WBGU
German Advisory Council on Global Change
(WBGU)

Solving the climate dilemma: The budget approach

Special Report

Members of the German Advisory Council on Global Change (WBGU)

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Special Report

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A new approach to the global climate problem

The vast majority of scientists now agree that if global warming exceeds a mean temperature of 2°C it will lead to dangerous, irreversible and practically uncontrollable consequences for both nature and mankind. A total of 133 countries, including the 16 major economies and the European Union, have acknowledged the significance of this temperature limit. Many of these countries have made it their target to limit the rise of the global mean temperature to 2°C or less as a guard rail for their endeavours in climate policy.

Latest research shows that there is only a realistic chance of restricting global warming to 2°C if a limit is set on the total amount of CO_2 emitted globally between now and 2050 (CO_2 global budget). WBGU is moving this global budget to the forefront of its considerations in creating a new global climate treaty, which is due to be negotiated at COP 15 of the UN Framework Convention on Climate Change (UNFCCC) in Copenhagen. Combined with fundamental concepts of equity the WBGU budget approach provides concrete figures for each of the emission limitations, which all countries will have to accept in order to prevent the destabilization of the planet's climate system.

The Kyoto Protocol only made provision for emissions reduction targets for a minority of countries in a rather arbitrary manner. The proposals made public by various countries and groups of countries in the run-up to the Copenhagen summit are not essentially more ambitious than their forerunners and hardly likely to bring about compliance with the 2°C guard rail. In future, however, not only the industrialised countries, but also the newly industrializing and developing countries will have to clearly limit the amount of greenhouse gases they emit, in order to prevent dangerous climate change. It is also becoming increasingly obvious that the explicit negotiating of individual emissions reduction commitments for a very large number of countries is highly likely to overburden the current mode of negotiation within the UNFCCC. The budget approach advocated by the WBGU will enable not only the reduction targets of the industrialised countries up to 2020 to be based upon a systematic foundation, but also the increasing decarbonization commitments that will have to be achieved by the newly industrializing and developing countries. This can lead to the growth of common understanding among all signatory states concerning the medium- and long-term actions necessary in order to implement the UNFCCC. The climate policy solution proposed by WBGU also has other merits: it creates a considerable degree of inter-temporal and interregional flexibility. The solution makes it possible to dispose largely without restrictions over national greenhouse gas budgets during the long budget time period, based on a small number of rules that ensure compliance with the national and global decarbonization targets up to the middle of the 21st century. The intensive trading of emission allowances between all countries should be explicitly possible. This flexibility and the taking into account of historical responsibilities give rise to various ways of financing mitigation and adaptation measures and promoting the transfer of technology between the industrialised and the developing countries.

The budget approach proposed by WBGU can provide new impetus and orientation for negotiations at the climate change summit in Copenhagen. Furthermore, based on the budget approach, WBGU's special report outlines framework conditions for a climate-friendly world economy of the future and describes institutional requirements. WBGU also points out that the urgently needed breakthrough in international climate policymaking cannot succeed without the strong leadership commitment of several key countries.

Urgent need to act from a scientific point of view

New research findings illustrate that the physical leeway for the protection of the Earth's climate has become very narrow. It is urgently necessary to take stock at both global and national levels.

- Several of the impacts of climate change are taking place far more rapidly than previously expected, particularly the global sea-level rise.

- The budget of CO_2 emissions still available worldwide could be derived from the 2°C guard rail. By the middle of the 21st century a maximum of approximately 750 Gt CO_2 (billion metric tons) may be released into the Earth's atmosphere if the guard rail is to be adhered to with a probability of 67%. If we raise the probability to 75%, the cumulative emissions within this period would even have to remain below 600 Gt CO_2. In any case, only a small amount of CO_2 may be emitted worldwide after 2050. Thus, the era of an economy driven by fossil fuels will definitely have to come to an end within the first half of this century.
- Prominent milestones must be put in place in order to implement a comprehensive transformation process of this magnitude: it is of paramount importance that the level of global emissions reaches its peak by the year 2020 at the latest because otherwise the reduction of emissions in the subsequent period would have to take place at a speed that would fully overstrain the technical, economical and social capacities of our societies.

The evidence of current research illustrates that the turning point towards sustainability can no longer be postponed. WBGU's analysis explicitly shows that over 100 countries immediately need to introduce a process of transformation that swiftly stabilises emissions levels, then significantly reduces them and finally achieves complete decarbonization of all relevant socio-economic processes by the middle of the 21st century. There are only 65 nations whose emissions paths currently seem to be within the climate-friendly range, and all of them are poor developing countries. This illustrates the extreme time pressure the climate negotiations are currently under and stresses that a radical global transformation process is necessary in order to achieve a low-carbon world economy. The negotiations are currently still in a deadlock because short-term national interests are blocking a prompt and effective global climate protection agreement which would be compatible with the 2°C guard rail.

Compass for the new global climate treaty: the WBGU budget approach

A whole range of greenhouse gases and several other factors are responsible for anthropogenic climate change. CO_2 from anthropogenic sources must, however, play a key role in all considerations regarding climate protection due to the large amounts released and the extensive length of time it is retained in the environment (up to thousands of years). Consequently, the WBGU budget approach concentrates on the predominant fossil-fuel CO_2 emissions. Separate measures are proposed for dealing with the other climate-relevant gases and sectors.

The starting point of the WBGU budget approach is the calculation of the global amount of CO_2 that may be emitted between now and 2050 in accordance with precautionary considerations. This global budget of cumulative CO_2 emissions needs to be equitably distributed among all countries. From an ethical point of view, the best solution is to equally allocate emissions on a per-capita basis, so that national emissions budgets can be calculated according to the size of the population. Thus each country has a precisely defined "atmosphere capital" which it can flexibly manage and trade on international markets between now and the year 2050. A number of variations on the budget approach are possible. In particular there are a small number of parameters via which the national distribution of the global budget can be politically negotiated. These are the time period, the probability of complying with the 2°C guard rail and the size of population. The option favoured by the WBGU takes the historical responsibility of the industrialised countries into account, but above all it looks towards the future: the entire CO_2 budget acceptable within the bounds of the 2°C guard rail for the time between 2010 and 2050 is equally distributed across the various countries of the planet on a per-capita basis, taking 2010 as the demographic year of reference (Fig. 1). Thus the responsibility for future emissions is distributed among the people of all regions and countries of the world. With respect to the "polluter pays" principle, an additional financial compensation between north and south will be aimed for, oriented on the national differences in terms of per-capita emissions in the time period from 1990 to 2010. The main purpose of these transfer payments is to finance adaptation measures and to stop deforestation in developing countries.

In order to guard against the danger of CO_2 mismanagement, in the opinion of WBGU, each country should draw up explicit decarbonization road maps that include internationally measurable and verifiable interim targets. These road maps would not only have to be oriented on the national CO_2 budgets, but also on the actual national emissions reduction potentials. The balance between the emissions paths of the various countries in accordance with their decarbonization road maps and the reference profiles in accordance with their CO_2 budgets is to be achieved by means of international emissions trading between states and by other flexible mechanisms.

The approach developed by the WBGU ties in with the vision of climate justice involving the long-term convergence of per-capita emissions jointly formulated by German Chancellor Angela Merkel and the Indian Prime Minister Manmohan Singh. For the period 2010–2050 the distribution of the global CO_2-budget proposed by WBGU amounts to average yearly emission allowances of around 2,7 t CO_2 per capita of the world population of 2010, which may in part be redistributed among states by making use of the flexible mechanisms. Each country should, however, tend to design its climate protection strategy in such a way that towards the end of the budget time period its real emissions converge with the approximate level of 1 ton of CO_2 per capita per year (Fig. 2).

Due to the currently striking differences between the per-capita emissions of industrialised and developing countries, emissions trading and other flexible mechanisms will bring about considerable financial and technological transfers, which could in turn open up attractive possibilities for sustainability investments for the countries supplying emission allowances. In this respect, the implementation of the WBGU budget approach would decisively promote climate-friendly and sustainable development worldwide. Figure 2 outlines the amount of leeway an international climate partnership using the proposed mechanisms would create and how the emissions profiles of the major groups of countries could then look. Thus the budget approach furnishes an opportunity for a worldwide historical climate compromise.

Within the context of the budget approach, all groups of countries will have to make far-reaching concessions: the industrialised countries will be expected to make extensive emissions reduction commitments as well as comprehensive technological and financial transfers. For their part, the newly industrializing and developing countries will also have to accept the fact that catch-up economic development based on the burning of fossil fuels no longer has a future, so that they also initiate the transition to a low-carbon society as soon as possible. The way, however, will be paved for them by means of considerable transfer payments, which means they can cost-effectively avoid the lock-in on fossil fuel pathways. All countries benefit from the fact that they avoid a no longer manageable climate change with all of its accompanying disastrous consequences and costs.

WBGU highlights how international climate protection can be combined with a global development partnership between "high-emission" and "low-emission" countries. It also becomes increasingly obvious that India could become a key player in a global climate treaty in the spirit of the WBGU budget approach. Due to its relatively low per-capita emission levels despite its high rate of economic growth, India can develop a somewhat slower transformation process towards a low-carbon economy than China, for instance. China would have to develop and implement an ambitious decarbonization strategy due to its currently higher per-capita emission rate. It should be in the interest of the industrialised countries to support China by means of cooperation in a spirit of partnership so that China does not become one of the main buyers of emission allowances.

