied. Implementing these resolutions will require a major, historically unique effort towards a modernization based on evidence and solidarity.

These issues will be dealt with in more detail in Chapter 2, in view of the fact that climate change has long since come dangerously close to crossing the red lines identified in the Paris Agreement. Also, humanity is now close to reaching other planetary limits within which the progress of civilization can develop with reasonable security. Water resources, fertile soil and biodiversity are all coming under mounting pressure, while the input of pollutants and toxins into the natural environment are increasing almost exponentially. The almost irreversible pollution of the world's oceans (WBGU, 2013) is perhaps the most scandalous expression of this worrying development. The 2030 Agenda, with its 17 fundamental SDGs is a policy response to this multidimensional challenge. However, the WBGU is of the opinion that dealing with the climate crisis is the *conditio sine qua non* for global society in the 21st century, which is why this paper intensively examines this topic.

State of the art scientific research shows that rising global temperatures can only be limited to less than 2°C if the global economic system is largely decarbonized by 2050. We must *immediately* set out on the path necessary to achieve this transformation so that global emissions can peak by around 2020. This is explained in more detail in Chapter 2. The WBGU has also examined alternative scenarios that rely less on rapid efforts towards transformation now, and more on massive technical interventions (e.g. geoengineering) later (Box 3.2-1). The WBGU takes the view that such strategies are irresponsible in several ways. Researchers cannot yet adequately answer the question of whether 'negative emissions' achieved through low-risk measures, such as afforestation campaigns, should *supplement* decarbonization after the middle of this century. It is quite evident, however, that such measures cannot *replace* the fastest possible phasing out of a fossil fuel-based economy. Thus, all efforts should be directed towards developing a 2050 Agenda for transformation and decarbonization.

Observation 2: International crises and a movement against transformation, cooperation and democracy are jeopardising the transition to sustainability

The success stories of the Paris Agreement and the 2030 Agenda are offset by bi-national, multinational and international crises. Wars, civil wars, transnational terrorism and mass migration are issues currently dominating global politics. Serious tensions and frosty political relationships are making cooperation between relevant actors, including G20 countries, more difficult. Ten years after the global financial crisis, debt and banking crises, with their negative effects on tax revenues and growth, are still on the international agenda. The EU, the prime example of cooperation among regional governments, is mired in an existential crisis. German diplomat, former State Secretary of the German Federal Foreign Office and Chairman of the Munich Security Conference, Wolfgang Ischinger, has spoken of an impending era of disintegration of the world order. In an environment dominated by crises, the transformation to sustainability risks being relegated to the margins of the G20 agenda.

This international turbulence is mirrored by crisis-ridden developments in many societies, including some within the G20. The belief that globalization creates growing disparities, inequality and social discord has become widespread. It has often been the poorest who have borne the consequences of financial market crises, while powerful multinational companies use systematic tax avoidance strategies to reduce their contributions to financing public assets. The OECD estimates the resulting national revenue losses at US$ 100–240 billion per year (OECD, 2015). The Panama Papers have come to symbolize the way in which wealthy segments of the population shirk their responsibility for contributing to the common good through tax evasion. These dynamics lend credence to the impression that globalization is an elite project, which has contributed to the rise of authoritarian, populist nationalism in many countries. 'Our country first' movements represent rejections of international cooperation and the protection of global public assets. The 'Great Transformation to Sustainability' (WBGU, 2011) is opposed by an authoritarian, neo-nationalist 'counter-transformation' that threatens the future viability and security of our societies, rule of law and democracy.

At this juncture, Germany's G20 presidency should demonstrate approaches and solutions for a transition to a sustainable international community based on cooperation. If this transition does not succeed, it is feared that sustainability policy and approaches towards functional global governance and achievements of the rule of law and democracy will be drawn into the vortex of global confrontations and internal crises facing many G20 countries.

The WBGU's perspective on required action

The historic resolutions agreed upon in Paris in 2015 and the 2030 Agenda were made in an era of volatile and escalating national and international conflicts that demand short-term crisis management and much political attention, and could make it harder to establish long-term sustainability reforms. In this situation, political leadership, farsightedness and a broad view of the world will be required to prevent the resolutions of the Paris Agreement and the 2030 Agenda from being relegated to the bottom of the international list of policy priorities.

Building on preliminary work carried out during China's presidency (e.g. the 'Action Plan on the 2030 Agenda for Sustainable Development'; G20, 2016a), Germany's G20 presidency in 2017 is an excellent opportunity to tackle the necessary transformation to sustainability not isolated from, but in connection with

the many other major issues facing global politics. The WBGU recommends that the G20 design the transformation to sustainability to become

- a central engine for modernising the stagnating global economy,
- an equity project for a global community that is drifting apart, and
- an international peace and cooperation project in an era of rampant violence for many regions of the world.

To promote this recommendation, the WBGU has developed a narrative in Chapter 3 that is based on its 'Great Transformation' scenario presented in 2011 (WBGU, 2011), updates it to reflect the latest research, and shapes it into a bundle of concrete recommendations for decision-makers (ranging from governments to consumers).

One fundamental prerequisite for implementing these proposals is the *guiding principle of the proactive state*. Public institutions, markets, civil society and science must be brought into a new balance to advance the transition to sustainability as a *global modernization project*. The first big globalization crisis between 1910 and 1930 sent the leading industrialized nations of the period into a state of dangerous tension and triggered a hysterical nationalism that suffocated the intellectual, cultural and technological creativity of the period, paralysed international initiatives such as the League of Nations, and finally led to two world wars. Only America's New Deal policy was able to stymie the impetus of a nationalist austerity plan, building welfare-state barriers against economic decline. In this current globalization crisis, we need another 'New Deal', a (global) social contract for sustainability and inclusion, that extends beyond the boundaries of nation states, and can overcome the global economy's current stagnation and integrate it into the project of *restoring harmony between civilization and nature*.

G20 countries produce 80% of the world's aggregate output (World Bank, 2016a) and 82% of greenhouse gases from fossil fuels (IEA, 2015a), making them essential actors in global political and socio-economic affairs and the main addressees of this study. Issues such as innovation, investment and infrastructure are regularly on the G20 agenda. In 2016, the highly relevant issue of limiting socio-economic disparities and promoting inclusion was added to the list (G20, 2016b). These are the central concepts around which this special report revolves: *Innovation, Infrastructure, Investment* and *Inclusion,* the Four Big 'I's. Germany should use its G20 presidency in 2017 to consolidate these concepts into a cohesive vision of progress. To help it do so, the WBGU has drafted a series of proposals described in detail in Chapters 3 and 4.

To make this debate more concrete, the WBGU is bringing two new policy elements into play, namely a *decadal carbon roadmap* and *transformative sovereign wealth funds*. With respect to the first element, the WBGU, with a view to the latest research and prospects offered by technology, has developed a roadmap for the transition from a fossil-nuclear to an efficient-renewable economy, which was agreed upon *de facto* in the 2030 Agenda and the Paris Agreement. It explicitly proposes innovations that must be introduced in *5 or 10-year stages in the relevant socio-economic sectors*, such as a swift substitution of coal in the energy sector, electrification of the transport sector well before 2050, and rapid reform to make the food sector sustainable. One potentially decisive instrument of modernization that the WBGU recommends to G20 countries is the establishment of 'future funds'. This proposal is inspired by institutions like Norway's government pension funds (Statens pensjonsfond utland), which are financed by oil and gas revenues yet are much more than just pension funds in their intention and effect. Such transformative sovereign wealth funds could turn the countries tasked with the responsibility for sustainability into proactive agents for change. A range of options are available: *direct investment* in future projects, *public-private partnerships* for mobilising and leveraging private liquidity, a market presence in the form of a *'federal shareholder'* (Corneo, 2015) and financial *support for accompanying socially relevant conversion processes*.

One German example excellently illustrates the effect of this double approach. The updating of the German Climate Action Plan, which has been required since the Paris Agreement of 2015, will have to be oriented towards the Four Big 'I's, especially concerning the complete end to the use of coal in the fourth decade of the 21st century. Affected regions will have to be offered prospects for modernization (such as the building of competitive industrial capacity in the area of energy storage), and the transformation process will require both funding and socio-political support for it to succeed in the time allowed.

The WBGU also goes a step further towards making its proposals more concrete by recommending the financing of a German future fund and their equivalents in other G20 countries (Box 3.3-1). It takes the view that this requires a *structural tax reform* that is oriented towards demands made in the 2030 Agenda and the Paris Agreement, no longer ignores what have become notorious externalities (such as destruction of the environment and detriment to human health) and contributes to a significant reduction in social inequality. Along with progressive CO_2 pricing, the issue of inheritance should no longer be considered taboo in this context.

The hope

As emphasized above, the post-war model of globalized wealth creation based on fossil fuels is grinding to a halt, yet this negative evaluation still fails to consider the resulting intergenerational damage. However, the WBGU is convinced that sustainably transforming this model will yield a double dividend. Not only will it prevent a fatal degradation of the global environment, it could also create the basis for a new economic dynamism, with positive effects on employment, prosper-

ity and equity. To put it more pointedly, there are many indications *that it is not the global economy that must be transformed to save the climate, but rather, it is the innovation required to sustain the natural life-support systems that will rescue the global economy!* The decarbonization described in Chapter 3 is nothing less than an industrial revolution on a global scale.

As the WBGU explains in detail in Chapter 4, the transformation dividend could be even greater. Climate and sustainability policy can help to *maintain internal and external peace* by defusing conflicts over resources and their distribution as well as preventing civil wars and mass migration. In contrast, limitless exploitation of nature undermines peace between nations. Climate protection and the 2030 Agenda could become a project for modernization, equity and peace.

The WBGU recommends to the G20 the following narrative for orienting the world economy towards the 2030 Agenda and the Paris Agreement:

1. Sustainability policy is not a luxury, not even in difficult geopolitical times. Delays in implementing the Paris Agreement and unabated climate change would further inflame current and future conflicts in the international community. Many societies would be overwhelmed and destabilized by the consequences of uncontrolled global warming (WBGU, 2008, 2014a).
2. The 2030 Agenda is an ambitious, future-oriented response to the forces sowing social discord, to the concerns of many sceptics of globalization and to the anxious nationalist reactions proliferating in many countries. It is becoming clear that decarbonization and the establishment of resource-efficient recycling economies can only succeed against a background of social reform and the improvement of developmental and life prospects for all people. Such prospects can counter authoritarian, nationalist movements that reject international cooperation as well as the narrow points of view that overly herald a free market economy, which have long ignored the social inequality and segregation they foster.
3. The Paris decisions can make climate policy, a symbol of deadlocked multilateralism for over two decades, into a beacon of hope for a renewed culture of global cooperation in an era of dangerous international tensions. Both global sustainability agreements are destined to fail if G20 countries do not make massive efforts to advance them.
4. The Paris Agreement and the 2030 Agenda propose policies that can create prospects for cooperation and a better future as well as stem the destructive effects of renationalization in many societies and of the escalating conflicts and violence in the international system. It can be demonstrated that *a global transformation to sustainability could in effect also be a project for modernization, equity and peace*. An intelligent climate and sustainability policy could serve to *modernise the global economy* and open up opportunities for economic development by creating major investment opportunities and sustainable employment as well as channelling money away from unproductive and speculative forms of investment and into industries and companies that will be viable and sustainable in future. Climate and sustainability policy can also become an *equity policy* if it can make decarbonization strategies socially responsible, combat inequality effectively and strengthen social cohesion. Climate and sustainability policy could contribute to maintaining *peace* by defusing conflicts over resources and their distribution, and thus prevent civil wars and mass migration.
5. Decarbonization plays a central role in the transformation to sustainability and is an essential element of the 2030 Agenda; without combating climate change, the SDGs, especially the radical reduction of poverty and inequality, cannot be implemented. At the same time, decarbonization can only succeed within the context of the SDGs, e.g. by massively expanding renewable energies while providing access to modern energy for the billions of people living in energy poverty, and by modifying, in a socially responsible way, production and industry that damage the climate.
6. As a project for global modernization, equity and peace, a transformative climate and sustainability policy will entail:
   - A redirection in technological and social *Innovation* to enable the progress of economy and prosperity within the guard rails of the Earth system;
   - A rapid, climate-friendly and resource-efficient modification of the central *Infrastructures* of national economies and the global economy;
   - The creation of appropriate framework conditions to trigger a boost in *Investment* in the transformation to sustainability;
   - The connection of all these goals with the guiding principle of social *Inclusion*, i.e. equity and participation; after all, inclusion will not simply emerge spontaneously and represents at once a precondition and a goal of a successful societal transformation towards sustainability.

To accelerate this transformation and align it with the Four Big 'I's, the WBGU promotes the idea of a *proactive state* – one embedded in a new balance between economy and civil society with the involvement of science – and proposes a tax reform oriented towards the 2030 Agenda to generate transformative sovereign wealth funds in helping implement future decarbonization strategies.

Climate protection: The challenge of Paris

2

The following considerations focus on climate protection, its new grounding in international law, and the requirements for action that have increased as a result, above all in terms of global infrastructure. Only by also considering other sustainability goals can a climate protection strategy make a successful contribution to a global project in support of modernization, equity and peace (Chapter 4).

2.1 What was decided in Paris

The Paris Agreement adopted on 12 December 2015 at the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) is a milestone in climate policy. Its central achievement is the determination of binding quality goals for the protection of the climate for nearly the entire international community.

The Paris Agreement is a treaty in the sense of the Vienna Agreement on treaties between states (Vienna Convention on the Law of Treaties, 1969) and develops – in correspondence to the mandate from Durban – fundamental binding obligations for the contracting parties (*pacta sunt servanda*; Schlacke, 2016; Bodle et al., 2016).

Nevertheless, the respective regulations of the Paris Agreement vary in scope in terms of their binding force; they address goals, concrete obligations, general guidelines still lacking details and mere recommendations. However, provisions stipulating concrete action, acquiescence or omission are the exception. The target audience also varies (parties to the agreement, developed countries, developing countries, secretariat, etc.). In this respect, the binding force of the agreement is dependent on the details of each individual regulation. The positioning of the G20 countries vis-à-vis the implementation of the Paris Agreement is thus of great importance.

The goal in Article 2.1 (a) – to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to even limit the temperature increase to 1.5°C – is binding for all parties (Frank, 2016). For the first time, the international community has agreed under international law to a quantified climate protection goal. As a result, the "dangerous anthropogenic interference with the climate system" from Article 2 of the UNFCCC has been defined in concrete terms (WBGU, 2014a; Morgenstern and Dehnen, 2016). Only through further specification can both the 2°C goal and the 1.5°C goal be enforced, monitored and non-compliance be sanctioned (Schlacke, 2016).

Although the global long-term goal from Article 4.1, aimed at all parties, to reach global peaking of greenhouse gas emissions as soon as possible, followed by a swift reduction in order to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of the century, is a binding goal, without further specification it can be neither enforced, monitored nor can non-compliance be sanctioned. The aim is greenhouse gas neutrality in the second half of the century, which need not be reached exclusively through the mitigation of greenhouse gas emissions, but also leaves open the establishment of geoengineering measures aimed at the creation of CO_2 sinks (e.g. afforestation, ocean fertilization, ocean alkalization; Morgenstern and Dehnen, 2016). Not included, however, are measures addressing solar radiation management, i.e. geoengineering technologies that target temperature limitations through the shielding of solar radiation (Box 2.3-2), as the sense, purpose and wording of Article 4.1 ('removals by sinks of greenhouse gases') are limited to emissions and sinks of greenhouse gases. According to Article 1.8 of the UNFCCC, sinks are processes by which climate-relevant substances are removed from the atmosphere (e.g. CO_2 uptake by forests, oceans or technological procedures). These goals are to be reached above all through Nationally Determined Contributions (NDCs). NDCs can target climate mitigation and adaptation, yet do not serve to address loss and damage (Article 3). The parties are obligated to communicate NDCs, and communicate every five years further developed and enhanced NDCs, as well as report in a clear and transparent manner their development, achievement and adherence (Articles 4.2, 4.3, 4.8, 13.7 (b)). There is a duty to act *per se* (Morgenstern and Dehnen, 2016), without concrete targets being specified. This represents both opportunity and responsibility for the nation states that are tasked with implementing the Paris goals. Since the failure to reach the announced NDCs is not sanctionable according to the Paris Agreement, the countries must make national provisions to guarantee enforcement of their commitments, or to issue sanctions in the case of nonattainment. The

double counting of emissions reductions is strictly forbidden (Article 6.5). The UNFCCC secretariat is obligated to record NDCs and adaptation measures (Articles 4.12, 7.12).

The Intended Nationally Determined Contributions (INDCs) or NDCs announced thus far are not always quantified or quantifiable. In order to measure them against the long-term temperature goal (well below 2°C) and the global long-term emissions goals formulated in Article 4.1, as well as to be able to verify the compliance efforts by the parties, uniform standards for the communication of NDCs must be developed. The success of the Agreement depends in large part on the improvement of the national contributions (Arens et al., 2015).

In contrast to the Kyoto Protocol, the Paris Agreement relies on all states assuming responsibility, be they industrialized countries, emerging economies or developing countries. Nevertheless, the Agreement refers back to a core principle of the UNFCCC: the principal of "common but differentiated responsibilities" (Article 3 of the UNFCCC; Article 2 (2) of the Paris Agreement). Thus, industrialized countries are assigned a leading role, e.g. in determining NDCs (Schlacke, 2016).

The promotion of adaptation measures has become part of the goal specifications of the Paris Agreement (Article 2 (1) (b)). As a result, adaptation to climate change has seen increased attention (Morgenstern and Dehnen, 2016; Doelle, 2016) and should be further strengthened. Adaptation measures can initially prepare population groups to face current and likely future impacts of climate change, and thus indirectly combat causes of flight. From the perspective of the WBGU, flight or migration as a reaction to the impacts of climate change can be understood as the *ultima ratio* of adaptation. The theme of migration is thus far treated under 'displacement', e.g. under the umbrella of 'loss and damage', only in the decision text that accompanies the Paris Agreement – non-binding under international law – and is subject to the Warsaw Mechanism (UNFCCC, 2015b: §§ 50–51; WBGU, 2014a).

Compensation for loss and damage resulting from climate change was not considered. Although loss and damage is addressed in Article 8 of the Paris Agreement, the parties made it clear that they considered this regulation not to include compensation or liability for damages directly or indirectly related to climate change (Morgenstern and Dehnen, 2016; Doelle, 2016). However, in the opinion of the WBGU the mere mention that loss and damage resulting from climate change is a problem in need of addressing is insufficient. One is almost bound to interpret such a weak formulation as taking it off the agenda. Rather, the causing of loss or damage should have concrete legal consequences, such as claims for compensation for small island states. The WBGU recommends beginning a discussion focussed on who must pay for these damages, how they will be compensated, and where, how and by whom claims can be enforced. Only by addressing these questions can future conflicts be avoided.

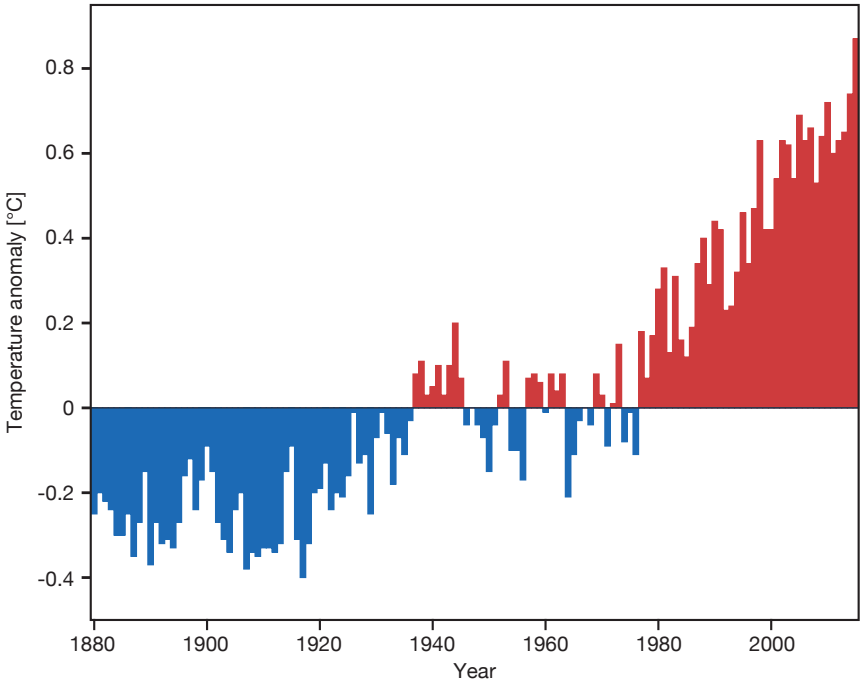
The issue of climate (protection) financing found prominent placement in the Paris Agreement as part of the goal specifications in Article 2.1 (c) (Morgenstern and Dehnen, 2016). Article 9 refers back to the obligation of industrialized countries, under the UNFCCC, to provide financial support for developing countries. However, concrete obligations, such as providing US$ 100 billion annually, were only addressed in the decision text (§ 54) that accompanies the Paris Agreement (Bodle et al., 2016). A legally binding phase-out of subsidies for fossil fuels was not agreed upon (Doelle, 2016). Rather, the focus of the measures agreed upon in Paris was on procedural provisions creating transparency. Therefore, the WBGU finds it important that (1) this procedural framework is filled out with measures (Section 4.3), and (2) the industrialized countries as well as emerging economies bear concrete financial obligations to promote climate mitigation and climate adaptation measures. In this vein, the G20 states should assume a leading role.

Overall, the Paris Agreement sends a very important signal for international climate protection. The framework created in Paris must soon be filled out with national measures. In this respect, what is needed most, besides the standardization and monitoring of NDCs, are ambitious, additional decarbonization efforts by the parties.

2.2
Limiting warming and avoiding climate extremes

Since the 15th Conference of the Parties to the UNFCCC in Copenhagen in 2009, limiting global warming to 2°C above preindustrial levels has been part of the international discussion. Climate impact research shows that exceeding this planetary guard rail makes dangerous anthropogenic impacts on weather and climate more likely (e.g. an increasing number of extreme weather events, droughts, floods, the disappearance of mountain glaciers, irreversible melting of Greenland's ice sheet, a strong rise in sea levels); however, hazards can occur even without exceeding this limit (WBGU, 1995, 2003, 2009b; UNFCCC, 2015a). The warming is not the same everywhere, but varies widely depending on region. For instance, the Arctic is warming at a rate that is more than twice the global average (Cohen et al., 2014). Also, the rise in sea levels varies regionally (Rhein et al., 2013). Therefore, impacts of climate change will vary widely by region. The goal decided upon in Paris to not only keep the increase in the Earth's average surface temperature well under 2°C in comparison to pre-industrial levels, but to undertake efforts to limit the temperature rise to 1.5°C, would considerably reduce the risks and impacts of changes in climate and is thus recommended from a precautionary point of view. As a consequence, only an additional warming of 0.5–1°C would be tolerable, since the global temperature has already risen approx. 1°C from 1880 to 2015 (Hansen et al., 2016; Figure 2.2-1). The latest measurements show that every single month

Figure 2.2-1
Development of the mean global surface temperature between 1880 and 2015. The graph shows the temperature deviation as compared to the average value in the years between 1951 and 1980.
Source: WBGU, on the basis of data from the Goddard Institute for Space Studies (NASA, 2016)



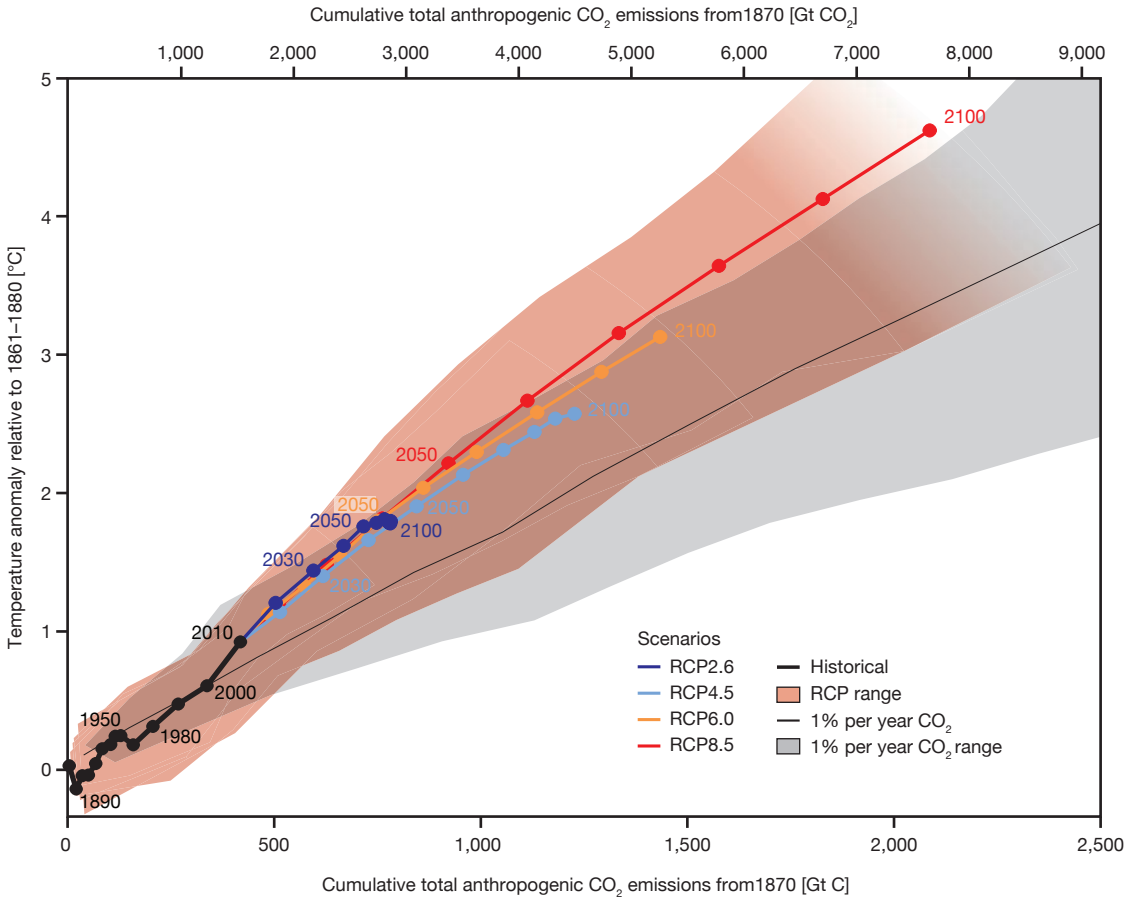


Figure 2.2-2
Global mean surface temperature increase as a function of cumulative CO_2 emissions. The chart summarizes results from various models. Depending on the scenario, certain figures are reached for cumulative emissions at different times (coloured bold lines and dots; the highlighted area shows the variance in the model results and scenarios). In these scenarios the effects of other greenhouse gases on the temperature are also taken into account. The thin black line with the grey-shaded area indicating the spread shows the extent of warming if no other greenhouse gases, i.e. only CO_2, were emitted; an increase in CO_2 of 1% per annum was assumed.
Source: IPCC, 2013; Knutti and Rogelj, 2015

from October 2015 to August 2016 has been warmer on average than all previous respective months since temperatures began being recorded (NASA, 2016).

The level of warming that will be reached depends decisively on the amount of CO_2 humankind continues to release into the atmosphere. Comprehensive analyses have shown that the average global air temperature at the Earth's surface correlates almost linearly to the amount of CO_2 emitted since the beginning of industrialization (IPCC, 2014a; Figure 2.2-2). In order to limit warming to 1.5°C or 2°C with a probability of two-thirds, future cumulative emissions may not exceed 200 Gt CO_2 or 800 Gt CO_2 respectively. These figures were derived as follows: according to the Synthesis Report of the latest Assessment Report of the IPCC (2014a), in 2011 a budget of 400 Gt CO_2 remained in order to limit the warming of the Earth to a maximum of 1.5°C, or 1,000 Gt CO_2 for 2°C (with a probability of 66%). In the last five years, global emissions reached roughly 40 Gt CO_2 per year, of which the burning of fossil fuels accounted for around 32 Gt CO_2, cement production and other industrial processes around 4 Gt CO_2 and changes in land use roughly 4 Gt CO_2 (Global Carbon Project, 2016). Thus, each budget decreased by 200 Gt CO_2, meaning that as of 2016 a budget of 200 Gt CO_2 was available for reaching 1.5°C, and 800 Gt CO_2 for 2°C. If global emissions remain at just under 40 Gt CO_2 per year, in approximately five years cumulative emissions would reach a level at which the average global temperature increase would remain just under 1.5°C with a probability of 66%; the corresponding level for a limit of 2°C would be reached in 20 years. All additional emissions would have to be compensated later by 'negative emissions', i.e. by removing CO_2 from the atmosphere. However, at the moment the science is still unclear as to how exactly negative emissions affect the global carbon cycle, and which effects of previous emissions they can actually reverse (Fuss et al., 2014). Also unclear is how the Earth system as a whole would react to a swift reduction in CO_2 concentrations.

In a scenario without effective climate mitigation, warming could reach more than 4°C by the end of this century (IPCC, 2014a). If all climate mitigation measures – (Intended) Nationally Determined Contributions, (I)NDCs – announced so far by the parties to the Paris Agreement are implemented, the emissions would follow a path that could limit warming to under 3–3.5°C (UNEP, 2015). By 2030, the current (I)NDCs, as compared to a business-as-usual path, would succeed in meeting 45% of the emissions reductions needed to reach a path compatible with 2°C (UNEP, 2015). Thus, keeping warming under 2°C (1.5°C) would require drastic – but quite feasible – CO_2 emissions reductions and a complete stop by 2070 (2050) (Chapter 3). After emissions ceased, the air temperature would remain for several centuries at roughly the same level, which is more or less determined by cumulative emissions. The level of CO_2 in the atmosphere would decrease only slowly due to uptake by the ocean and biosphere (Section 2.3; Collins et al., 2013:1106).

2.3 Sustainable management of natural and anthropogenic carbon sinks

How much of the anthropogenic CO_2 remains long term in the atmosphere and contributes to global warming depends on the interaction of CO_2 sources and sinks. About half of the CO_2 emitted since 1750 is still in the atmosphere, while the other half has been absorbed in more or less equal parts by the ocean and the terrestrial biosphere (Ciais et al., 2013). In the long term (i.e. over about 1,000 years), the oceans absorb the majority of the CO_2 emitted by humans.

Due to the uptake of CO_2, the pH-value of the ocean surface has already decreased by 0.1 as compared to preindustrial levels (Rhein et al., 2013:294). This corresponds to an increase in the ocean's acidity of almost 30%. A continued progression of acidification could lead to critical strain on marine ecosystems and species (e.g. coral reefs, calcifying organisms; WBGU, 2006, 2013:43; Ciais et al., 2013). The basis for the ocean functioning as a sink is the rise of CO_2 in the atmosphere; the exchange of CO_2 between atmosphere and ocean is driven by partial pressure differences in CO_2 and can scarcely be influenced or stopped by humans (Figure 2.3-1). Exceptions include methods of ocean alkalization and ocean fertilization (geoengineering measures) described in Box 2.3-2.

In parallel to the ocean sink, terrestrial ecosystems not affected by land-use change have, since the beginning of industrialization, increasingly functioned as

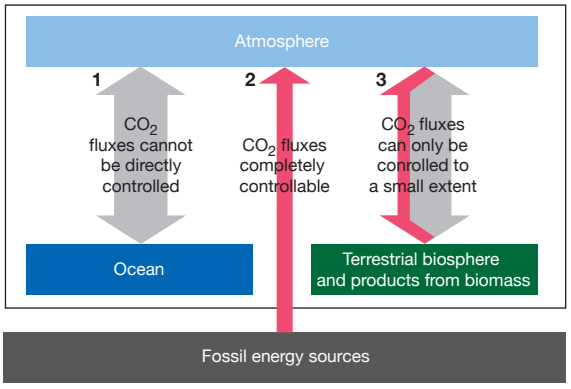


Figure 2.3-1
The global carbon cycle. Atmospheric CO_2 concentration is largely determined by (1) The fluxes of CO_2 between atmosphere and ocean; these are large natural fluxes of CO_2 that can scarcely be controlled by humans using today's technology, (2) CO_2 emissions from the use of fossil fuels. These fluxes are entirely human-induced and thus controllable. (3) The fluxes of CO_2 between the terrestrial biosphere and the atmosphere. These are large, predominantly natural fluxes that can only be influenced by humans to a small extent (mainly through land-use change or land management). The reconfiguration of land use can within limits alter the distribution of carbon between the atmosphere and terrestrial biosphere. These measures are predominantly reversible.
Source: WBGU, 2009a:89

Box 2.3-1

Bioenergy and carbon storage (BECCS)

During growth, plants take up CO_2 from the atmosphere by way of photosynthesis and convert it into biomass. Without human intervention, the overwhelming share of the CO_2 is later released back into the atmosphere through metabolic processes or biodegradation. In order to remove the CO_2 permanently from the atmosphere, the plant mass could be used to generate energy, whereby the released CO_2 is captured from flue gas and stored permanently. This procedure, known as BECCS (Bioenergy with Carbon Dioxide Capture and Storage), could create 'negative emissions' and lower the atmospheric concentration of CO_2. From the standpoint of sustainability, a large-scale application of this technology presents two questions above all:

First: It must be guaranteed that the biomass used is gained in a sustainable way. Using energy crops cultivated expressly for this purpose will result in multifaceted competition with other land uses, such as those for food production and nature conservation. Depending on the cultivation system and land area used, the cultivation of energy crops can itself cause considerable CO_2 emissions. In its report titled 'Future Bioenergy and Sustainable Land Use' (2009a), the WBGU presented comprehensive analyses of the potential of sustainable bioenergy and recommended to prioritize the use of waste and residual materials, as these sources face only scarce competition in terms of existing land use. The cultivation of energy crops especially for this purpose should preferably be carried out on marginal – i.e. less fertile – land, while perennial crops and energy grasses should generally be given priority over annual crops (WBGU, 2009a: 6).

Second: The question of CCS technology (Carbon Dioxide Capture and Storage) and the feasibility of geological storage. In principle, CCS technology is technically mature and available today, but it has yet to be tested on a large scale. The application of CSS in the use or production of fossil fuels does not lead – as it does in combination with bioenergy – to negative emissions, but can only reduce anthropogenic emissions.