The recommendations in detail

The WBGU budget approach is designed to serve as a compass and a framework of orientation for international climate protection policy-makers in the medium and long term. Based on its analyses, WBGU concludes that parties to the UNFCCC will have to agree on the following general principles in Copenhagen:

- The *2°C guard rail* is adopted as legally binding in international law.
- For carbon dioxide – the greenhouse gas crucial to climate protection efforts in the long term – a *global emissions budget* for fossil sources up to the year 2050 that is compatible with the 2°C guard rail is adopted on a legally binding basis.
- The following *milestones* are stipulated: (1) The peak year of worldwide CO_2 emissions is to be reached between 2015 and 2020; (2) Global emissions by mid-century are to be reduced to a level consistent with the narrow emissions budget remaining post-2050.
- The global CO_2 budget is distributed among the world's population on an equal per-capita basis so that *national CO_2 budgets* can be calculated for all countries, and adopted on a legally binding basis. These budgets provide orientation for countries on how swiftly and substantially their CO_2 emissions need to be reduced.
- Each country is committed to producing internationally and objectively verifiable *decarbonization road maps*, which provide information on the planned national emissions path up to the year 2050. These road maps should be based on the national CO_2 budgets as well as on the national emissions reduction potential.
- In addition, for the countries with presently high per-capita emissions, *reduction commitments up to 2020* are agreed in order to avoid delaying decarbonization efforts.
- *Flexible mechanisms* (international emissions trading and Joint Implementation) as well as appropriate additional financial and technological transfers by the industrialized countries are agreed upon.
- A decision is taken to establish a *world climate bank,* which will be responsible (1) for scrutinizing the national decarbonization road maps as to their plausibility and feasibility, and (2) for enabling the flexible mechanisms and transfers.

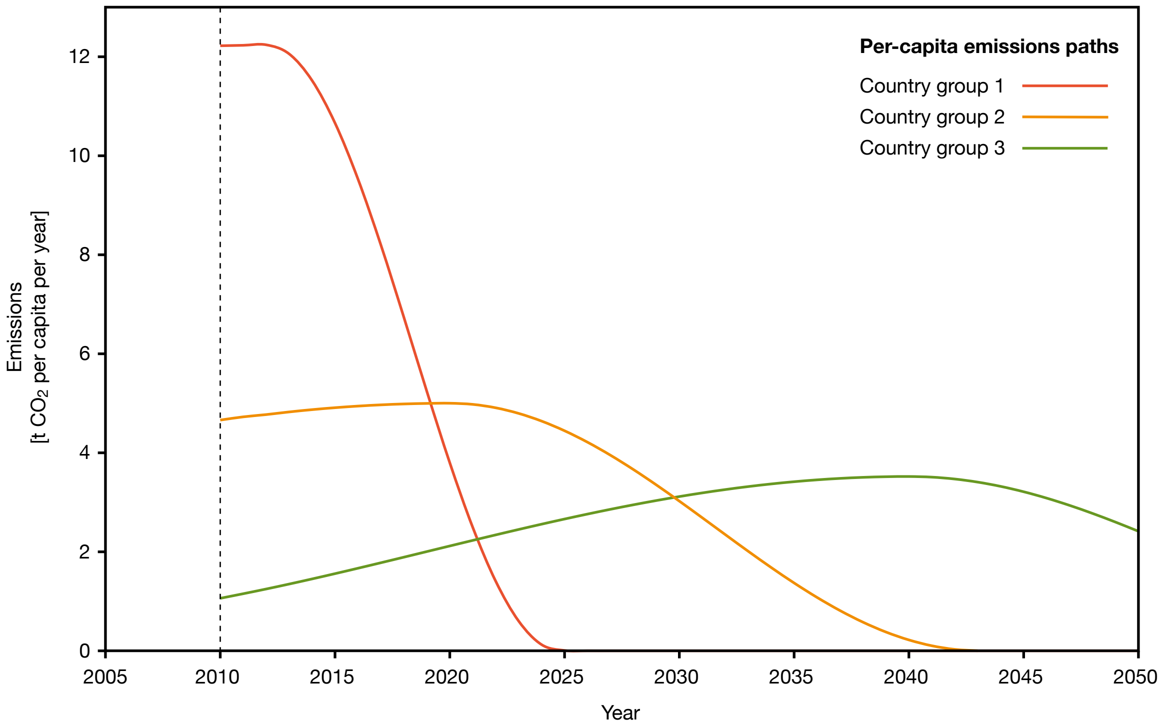

Figure 1
Examples of per-capita emissions paths of CO_2 for three groups of countries according to the WBGU budget approach without emissions trading. Although they allow compliance with national budgets, they would only be partly practicable in reality. The countries are grouped according to their annual CO_2 emissions per capita from fossil sources, whereby the CO_2 emissions are estimates for 2008 and the population figures are estimates for 2010. *Red:* Country group 1 (>5.4 t CO_2 per capita per year), mainly industrialised countries, (e.g. EU, USA, Japan) but also oil-exporting countries (e.g. Saudi-Arabia, Kuwait, Venezuela) and some newly industrializing countries (e.g. South Africa, Malaysia). *Orange:* Country group 2 (2.7–5.4 t CO_2 per capita per year), which includes many newly industrializing countries (e.g. China, Mexico, Thailand). *Green:* Country group 3 (<2.7 t CO_2 per capita per year), mainly developing countries (e.g. Burkina Faso, Vietnam) but also large newly industrializing countries (e.g. India, Brazil).
Source: WBGU

- The *separate regulation of CO_2 from non-fossil sources, other relevant greenhouse gases and further radiative forcing substances* creates opportunities for swift reductions in total emissions harmful to the climate. The following agreements are made in order to achieve these objectives: (1) In order to avoid CO_2 emissions resulting from deforestation and land-use changes and to conserve terrestrial carbon stocks, a separate legally binding regime is agreed upon in which swift and effective measures taken in developing countries have absolute priority. (2) The fluorinated greenhouse gases (industrial gases) currently covered by the Kyoto Protocol are dealt with in a special agreement modelled on the Montreal Protocol. (3) The other persistent greenhouse gases dealt with in the Kyoto Protocol are included in the budget calculation. (4) For non-persistent radiative forcing substances not covered by the Kyoto Protocol at present (including soot particles and ozone-forming gases), special reduction commitments are agreed upon within the framework of national air pollution control measures in order to achieve an effect as quickly as possible.

This package of measures implies a clear and long-term oriented course of action, incentives and institutional framework conditions designed to foster a low-carbon world economy. International competition for the most innovative decarbonization strategy could then begin.

The stocktaking of climate research and climate policy carried out by WBGU shows that the race against time must be won: climate-friendly innovations, investments and institutions in both business and society at national and international levels have to be pushed ahead with at a greater pace in order to avert a no longer manageable level of global warming with all its implications. Above all, the changes necessary in the global society must take place by decoupling economic growth from the burning of fossil fuels – including the newly industrializing and developing countries. The imminent transformation of the modern global industrial society towards a low-carbon society is an unprecedented histori-

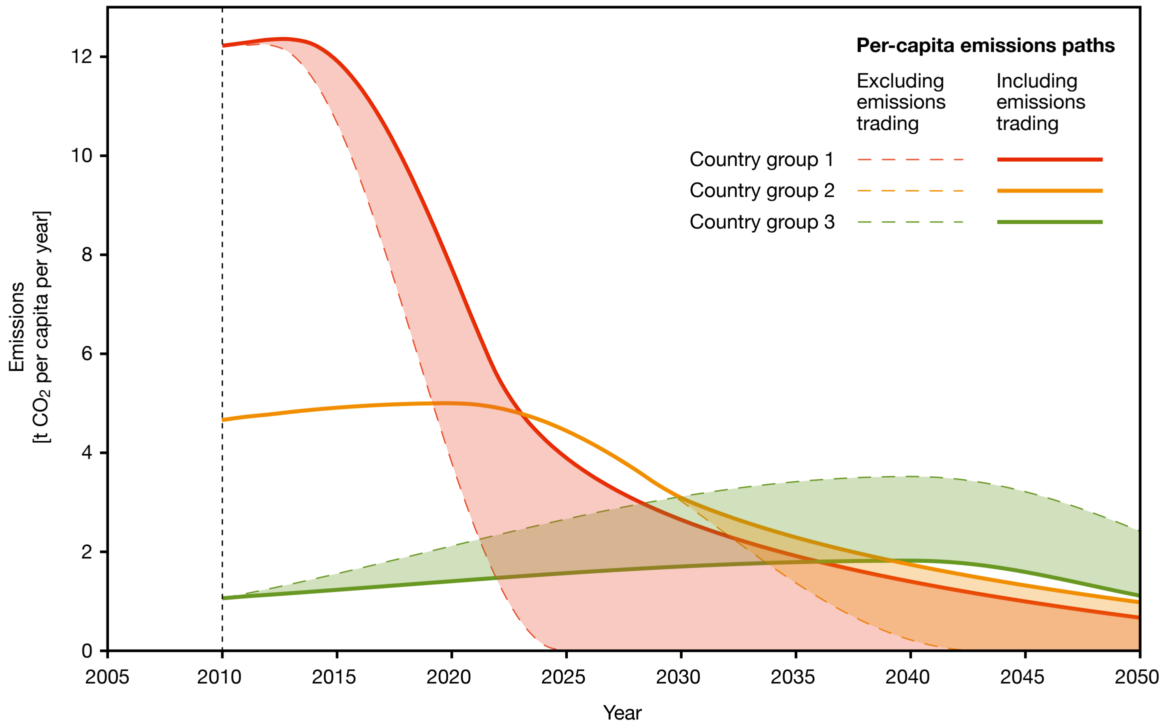

Figure 2
Examples of per-capita emissions paths of CO_2 from fossil sources for three groups of countries according to the WBGU budget approach, which could emerge through emissions trading (*unbroken curves*). Here it is assumed that the countries of group 1 will raise their budgets by 75% by purchasing emission rights for 122 Gt CO_2. The countries in group 2 purchase additional emission rights for a total amount of 41 Gt CO_2. The countries of group 3 become sellers of a total of 163 Gt CO_2 and, accordingly, their budget sinks by approximately 43%. Towards the end of the budget time period there is a convergence of the actual CO_2 emissions at approximately 1 t CO_2 per capita per year (relating to the population in 2010). The *broken curves* show the theoretical per-capita emissions paths for CO_2 without emissions trading from fig. 1. The areas between the curves illustrate the traded amount of emission allowances. Due to the fact that the illustration shows the per-capita situation and the country groups have varying sizes of population, the areas between the purchasing country groups 1 and 2 do not coincide with the area of the selling country group 3.
Source: WBGU

cal challenge – technologically, economically and socially. Courageous political action is now called for – either that or an honest declaration of surrender in the face of the size of the climate challenge and the years lost in the cause of climate protection since the Earth Summit in Rio de Janeiro of 1992.