Since the availability of CO_2 storage sites with long-term safety – i.e. storage sites that are sealed from the atmosphere – is unclear and acceptance of their use difficult to predict, BECCS could come into competition with CCS in connection with the use of fossil fuels (van Vuuren et al., 2013). In any case, a possible and relevant future use of BECCS will require further research and testing.

sinks due to intensified photosynthesis, resulting in accelerated plant growth. This is also caused in part by the rise of the CO_2 concentration in the atmosphere and the increased input of nitrogen, as well as by the impacts of climate change, which include longer growth periods at mid and high latitudes (Ciais et al., 2013: 487). The conservation and restoration of natural ecosystems can contribute to maintaining these sink processes. Also, land-use change – e.g. the expansion and higher biomass density of forests – can contribute to the uptake of CO_2 and compensate for some of the emissions that are caused by other types of land-use change, such as deforestation. The terrestrial CO_2 sink is subject to interannual fluctuations and can disappear completely in some years (Ciais et al., 2013: 504).

Land use management as well as the conservation and restoration of natural ecosystems can contribute to climate protection in various ways:

- Prevention of emissions caused by reducing natural carbon stocks, e.g. from deforestation and conversion of natural ecosystems in agricultural areas,
- Protection of ecosystems to maintain the capability of the terrestrial biosphere to function as a CO_2 sink,
- Facilitating the accumulation of carbon in soil or in the biomass on agricultural lands (e.g. through land or forest management, reforestation),
- Substitution of emissions-intensive materials and energy sources by using biomass to produce materials or generate energy (e.g. bioenergy, wood as a building material).

Since fertile soil is a scarce, indispensable resource that cannot be substituted, these options are in competition not only with one another, but also with other demands for land use (WBGU, 2009a). Therefore, each large-scale change in land use should always be considered within the context of the entirety of the 2030 Agenda and the SDGs. This includes not only the primacy of food security (SDG No. 2: "Ending hunger…"), but also, for example, the long-term preservation of soil fertility, the conservation of biological diversity and ecosystem services (SDG No. 15) as well as the long-term substitution of materials made from petroleum (e.g. plastic) with bio-based products. Thus, by no means can land use be optimized solely for the purposes of climate protection, be it through large-scale afforestation or bioenergy use.

One much-discussed possibility for creating an anthropogenic CO_2 sink (i.e. 'negative emissions') is the combination of bioenergy use with carbon dioxide capture and storage (Bioenergy with Carbon Dioxide Capture and Storage, or BECCS). This denotes a process that targets the permanent removal of CO_2 from the atmosphere, where plant mass is used to generate energy and the released CO_2 is captured from flue gas and stored in underground repositories (Box 2.3-1). The WBGU advises against viewing BECCS as a large-scale solution for climate protection. A limited application of BECCS based on the use of waste and residual materials as well as energy crops from cultivations that do not conflict with food production or the conservation of ecosystems, could support efforts to limit anthropogenic climate change. With a presumed waste-material potential of 50 EJ for energy generation, about 3 Gt CO_2 per year could theoretically be available for sequestration (WBGU, 2009a: 130). This corresponds to about one-tenth of today's annual emissions from the burning of fossil fuels.

The WBGU also advises against considering large-scale afforestation, iron fertilization or the alkalization of the oceans as further possibilities for creating negative emissions, as these entail widely varying problems, potential harm and risks that are difficult or impossible to calculate (Box 2.3-2).

Box 2.3-2

An evaluation of geoengineering

The term 'geoengineering' denotes the attempt to deliberately influence the climate system in order to reduce future global warming. It involves large-scale interventions into a complex system, the effects of which are insufficiently understood. There are two basic methods of geoengineering: the manipulation of the Earth's radiation budget (Solar Radiation Management – SRM), which directly influences incoming solar radiation, and the reduction of the atmosphere's CO_2 concentration (Carbon Dioxide Removal – CDR). Both methods are described in detail in the literature (e.g. The Royal Society, 2009; UBA, 2011; Rickels et al., 2011).

Climate calculations using Earth system models have shown that most of the currently discussed processes can only slightly slow global warming (< 8%), and usually entail grave consequences for the climate system and for ecosystems (Keller et al., 2014).

SRM would be the only method that could effectively reduce the warming of the Earth; however, the atmospheric cooling it would achieve would come with enormous side-effects and uncertainties. Firstly, SRM would present unprecedented challenges to global intergovernmental cooperation, since SRM measures could be used by individual states to pursue their own purposes, yet would also have global effects. Furthermore, an intermediate abandonment of ongoing SRM geoengineering would catapult the temperature of the Earth's surface back to its 'normal state'. The result would be rapid climate change within a few years (Keller et al., 2014), with unforeseeable consequences for humans and societies. Not least, the application of SRM would have considerable impact on systems of all orders of magnitude, such as monsoon circulation, local weather patterns, ocean circulation and the ozone layer. It is the opinion of the WBGU that the risks of applying SRM to counter climate change far outweigh its potential benefits. The WBGU therefore opposes the use of SRM.

In contrast to SRM, CDR could also address the problem of ocean acidification, while erratic changes to the Earth's surface temperature, e.g. in the case of halting the use of SRM, could be more or less ruled out. Many CDR technologies are similar in the fact that they require an inordinate amount of land and could have partly considerable side effects for the biosphere and geosphere.

- *Ocean alkalization:* The acceleration of the natural chemical decomposition of rock could theoretically cause CO_2 to be more quickly withdrawn from the atmosphere and transferred into the ocean. The accelerated carbon capture can be achieved through the crushing and grinding of, for example, olivine (limestone and silicate bedrock) (Köhler et al., 2010). This process has requirements similar to those of mining, would be extremely energy-intensive and would warrant sizeable infrastructure and a considerable amount of rock (3 billion tonnes of olivine would be needed to neutralise only 9% of anthropogenic CO_2 emissions; Köhler et al., 2010). The crushed rock would then have to be introduced over wide swaths of the ocean to eventually reach the deep waters. This method is highly invasive to both the land and the ocean, and many of its side effects are still inestimable (e.g. the consequences of ocean alkalization on ecosystems). The WBGU advises against this technology.
- *Manipulation of marine biomass production:* The enhancement of marine carbon sinks by increasing biomass growth in nutrient-poor regions of the ocean could be attainable through fertilization with micro- (e.g. iron, iron fertilization) and macronutrients (e.g. nitrogen, phosphorus). The sinking of biomass into deeper ocean layers could lead to a long-term storage of fixed carbon. However, the effectiveness of this method depends on various physical and biological factors (e.g. deep-water formation or the premature re-emission of the stored carbon into the atmosphere through bacterial decomposition of the biomass). The results of model studies and in situ experiments are somewhat contradictory and insufficiently reliable to quantify the effectiveness of large-scale ocean fertilization (e.g. Jin et al., 2007; CBD, 2009; Smetacek et al., 2012). Given the only partially researched potential side effects of ocean fertilization on marine ecosystems, the WBGU also opposes this method of geoengineering.
- *Large-scale afforestation:* Due to the limited agricultural land and the competition between the production of food, lumber and bioenergy as well as the conservation of biological diversity, natural ecosystems and ecosystem services, large-scale afforestation would be sensible only in areas that are thus far unused and for which no valuable natural ecosystems would need to be converted. Several studies have focussed on the cultivation of semi-deserts and deserts by means of artificial irrigation using desalinated seawater (e.g. Sahara, Australian Outback; Ornstein et al., 2009; Keller et al., 2014). Simulations with Earth-system models show that although large-scale reforestation of these areas would slightly reduce the CO_2 content of the air, the temperature would not decrease, but even increase somewhat. This is largely due to the low reflectivity of forests in comparison to the desert, and thus the heightened absorption of solar radiation (Keller et al., 2014). Additional grave disadvantages include the immense cost of irrigating these desert areas and the consequences in case of a failure of irrigation. Yet to be examined are the impacts of the destruction of desert ecosystems and the likely strong reduction in the Saharan dust transport system and subsequently in the fertilization of the Atlantic Ocean and the Amazon rainforest. Its high costs, negative impact on air temperature and its under-researched effects on ecosystems currently render this option inadvisable.
- *CO_2 binding from air through chemical sequestration:* The direct binding of CO_2 from air could theoretically be achieved through chemical sequestration (Direct Air Capture – DAC). However, testing of this technology has thus far been limited to only a few areas, and the scaling of DAC to dimensions that would have a significant influence on atmospheric CO_2 concentrations cannot be realized with today's technology and would be highly energy-intensive. Nevertheless, research and development work could significantly reduce energy requirements and costs (Lackner et al., 2012).

2.4 The transformation of infrastructure

The goals agreed upon in the Paris Agreement represent a considerable challenge for the transformation of global infrastructure. Considering the current state of affairs, transformation processes must be radically accelerated in order to execute the required leaps in technology. For example, combustion engines in the automobile industry must be replaced by emissions-free propulsion technology well before the potential for improving the efficiency of combustion engines is exhausted, the requirements for which include corresponding infrastructure (e.g. charging stations). Urban development must also be rerouted. The tremendous surge in urbanization expected in the coming decades (with an additional 2.5 billion city-dwellers by the middle of the century), including the resource- and climate-compatible design of our cities, is critical to a sustainable global development. The cities are where it will be decided whether the transformation towards sustainability succeeds (WBGU, 2016a: 5 f.).

However, this awareness is not yet prevalent among many decision-makers or in wide sections of the public. Clear signals to industry from the G20 decision-makers would be very helpful in establishing a reliable planning horizon.

Key factor: Time

Fossil energies, at 32 Gt CO_2, along with cement production and industrial process, at 4 Gt CO_2, are currently responsible for the bulk of annual greenhouse gas emissions (Global Carbon Project, 2016; IPCC, 2014a: 45). These emissions are determined to a large degree by the configuration of global infrastructure systems. To reach the climate goal set in Paris, the future rate of decarbonization – measured as a reduction in carbon intensity (t CO_2 per € billion of GDP) – must reach levels significantly higher than the past rate. Between 2000 and 2014, global carbon intensity decreased annually by an average of 1.3%; however, achieving a stabilization of global warming under 2°C requires that the carbon intensity be reduced by a rate of more than 6% per year (PWC, 2015). This cannot be attained solely by substituting existing energy production infrastructure with low-emission or zero-emission alternatives, especially in light of the narrow timeframe. Rather, in addition to an accelerated expansion of renewable energies, efficiency and sufficiency measures must be implemented with equally high priority in all areas of industry and society.

Transformation potential: not to be underestimated

It is the opinion of the WBGU that the potential for a quick renewal of our present energy infrastructure has been underestimated. A strong technological transformation is already underway; the global power generation capacity of wind and sun has grown exponentially in recent years, whereby costs have decreased sharply (Figure 2.4-1).

Schellnhuber et al. (2016) have indicated a possible surpassing of tipping points for the transition to a purely renewable energy system, which are either insufficiently or not at all depicted in current mitigation narratives or scenarios. Fossil fuel capacities could thus be removed from the energy system much more quickly than is often assumed. Moreover, exit barriers such as profitability and 'sunken' costs can be addressed through regulatory or compensatory measures.

An additional important approach is a radical reduction in the use of cement in the building sector (WBGU, 2016a). In future, wood could be used on a large scale, above all in housing construction. The fact that wood requires less energy to produce in comparison to conventional construction materials (e.g. concrete, steel and aluminium) and entails no process emissions means considerable overall emissions savings. However, how much wood might be available on a sustainable basis is an open question that must be studied in more detail (Churkina, 2016).

Another important determining factor, whose potential the WBGU finds often underestimated, is the transformation of lifestyles and consumption patterns, which can prime and accompany infrastructural transformation. These options are not usually constrained by technological restrictions and could be immediately effective. One positive example is the currently ongoing transformation of dietary patterns in parts of Western societies. The reduction of the consumption of animal products could reduce the use of agricultural land, which could instead be used for other applications that are difficult to substitute, such as the production of wood or biomass for the building sector.

Compliance with the climate mitigation goals set in Paris could be achieved through various technology portfolios, which are laden with different risks and difficulties. One conceivable portfolio would contain a massive increase in nuclear energy, the large-scale application of CCS and BECCS (e.g. in the RCP2.6 scenario; van Vuuren et al., 2011) and, if need be, geoengineering measures in case emissions reductions do not follow at an adequate pace. However, it is the opinion of the WBGU that there is no justification for taking such risks as long as there are alternative portfolios fraught with far fewer risks.

One alternative portfolio with a completely different focus comprises a highly accelerated expansion of renewable energies and simultaneous significant increase in energy efficiency, along with an accelerated phasing out of fossil fuel use. This would allow foregoing such mitigation options or technologies seen as too risky by the WBGU. Such a path is outlined in Section 3.2 (Box 3.2-1). The WBGU proposes that within the space of possibilities a path should be taken that places highest priority on an accelerated expansion of renewable energies and employs riskier options like BECCS only to a small degree and as a fall-back option. The high-risk geoengineering options (Box 2.3-2) should be abandoned altogether. The implementation of such

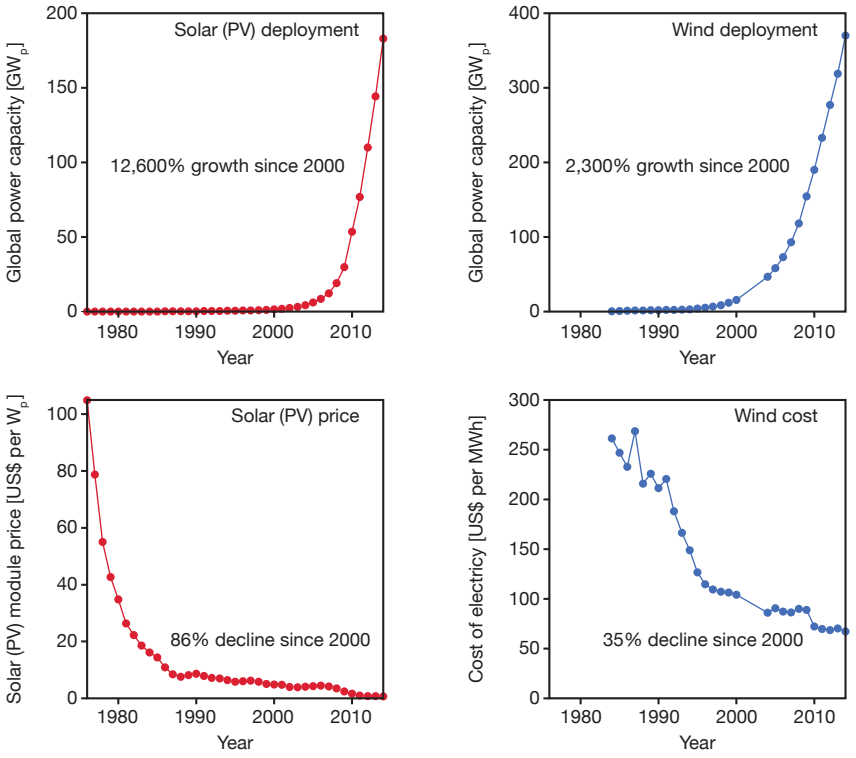


Figure 2.4-1
Development of renewable energies. The growth of installed solar and wind energy capacities has far exceeded expectations, while costs have rapidly fallen: by 35% for wind energy and 86% for solar energy since 2000 (PV = photovoltaics).
Source: Trancik et al., 2015

a path is described in Section 3.2 as part of a carbon roadmap.

2.5 Recommendations

Halting the further warming of the climate requires a complete stop of CO_2 emissions. To keep climate warming below 2°C, these zero-emissions should be achieved by 2070 at the latest, and by as early as 2050 to meet the 1.5°C target. The global transformation should be accelerated to decrease emissions and finally bring them to zero as quickly as possible. Core elements of this transformation are the rapid expansion of renewable energies, the effective limiting of energy consumption and the rapid phase-out of the use of fossil fuels. The application of technologies that are not yet mature or adequately tested – such as Carbon Dioxide Capture and Storage (CCS) or the combination of bioenergy use and CCS (BECCS) – should be avoided to the greatest possible extent. The WBGU recommends largely forgoing the use of biomass in energy production, with the exception of waste and residual materials, and using the available, sustainable potential of biomass or wood as much as possible in the building sector.

G20: Promoting transformation

As key protagonists within the framework of the Paris Agreement, the governments of the G20 states should promote the global transformation to a climate-compatible society by 2020. During Germany's G20 presidency, the German federal government should strive for G20 consensus on a decarbonization goal similar to that which was agreed upon in 2015 at the G7 summit in Elmau.

- The G20 should agree to reduce to zero their CO_2 emissions from fossil fuels by 2050. For their economies, they should develop comprehensive and verifiable decarbonization strategies that include a phase-out of the use of fossil fuels by 2050, for which the WBGU proposes key milestones (Chapter 3).
- The G20 should work to ensure the conservation or restoration of natural ecosystems so that natural carbon stocks (e.g. forests, peatlands) and the capability of the terrestrial biosphere to function as a sink are preserved. Land-use change and land-use management should not only reflect climate protection criteria; the entirety of the 2030 Agenda, i.e. all SDGs, should be considered.
- The G20 should adopt a position on geoengineering. The WBGU advises that measures targeting the Earth's radiation balance should not be pursued. It also advises against the large-scale alteration of the carbon cycle. Exceptions include the combining of bioenergy with CCS (BECCS) on a small scale as well as the chemical binding of CO_2 from the air, both of which require additional research and testing.
- The G20 should work towards establishing a binding and universal international legal framework for the 'if' and 'how' of geoengineering measures. This framework should observe the precautionary

principle while specifying moratoriums and liability regulations. The G20 should initiate this development.