Introduction 1

At their meeting in the Italian city of L'Aquila in July 2009, the heads of state and government of the G8 countries and the Major Economies Forum on Energy and Climate (MEF), whose members include India, Brazil and China, acknowledged the importance of ensuring that global warming does not exceed the 2°C guard rail if dangerous climate change is to be avoided. WBGU views this as an extremely important step towards the adoption of a binding international agreement which establishes a well-founded target for global climate protection. The task now is to build on this consensus and reach agreement, at Copenhagen, on a follow-up treaty to the Kyoto Protocol, which is due to expire in 2012. This new international agreement should translate the relevant scientific knowledge into a fair and practicable global strategy to combat global warming. So far, however, the lack of unanimity between the countries involved in the negotiating process has meant that there is no clear leitmotif pointing the way towards such an agreement.

Even now, there is discord between the industrialized countries and the emerging economies, the affluent and the aspiring, as well as present and future generations. Governments still appear to be fixated on the task of supposedly establishing, maintaining or restoring their national economic competitiveness rather than on preserving the natural life-support systems which are the basic prerequisite for any form of economic activity. The situation is reminiscent of the nuclear arms race which ended just 20 years ago, when the apparently compelling logic of 'mutually assured destruction' (MAD) brought our civilization to the brink of the abyss more than once. The climate issue is without doubt a different type of problem, for every country is both the cause and the victim of climate change, albeit to widely varying extents. Nonetheless, the threats to our societies are just as overwhelming and the mutual distrust which prevails today is still as paralysing as the doctrine of MAD in the past.

The 'social dilemma' concept in game theory aptly describes the current situation, for individual and collective rationality are tragically at odds here. In a social dilemma, players attach more weight to their short-term individual interests than to the long-term mutual benefits of a cooperative solution – thereby ultimately harming everyone, including themselves. With many countries currently inclined to scale down their own climate change mitigation efforts to the bare minimum due to a short-sighted focus on competitiveness, the international community could well find itself locked into a non-sustainable course for centuries to come.

In order to break through this climate policy dilemma, two important preconditions must be in place. Firstly, there must be an equitable, convincing and comprehensive strategy which is acceptable to the large majority of nations. Secondly, there must be respected pioneers who are confident in their own abilities and in the prospect of concerted action and who are therefore prepared to take the initiative and undertake substantial risks in order to push the negotiations ahead. Fortunately, given the nature of the climate problem, both these conditions are in place.

The crucial climate policy debate about swift measures to reduce carbon dioxide emissions und the phasing out of these emissions in the long term must be conducted in light of the 2°C guard rail. Although other greenhouse gases (GHGs) (such as methane and nitrous oxide) have far greater warming potential per unit gas, it is anthropogenic carbon dioxide (CO_2) which, due to the sheer quantity and immense longevity in the atmosphere, is the key factor in climate policy deliberations. Current research findings show that the scale of human-induced climate change largely depends on accumulated CO_2 emissions – in other words, the total amount of carbon dioxide emitted from anthropogenic sources. This is a useful fact, not only in terms of greatly simplifying the situation in the climate negotiations but also because it facilitates the strategic application of basic ethical and operational principles.

A number of countries or groups of countries – not least Germany and the EU – have demonstrated convincingly that as pioneers in the field of climate change mitigation, they not only want to take on a lead role and responsibility in the international community's mitigation efforts but are also well-placed to do so due to their strong technological and economic capacities. There are many signs that the USA, a country with great capacity for innovation, is also about to take on a lead role in the climate arena. China, long a sleeping giant when it came to environmental protection, has already awoken. The second Nobel Laureate Symposium on Global Sustainability, which took place in London in May 2009, urges these countries in particular to show leadership in the battle against global warming and formulates a categorical imperative for climate policy cooperation: 'In this spirit of trust, every country must act on the firm assumption that all others will also act' (St. James's Palace Nobel Laureate Symposium, 2009).

Starting from this basic premise and building on its previous scientific, strategic and ethical analyses on this topic (WBGU, 1995; 1998; 1999; 2000; 2003; 2004; 2008; 2009), WBGU presents, in this special report, an integrative solution to international climate policy. Its approach ties in with the vision set out by German Chancellor Angela Merkel and Indian Prime Minister Dr Manmohan Singh of the convergence of per-capita emission rights for all humans as the basis for international agreements on the protection of the global climate (Bundesregierung, 2007). WBGU's strategy is derived from a small number of core principles and sums up the key policy options in simple parameters. It thus creates transparency in a field which has become so complex that it is now only understood by a handful of experts.

The new WBGU budget approach includes a process for the distribution of a globally permissible quantity of emissions among the individual countries. The approach offers a frame of reference for the forthcoming climate negotiations and builds a bridge towards a low-carbon society. WBGU's analysis shows that very ambitious reduction commitments must be agreed very swiftly with a view to largely decoupling global economic growth from CO_2 emissions in the coming decades – in other words, the accelerated transformation of the majority of countries towards sustainability. The WBGU budget approach charts a course towards a historic climate compromise which greatly reduces the complexity of the negotiations,

- puts the individual countries' commitments and financial transfers between developed and developing countries on a clear and comprehensible footing,
- via national CO_2 emissions budgets, establishes the basis for future international emissions trading and for appropriate inter-country partnerships (technology, adaptation, etc.), and
- through national and global reduction of greenhouse gas emissions, sets a clear and sustainable course towards a climate-compatible economy.

With this climate policy framework in place, the competition to develop the best, fastest and most beneficial climate innovations can begin. The window of opportunity for setting this vital new course is narrow, however. Countries will need to adopt ambitious decarbonization road maps, and the requisite political, economic and social reforms must begin without delay.

These efforts to cut the 'Gordian Knot of climate policy' must succeed, for the world has already travelled a considerable distance towards climate destabilization. But there is no alternative: a more 'convenient truth' simply does not exist.

Limiting global warming to 2°C 2

2.1 Climate change due to greenhouse gases

In the 19th century, the works of Fourier, Tyndall and Arrhenius shed light on the influence of greenhouse gases on the global climate. Scientifically it is now beyond doubt that in accordance with the laws of physics, an increase in the concentration of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere must lead to a global rise in temperature (Box 2.1-1). In addition, data gathered since the late 1950s confirm that the atmospheric CO_2 concentration is indeed rising as a result of anthropogenic emissions. Since the pre-industrial era it has risen from 280 ppm (a ratio of 280 parts of the atmosphere per million) to 384 ppm (CDIAC, 2009) – by far the highest concentration for at least 800,000 years.

Natural causes may also exert additional and significant influences on the climate, but make no difference to the radiative forcing effect of anthropogenic CO_2 emissions. In the past 50 years, natural causes have had a slight cooling effect on the climate, mainly because the brightness of the sun has declined and, in recent years, reached its lowest level since satellite readings began in the 1970s (Lockwood and Fröhlich, 2007, 2008).

Since 1880 the globe has warmed by 0.8°C. Further warming will mainly be determined by future anthropogenic emissions, which can be estimated in approximate terms from scenarios of how global society might develop. If it takes a high-emission path, warming by 2100 will be 3–7°C from the pre-industrial level, as against 2–3°C for a low-emission path (IPCC, 2007a). Only ambitious action to mitigate climate change can keep emissions below

Box 2.1-1

Radiative forcing and climate sensitivity

The factor that determines mean global temperature is our planet's heat balance and hence radiative forcing, measured in watts per square metre of the Earth's surface (W per m^2). This is quite analogous to the temperature in a house, which is determined by the output of the heating system (in watts) and the heat losses that leak outside the house.

So far human activities have increased Earth's radiative forcing by 1.6 W per m^2. The rise in concentration of CO_2 accounts for +1.7 W per m^2 of this, other greenhouse gases a further +1.3 W per m^2, while cooling effects, mainly from air pollution with sulphur particles, reduce it by -1.4 W per m^2. As well as cooling particles, the atmosphere also contains warming soot particles (Box 5.7-3). Nevertheless, all particles on aggregate contribute to a net cooling. Therefore this effect currently masks almost half of the 'programmed' global warming caused by greenhouse gases. However, the cooling substances are short-lived whereas greenhouse gases are very long-lived.

Radiative forcing can be converted into a global temperature change using a simple conversion factor, climate sensitivity (a measure of the climate's sensitivity to perturbations). Climate sensitivity can be calculated with the aid of climate models from the feedback loops in the climate system, or it can be determined using data from the planetary past. Various natural climatic changes in the Earth's history show how sensitively the system has reacted to previous perturbations. The best estimate of climate sensitivity amounts to 0.8°C per W per m^2. This equates to warming of 3°C with a doubling of the atmospheric CO_2 concentration, since the latter implies radiative forcing of 3.7 W per m^2.

In the long term, radiative forcing at the current level of 1.6 W per m^2 will thus produce 1.3°C of warming. However, this calculated level of warming is not immediately noticeable because the thermal inertia of the oceans delays the full effect by several decades. That is why warming of only 0.8°C has been observed so far. Natural drivers of climate change, such as fluctuations in solar activity, have been too minor over the last century to play a meaningful role. The remaining (approx.) 0.5°C of warming will still occur even if radiative forcing is held at a constant level from now on.

Without the cooling effect of particulate air pollution, the current radiative forcing of 3.0 W pro m^2 from existing atmospheric greenhouse gases would already be causing 2.4°C of warming. So without this 'cooling screen', today's levels of greenhouse gases would be high enough to push global warming over the 2°C threshold. Hence, in the event of a rapid reduction in air pollution, it would be essential to step up the pace of greenhouse gas emissions reduction accordingly.

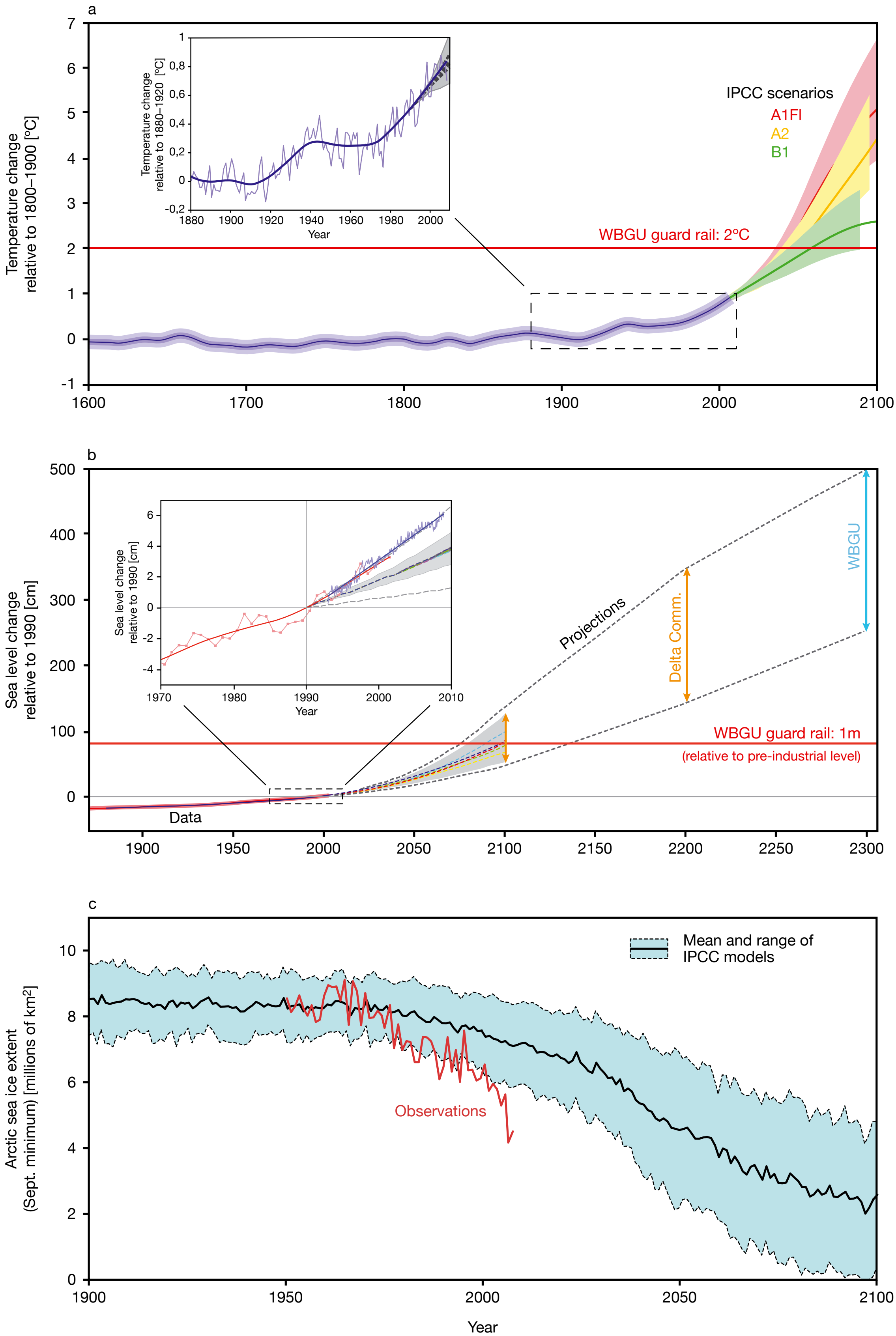
a
Temperature change relative to 1800–1900 [°C]
Temperature change relative to 1880–1920 [°C]
Year
IPCC scenarios
A1FI
A2
B1
WBGU guard rail: 2°C
b
Sea level change relative to 1990 [cm]
Year
Projections
Delta Comm.
WBGU
WBGU guard rail: 1m
(relative to pre-industrial level)
Data
c
Arctic sea ice extent (Sept. minimum) [millions of km²]
Mean and range of IPCC models
Observations
Year

Figure 2.2-1
Development over time of temperature, sea level and Arctic sea ice extent.
a) Three different emission scenarios are shown (B1, A2 and A1FI); the coloured areas are the associated climatological uncertainty spans. Without successful action to mitigate climate change, the 2°C guard rail will be crossed even under the most optimistic emission scenario (B1). Inset: Comparison of observed temperatures up to 2008 (NASA, 2009) with the projections of the IPCC Third Assessment Report (IPCC, 2001) (grey area and dashed lines). The data give annual values for global temperature (relative to 1880–1920, in contrast to the main graph) and a smoothed climate trend line.
Source: modified after Rahmstorf et al., 2007
b) Recent projections of global sea-level rise up to 2300 (relative to 1990). The WBGU guard rail of 1m above the pre-industrial level is also shown (WBGU, 2006). As the sea level rose by around 15 cm between the onset of industrialization and 1990, the line is entered here at less than 1m. Inset: (1) observed data ('data': sea-level data after Church and White, 2006; satellite data up to 2008, updated after Cazenave et al., 2008). (2) Projections of the IPCC Third Assessment Report (IPCC, 2001); Rahmstorf (2007), grey area and dashed lines); yellow bar after Delta Committee (2008); light blue bar after WBGU (2006). The differing assumptions underlying these projections are explained in the sources cited.
Source: updated after Rahmstorf et al., 2007
c) Extent of Arctic sea ice at the summer minimum (September) from observations and according to IPCC models.
Source: modified after Stroeve et al., 2007

the spectrum of these scenarios, i.e. reduce them enough to ensure that warming does not cross the 2°C guard rail.

2.2 Climate impacts on nature

Even given the moderate 0.8°C of global warming measured to date, the impacts can already be felt in every part of the world (Fig. 2.2-1a). For example, the summer extent of the ice mass in the Arctic Ocean has already shrunk by about half since the 1970s (Fig. 22-1c, 2.2-2; Stroeve et al., 2007). Since the ice is also thinning dramatically at the same time, the volume of ice declines even more rapidly (Kwok et al., 2009). If warming should escalate unabated to 4°C or more, it would fundamentally change the Earth system along with all its ecological resources and services. Global temperature differences on such a scale would roughly correspond to the difference between temperatures at the peak of the last Ice Age 20,000 years ago and temperatures today. Global warming has the following concrete consequences:

- The *sea level rises* due to the thermal expansion of sea water and the influx of meltwater into the oceans (Fig. 2.2-1b; Domingues et al., 2008); and the warmer it becomes, the faster the sea level rises (Rahmstorf, 2007). Since 1880, the global sea level has risen by around 20 cm. It could, however, rise by 50–150 cm by 2100 (Rahmstorf, 2007), 1.5–3.5 m by 2200 (Delta Committee, 2008) and 2.5–5.1 m by 2300 (WBGU, 2006).
- Already, an increase in *extreme weather events,* such as heatwaves, droughts, extreme rainfall events, floods and tropical storms, has been observed in many regions (IPCC, 2007a). A further rise of extreme weather events in the wake of additional warming is deemed probable to very probable, depending on the type of event.
- Global warming in excess of 2°C threatens to accelerate the *loss of genetic, species and ecosystem diversity*, since many regions of the world will very rapidly enter climatic conditions not experienced for several million years. According to the IPCC (2007b), this would place such an intolerable strain on nature's adaptive and regenerative capacity as to risk the irreversible loss of 20–30% of animal and plant species and associated genetic resources. Ecosystems such as mangrove forests, coral reefs and possibly the Amazon rainforest would suffer irreversible damage or destruction. Biodiversity loss would entail loss of ecosystem resources and services – e.g. protection from storm surges and coastal erosion, the availability of clean drinking water and genetic resources (MA, 2005) – which are also crucial functions for society's efforts to adapt to climate change.
- Today's anthropogenic CO_2 emissions are already causing measurable *acidification of the oceans*. Until now, the oceans have taken up around one-third of anthropogenic CO_2 from the air. This combines with seawater to form carbonic acid. As a result, the concentration of hydrogen ions has already risen by approx. 30%, which equates to a drop of about 0.11 pH-units from the pre-industrial level (WBGU, 2006). If this trend were to continue without restraint, it would lead to a degree of ocean acidification that is without precedent in several million years. Acidification disrupts the growth of calcifying organisms (e.g. corals, shellfish, molluscs and certain plankton groups), causes biodiversity loss, can produce anoxic 'dead zones' in the oceans (Hoffmann and Schellnhuber, 2009) and, overall, poses an existential threat to marine ecosystems (e.g. coral reefs; Hoegh-Guldberg et al., 2009).
- A series of *tipping elements* have been identified within the climate system. Triggering these tipping elements may lead to catastrophic ecological consequences (Fig. 2.2-3; Lenton et al., 2008). Among