G20 states: Assuming a pioneering role in international climate policy

The particular responsibility of the G20 states should also find expression in their roles as parties to the UNFCCC and as signatories to the Paris Agreement. They could develop pioneering roles in the following three areas:

1. The current reduction promises – (Intended) Nationally Determined Contributions: (I)NDC) – of the parties to the UNFCCC still lie well under the level required to implement the goals of the Paris Agreement. The G20 states should move forward with highly ambitious reduction targets and implementation plans and improve their (I)NDCs accordingly. The G20 states should not only ambitiously formulate their climate protection contributions, but they should do so in accordance with comparable standards as well as monitoring and review processes.
2. In order to reach the Paris Agreement climate mitigation goals, the G20 states are tasked with developing decarbonization strategies in the four remaining years before the Paris Agreement takes effect. This entails the formulation of concrete plans for the phase-out of fossil fuels as well as the development of roadmaps for phasing out fossil fuel subsidies by 2020.
3. The G20 states should also send clear signals in the following areas:
   - The G20 states should formulate ambitious targets regarding the adaptation of their countries to climate change and adopt effective measures accordingly. They should work towards agreement on adaptation goals within the framework of the Paris Agreement.
   - The G20 states should advocate for strengthening the theme of 'loss and damage' within the UNFCCC and the Paris Agreement, above all by swiftly developing principles and regulations for compensation obligations.
   - The issue of climate change-induced migration should be promoted by the G20 states. This should include providing assistance to environmental migrants and promoting their rights to protection within the framework of the UNFCCC, based on the principle of responsibility.
   - In terms of financing, the G20 states can send strong signals through corresponding pledges, in particular by assuming costs for climate mitigation, the adaptation to climate change as well as for loss and damage. Discussion and development of a comprehensive system regulating liability for climate change-related damage and the enforcement of such claims are necessary.
   - As a general measure, the WBGU recommends upgrading the theme of 'urbanization and transformation' to a standing item on the G20 agenda (WBGU, 2016a). Germany's G20 presidency should be used to place this theme firmly on the agenda. International policymakers' weak reaction to Habitat III as an initial international implementation conference after the two world conferences 2015 shows that the pending, massive boom in urbanization has not yet been anchored with adequate prominence in the political agenda (WBGU, 2016b; Pilardeaux et al., in press).

To summarize, in the coming years the G20 states will be required to assume a pioneering role in the Great Transformation. This would also lead to synergies with the implementation of the SDGs.

Advancing the transformation towards sustainability in G20 countries – prospects for reform

3

Successfully implementing the 2030 Agenda and the Paris Agreement requires preparedness to cooperate internationally as well as the development and execution of effective national strategies, implementation roadmaps and instruments of transformative governance. G20 governments should campaign (1) to realign *Innovation* so that it extends beyond the 'G20 Blueprint on Innovative Growth' (G20, 2016c) to enable economies and prosperity to develop within the planetary guard rails (WBGU, 2014b). They should (2) rapidly advance a climate-friendly and resource-efficient restructuring of the global economy's central *Infrastructures*. The G20 should promote (3) *Investments* that further the transformation towards sustainability. Infrastructures, investment and innovation are already essential elements of the G20 agenda. G20 countries should now link these to the principle of social *Inclusion*, which is at once a precondition and the goal of a successful transformation of society towards sustainability and should guide all actions in this area. The principle of inclusion includes the dimension of social justice as well as those of social, cultural and political participation.

Only this re-balancing of the state, markets and civil society will make exacting sustainability and climate protection goals achievable (Figure 3-1). As described below, they will need a plausible, realistic, globally-coordinated timetable (carbon roadmap, Section 3.2). Its framework would enable G20 member states to pursue individual national projects to open up new financing opportunities. One example of such a project are the new transformative sovereign wealth funds proposed by the WBGU (Section 3.3). To integrate civil society into this global initiative, all G20 countries will need a better 'transformative literacy' as well as a general knowledge of and a narrative on the transformative policy possibilities that are available and can be developed at the local, national and international level (Schneidewind, 2013: 120).

3.1
Re-balancing states, markets and civil society

One essential prerequisite for achieving the SDGs is the orientation of political and government functions towards a viable future democratic polity with free civil societies and markets that are embedded in other social systems. To create these preconditions, the WBGU takes the view that the *model of the proactive state*, which has been suppressed in the economic deregulation and privatization of recent decades in many countries in favour of a 'minimal state' (Nozick, 1974), should be strengthened. The idea of a proactive state conveys "two aspects, frequently thought of as separate or contradicting: on

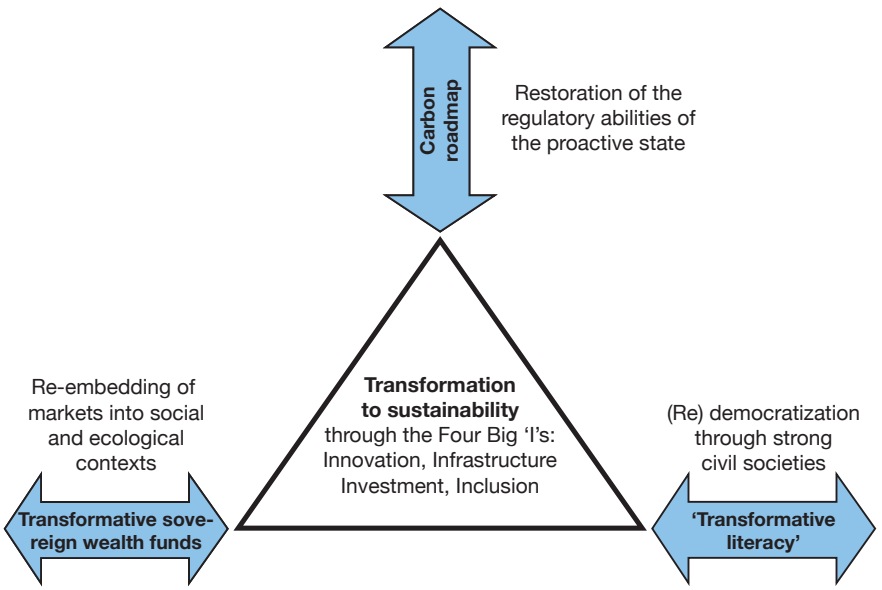


Figure 3-1
Re-balancing the state, markets and civil society in the course of the transformation to sustainability.
Source: WBGU

Box 3.1-1

Actively pursuing constitutional obligations to sustain the natural life-support systems

A constitutional foundation for protecting global commons largely exists in all G20 states. The constitutions of 15 G20 countries oblige them to preserve the natural life-support systems and thus to protect the climate. The other countries also recognize an obligation of the state to provide preservation and protection. Article 20a of the German Federal Constitution (GG) charges the German state, and especially German legislators, also on behalf of future generations, with protecting natural life-support systems within the framework of constitutional order. International opinion agrees unanimously that the concept of environmental assets requiring protection should be broadly interpreted and that climate is one such global public asset. Article 37 of the European Union Charta of Fundamental Rights stipulates an EU-wide obligation to ensure environmental protection and environmentally friendly interpretation of EU and national law (Jarass, 2011). Only the constitutions of Australia, Canada and the U.S. do not contain these kinds of regulations (Boyd, 2012) although in the U.S. there are some similar provisions at the state level (UNEP, 2014:4). Despite the absence of a constitutional document, Great Britain also recognizes environmental protection as a national objective (Kloepfer and Mast, 1995:116; Boyle, 2007:10). The existence of a fundamental law governing environmental protection in the Japanese constitution is disputed, but at least arguable (Iwama, undated).

Despite these constitutional obligations to protect the environment, the withdrawal of the state and privatization of public responsibilities have meant that many G20 countries have in recent decades failed to perform essential government environmental protection tasks, e.g. in the waste, water and energy sectors. G20 countries should make the public task of environmental and climate protection a priority that mirrors its constitutional standing and underpin it with effective instruments, e.g. by establishing transformative sovereign wealth funds and decarbonising energy systems (Section 3.2).

the one hand empowering the state, which actively determines priorities and underlines them with clear signals, and on the other hand, giving citizens more extensive opportunities to have a voice, to get involved in decision-making and to take a more active role in politics. […] The proactive state is firmly anchored in the tradition of a liberal and constitutional democracy, but it develops this democracy further with a view towards the future sustainability of democratic communities and liberal civil societies." (WBGU, 2011:278). A proactive state and a *free civil society* are mutually dependent.

The debate conducted in the field of economic sociology, and based on the ideas of the Hungarian economic historian Karl Polanyi, postulates 're-embedding' markets and market economies in society. Polanyi claimed that in the 19th century, markets and economic activities had 'dis-embedded' or disengaged themselves from the wider everyday life of society and that they would have to be 're-embedded' if people's freedoms, security and equality were to be ensured (Polanyi, 1944, 1968). His central idea is still being heard amid the increasingly loud criticism of some economically liberal notions of order. Today, with a global climate and sustainability policy on the agenda, economic globalization's overall welfare effect being questioned and a national-protectionist backlash that has arisen in response to it, an innovation in global governance institutions and national statehood is needed, which is where calls for 're-embedding' market economies and free trade become relevant.

By the 1970s, the paradigm of the 19th-century interventionist welfare state and New Deal period (1930–1975) had reached its limits because it could often only fulfil its diverse range of tasks by means of growing bureaucracies and debt, which encumbered following generations. As a result, essential public tasks were again increasingly left to the forces of market competition and the model of the citizen was replaced by the model of the consumer in many areas. Scepticism about the ability of public policy (such as the 'Washington Consensus') to influence events became widespread and appeals to the common good, solidarity and justice no longer seemed to fit in with the times.

In parallel to this withdrawal of the state (which is ongoing and entirely appropriate in some areas) and as a result of growing international economic, political and cultural interconnectedness, the belief that intervention in economic processes is necessary to ensure fairness, equality and solidarity has again gained ground. This has resulted in demands for more state involvement. Meanwhile, new tasks for governments have appeared on the agenda, such as international environmental policy, which became increasingly important with the growth of the environment movement and after the 1992 Rio Conference. Protection of our natural life-support systems is anchored in the constitutional law of most G20 countries (Box 3.1-1). This has again changed how the state is viewed, with a move towards a more active and engaged government that can protect global public goods. To the classic tasks of government (public infrastructure and investment) have now been added the proactive state tasks of promoting social innovation and ensuring inclusive development under the conditions of globalization (Messner, 1997).

This report sets out concrete tasks for a proactive state in this area, with a carbon roadmap for implementing the climate goals set in Paris and the 2030 Agenda. To implement the Paris Agreement in particular, disruptive reforms must be carried out quickly if the emissions budget for achieving the 1.5°C goal is not to be used up in the next five years. G20 countries bear a special responsibility for doing this, which is explained in the following chapter.

3.2 Decadal carbon roadmap

To achieve the goal of keeping the global temperature well below 2°C, the WBGU, following the work of Rockström et al. (in press), proposes below a 'carbon roadmap' that outlines, in decadal steps, the major changes necessary for implementing the Paris Agreement while excluding or minimising the use of high-risk technologies (Figure 3.2-3). This roadmap is a possible way to put the social contract needed for the Great Transformation into practice (WBGU, 2011) and outlines urgently required steps towards action. While the 'Jürgen Schmid scenario' (Box 3.2-1) focuses on the energy mix, the carbon roadmap is about concrete decisions by the world society. Unlike the Jürgen Schmid scenario, the roadmap includes the limited use of sustainable technologies for eliminating CO_2 as a possible option during the second half of the century. Nevertheless, there is a need for swift action. The WBGU recommends that the G20 rapidly implement the roadmap and in particular the first step, emphasizing four core strategies: (1) a complete elimination of CO_2 emissions from fossil fuel use; (2) a rapid and major reduction in levels of other climate forcers (black carbon, methane, ozone precursors, etc.); (3) measures to protect and restore indispensable carbon stocks and natural sinks (e.g. tropical rainforests and boreal wetlands); (4) the development and deployment of sustainable technologies to remove CO_2 from the atmosphere.

2016–2020: No-brainers

Expanding and improving proven instruments such as CO_2 taxes and trading systems, feed-in tariffs and quota systems will be of central importance by 2020. Energy efficiency incentives should also be provided in the business and private sector to speed up progress. This includes the ending of all state subsidies for fossil fuels in G20 countries by 2020, with other countries quickly following suit. All the major cities and companies in industrialized countries should draw up a decarbonization strategy by 2020. By 2020, at least two dozen countries should designate a year in which they will finally stop using fossil fuels. Food production, which is a major source of greenhouse gases that also destroys natural carbon stocks, should be included in this strategy, e.g. through campaigns on eating fewer animal products and against food waste. This diverse range of reforms, which could be globally coordinated, would enable the UNFCCC to play a new, central role in the international community in coming years.

2020–2030: Herculean efforts

By 2030, all countries should have phased out registration of new vehicles with combustion engines. Over this period, CO_2 should be more heavily taxed, at around US$ 30 per t CO_2. This price should double every decade until it exceeds US$ 240 per t CO_2 in 2060. All subsidies for fossil fuels (currently worth around US$ 500 billion per year; IEA, 2015c) should be channelled into investments in renewable energies. Public and private funding for sustainability-related research and development should have increased at least tenfold by 2030, compared with today. Core issues here include extending the durability of batteries and improving energy storage, alternative propulsion systems for aircraft, smart materials and new construction materials for cities, approaches towards creating sustainable lifestyles and concepts for sustainable urbanization in polycentric structures (WBGU, 2016a). Investments should be made in preserving and regenerating natural carbon stocks and sinks (e.g. the protection of natural ecosystems or sustainable forest management) and in the sustainable removal of CO_2 from the atmosphere (e.g. by using BECCS; Box 2.3-1) in order to remove up to 100 Mt of CO_2 per year from the atmosphere. These investments should also help to further develop relevant technologies.

2030–2040: Multiple breakthroughs

As of 2030, all new urban quarters should be planned and built to generate more energy than they consume. This could be achieved by building energy-plus houses that both recycle energy (e.g. through waste water heat recovery) and produce energy (e.g. in photovoltaic plants). All fluctuating energy sources should have a minimum storage rate of 90%. Energy transport should be optimized by the use of superconductive cables, including in countries outside the OECD. Floating and flying renewable energy technologies should also make major contribution to energy supplies, especially in countries with limited space for 'traditional' renewable energy technologies (e.g. Japan). Some examples of these are solar platforms on lakes and wind power technologies that use kites and gliders at various heights to produce wind energy. Roads and streets should become self-contained mobile infrastructures that supply drive power and minimize friction. One promising development in this context are super-robust surface materials where renewable power is transmitted to vehicles via electromagnetic induction. In the construction sector, materials such as concrete and steel should be replaced by climate-friendly substances such as timber, clay and stone, supported by high-tech components made of materials such as carbon fibre. The amount of CO_2 eliminated from the atmosphere should be doubled by means of extensive reforestation and a limited, sustainable use of BECCS (Box 2.3-1).

2040–2050: Revisions and reinforcements

The successes of recent decades should be reinforced and any failures corrected. Most European countries aim to have their economies decarbonized by the 2040s. The American and Asian continents should be close to this goal at the end of that decade. Natural gas will still be used to a limited extent, but it will be CO_2-neutral due to advanced CCS technology (Matter et al., 2016). Removal of CO_2 from the atmosphere will be continued within the limits outlined in Box 2.3-1.

Box 3.2-1

A vision of a renewable energy system based on the ideas of Jürgen Schmid

The following scenario further develops a vision for a global regenerative energy system by 2050 that was presented in 2011 (WBGU, 2011:129) and is published by the WBGU in memoriam Jürgen Schmid, who, as a WBGU member, contributed substantially to drafting it.

To answer the question of how global warming can be kept well below 2°C or even 1.5°C, various scenarios have been developed since the Paris conference that will also be incorporated into the special report on 1.5°C that the IPCC has been commissioned with drafting. A transformation of energy infrastructure like the one described in Section 3.2 is only possible with profound changes to framework conditions that are not currently extant. So far, the vast majority of the scenarios presented have overused the permissible emissions budget and complied with it later by introducing net negative emissions. If current scenarios assume however, that a faster transformation is not possible, political and legal frameworks will also be designed to accommodate only a gradual transformation.

The WBGU therefore presents below a scenario (Sterner and Bauer, 2016) that deliberately forgoes all options regarded as risky (e.g. geoengineering). This scenario is designed to stimulate readers to question the scenarios and climate mitigation programmes being currently developed and examine the plausibility of the speed of the conversion that they assume.

This scenario removes coal from the system as quickly as possible, by 2030, (Figure 3.2-1). Oil use is gradually reduced, although at a slower rate because it is harder to completely replace in the short term. Gas, in contrast, is used as a bridging technology by 2050. It can be seen that the use of all fossil fuels, due to their subsidization, initially declines very gradually, then falls at a steeper rate to zero in 2050. The use of renewable energies moves in the opposite direction to fossil fuel use. Biomass is expanded up to its technical potential and remains at this level until 2035, because it is a CO_2-neutral option for balancing out fluctuations and is readily available in the short term. After that, it declines linearly until in 2050 and, apart from residual materials, completely disappears out of the energy mix, allowing the construction materials sector to access its available sustainable potential. In this ambitious scenario, hydropower and marine energy will also be needed to the limits of their sustainable potential, which is fully exploited as of 2025. Global primary energy demand reaches its maximum of 542 EJ in 2020, after which it falls to 402 EJ in 2050. For this scenario it is assumed that efficiency measures will enable global demand for heating and cooling to be kept fairly constant, and that growth in final energy demand for transport and global growth in the demand for power can be limited to 1% per year. This could be achieved through a series of measures, including improving building insulation, using heat pumps, measures to improve efficiency in industry, and extreme improvements in efficiencies in the area of energy conversion (electromobility, renewable electricity generation). For the transport sector, transforming primary energy demand means that, as of 2030, no new combustion engines can be allowed into the system and that they completely disappear by 2050, as they are gradually replaced by electromobility and power-to-gas.