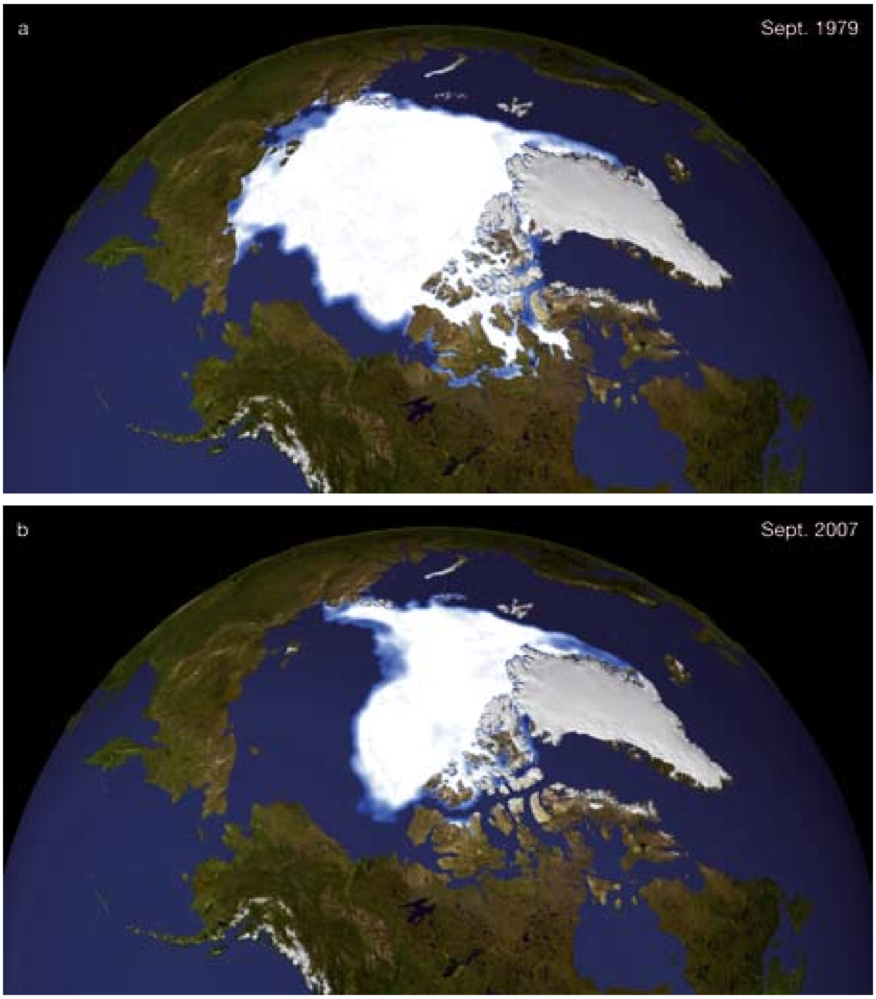

Figure 2.2-2
Satellite images of Arctic ice cover
a) September 1979;
b) September 2007.
Source: NASA/Goddard Space Flight Center Scientific Visualization Studio, 2009

the most significant risks are the abrupt cessation of ocean currents, dieback of the Amazon rainforest, unpredictable shifts in the monsoon system or irreversible destabilization of large ice masses. One example is the Greenland ice sheet: if it melted completely, it would cause a global sea-level rise of 7 m. Even global warming of more than 1.9°C for a prolonged period of time may be sufficient to trigger melting of the entire ice sheet (IPCC, 2007d).

2.3
Climate impacts on societies

Climate change has the potential to trigger major social and economic crises. Poor populations are especially at risk but wealthy nations also face considerable dangers. The scientific community has increasingly come to the conclusion that the consequences of a temperature rise of 2°C above the pre-industrial level can only just be managed. The most recent evidence for this consensus is the synthesis report of the Scientific Conference on Climate Change held in March 2009 in Copenhagen: 'Temperature rises above 2°C will be difficult for contemporary societies to cope with, and are likely to cause major societal and environmental disruptions through the rest of the century and beyond.' (Richardson et al., 2009).

If climate change continues unabated, the following impacts must be anticipated:

- *Water supply* – for households, health systems, agriculture and industry (cooling water, hydropower stations) – will be jeopardized by weather extremes, altered precipitation patterns and glacial retreat. For example, the Peruvian coastal region including the city of Lima with its millions of inhabitants is dependent on glacier meltwater for 80% of its water supply (WBGU, 2008).
- *Food production* is expected to decline worldwide if warming of 2–4°C occurs. This has the potential to trigger regional food crises and undermine the economic productivity of affected states. In China even a 2°C rise in global temperature threatens to

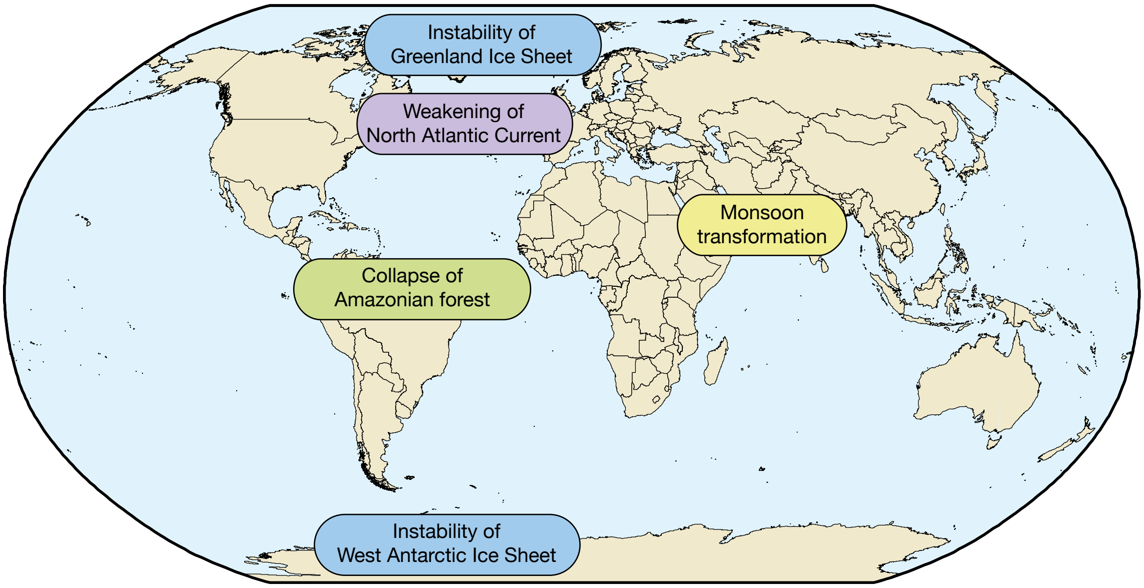

Figure 2.2-3
Selected tipping elements within the climate system.
Source: WBGU, 2008

cause a 5–12% decline in the rice yield from rainfed agriculture (IPCC, 2007b).

- Warming intensifies *health risks* through the possible spread of infectious diseases (malaria, diarrhoea) and occurrence of circulatory disorders (heatwaves). Risks of injury as a consequence of extreme weather events increase. Without adaptation measures, even a 40 cm rise in sea levels would dramatically increase the storm surge risks for over a hundred million people (IPCC, 2007b). In 2000, climate change was responsible for around 150,000 fatalities (WHO, 2008); the Global Humanitarian Forum (2009) puts the figure for annual climate-related fatalities higher still, at over 300,000.
- As a result of increasing drought and soil degradation, as well as losses of islands or coastal regions to rising seas, the prospect of a substantial increase in *environmental migration* is also a concern (Warner et al., 2009).
- The *economic potential* of many countries – especially in the agriculture, forestry and fisheries sector – is adversely affected by climate change, both directly and indirectly. Likewise, global warming accelerates the loss of biodiversity and corresponding ecosystem services, which gives rise to substantial economic costs worldwide and thus creates new poverty (Sukhdev, 2008). In addition – in coastal areas especially – cities and vital infrastructure are threatened by sea-level rise and weather extremes. Unrestrained climate change thus results in a massive global welfare loss: for a 4°C temperature rise, this loss could account for up to 20% (Stern, 2006) of global gross domestic product under the most pessimistic assessment.
- Climate change is increasingly becoming a *security risk* because in almost all regions it undermines the natural life-support systems on which people depend. It heightens the scarcity of water and food resources and, via sea-level rise, poses a threat to the inhabitants of coasts worldwide. The consequences of unabated climate change would overstretch many countries' adaptive capacity, contribute to political destabilization, trigger migration and turn more and more countries into 'fragile states'. As warming progresses, it is likely to intensify national and international conflicts over scarce resources and over responsibility and liability for the damaging impacts of climate change around the world. Large-scale 'accidents' in the Earth System (tipping elements; Fig. 2.2-3) may trigger systemic crises in societies and regions (WBGU, 2008). These may result in the emergence of new and unpredictable tensions and conflicts in global politics, which jeopardize international stability and security (CNA Corporation, 2007; WBGU, 2008).

2.4
The 2°C guard rail

WBGU already proposed in 1995 that global warming should be limited to a maximum of 2°C from the pre-industrial level in order to prevent dangerous anthropogenic interference with the climate system

(WBGU, 1995, 2006, 2008). However, even warming of 2°C cannot be regarded as 'safe', but already has serious consequences – such as sea-level rise that is likely to render some island states and densely populated coastal regions uninhabitable (Sections 2.2 and 2.3). By now, the importance of limiting global warming to 2°C or less has now been acknowledged by 133 states representing 80% of the world population and 75% of global emissions. They include the G8 countries and major emerging economies such as Brazil, India and China. Many of these countries have made the 2°C guard rail an official goal of their climate policy. Scientists broadly support this climate protection guard rail (Schellnhuber et al., 2006; Richardson et al., 2009). For growing numbers of studies indicate that in a world that has overshot the 2°C limit, our civilization which has developed in the stable climatic conditions of the Holocene would face unprecedented challenges.

The need for action: Scale and urgency 3

Unlike the current global economic crisis, the climate impact of our present CO_2 emissions will persist for a very long time. Even if fossil CO_2 emissions are reduced to zero, the concentration of atmospheric CO_2 will only decrease very slowly. Around half the quantity of CO_2 remaining in the atmosphere in the first few years after emission – i.e. amounts not immediately absorbed by the oceans or the terrestrial biosphere – will persist there for 1000 years. For that reason, even in a zero emission scenario, temperatures will only drop by a few tenths of a degree over the course of many centuries (Solomon et al., 2009).

Atmospheric warming can therefore be curbed if CO_2 emissions cease. However, once the CO_2 has reached the atmosphere, warming cannot be reversed with currently available methods. Some of the major effects of atmospheric warming are also irreversible: these include sea-level rise, which will continue for centuries even if global warming is successfully halted, and species and ecosystem loss. Due to this irreversibility, climate policy must be forward-thinking and -acting, and success is imperative, for there will be no second chance!

In estimating the level of emissions reductions necessary for compliance with the 2°C guard rail, various factors must be considered: these include the emitted quantity of CO_2, but also emissions of other greenhouse gases, the cooling effect of air pollution (especially sulphur particles), the warming effect of soot particles, the inertia of the climate system, and all the other uncertainties which make a probability analysis a necessity.

Recent studies show, however, that this complexity can be substantially reduced (Meinshausen et al., 2009; Allen et al., 2009). Due to the great longevity of CO_2 in the atmosphere, this particular substance will become increasingly dominant in the long term compared to short-lived greenhouse gases and aerosols. For that reason, the trend of atmospheric warming over the course of the century will mainly depend on how much more CO_2 is emitted in total. Specifically, cumulative CO_2 emissions to 2050 will largely determine the extent to which global temperature rise can be kept within the 2°C guard rail. In order to achieve this with a probability of 67 %, CO_2 emissions to mid-century must be capped at around 750 Gt, with only a small residual amount being emitted post-2050. At current emissions rates, however, this CO_2 budget will be exhausted within around 25 years – and even sooner if emissions continue to rise.

The reversal of the emissions trend must therefore start as soon as possible – for in view of the very limited CO_2 budget, any delay will result in almost unachievable reduction requirements. With a reversal of the trend (and the emissions peak being crossed) by 2010, global emissions would need to fall to 50–80 % below the 1990 baseline by 2050, with further reductions towards zero emissions being achieved thereafter. Even a slight delay in the reversal of the trend, i.e. postponement of the peak year to 2015, would trigger annual global emissions reduction requirements of up to 5 % (relative to 2008) (Fig. 3.2-1). In other words, the world would then have to meet *annual* emissions reduction targets equivalent to those established by the Kyoto Protocol for a full two decades. Delaying the peak year even further to 2020 could necessitate global emissions reduction rates of up to 9 % per year – i.e. reductions on an almost inconceivable scale, entailing technological feats and social sacrifices on a scale comparable to those of the Allied mobilization during the Second World War. Whatever the details, there is thus no option but to halt the hitherto unabated rise in CO_2 emissions as quickly as possible and then immediately switch to emissions reductions on a global scale. Any further delay is likely to drive up the costs of climate change mitigation and put a question mark over compliance with the 2°C guard rail as a whole.

This analysis makes clear the challenge posed by the given scenario – i.e. an extreme problem situation with rapidly closing windows of opportunity – to democratic systems, in which decisions are generally adopted on the basis of time-consuming consensus. However, unless the international community can agree the required global emissions reductions to 2020 and implement them accordingly during the course of the next four to five years, the German Government subsequently in office from 2013 would

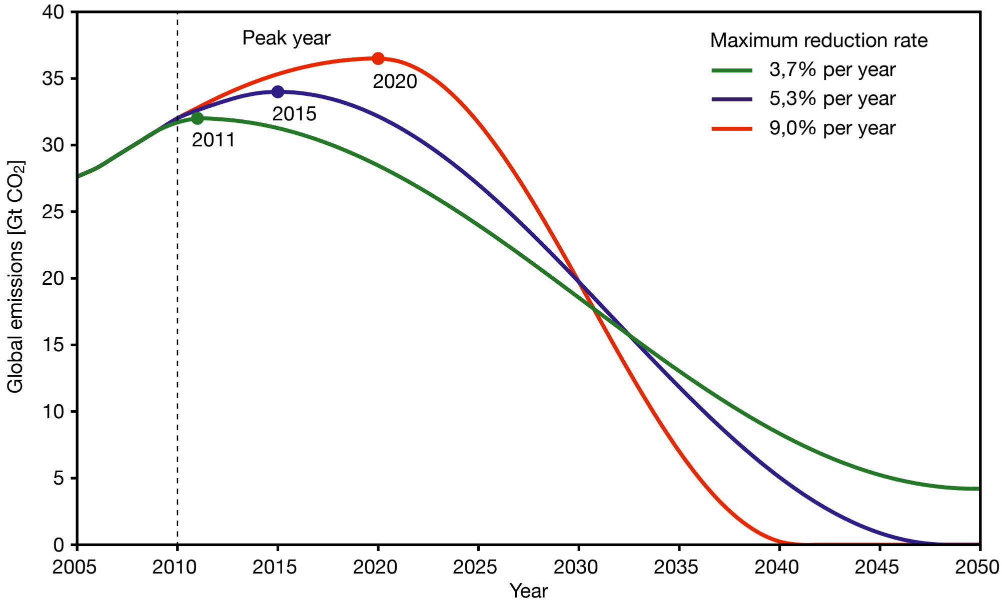

Figure 3.2-1
Examples of global emission pathways for the period 2010–2050 with global CO_2 emissions capped at 750 Gt during this period. At this level, there is a 67% probability of achieving compliance with the 2°C guard rail (Chapter 5). The figure shows variants of a global emissions trend with different peak years: 2011 (green), 2015 (blue) and 2020 (red). In order to achieve compliance with these curves, annual reduction rates of 3.7% (green), 5.3% (blue) or 9.0% (red) would be required in the early 2030s (relative to 2008).
Source: WBGU

be left without any further climate policy leeway. The only issue left open for negotiation would be global reduction rates that are unrealistic in the extreme. However, there appears to be little awareness among the relevant decision-makers in politics and business – and, indeed, among the public at large – of just how little time is actually left to avert dangerous climate change. The immense risks of global warming seem to remain remote and abstract.

In reality, then, just how close are we to the critical stages of climate change? This can be illustrated using the fictitious lifetime of a child born in 2004, who starts school in 2010. Even before this child (we'll call him Paul) moves to secondary school (2014/16), society must have set a course towards climate compatibility, so that in 2049, Paul should be able to celebrate his 45th birthday in a world with 50–80% less emissions. This implies that the economy will have to be transformed from its current fossil basis to a largely climate-neutral mode within a single generation. However, if emissions remain at their current level, humankind will already have emitted so much CO_2 that global warming will already have exceeded the 2°C guard rail by the time Paul is in his mid 20s. It is clear that climate protection is not something that can simply be left for future generations to deal with. Unless we take action now, our own offspring will find that in terms of their quality of life, their options are greatly restricted.

The Gordian Knot of climate policy 4

The international climate policy context is far from unfavourable: the three most powerful players – China, the USA and the EU – are finally taking the climate crisis seriously. At the meeting in L'Aquila in July 2009, all 16 leading economies and the EU (G8 + MEF members), which together are responsible for around 80 % of global greenhouse gas (GHG) emissions, acknowledged for the first time the importance of limiting global warming to below 2 °C.

Yet the current climate negotiations on specific GHG reduction targets bear witness to an arena rife with political discord, in which short-term national interests could obstruct an effective global agreement to avert dangerous climate change. Despite consensus in L'Aquila, there is still a real risk that the UN Climate Change Conference in Copenhagen later this year will produce a weak compromise which cannot prevent dangerous climate change. According to recent analyses, the emissions reduction proposals currently on the table would be virtually certain to result in warming of significantly more than 2 °C (Rogelj et al, 2009).

So far, in their preparations for Copenhagen, the world's countries have clung to their usual long-winded approach, in which complex interests are weighed up in minute detail. The major polluters lay the responsibility at each other's doors: China and other newly-industrializing economies, supported by the Least Developed Countries, point to the high per-capita emissions produced by the industrialized countries and their emissions-based economic growth since the Industrial Revolution. Meanwhile the industrialized countries emphasise that China is now the largest emitter of GHGs and that emissions in the developing regions, especially Asia, will increase substantially in future. Finally, the EU stresses that the USA's per-capita emissions are twice as high as its own. So despite the consensus in L'Aquila, the negotiations appear to have stalled.