This scenario describes the possibility of a rapid restructuring of energy infrastructure. Figure 3.2-2 shows the emissions that this scenario would entail. The carbon roadmap outlined in Section 3.2 specifies the concrete actions needed to achieve this restructuring in decadal steps. In contrast to the carbon roadmap, the scenario deliberately dispenses with negative emissions to emphasize that this option, which involves major uncertainties, can be dispensed with if immediate and ambitious action is taken. If, despite all efforts, energy infrastructure cannot be transformed in time, it would be possible to fall back on sustainable technologies to eliminate CO_2 from the atmosphere to a limited extent (Box 2.3-1). This is why these technology options and further concrete steps for action for implementing the Paris Agreement are included in the carbon roadmap (Section 3.2).

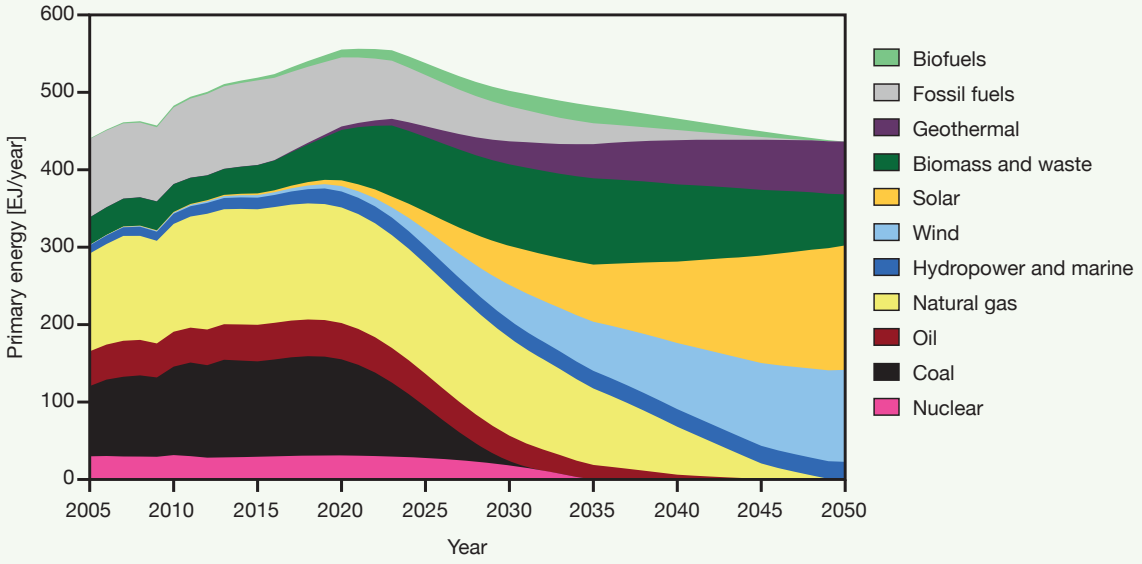


Figure 3.2-1
The Jürgen Schmid scenario: a vision of a global renewable energy system by 2050. It shows the distribution of global primary energy needs by energy source. The simulation aims to cover global final energy demand while at the same time limiting cumulative CO_2 emissions from fossil fuel use to 660 Gt and the reduction of emissions to zero by 2050.
Source: Sterner and Bauer, 2016

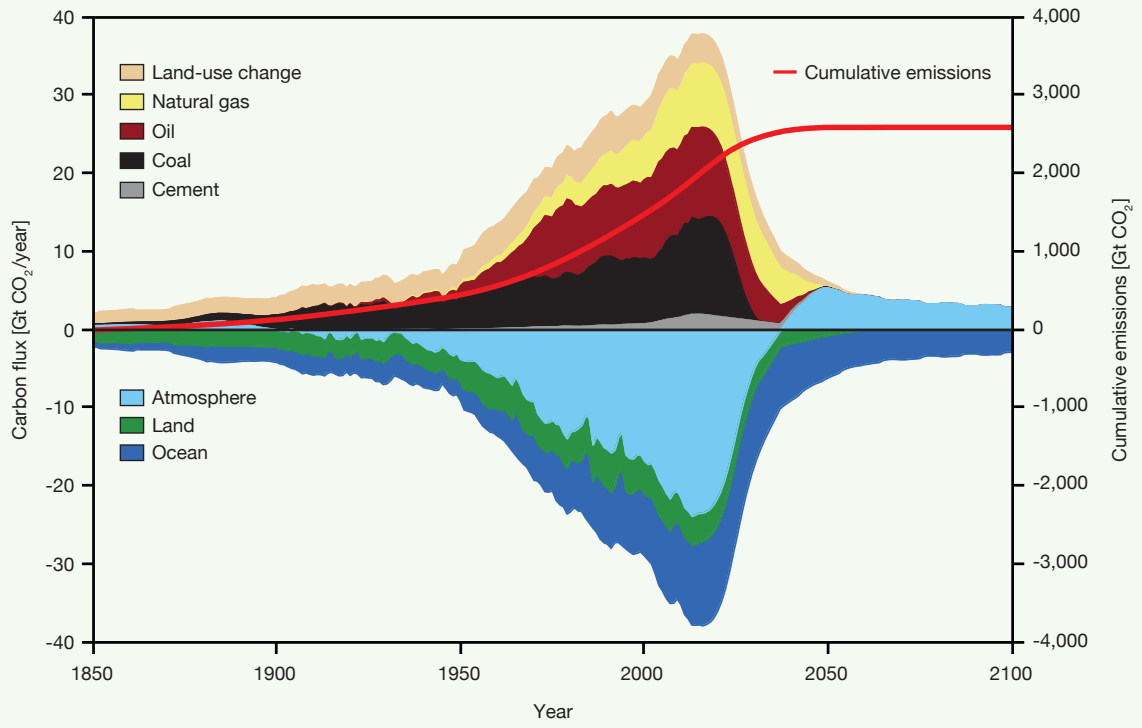


Figure 3.2-2
The emissions generated in the Jürgen Schmid scenario (Figure 3.2-1) and resulting changes in the carbon cycle. CO_2 emissions from fossil fuels, cement production and changes to land use by 2050 (left axis, figures > 0 are CO_2 sources) are absorbed by the atmosphere, land and ocean (left axis, figures < 0 are CO_2 sinks). After anthropogenic emissions fall to zero in about 2050, CO_2 from the atmosphere is still transferred into the land and ocean (Section 2.3); the atmosphere is then shown in the graph as a source. The red line shows cumulative CO_2 emissions, which stabilize after 2050 (right axis). The emissions development in this scenario provides grounds for the expectation of a temperature increase limited to well below 2 °C (Section 2.2).
Sources: IIASA, based on calculations carried out using the MAGICC climate model (Meinshausen et al., 2011), based on data from Sterner and Bauer, 2016 (CO_2 emissions from the use of fossil fuels) and RCP 2.6 (CO_2 emissions land-use change). For CO_2 emissions from cement production, a linear decrease to zero by 2050 was assumed for the sake of simplicity.

The global decadal carbon roadmap will require *Innovation, Investment* and improved *Infrastructure* and can only succeed through *Inclusion*. The latter issue should factor into all measures necessary for influencing Innovation, Investment and Infrastructure, and adequate compensation may have to be provided to ensure that transformation goals are not achieved at the cost of increasing inequality. Despite the technical nature of the carbon roadmap's approaches to solutions in the discourse on achieving climate protection goals, the WBGU advocates taking a systemic view and comprehensively taking into account not only effects on climate systems, but also the ecological, economic, political and socio-cultural risks and side effects. Predominantly technical solutions or a mainly technical perspective run the risk of overlooking a range of possible opportunities as well as negative consequences and risks while creating irreversible path dependencies.

3.3 Transformative sovereign wealth funds for a sustainable future

Structural changes and new powerful policy instruments will be required if the SDGs and goals set in the Paris Agreement are to be achieved and the proposed carbon roadmap (Section 3.2) implemented. The WBGU proposes that to do this, the G20 countries should establish 'future funds' – national, transformative sovereign wealth funds financed through a sustainability levy. This levy should consist of a progressive estate tax, CO_2 taxes and revenues from emissions trading. The future funds would manage the money on behalf of the national government and invest it in the financial market in industries key to the transformation, so as to accelerate it and overcome 'CO_2 dependency'. At the same time, dividends from the future funds should be used to provide social and structural policy support for the transformation to a sustainable economic and social system.

By establishing future funds, G20 countries could open up new scope for government action. States would

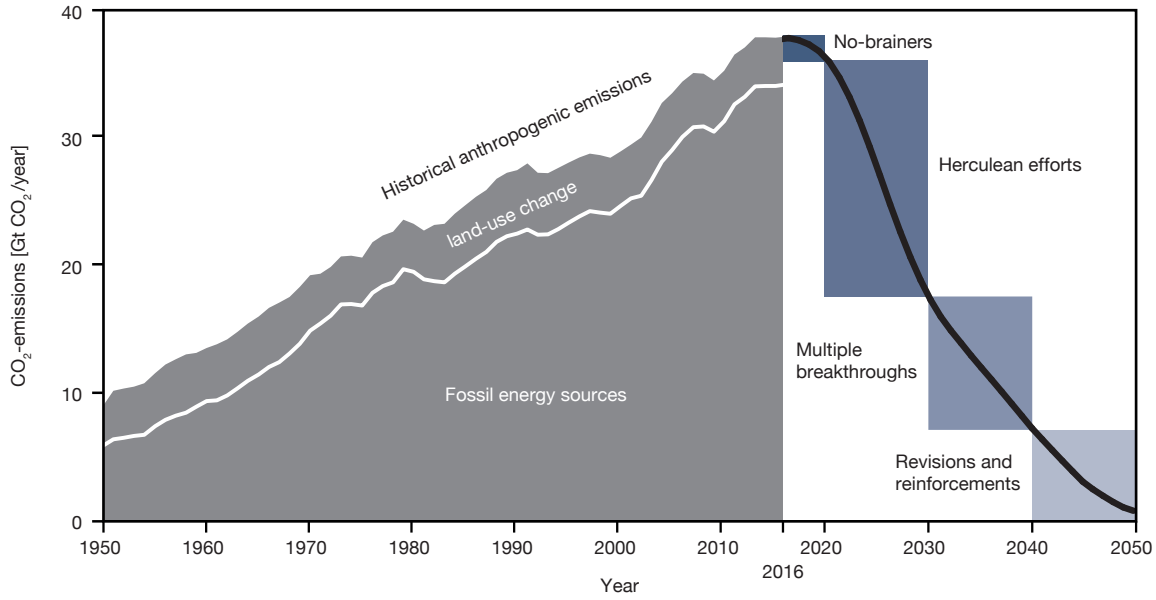


Figure 3.2-3
Carbon roadmap for stepwise decadal decarbonization. The emissions shown are based on the Jürgen Schmid scenario (Box 3.2-1). The blue squares indicate decadal steps to be taken by 2020, 2030, 2040 and 2050, which should result in a decarbonization by the middle of the century.
Source: WBGU, based on Rockström et al., in press; Sterner and Bauer, 2016

have a more powerful presence as investors in international financial markets and be able to help accelerate national and global transformation processes by linking investments to strategic, long-term sustainability and climate protection goals, such as the 2°C guard rail, and increasing investment in related industries key to the transformation (e.g. storage technologies, electromobility or climate-friendly building materials). Proprietary rights from the shares held could be used to exert a stronger influence on company decisions in favour of sustainability aspects. Sovereign wealth funds also offer an opportunity to act where private investors have so far held back because of their shorter-term profit expectation horizons and the financial system's incentive structures. The investment strategy of future funds should be oriented towards strong, long-range financing and earning profits for the long term.

The steering effect that G20 countries could have on international capital flows by establishing future funds (Element ① in Figure 3.3-1) would increase with the funds' volumes, which would be continuously built up in subsequent decades. To accelerate and scale up the transformation while the funds are being established and to accommodate international climate equality, only around 30% of the revenues from CO_2 taxes and emissions trading should flow directly into the future funds. 40% of the revenues from CO_2 taxes and emissions trading should be used to support direct, project-based investment, especially in climate-friendly infrastructures, or to mobilize private investment by reducing investment risks (e.g. de-risking) (Element ③ in Figure 3.3-1). The first is already occurring in Germany (on a small scale) through the government's Special Energy and Climate Fund. G20 governments should use the remaining 30% of the revenues from CO_2 taxes and emissions trading to help developing countries to protect the climate and adapting to changes (Element ④ in Figure 3.3-1). This could be done through bilateral cooperative climate projects or the Green Climate Fund.

Returns from the future funds (Box 3.3-1) could be used to finance measures that, although essential to the success of the transformation, are not economically profitable, so no private investor would be actively involved in them. Such measures could include action on structural change and support for the 'losers of change', e.g. fossil energy industry employees, to prevent or minimize social upheaval or dispel resistance to the transformation resulting from such upheavals. Although the energy sector's conversion to renewable energies is expected to result in a net increase in jobs (ILO, 2012), some regions, especially mono-industrial regions, will experience substantial job losses, which could plunge them into long-term crisis (ILO, 2012; Haywood, 2016). Along with national measures to reduce inequality, regional political measures will be required to provide social and structural political support for the transformation (Element ② in Figure 3.3-1).

Along with the future funds' investment strategy, their governance structures will be of central importance. The principles of Norway's pension funds offer orientation for the future funds' institutional structure (Statens pensjonsfond utland; such as high levels of transparency, compliance with ethical guidelines and prevention of political influence through low levels of average share ownership; Velculescu, 2008). These governance structures should ensure economic efficiency by including elements important to the legitimization of the funds, such as participatory management (through

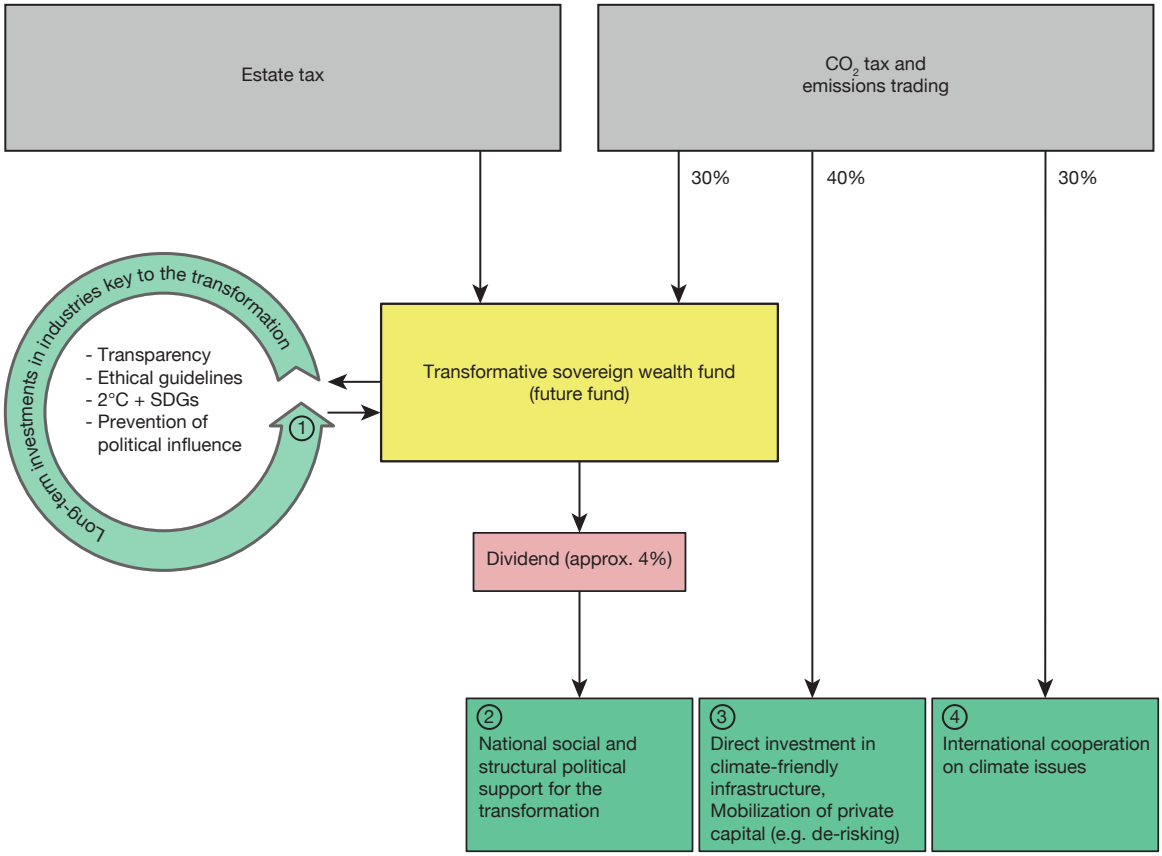


Figure 3.3-1
Elements of the future funds. This kind of transformative sovereign wealth fund, which every G20 country should establish, links its investment strategy to long-term sustainability and climate goals and invests in key industries that will be essential to the transformation (Element ①), helping to close gaps in financing for the transformation. Dividends from the future funds should be used nationally to provide social and structural political support for the transformation (Element ②). The future funds would be drawn from an estate tax (this kind of tax is levied on the entire estate, in contrast to the situation in which the tax is levied on the share of the recipient, e.g. in Germany) and some of the revenues from CO_2 pricing (CO_2 taxes or emissions trading). 30% of revenues from CO_2 pricing should flow into the future funds, 40% should be used for project-based investments in domestic climate-friendly infrastructures and to mobilize private capital (e.g. de-risking), to accelerate the transformation immediately and not wait until the future funds have reached a relevant volume (Element ③), and another 30% should be used for cooperative international climate projects (Element ④).
Source: WBGU

discussion of the investment strategy in parliament), transparency (through publication of the investment strategy and investment decision) and an obligation to contribute to the common good. Taking participative elements into account could also help to make financial and economic power more democratic (Corneo, 2015).

Generating funding: combining climate protection and equity

Sovereign wealth funds in practice often draw on revenues from the sale of resources, especially from oil and gas. In contrast, levying means for the future funds should aim to have a climate-friendly steering effect: current emissions should be priced by means of CO_2 taxes and revenues from emissions trading, and historical and accumulated CO_2 emissions through an inheritance tax as a generational component (in the form of an estate tax). These taxes take into account the *polluter-pays principle* and its associated *historical responsibility principle*. The funds would be used in the interests of future generations, so they also involve *responsibility for the future*. A progressive estate tax would also promote *social equity* between current and future generations, by counteracting existing wealth inequalities and ensuring more equal baseline conditions. The WBGU regards an estate tax – in combination with CO_2 taxes and proceeds from emissions trading – as a sustainability levy that can be used to tackle the core concerns of the 2030 Agenda.

Production processes in almost all countries are currently based mainly on high-emission energy sources, although in 2014 the global economy grew for the first time without increasing global carbon dioxide output from energy use (IEA, 2015b). Carbon pricing already exists in 40 countries at the national level and in another 24 sub-national jurisdictions (e.g. American states and Chinese cities). Existing systems, however, cover only 7 Gt CO_2eq, or around 13% of global greenhouse gas emissions (World Bank, 2016b: 22 f.). There are other taxes, such as Germany's mineral oil tax, with a steering effect like that of CO_2 pricing, but the rates levied on the various energy sources (petrol, diesel) are not necessarily linked with the carbon content of those energy

Box 3.3-1

Illustration of the estimated volume of the German future fund

Low-level ambition

A 2020 price of US$ 30 per t CO_2, which subsequently doubles every decade, could earn Germany annual revenues averaging around € 18 billion between 2020 and 2050. This revenue stems from CO_2 taxes and auctioning certificates within the framework of European emissions trading (EU ETS) for CO_2 emissions from fossil fuels and industrial emissions (CO_2, N_2O, FKW). The annual revenues would increase from around € 13 billion in 2020 to € 22 billion in 2036, and then fall again until they drop to zero in 2050 due to decarbonization. Decreasing quantities of emissions and increasing CO_2 prices largely offset each other, so there would be relatively stable revenue volumes until decarbonization.

In keeping with the structure of the future funds suggested by the WBGU and the proposed distribution of revenues from CO_2 taxes and proceeds from emissions trading (Figure 3.3-2), an average of around € 5.3 billion for the future funds, € 7.1 billion for project-based investments and € 5.3 billion for cooperative international climate protection projects would be available annually.

With a target figure of 10% of inheritance and gift volumes for the generational component, an additional amount of € 20 billion per year would become available for the future fund in Germany. With the sum of the generational component (estate tax) and around € 5.3 billion from CO_2 pricing, the fund would grow to € 278 billion between 2020 and the end of 2030. Based on an annual rate of return of 4%, there would be an annual dividend of around € 1 billion in 2020, which would rise to € 11 billion in 2030 (Table 3.3-1).

High-level ambition

Given a target figure of 20% of inheritance and gift volumes for the generational component and a CO_2 price that rises from US$ 40 in 2020 to US$ 80 in 2030, the volume of the future fund at the end of 2030 would be around € 517 billion and the dividend around € 21 billion. In this scenario, an annual average of about € 9.5 billion would be available for project-based investment and € 7.1 billion for cooperative international climate projects. A further annual average of € 7.1 billion would flow from CO_2 pricing into in the future fund.

These estimates are based on data from Germany's National Inventory Report on emissions from the energy and industrial sectors (UBA, 2015) and information from the German Emissions Trading Authority on Germany's share of emissions under the EU ETS in 2020. Like the carbon roadmap (Section 3.2),

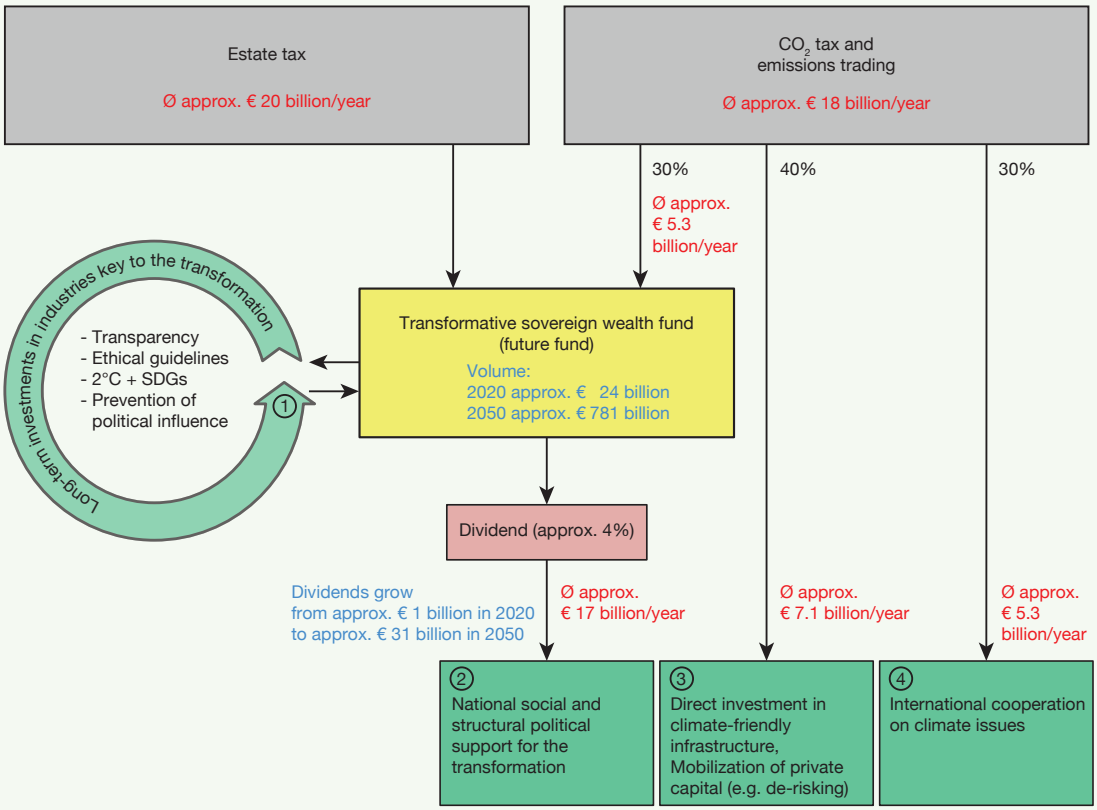


Figure 3.3-2

German future fund: average potential revenue from CO_2 taxes, emissions trading and inheritance tax in the period from 2020–2050 for Germany. The information is based on a target generational component figure of 10% and a CO_2 price of US$ 30 per t CO_2 in 2020, which doubles in each following decade (low-level ambition). Revenues from CO_2 taxes and emissions trading in this period (2020–2050) amount to an average of approx. € 18 billion per year, revenues from inheritance tax approx. € 20 billion. The fund would grow from € 24 billion in 2020 to € 781 billion in 2050. For international climate cooperation projects, an average of approx. € 5.3 billion per year would be available, for direct investment and mobilising private capital, this figure would be € 7.1 billion per year. With a dividend of 4% in the period 2020–2050, average revenues would be € 17 billion per year for providing social and structural political support for the transformation. Starting at € 1.0 billion in 2020, the dividend would grow to € 31 billion in 2050.
Source: WBGU

Table 3.3-1
German future fund. Estimates of revenues from CO_2 taxes, emissions trading and estate tax, and the fund's volume and the dividends expected for the decades from 2020 to 2050. Estimates are based on two different levels of ambition for building up the volume of the fund.
Source: WBGU

Year	CO_2 taxes and emissions trading [€ billion]	Estate tax [€ billion]	Volume of the future fund [€ billion]	Dividend [€ billion]
Low-level ambition: Target figure for estate tax: 10%; CO_2 price in 2020: US$ 30 per t				
2020	14	20	24	1.0
2030	21	20	278	11
2040	21	20	543	22
2050	0	20	781	31
High-level ambition: Target figure for estate tax: 20%; CO_2 price in 2020: US$ 40 per t				
2020	17	40	45	1.8
2030	28	40	517	21
2040	28	40	1,005	40
2050	0	40	1,454	58

they assume a linear reduction in current CO_2 emissions to zero by 2050 and an auction rate under the EU ETS rising from 80% in 2020 to 90% in 2027. They also take into account the fact that only 88% of the proceeds from auctions would remain in Germany, with 12% going to the EU. It is also assumed that not all emissions outside the EU ETS can be subject to taxes, so only 90% of the emissions were taken into account.

The estate tax is based on the lower inheritance and gift volume in Germany, as estimated by Bach and Thiemann (2016), which corresponds to € 200 billion per year. For the sake of simplicity, it was assumed that inheritance and gift volumes would remain constant in the period between 2020 and 2050.

The triad of CO_2 taxes, emissions trading and estate taxes, and current and past CO_2 emissions can be drawn on equally to build a powerful transformation instrument that could also reduce existing assets inequality, if inheritance reform is structured to be progressive. This would benefit future generations in two ways: first, through investment in sustainable structures and preservation of the natural foundations of life; and second, by strengthening social justice by counteracting ongoing current economic inequality.

sources. The OECD regards CO_2 taxes and revenues from emissions trading, together with other taxes and levies on energy and industrial processes, as a single 'effective CO_2 price' (OECD, 2016). This is especially high in the transport sector, which has nearly no CO_2 taxes, but has other taxes and levies that are comparatively high.

The CO_2 price varies greatly in different CO_2 tax and emissions trading systems, ranging from less than US$ 1 per t CO_2 in Japan up to US$ 131 per t CO_2 in Sweden (for emissions not covered by the European emissions trading system EU ETS). For 75% of the emissions subject to global pricing, the price is under US$ 10 per t CO_2 (World Bank, 2016b: 11). When taking into account direct and indirect subsidies for fossil fuels, which were worth US$ 4,900 billion in 2013 (Coady et al., 2015), the average CO_2 price for fossil sources is in fact negative. In 2013, every tonne of CO_2 attracted a US$ 150 subsidy (Edenhofer, 2015).

Many of the scenarios evaluated by the IPCC that are compatible with the 2°C guard rail assume that the average global price will be around US$ 50 per t CO_2 by 2020, and rise to about US$ 90 per t CO_2 by 2030 (Clarke et al., 2014: 450). To achieve the steering effects required to reach the 1.5°C goal, these prices will have to be much higher (Rogelj et al., 2015: 525). In almost all models, however, the CO_2 price is the only steering element. Other regulatory measures, such as a political decision to opt out of coal-fired power generation, regardless of how high the CO_2 price is, are not taken into account. It can therefore be assumed that a sufficiently strong transformation can be achieved even with a lower CO_2 price, if it is flanked by further measures (Bertram et al., 2015).

G20 countries generate 82% of global CO_2 emissions (IEA, 2015a), so they have a special responsibility to ensure that there is adequately high comprehensive CO_2 pricing worldwide. Where this is not yet the case, the WBGU recommends that G20 countries introduce CO_2 pricing through CO_2 taxes or emissions trading systems for CO_2 emissions from fossil energy sources and industrial processes. They should also ensure that CO_2 prices reach at least US$ 30 per t CO_2 in 2020 and then double in decadal steps (Section 3.2). To maximize the effect of this pricing, both instruments – the levying of CO_2 taxes and emissions trading – should be coordinated as far as possible. A coordinated approach by G20 countries to increase CO_2 prices would reduce distortions in competition.

If the G20 pursues the direction the WBGU recom-

mends, it should recommend to the EU that it harmonize CO_2 taxing and further develop the EU emissions trading system (EU ETS), orienting it towards the G20 strategy for setting a CO_2 price. CO_2 pricing measures by individual governments would only distort competition and may breach primary laws (Article 34 of the Treaty on the Functioning of the European Union; Free Movement of Goods). The EU Commission made a practical and expedient proposal in this context in 2011 (EU Commission, 2011), which envisaged amending the Energy Taxation Directive (EU, 2003) for this purpose and aimed to abolish the privileged status of fossil energy usage, especially tax incentives for energy-intensive companies, privilege electricity generation from renewable energy sources and coordinate CO_2 pricing with the EU ETS, particularly regarding the taxation of energy use in areas not covered by the EU ETS.

CO_2 taxes or emissions trading systems can only price current emissions, yet CO_2 builds up in the atmosphere, so current global warming is also the result of accumulated historical emissions. Economic development has historically been accompanied by an intensive use of fossil energies, and thus by CO_2 emissions. In keeping with the polluter-pays principle, highly developed, prosperous states are the main generators of climate change and should bear most of the costs for preventing and adapting to it. Various proposals made at the international level for sharing the historical burden among countries (e.g. the 'Brazilian Proposal': La Rovere et al., 2002, or the WBGU's budget approach (2009b)) have not yet resulted in international agreements.

As well as an overall responsibility of national economies for historical emissions, the WBGU has identified an individual responsibility for them, because positive economic development in industrialized and more prosperous emerging economies has resulted not only in a high level of national development, but in the accumulation of private capital. The individual assets acquired during industrialization and in the 20th century, especially during the post-war economic boom, were accumulated by way of fossil energy use. The WBGU takes the view that taxing these assets would be an appropriate instrument for pricing accumulated historical emissions.

The WBGU suggests that G20 countries should introduce a *generational component* on individual assets in the form of a progressive inheritance tax on estates (estate tax). To achieve greater sustainability and preserve the natural foundations of life for future generations, it is both ethical and necessary to transfer assets not just privately to our own descendants, but to use them to contribute to a shared future (Atkinson, 2016; Beckert, 2004). Different population groups have profited to varying extents from past economic growth, and in affluent OECD countries and large emerging economies such as Russia, China and South Africa, income and wealth inequality has increased sharply in recent decades (Dabla-Norris et al., 2015). To balance out the social costs of this accumulation of assets, such as more fragile social stability and inequality in people's opportunities and prospects, there have been many calls for a greater openness to reallocation measures (Ostry et al., 2016). An estate tax would be one appropriate way of taking such measures. In contrast to inheritance tax, which is levied on the assets inherited by an individual heir (e.g. in Germany), estate taxes are levied on the value of the entire estate (e.g. in the U.S. and UK). Depending on the number of heirs and their relationship to the testator, inheritance tax can result in assets of the same value being subject to very different effective tax rates, possibly imposing an unequal tax burden in the context of historical ecological responsibility. In countries that already have an inheritance tax (such as Germany) both models could be combined.

An effectively structured estate tax in combination with a gift tax offers comprehensive financing potential (IMF, 2013). Over recent decades, the volumes of inheritances and gifts has increased significantly as a proportion of GDP in highly developed countries. However, tax revenues in countries that levy taxes on inheritance and gifts are usually low, because high tax exemption limits and special regulations on tax avoidance substantially reduce the national tax base (IMF, 2013).

Germany's inheritance and gift volume is estimated at € 200–300 billion per year, of which € 30–40 billion comes from corporate bequests. The volume of the largest 1.5% of inheritances makes up around one-third of all assets bequeathed in Germany (Bach and Thiemann, 2016). Annual revenues from inheritance tax are worth around € 5 billion. High tax exemption limits (up to € 500,000) for private asset bequests and comprehensive exemptions for company assets in Germany mean that many German estates are bequeathed almost tax-free.

The WBGU proposes structuring the inheritance tax so that 10–20% of national inheritance and gift volume would go into financing the future funds. For the German future funds, this would result in annual potential revenue of at least € 20 billion for a target figure of 10% or at least € 40 billion for a target figure of 20%. The money should go directly to the funds or, if there are legal restrictions, flow into the government budget as a reciprocal financing model. In this case, the state should undertake to fill the funds with a share of the annual tax revenues. Only the latter would be possible in Germany for constitutional reasons.

Introducing an estate tax – also in combination with the existing inheritance tax – should be admissible under the German constitution, but would face major political challenges. Under Article 106 Paragraph 2 of the German constitution, the German federal states are entitled to inheritance and gift tax revenues, so the sixteen federal states would have to be willing to use the proceeds from inheritance and gift taxes for the purposes of the transformation or for a sovereign wealth fund dedicated to achieving transformation goals.

3.4 Strengthening participatory democracy for the transformation

A lasting and inclusive project for modernization, equity and peace should include civil society in its design and implementation.