This 'Gordian Knot of climate policy' – a knot tied mainly by the USA, the EU, China and the G77 countries – can be described in terms of game theory as a 'social dilemma': rationally justified individual preferences lead collectively to an outcome whereby all players end up worse off in the future and furthermore – in the case of climate change – sustain massive and irreversible damage. Unless the key players rise above the tactics of self-interest at the forthcoming climate negotiations, 'dangerous anthropogenic interference with the climate system' (Article 2 UNFCCC) can no longer be prevented.

A further factor impeding the negotiations is that even an agreement on ambitious and binding greenhouse gas reductions between the industrialized countries and the populous or fast-growing newly-industrializing economies is no longer enough to keep warming below the 2 °C limit. Many developing countries are now achieving extremely dynamic economic growth, accompanied by rising fossil fuel consumption. For that reason, a course must be set on a global basis towards a low-carbon economy.

Around 60 countries currently emit more than 5.4 t CO_2 per capita per year and will need to achieve comprehensive decarbonization by mid-century (Fig. 4-1; WRI-CAIT, 2009). This group includes not only the industrialized countries but also some Arab states, as well as South Africa and Venezuela. Other countries such as Mexico, Thailand and China are already producing per-capita emissions of 3.7 t CO_2 and above, which must be reduced substantially by 2050. China in particular, in view of its strong economic growth, must embark on comprehensive decarbonization without delay. Other fast-growing economies such as Chile, Algeria and Syria should nevertheless keep their current per-capita emissions of 2.7 t CO_2 or more at a constant level in the first instance, and reduce them in future, because of the increasing world population, global CO_2 emissions will have to be cut by around two-thirds by 2050 (against the 1990 baseline). This is equivalent to average annual CO_2 emissions of around 1 t per capita by mid-century. India's emissions today are still close to this level. In total, there are around 30 countries worldwide whose annual emissions are between 2.7 and 5.4 t CO_2 per capita.

A further 95 countries currently emit less than 2.7 t CO_2 per capita per year. Around 65 countries, most of them in sub-Saharan Africa, still produce less

Box 4.1-1

How an apparently positive outcome at Copenhagen could breach the 2°C guard rail

The following scenario shows how an apparently satisfactory and viable policy outcome at Copenhagen could result in the 2°C guard rail being breached. For global emission pathways (and hence the level of temperature rise) are not determined by the agreed reduction targets alone. Arrangements which, on the face of it, seem only to concern points of detail could considerably water down reduction targets and undermine the key task of mitigating climate change.

Let's assume that the majority of industrialized countries commit to greenhouse gas reductions of 30% by 2020 against the 1990 baseline; that the USA commits to reduce its emissions to the 1990 level by 2020; that China announces measures to increase energy efficiency by 5% per year and, together with other newly-industrializing countries, signals its willingness to undertake voluntary climate change mitigation measures; and that the newly-industrializing economies do not undertake any quantitative reduction commitments but pledge to reduce their emissions – instead of continuing along a business-as-usual pathway – with support in the form of financial and technology transfers from the industrialized countries.

Let's also assume that in order to make it easier for the industrialized countries to fulfil their emissions reduction commitments, various detailed arrangements are then agreed which allow these countries to count, as emissions reductions, measures which only go part of the way towards achieving real reductions. Various options are conceivable: for example, unused emission allowances from the first Kyoto commitment period could be offset against future commitments. These would account for at least 4% of the 1990 reference emissions of the industrialized countries (including the USA) (EU Commission, 2009). If these allowances are treated as eligible, a reduction target of 30% against the 1990 baseline can be achieved with a real domestic emissions reduction of just 26%, since 4% of the reduction is being achieved on paper with the unused emission allowances. A further example is land use. Until now, UNFCCC signatory states have been able to selectively offset CO_2 sinks in the land use, land-use change and forestry (LULUCF) sector against their commitments. If this or a similar rule continues to apply, CO_2 sinks could make up as much as 9% of the 1990 reference emissions of the industrialized countries (Annex I countries) (EU Commission, 2009).

A further issue under discussion is the eligibility of allowances granted under an agreement on Reducing Emissions from Deforestation and Degradation in Developing Countries (REDD). If annual emissions from deforestation, currently 5.5–8 Gt CO_2, were limited to half this figure by 2020, this would amount to 15–22% of the industrialized countries' 1990 reference emissions. Similar effects would be achieved through the retention of the Clean Development Mechanism (CDM). If all reduction certificates from the current CDM projects and those planned for the post-2012 period were acquired by industrialized countries, this would correspond to more than 6% of their 1990 reference emissions. Furthermore, it is by no means certain that all the CDM projects are actually reducing emissions in developing countries. There has been much criticism of the fact that projects would have been carried out even in the absence of the CDM and therefore do not fulfil the 'additionality' criterion (Schneider, 2007).

The following impacts on global emissions would then be plausible: even adopting some of the accounting modalities described could result in the industrialized countries – excluding the USA – meeting their agreed reduction targets while only reducing their national emissions by 10–15% in real terms against the 1990 baseline, and the USA's emissions in 2020 could still be 5–10% higher than the 1990 baseline. The newly-industrializing economies could – as desired – demonstrably slow their rate of emissions growth compared with the reference pathway, with the assistance of the agreed financial and technology transfers from the industrialized countries and the latter's option of fulfilling their own reduction commitments abroad (not least through offsetting mechanisms such as the CDM). As a result, China's emissions would 'only' increase by 150–200% from the 1990 level by 2020, rather than by the expected 300% or more (IEA, 2008), and the emissions of the other developing and newly-industrializing countries would only increase by 50–100% instead of by 70–200%.

The outcome of this scenario is that global greenhouse-gas emissions would continue to rise and by 2020, would be 25–50% above the 1990 baseline! As this trend would delay or even obstruct many of the transformation processes required to bring the world's production and consumption patterns into line with climate policy (especially with regard to the phasing-out of fossil fuels, which will entail radical restructuring of energy and transport systems), lock-in effects would undoubtedly ensue: an emissions-intensive infrastructure (including fossil-fuel-based electric generating systems) would be entrenched for decades, making it extremely difficult to achieve the subsequent radical emissions reductions that would be needed to facilitate compliance with the 2°C guard rail. In this by no means unrealistic climate policy scenario, the international community would find itself heading towards global warming of 3°C by the end of the century.

than 1 t CO_2 per capita per year and will therefore be able to increase their emissions in the first instance (Section 5.3).

From the above panorama it is clear that even for the majority of developing countries, persisting with fossil-fuel-driven growth is no longer an option if dangerous climate change is to be averted. Economic and social development must be decoupled from greenhouse gas emissions worldwide.

But any future attempt to accomplish this based on the present model of international climate policy would require all 192 signatories to the UNFCCC to negotiate emissions reduction targets for around 100 countries! The process is at risk of deteriorating into a 'talking shop' in which negotiators haggle over every decimal point and comma at marathon bargaining sessions even as global warming spirals out of control (Box 4-1). Against this background, WBGU is developing the basic structure for a global architecture for climate protection, and showing how compliance with the 2°C guard rail can be achieved. The fundamental concept behind the global climate compro-

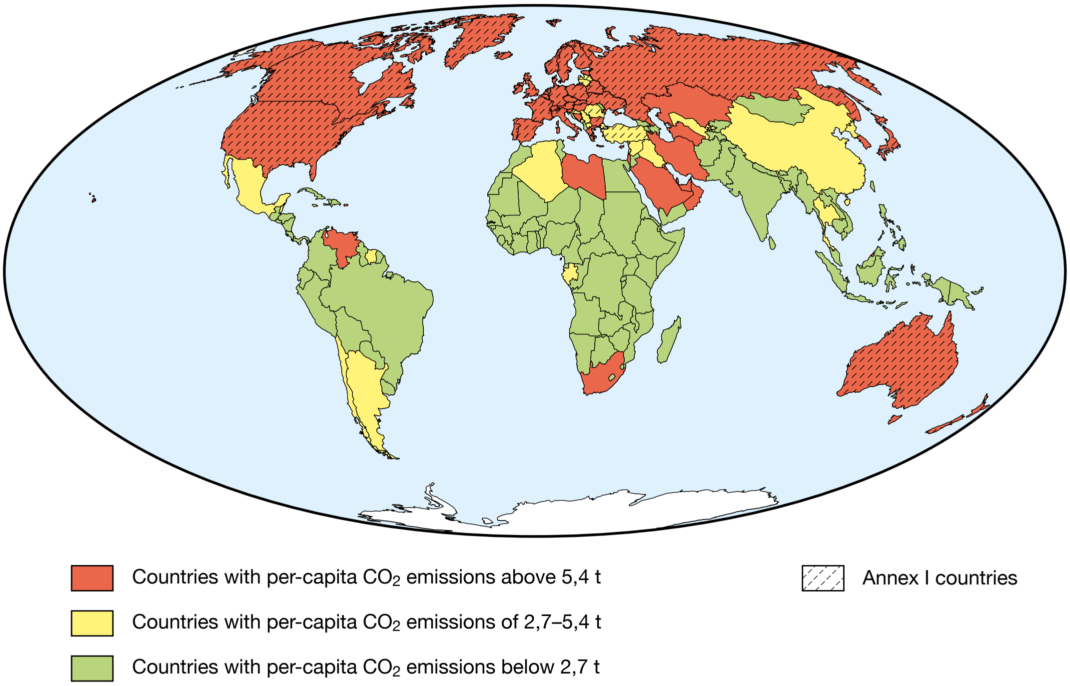

Figure 4.1-1
Per-capita CO_2 emissions in 2005, differentiated by emissions level and country (not including land-use changes).
Source: WBGU, using data from WRI-CAIT, 2009

mise proposed by WBGU is that countries agree on a simple and equitable 'climate formula' as the basis on which all countries can be allocated a precisely determined national emissions budget in future.