- Innovation often emerges in social niches and through social learning processes (WBGU, 2011; Messner, 2016). Its potential can best be developed when the society is open to diversity and niche groups are well connected with wider social groups.
- Environmentally friendly infrastructure can only be built up at the required speed and with the necessary consistency if it is supported by civil society and not blocked by resistance.
- G20 governments will only be able to procure the necessary investment with support from non-state investors that are accepted by the wider society.

The concept of a new, proactive state described above centres on equity, participation and quality of life while focusing on the promoting of "quality of life for all" (Stiglitz et al., 2010; EU Commission, 2009). A proactive state is embedded in a vigilant civil society, whose people see themselves not as passive observers of government action and social developments, but as 'citizens', responsible members of the public actively participating in networked societies (Messner, 1997). In the willingness of national and international civil society to take responsibility for climate mitigation, which has grown in recent years (WBGU, 2014a), the WBGU sees an opportunity for citizens to develop a broad 'transformative literacy', the ability to "adequately understand transformation processes in their many dimensions and bring their own activities to bear in transformation processes" (Schneidewind, 2013: 120). This does not relieve the state of its responsibility to persuade citizens of the necessity of the transformation, but opens up possibilities for shaping this communication with and through civil society.

Inclusive communication about the causes and consequences of climate change

In a proactive state, the discourse on the sustainability and climate goals agreed upon in New York and Paris is not conducted only among experts. Involving societies sufficiently in this discourse will require an adequate communication of climate problems and climate goals, including a realistic evaluation of the possible risks, effects and side effects of the various options for action. The great complexity and abstractness of systemic interconnections pose major challenges for the communication of options for climate mitigation action. Even in countries with good education systems, populations do not well understand risks or conditional probabilities related to risk factors ('statistical illiteracy': Gaissmaier and Gigerenzer, 2011). To this issue is added the phenomenon of the 'illusion of certainty', a term from risk research (Hertwig, 2013; Gigerenzer, 2008). In our modern, technically engineered world, people like to believe that risks can be completely controlled. They think in linear, often mono-causal contexts, overrate the effective power of technologies, prefer simple solutions and underestimate possible negative consequences (Renn, 2008).

Involving civil society in a discourse on the options for acting within the framework of sustainability policy is therefore an education project as well. Experiences and discoveries made in the area of climate protection could help people understand the general dynamic of processes of change in their many dimensions, without making them feel powerless as individual actors. To develop a basic 'transformative literacy', collective and individual abilities to deal productively and creatively with challenges should be promoted so that the uncertainties and fears that accompany any confrontation with complex and unusual tasks can be diminished. In this context, it is important to always link information on risks with collective and individual options for action (Rogers, 1975, 1983).

Enabling people to develop solidarity-based lifestyles

Achieving the goal of complete decarbonization requires a change to our concept of quality of life, which is linked with resource-intensive forms of consumption in many socio-cultural circles (Schneidewind and Zahrnt, 2013). The WBGU, in coining the term 'solidarity-based quality of life' has proposed a model designed to open up a discourse space for a social dialogue on how to create a sustainable quality of life (WBGU, 2016a: 144f.). In particular, it is designed to sound out options for establishing an individual quality of life that is not lived at a cost to present and future generations and their opportunities for fulfilment (Nanz and Leggewie, 2015). The WBGU is of the opinion that a comprehensive notion of the individual as someone whose role as private consumer is not artificially separated from the role of citizen could make an essential contribution to this discourse. The prevailing discourse on the modifiability of lifestyles is based on an undifferentiated understanding of human action, which regards decisions on consumption as exclusively oriented towards individual benefit, although people base decisions to act on standards and values that do not directly serve their own self-interest (Messner and Weinlich, 2016; Steg, 2016; Stern, 2000). There remains the question of under which contextual conditions an individual's own standards can be applied to their actions, and how the various forms of political consumption (Thoresen et al., 2015; Soper and Trentman, 2008) can be more effectively encouraged.

To create incentives and structures for changing lifestyles and consumer behaviour, the WBGU recommends taking a differentiated view of the modifiability of behaviour. From a systemic point of view, human thinking and acting are embedded in diverse contexts. Supporting this change requires that equal attention be paid to structural interdependencies (infrastruc-

tural restrictions, but also cultural forces) as to the degrees of individual freedom and windows of opportunity for change. Structure-focused top-down strategies (such as regulations and incentives) should be deployed where the greatest possible effect on the reduction of resources and energy consumption can be expected (in north-western Europe this would be the areas of mobility or interior heating). To make use of existing potential to develop conscious, solidarity-based lifestyles, G20 countries should also support top-down approaches as well as bottom-up processes in 'ecologically minded milieus'. Although their ecological footprint is still fairly large, these milieus often have the resources required to be effective through strategic consumption or targeted divestment. In this sense, G20 governments should support 'pioneers of change' (WBGU, 2011) and the socio-ecological innovation they are proposing and propagating (e.g. actors in the collaborative economy, eco-villages and transition towns; WBGU, 2014a).

3.5 Recommendations

To bring about the necessary transformations quickly enough to keep global warming well under 2°C and implement the 2030 Agenda goals, the WBGU recommends that the G20 countries implement the following measures:

- The G20 states should revise their current (I)NDCs in light of the agreements made in Paris, develop decarbonization strategies to implement them and orient their efforts towards the decadal steps in the carbon roadmap, in which global emissions are reduced to zero by 2050. As a first step, an emissions peak must be reached and subsidies for fossil energy sources in the G20 be abolished by 2020.
- In setting up future funds (transformative sovereign wealth funds) G20 countries should become more active as actors in financial markets with the goal of advancing socially responsible structural change and creating a sustainable economic and social system. The future funds should be filled (1) through the pricing of current and historical CO_2 emissions. They should (2) align the investments with climate change targets and the SDGs while also using ownership rights to this end, and (3) use the dividends to enhance the common good and improve equity. Some of the revenues from CO_2 taxes and emissions trading should be directly invested in individual projects or used to mobilize private investment (e.g. de-risking), so that states do not wait for the funds to reach a critical size, but start working immediately to create sustainable infrastructure. A further share of this revenue should flow directly into cooperative international climate projects and benefit developing countries.
- To produce the steering effect necessary for the transformation and generate the financial resources needed for the future funds, the G20 countries should introduce a system for pricing CO_2 emissions from fossil energy sources and industrial processes where they are not yet priced, either through CO_2 taxes or emissions trading systems. They should ensure that the price is oriented towards the carbon content of the specific energy source and that a minimum price of US$ 30 per t CO_2 – a target considered to be essential – is reached by 2020 and then doubles in every following decade.
- To finance the future funds, the WBGU also recommends that the G20 countries introduce a generational component in the form of a progressive estate tax (which taxes all the assets in an estate instead of the shares of individual heirs in the inheritance). The tax should be structured so that 10–20% of national inheritance and gift volume is available for financing the future funds.
- In implementing the transformation, the G20 states should make use of regulatory top-down strategies as well as knowledge-based, motivational, bottom-up approaches. The G20 governments should more actively support 'pioneers of change' (WBGU, 2011) and the social and ecological innovations they propose and propagate.
- The G20 countries should take advantage of national and international civil society's increasing willingness to take responsibility for climate protection (WBGU, 2014a) and promote a widespread 'transformative literacy' among their citizens.
- The G20 states should grant the public task of environmental and climate protection a priority that mirrors the constitutional standing it already has and underpin it with effective instruments.
- The German Federal Government and the G20 countries should work towards ensuring that the new IPCC special report on the 1.5°C goal contains a broad spectrum of prevention scenarios (with and without negative emissions and with and without disruptive technological change) to illustrate a balanced relationship of solutions and highlight both the opportunities and benefits of disruptive change.

Transformation as a project for modernization, equity and peace

4

The governments of the G20 states should campaign not only 'at home' for innovation, infrastructure, investment and inclusion measures, but should also assume a pioneering role in climate and sustainability policy at the international level, and thereby further transnational cooperation and help to find solutions to global problems. Along with the SDGs, climate protection is currently the only human undertaking in which all nations of the world participate. The achievements of the conference in Paris and the unanimous adoption of the Paris Agreement by 196 states shows that multilateralism functions very well in the area of climate protection. Even states such as China or the U.S., which formerly had a reputation for impeding progress, contributed constructively. The 2030 Agenda is also a decidedly global project; the system of goals is universal and will establish the basis for a diversified global partnership.

As projects for humanity with a long-term focus, climate protection and the 2030 Agenda constructively bring together actors that would not cooperate in other contexts or even those that stand in open conflict with one another.

It is not a new idea that solving shared sustainability and climate policy challenges offers conflicting parties opportunities for rapprochement. At times during the Cold War it was championed by Willy Brandt: "The solution of mutual problems implies establishing links through meaningful cooperation among states […] It means building up confidence through practical arrangements. And this confidence may then become the new basis for the solution of long-standing problems." (Willy Brandt, upon the occasion of his receiving the Nobel Peace Prize in Oslo, 11 December 1971).

If appropriately drafted, sustainability and climate policy can become a global project for modernization, equity and peace:

- Prudent climate and sustainability policy serves to modernize the global economy and creates opportunities for economic development, as it inspires a new understanding of *Innovation* and creates substantial possibilities for *Investment* and sustainable employment while channelling investment into future-proof industries and business as well as into sustainable *Infrastructure*.
- Climate and sustainability policy can also be equity policy by promoting *Inclusion* while designing socially compatible decarbonization strategies, effectively combatting inequalities and strengthening social cohesion.
- And climate and sustainability policy can contribute to preserving peace by deescalating conflicts over resources and distribution – thus promoting *Inclusion* at the global level – and thwarting civil wars and mass migration.

The suitable arrangement of both the transformation towards sustainability and the climate agenda can contribute to solving international crises, particularly the blockages preventing innovation and investment, high inequality within and between nations – which runs contrary to inclusion – and international peace and security problems. The G20 should strengthen the Four Big 'I's of sustainability transformation, engage at the international level as pioneers, and help make sustainability and climate policy – which constitute a historic project for the global community – a lever for solving problems of global policy. In what follows, the WBGU presents examples of concrete initiatives that the G20 could pursue.

4.1 Climate and sustainability policy as a global modernization project

Global economic growth has weakened in recent decades and global stagnation looms (IMF, 2016). Low interest rates and insufficient investments and investment opportunities are presenting the world economy with major challenges, which is altering the economic perspective on sustainability questions. As a modernization project, climate and sustainability policy offers much potential for investment possibilities and great economic opportunities. At the same time, climate and sustainability policy's long-term and strategic perspective makes it a guarantor of ecologically stable economic development. The G20 should campaign at the global level for a new understanding of a social and ecological market economy and place a new global understanding of innovation on the international agenda as a model for a global mission for stability and future viability.

Directed and productive investment

The increasingly prevalent political and societal recognition that early action on climate mitigation

Table 4.1-1
Dimensions of a new understanding of innovation.
Source: WBGU

Dimension	Thus far	In future
Overall goal of innovation	National competitiveness	The common national and global good: economic capability facilitates the implementation of the Paris Agreement and the 2030 Agenda – innovation for sustainability
Economic goals of innovation	Precedence of private interests and goods	Embedding of markets and the strengthening of public goods
Focus of innovation	Technological innovation	Technological innovation is coupled to a high degree with social, institutional and cultural innovation
Depth and reach of innovation	Incremental innovation (within existing socio-economic systems)	Disruptive or systemic innovation (with intended or sought systemic change towards sustainability; global)
Sources and locations of innovation	Industrial countries as drivers of innovation – transfer to the rest of the world	Global innovation – strengthened international cooperation for global innovation exchange

helps minimize costs and risks and forges the path to a resilient economy is already creating market adjustments, such as a stronger focus on electromobility by car manufacturers and divestment by renowned investors (Norwegian pension fund, Allianz, etc.). Moreover, the climate mitigation currently underway will limit climate risks in the 21st century and beyond, as well as reduce the long-term costs and challenges of adaptation (IPCC, 2014c). Early action also creates possibilities for a 'softer' global structural transformation. The Paris Agreement has rendered the strategic reorientation of CO_2-intensive industries unavoidable. Miscalculations of the need for structural economic adaptations heighten the risk of abrupt changes, such as sudden insolvencies and mass layoffs, which can lead to structural crises for entire economic regions. A possible 'carbon bubble' (Carbon Tracker Initiative, 2011; WBGU, 2014a; Carney, 2015; ESRB, 2016), i.e. the overvaluation of companies that have concessions for global oil, coal and gas extraction, heightens the risk of abrupt revaluations by the financial markets. Economic adaptations undertaken today in the spirit of the Paris Agreement and the 2030 Agenda will lead to greater future stability in the economic and financial system.

On the path to a new understanding of innovation

The dominant guiding theme of the G20 has thus far been the promotion of growth and innovation. The challenges faced by transformation necessitate a broader understanding of innovation and investment, by which far-reaching systemic changes via corresponding technological innovations will be networked more strongly with social, institutional and cultural innovations. This involves a new orientation for growth and innovation that goes beyond the already developed 'G20 Blueprint on Innovative Growth' (G20, 2016c); the economic capability and alignment of innovations should facilitate the implementation of the Paris Agreement and 2030 Agenda.

The cornerstones of such a new understanding of innovation are summarized in Table 4.1-1:

1. In order to improve the predictability of long-term investments in the transformation towards sustainability, there must be a reliable expectation that the G20 states take seriously and will implement the Paris Agreement and the 2030 Agenda. The overall goal of innovation should no longer exclusively be the promotion of national competitiveness per se, but rather the furtherance of the common national and global good, so that economic capability serves the implementation of the Paris Agreement and the 2030 Agenda. To protect the global climate system, innovative decarbonization policy should become the dominant modernization policy of the 21st century.
2. This goes hand in hand with the extension of private interests, investments and goods through embedded markets, i.e. societally formed markets that integrate economic activity into non-economic institutions (Polanyi, 1968; Kay, 2003). A new balance must be struck between markets and the state; the radical variants of each isolated approach have failed. The diversity of steering mechanisms in embedded markets can strengthen economic resilience and form the basis for socio-ecological market economies.
3. The primary focus of innovation is also shifting, from technological innovation to a close combination of technological innovation with social, institutional or cultural innovation, e.g. new forms of institutional configurations, new business models or changing lifestyles.
4. At the same time, the range of innovation is widening from rather incremental changes (like new drive technologies, new materials, efficiency improvements for renewable energy sources) to disruptive, transformative socio-technological innovation. Not only does this tap into the disruptive potential of certain technologies, such as information and com-

munications technologies, but it also requires a comprehensive system transformation. For example, the shift to electromobility represents a system innovation that includes vehicles, energy generation and storage, infrastructures as well as the entire value-added chain of the automobile sector.

5. The sources of innovation and the locations of innovation generation in the new understanding of innovation are far more diverse than they are today, with industrialized countries' patterns of innovation transfer still dominating the rest of the world. However, social innovation, approaches to securing global common goods, approaches to social participation and alternative concepts of prosperity are already increasingly being generated in emerging economies and developing countries (Stamm et al., 2012). For example, China has now become the lead market and most important manufacturer of electric vehicles, and Brazil is the global technology leader in terms of producing energy from sugar cane. The diversity of innovation sources, spanning to include parts of society that have not been directly related to research in the past, is an appropriate starting point for the urgently needed national as well as international networking of research programmes on innovation. The G20 states should strengthen international cooperation on the promotion of innovation.

4.2 Climate and sustainability policy as a global equity project

In addition to climate change, increasing global socioeconomic inequality is one of the greatest challenges facing sustainable development. The issue of inequality has already been addressed by the G20 Hangzhou communiqué (G20, 2016b). The G20 should become even more active in finding solutions to global problems of inequality. Climate protection can be an important part of the answer; since climate change often has the greatest impact on the most vulnerable population groups, effective climate protection harbours great potential both for greater global equity and realization of the SDGs. However, climate mitigation does not automatically foster equity. The WBGU proposes that the G20 states develop climate protection measures in such a way that they combat poverty and inequality, and thereby link and simultaneously address climate protection and equity. The G20 states should campaign to give climate protection an important role in the international agenda as a project to promote equity. Together with their cooperation partners, they should develop strategies such as those that prioritize investment in areas where climate protection also creates inclusive growth – i.e. where the 40% segment of the population with the lowest incomes profits overproportionately (Shared Prosperity Index: World Bank, 2015) – or focus on nutritional equity and the sustainability of global dietary patterns. Such goals should be promoted not least through the activities of multilateral banks. The G20 should push for the Green Climate Fund, along with institutions like the World Bank and regional development banks, to place a particular focus on financing and implementing measures and projects that combine climate mitigation and equity.

Managing urbanization to achieve climate mitigation and inclusive growth

Managing urbanization is an important area in which the G20 states can combine climate mitigation and inclusive growth. Urbanization develops differently in the various states of the G20. In some countries, building works in mature cities tend to focus on renovation and redevelopment, while in other countries cities and settlements are rapidly growing to unimaginable dimensions. In consideration of the pending boom in global urbanization, the style and method of how cities are built must be thought about in a completely new light. This includes, for instance, their structural and spatial design, urban transport systems, urban energy supply and the building materials that are used (WBGU, 2016a). At the same time, income and wealth inequality are becoming more acute in many cities and are leading to spatial segregation and social disadvantage, which is especially visible where there are slums and gated communities in immediate proximity to one another. The growing disparities are having an increasingly negative effect on the social cohesion of urban societies, urban economic development and the governability and safety of cities (WBGU, 2016a).

If global urban development followed the model in industrialized countries, the emissions caused through the construction of new infrastructure for the additional 2.5 billion city-dwellers expected by 2050 would alone correspond to one-third of the remaining CO_2 budget if climate change is to be limited to 2°C, and more than three-quarters of the budget if the 1.5°C target is to be met (WBGU, 2016a; Müller et al., 2013). While SDG No. 11 ('Make cities and human settlements inclusive, safe, resilient and sustainable') has made the theme of sustainable urban development part of the 2030 Agenda, the challenges and opportunities of urbanization in the context of the Paris Agreement and in the (I) NDCs have thus far found little or no consideration. The G20 states should address this deficit by making sustainable urban development a core element in national and international decarbonization strategies and should campaign for greater consideration of the theme within the Framework Convention on Climate Change.

Several fields of action within urban development offer potential for the coupling of climate mitigation and equity, such as land use, the recycling economy and renewable energy sources (WBGU, 2016a). Mobility and transport in particular are of great significance: urban transport systems are responsible for a considerable share of cities' CO_2 emissions; and their structure determines which segments of the population can move more easily throughout the city in order to, for instance,

participate in the employment market and profit from the gains in growth. The configuration of urban transport systems is therefore an important lever for creating urban equity. Poorer urban population groups suffer more than others from the consequences of motorized private transport and are disproportionately affected by less efficient public transport systems, as they typically depend on them to a large degree (WHO and UN-Habitat, 2010). Functioning public transportation infrastructure is thus a key element for the eradication of urban inequality (UNEP, 2012; UKAID and DFID, 2012; Beard et al., 2016).

The WBGU recommends that the G20 states configure their inner-city transport systems as quickly as possible to be inclusive and emissions-free (Subgoal 'accessible cities' of SDG No. 11; WBGU, 2016a: 165ff.) and, within the framework of their international development cooperation, join with their partners in forging strategies to enable its implementation in their cities. For this to succeed in light of strong path dependencies, a corresponding course must rapidly be set. The time window for the necessary transformation is open now and must be utilized before it closes.

Urban mobility should be designed so that people of all income groups can move comfortably and inexpensively through a city in order to profit without restrictions from its economic, social and cultural possibilities. As poorer population groups tend to suffer most from motorized private transport, while benefitting from it the least, this requires functioning and well-developed local public transport as well as good infrastructure for pedestrians and bicycles. At the same time, adequate mobility systems can create positive employment effects, above all for poorer strata of the population. Local public transport should be made accessible to everyone, and streets should be made safer for non-motorized traffic (Pro-poor Transport Policies; WBGU, 2016a: 165ff.). Above all, the modes of mobility and safety needs of vulnerable groups such as the elderly, children and women should figure prominently in the planning process (Hamilton et al., 2006).

Nutritional equity and sustainable dietary patterns

The G20 should campaign to strengthen sustainability and equity in the context of global dietary patterns. It should promote the issue in international discussions, work towards placing it on the agenda of international organizations, and support it with structural measures. The 2030 Agenda also calls to address this issue: SDG No. 2 obliges the world community to end world hunger, including malnourishment, and make food production sustainable.

From a global perspective, the high share of the world's population suffering from hunger and malnourishment is not attributable to a lack of fertile land, but to inefficient production and consumption practices as well as inequitable distribution (WBGU, 2011: 63). According to a study by the WWF (2015), one-third of all food in Germany is lost on the way from field to consumer or is thrown away in households. The global share of produced food that either spoils, is lost or is thrown away is also one-third (FAO, 2011), while an additional third is used to feed livestock (de Schutter, 2011). The cattle industry uses (directly and indirectly) around 70% of all agricultural land (Steinfeld et al., 2006). Its products are predominantly consumed by the populations of industrialized countries and the growing middle classes of emerging economies, whereby the quickly rising consumption of meat is posing increasing health risks (McMichael et al., 2007). Today's intensive agriculture is mostly performed in an unsustainable way, and leads to land degradation and a loss of biodiversity and ecosystem services. It also accounts for between 10–12% of the world's anthropogenic greenhouse gas emissions (IPCC, 2014b: 822).

The G20 states play a key role with regard to food security and nutritional equity. This includes urgently needed structural measures such as curbing land degradation, promoting sustainable agriculture and preventing food loss along the value chain (as explained by the G20 agriculture ministers in May 2015). In order to remain effective, structural measures must be carried out through a transformation of food practices of citizens in all G20 states. Moreover, it is especially the industrial countries and emerging economies that are responsible for contributing to this transformation through measures not only structural, but knowledge- and motivation-based as well. Without responsible citizens, a solution to this problem is impossible.

The societies of the G20 states face the challenge of encouraging sustainable diets, such as those based on regional, ecologically farmed foods and on fewer animal products, while not encroaching too forcefully on the autonomy and self-determination of the citizens, which could have a reactionary or backlash effect. Moreover, less consumption of animal products would be fundamentally healthier for the populations of industrial countries and the quickly growing middle classes in developing countries and emerging economies (WBGU, 2011: 65).

Top-down regulatory measures should be coupled with improved access to healthy and climate-friendly foods. In the sense of collaborative action by both the state and citizenry, initiatives and practices should be promoted in which people want to perform their roles as responsible consumers, e.g. through food sharing. These initiatives should be more institutionally bound, cooperating, for instance, with international organizations, educational institutions, employers and authorities. The FAO, for example, should further strengthen its food-saving program, 'SAVE FOOD: Global Initiative on Food Loss and Waste Reduction'.

4.3 Climate and sustainability policy as a global peace project

Climate and sustainability policy can help maintain peace by combatting the causes of civil war and mass flight. As early as 2008, the WBGU report 'Climate Change as a Security Risk' called attention to the fact that climate change, in the absence of decisive countermeasures, will overstrain the adaptability of many societies in the coming years (WBGU, 2008). Climate change contributes – with regionally varying intensity – to the endangerment of human security, since it jeopardizes the fulfilment of people's basic needs, exacerbates conflicts over resources and distribution, reduces cultural development and identity, and contributes to the causes of migration, which in turn can cause instability in migrants' destination societies (Adger et al., 2014:758; Oppenheimer et al., 2014:1061). Climate mitigation and adaptation measures are therefore important strategies for the protection of human and societal security.

According to the assessment by the IPCC, climate change will increase the future danger of violent conflicts between states in certain regions (Adger et al., 2014:772). Moreover, climate change will gain importance with regard to future migration decisions (WBGU, 2008, 2014). The multiple causes of crises, conflicts and migration decisions make data acquisition and prognoses more difficult (IDMC, 2015; UNHCR, 2015; Adger et al., 2014; Oppenheimer et al., 2014). According to assessments by the International Organization for Migration (IOM), the effects of climate change could create up to 200 million migrants by 2050 (IOM, 2009; WBGU, 2014a:62f.).

The literature refers to human mobility, which can be subcategorized into displacement, (predominantly voluntary) migration and planned resettlement (UNHCR et al., 2014). Neither the Framework Convention on Climate Change (UNFCCC, 1992) nor the Paris Agreement explicitly address the issue of climate-induced flight (Chapter 1). The terms 'climate refugee' and 'climate migrant' have not yet been defined under international law (WBGU, 2014a:62f.; Brouers, 2012; Nümann, 2015). The Geneva Refugee Convention (GRC) does not protect 'climate refugees' (Nümann, 2015), since the criteria according to Article 1 of the GRC (in short, well-founded fear of persecution on the grounds of certain characteristics, such as political conviction) are not fulfilled by climate-related natural catastrophes or damage to the environment (Nümann, 2015:168). The existing international regulations on refugee protection stipulate – with overwhelming consensus – no obligation for (mandatory) acceptance of 'climate refugees' (Brouers, 2012; Nümann, 2015). Internal migrants as a result of natural catastrophes or climate change are recognized only by the geographically limited intra-African Kampala Convention and the (non-binding) Guiding Principles on Internal Displacement.

Changing the GRC looks unpromising due to the considerable amount of political resistance it faces. On one hand, an expanded scope for the applicability of the Convention on Climate Refugees is seen as undesirable by many potential receiving countries; on the other hand, there is concern that renewed negotiations of existing agreements would lead to an erosion of the current system of refugee protection, rather than its expansion. As an alternative to modifying the Geneva Refugee Convention, a protocol to the Framework Convention on Climate Change should be proposed that would offer populations in dangerous areas the possibility to resettle (Biermann and Boas, 2008).

As a contribution to the security of global peace, the G20 states should place climate protection measures on the agenda and explore possibilities for intervention. These depend on factors of both time and space; slowly occurring catastrophes (e.g. desertification) and latent conflicts can be addressed differently than sudden catastrophes (e.g. floods) and escalating violence. And there are big distinctions as to whether people must, can or want to migrate, and whether migration (or flight) is planned or unplanned, remains domestic or requires crossing national borders. The WBGU sees three particular areas where action is required:

Micro-level: combatting local, climate-induced causes of conflict and flight

In many regions, climate-induced catastrophes and conflicts jeopardize the development progress of recent decades, threaten human security and exacerbate global inequalities. The IPCC report (2014c), the SDGs (No. 13) and the Paris Agreement emphasize the urgency of adaptation measures and demand their implementation in order to combat local climate-induced causes of conflict and flight at the micro-level. Especially in regard to slowing occurring climate-induced catastrophes, the far-reaching socio-economic and political implications necessitate the early, proactive and appropriate selection and suitable implementation of short-, medium- and long-term adaptation strategies.

In addition to technical adaptation measures (e.g. flood protection, hurricane shelters), social and institutional measures (e.g. risk management) are increasingly being promoted (Noble et al., 2014:836). This requires not only a continual integration and expansion of existing political framework conditions, but also the integration into and the strengthening of coping strategies for the local populations (NRC and IDMC, 2014:12; Noble et al., 2014:836). Capacity building and financial support from local actors should find greater resonance in the G20's international climate and development policy, and more funding should be earmarked for these areas.

Meso-level: strengthening settlement programmes

When climate-induced migration is inevitable or has already occurred, the central challenge becomes strengthening the resilience of the migrated groups and the populations in their destination regions. If future

migration is unavoidable as a last resort to adaptation, it should take the form of an informed, planned and jointly conceived resettlement as far as possible, especially in the case of slowly occurring catastrophes (Advisory Group on Climate Change and Human Mobility, 2015). The G20 states should therefore promote the expansion as well as the financial security of settlement programmes. At the institutional level, consideration for this task would be given to the UNHCR and IOM, whose institutional capacities in this regard should be strengthened. The discussion surrounding an official expansion of the UNHCR's mandate in this context should be taken up again by the G20 (on the mandate: Hall, 2013). Emergency assistance and medium-term development cooperation must be better coordinated. Moreover, structured return programmes should be offered to migrants who are able to remigrate to their home countries. Urban settlement programmes for migrants without this option should be strengthened in order to avoid the growth of slums as well as crises and conflicts in the destination areas. It is therefore important to reinforce multi-actor approaches to the support and cooperation of local, regional, national and, in some cases, international actors from government and civil society.

Macro-level: putting climate migration on the agenda

The climate agreement reached in Paris should be implemented with urgency in order to use climate mitigation and climate adaptation policy to combat the causes of flight early on. As mentioned in the coalition agreement between the CDU, CSU and SPD (CDU et al., 2013: 125), clarifying the status of climate refugees who migrate over national borders – while allowing for the option of developing an international protection instrument – is an international imperative. The WBGU proposes concluding additional protection agreements beyond those covering refugee rights. The G20 states should begin this discussion and arrange for protection and an equitable sharing of costs. Local adaptation as well as migration from high-risk areas should be facilitated, e.g. through financing within the scope of the Green Climate Fund. In this regard, the Nansen Initiative on 'Disaster-Induced Cross-Border Displacement', founded by Switzerland and Norway in 2012, can serve as a model and connecting factor. It targets the development of a protection agenda for climate-induced migration while focussing on international cooperation, the application of uniform standards for dealing with refugees, and operative mechanisms (e.g. financing mechanisms and the assumption of responsibility by international humanitarian and development actors). The Nansen Initiative has launched an international process that ultimately aims to achieve political consensus on the protection of people displaced across national borders by climate change and environmental catastrophes. This process should be supported by the G20.

4.4 Recommendations

With the right configuration, sustainability and climate policy can become a global project for modernization, equity and peace. The G20 governments should push for the Four Big 'I's of sustainability transformation and, as pioneers at the international level, help make sustainability and climate policy – which constitutes a historic project for the global community – a lever for solving problems of global policy. The WBGU recommends the following actions to the G20 governments:

Climate and sustainability policy as a global modernization project – seizing opportunities for economic development

- *Promote an expanded understanding of innovation:* Focus on the development of new key technologies along with social innovations that target the common national and international good as well as the provision of public goods and capital; focus on systematic and disruptive innovations that serve the implementation of the Paris Agreement and the 2030 Agenda; strengthen international cooperation in innovation promotion.

Climate protection as a global equity project

- *Shape the development of urbanization to achieve climate protection and inclusive growth:* Consider sustainable and inclusive urban development while developing decarbonization strategies and national contributions; strengthen the role of sustainable development within the (I)NDCs and the Framework Convention on Climate Change.
- *Promote nutritional equity and sustainable dietary patterns:* Combine top-down regulatory measures and the improvement of access to healthy and climate-friendly foods with the promotion of bottom-up initiatives and improved institutional frameworks; strengthen relevant initiatives of international organizations.

Climate protection as a global peace project – climate protection and human security

- *Reduce the causes of civil war and mass flight at all levels:* (1) At the micro-level: reduce local climate-induced causes of conflict and flight; (2) At the meso-level: strengthen settlement programmes; (3) At the macro-level: in the allocation of funds, e.g. the Green Climate Fund, take into account in situ and ex situ adaptation through capacity building in vulnerable regions and in migration destinations; reach additional protection agreements beyond those concerning only refugee rights (e.g. within the UNFCCC) and strengthen the Nansen Initiative.

Key messages

5

After the 2015 consensus on Sustainable Development Goals (SDGs) and global climate goals (Paris Agreement), the focus must now be on implementation. The necessary changes can be described as the Four Big 'I's: the Great Transformation towards sustainability requires and inspires *Innovation* while channelling *Investment* towards sustainability and climate protection, e.g. towards the construction of sustainable *Infrastructure*. At the same time, the transformation can be used to combat inequality and promote *Inclusion* within societies and globally, thus becoming an equity project. The group of the 20 most important industrialized and emerging economies (G20) should play a leading role in the transformation.

G20 for climate protection

- During Germany's G20 presidency, the German federal government should strive for G20 consensus on a decarbonization goal to reduce the G20's CO_2 emissions to zero by 2050. The G20 states should move forward with ambitious reduction targets and develop decarbonization strategies. Core elements include the rapid expansion of renewable energies, an effective limiting of energy consumption, a swift phase-out of the use of fossil fuels as well as the protection and restoration of natural ecosystems.
- The G20 should position itself critically in terms of geoengineering. Measures targeting the manipulation of the Earth's radiation balance should not be pursued. Also, large-scale alterations of the carbon cycle should be avoided. Exceptions include the combining of bioenergy with carbon dioxide capture and storage (BECCS) on a small scale as well as the chemical binding of CO_2 from the air, both of which require additional research and testing.

Financing a sustainable future

- To implement the sustainability and climate goals, the G20 states should establish transformative sovereign wealth funds, which the WBGU also calls 'future funds'. These should be fed from two sources: (1) the pricing of CO_2 emissions; this should reach US$ 30 per tonne by 2020 and double with each successive decade; (2) a progressive estate tax as a generational component; the revenue goal should be set at 10–20% of the national inherited or gifted wealth.
- The future funds should orient their investment strategies towards long-term sustainability and climate protection goals and invest in corresponding key industries. The dividends should be used to fund national social and structural policy in support of the transformation. A share of the income derived from CO_2 taxes and emissions trading should be invested directly at the project level, applied to the mobilization of private investments and used for international climate cooperation.

Climate and sustainability policy as a global modernization project

- The G20 should propagate an expanded understanding of innovation for stability and sustainability in harmony with the SDGs and the Paris Agreement. It should also be geared towards the social and ecological embedding of markets and acknowledge that social and institutional innovations are necessary as well.

Climate and sustainability policy as a global equity project

- The G20 states should strengthen sustainable urban development as well as nutritional equity and sustainable dietary patterns as examples of furthering not only climate protection, but also inclusive growth.

Climate and sustainability policy as a global peace project

- The G20 states should promote inclusion at a global level through combatting local, climate change-induced causes of conflict and migration as well as giving stronger support to settlement programmes. The G20 should initiate solutions for climate change-induced migration.

Counteracting nationalism and authoritarian movements

- A proactive national as well as international sustainability and climate policy would be a G20 project suitable to curtail nationalist or authoritarian movements and their rejection of international cooperation.

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Development and justice through transformation

2015 saw a historic double success for sustainability and climate policy. The 2030 Agenda for Sustainable Development, with its Sustainable Development Goals (SDGs), and the Paris Agreement on climate protection establish a system of ambitious policy goals for the world. The group of twenty major industrialized and emerging economies (G20) now needs to resolutely advance implementation of both agreements, seizing the opportunity of this 'Great Transformation' to sustainability as a unique modernization project that could offer substantial economic development opportunities. Complete decarbonization of the world economy by 2070 at the latest can only be achieved by profoundly transforming energy systems and other high-emissions infrastructures. This transformation could inspire *Innovation* and channel *Investment* into sustainability and climate protection, and into the kinds of sustainable *Infrastructures* that need to be established and expanded. At the same time, the transformation could combat inequality and promote *Inclusion* within societies and globally, thus becoming an equity project.

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