WBGU's approach reduces the complexity of the climate negotiations and thus identifies a way forward for Copenhagen which helps countries to move on from their narrow national agendas. It also illustrates how technological and financial transfers between countries with high and low CO_2 emissions can be developed, and creates a global framework for the transition to a low carbon world economy. The strategy also identifies important ways of accelerating the decarbonization of modern societies.

To ensure that a breakthrough is achieved at Copenhagen, courageous pioneers and countries willing to take the initiative have a key role to play. Based on a far-sighted view of the global future, they should demonstrate that they are prepared to take responsibility on behalf of future generations. By adopting brave decisions, Barack Obama, Angela Merkel and other European heads of government, Wen Jiabao and Luiz Inácio Lula da Silva can lead the world towards a cooperative climate-policy pathway. If they fail, the consequences would be of historic magnitude.

5 The WBGU budget approach: Principles, leeway and milestones

For the international climate negotiations, WBGU proposes a new approach that derives national emissions budgets by determining the total ecologically tolerable quantity of global CO_2 emissions up to the year 2050, and apportioning this in line with fundamental principles of equity. The WBGU budget approach can greatly facilitate negotiations at the meeting of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 15) in Copenhagen in December 2009. Based on a simple, transparent and equitable 'climate formula', countries' reduction commitments and the requisite financial transfers between industrialized and developing countries are established on a clear and comprehensible basis.

So that the WBGU budget approach can serve as a compass and framework of orientation for international climate policy in the long term, the countries meeting in Copenhagen should adopt the following decisions to set the process on track:

- The *2°C guard rail* is adopted as legally binding in international law.
- For carbon dioxide – the greenhouse gas crucial to climate protection efforts in the long term – a *global emissions budget* for fossil sources up to the year 2050 that is compatible with the 2°C guard rail is adopted on a legally binding basis.
- The following *milestones* are stipulated: (1) The peak year of worldwide CO_2 emissions is to be reached between 2015 and 2020; (2) Global emissions by mid-century are to be reduced to a level consistent with the narrow emissions budget remaining post-2050.
- The global CO_2 budget is distributed among the world's population on an equal per-capita basis so that *national CO_2 budgets* can be calculated for all countries, and adopted on a legally binding basis. These budgets provide orientation for countries on how swiftly and substantially their CO_2 emissions need to be reduced.
- Each country is committed to producing internationally and objectively verifiable *decarbonization road maps*, which provide information on the planned national emissions path up to the year 2050. These road maps should be based on the national CO_2 budgets as well as on the national emissions reduction potential.
- In addition, for the countries with presently high per-capita emissions, *reduction commitments up to 2020* are agreed in order to avoid delaying decarbonization efforts.
- *Flexible mechanisms* (international emissions trading and Joint Implementation) as well as appropriate additional financial and technological transfers by the industrialized countries are agreed upon.
- A decision is taken to establish a *world climate bank*, which will be responsible (1) for scrutinizing the national decarbonization road maps as to their plausibility and feasibility, and (2) for enabling the flexible mechanisms and transfers.
- The *separate regulation of CO_2 from non-fossil sources, other relevant greenhouse gases and further radiative forcing substances* creates opportunities for swift reductions in total emissions harmful to the climate. The following agreements are made in order to achieve these objectives: (1) In order to avoid CO_2 emissions resulting from deforestation and land-use changes and to conserve terrestrial carbon stocks, a separate legally binding regime is agreed upon in which swift and effective measures taken in developing countries have absolute priority. (2) The fluorinated greenhouse gases (industrial gases) currently covered by the Kyoto Protocol are dealt with in a special agreement modelled on the Montreal Protocol. (3) The other persistent greenhouse gases dealt with in the Kyoto Protocol are included in the budget calculation. (4) For non-persistent radiative forcing substances not covered by the Kyoto Protocol at present (including soot particles and ozone-forming gases), special reduction commitments are agreed upon within the framework of national air pollution control measures in order to achieve an effect as quickly as possible.

5.1 Ethical bases of international climate policy

Proposals for the allocation of emission rights have particularly good prospects of being accepted by the international community if they are viewed as fundamentally equitable by as many stakeholders and affected parties as possible. In this context, WBGU proposes that allocation be based on three principles, namely the polluter pays principle, the precautionary principle, and the principle of equality.

In accordance with the *polluter pays principle*, the industrialized countries have a particular responsibility to cut their greenhouse gas emissions due to their high cumulative emissions in the past. Unless the industrialized countries act on this responsibility, no global climate treaty will be achieved.

In line with the principle of sustainability (Article 3, paragraph 4, first sentence UNFCCC, 1992) and based on the 2°C guard rail, the *precautionary principle* (Article 3, paragraph 3 UNFCCC, 1992) must be respected; this means that timely action is required to prevent irreversible damage to present and future generations. The global emissions budget, capped by the 2°C guard rail, requires not only the industrialized countries but also the newly-industrializing and developing countries to adopt a course towards a low-carbon future. 'Catch-up' development in Africa, Asia and Latin America during the 21st century that is based primarily on fossil fuels would gamble with much of humankind's natural life-support systems.

Conversely, the populations of the industrialized countries do not have a natural right to per-capita emissions many times greater than those of the developing countries. The *principle of equality* – which postulates individuals' equal rights, without distinction, to the benefits of the global commons – is recognised by many countries but is not yet enshrined in law. The UN General Assembly (Resolution 43/53, 1989) and the UNFCCC (Preamble UNFCCC, 1992) acknowledge 'that change in the Earth's climate and its adverse effects are a common concern of humankind'.

From a theory of justice perspective, this concern does not permit any differentiation based on national or individual interests (Rawls, 1971). It requires emissions to be allocated in a manner which reflects the interests of the global community and humankind as a whole. The principle of equality cannot be used to derive an individually enforceable right to equal per-capita emissions, but it does imply that equity in per-capita emissions should be the basis for the allocation of national emissions budgets. WBGU proposes such allocation and thus supports the shared vision set out by German Chancellor Angela Merkel and Indian Prime Minister Dr Manmohan Singh, which postulates long-term convergence of per-capita emissions rates as one of the most important principles for international climate change mitigation (Bundesregierung, 2007).

Allocation of a global emissions budget based on equal per-capita emissions requires further differentiation, however. The ability to pay principle and specific mitigation capacity must also be considered in light of countries' 'common but differentiated responsibilities and respective capabilities' stated in Article 3, paragraph 1 UNFCCC. This requires that the climate change mitigation measures to be adopted by the Parties to the UNFCCC should be defined and agreed with due regard for the Parties' respective financial, economic and technological capacities (WBGU, 2003). Such consideration of additional factors accords with the principle of equality, whereby essentially identical cases should, as a matter of principle, be treated equally. Unequal treatment of essentially identical cases is only possible if it can be convincingly justified on objective grounds. Such grounds can certainly include individual countries' ability to pay and mitigation capacity and their contribution to climate change, which means that notwithstanding their common responsibility, Parties to the UNFCCC can be expected to shoulder different mitigation burdens.

In recognition of the stated principles and in light of the 2°C guard rail, WBGU proposes that in the further climate negotiations, individual reduction commitments for groups of countries or for individual countries should not be bargained freely but should be derived from a globally permissible CO_2 emissions budget according to the above-mentioned principles of justice. Based on the ethical principles outlined above, an allocation of equal per-capita emission allowances should be applied as a first approximation.

5.2 The WBGU budget approach

5.2.1 The basic concept

As early as 1995, in a paper for the Conference of the Parties to the UNFCCC (COP 1) in Berlin, WBGU developed the idea of determining an upper limit for tolerable warming of the mean global temperature (the 2°C guard rail; Section 2.4) as a basis for deriving a global CO_2 reduction target by means of an 'inverse approach', i.e. a backward calculation (WBGU, 1995). The budget approach is the further development of this concept and links it to current international climate policy.

Starting with the scientific knowledge that to keep atmospheric warming below 2°C, the total amount of anthropogenic CO_2 emitted to the atmosphere must be limited (Chapters 2 and 3), WBGU proposes the adoption of a binding upper limit on the total amount of CO_2 that can be emitted from fossil sources up to 2050 (or an alternative meaningful deadline). This ceiling is an essential prerequisite for ensuring, with a certain level of probability, that the 2°C guard rail will be obeyed. In this way, humankind would have a specific and defined amount of emissions available, whose allocation is subject to negotiation. This global budget can be broken down into national emissions budgets based on equal allocation per capita worldwide (Section 5.2.2). After 2050, only a small residual global budget would be available.

Due to the socio-economic conditions, however, the global budget cannot be utilized entirely without time constraints, as the 2°C guard rail can only be maintained if realistic decarbonization dynamics are taken as a basis (Chapter 3). Firstly, it takes time to restructure emission-intensive infrastructures and production processes and to change consumer behaviour, so there is no easy way to reduce global emissions at high speed. Secondly, global decarbonization must commence as soon as possible, as current knowledge indicates that any postponement now would necessitate emissions reductions at an unattainable rate in future. Thirdly, at the end of the budget period, i.e. around 2050, a largely zero-emissions economy must be in place, as the geophysical leeway in subsequent decades is likely to be very limited and the accumulation of CO_2 in the Earth System, although just about tolerable, will persist for some long time.

The budget approach must therefore be fleshed out with specific rules, for which WBGU makes the following proposals:

1. *Global interim targets:* As an important milestone, it should be stiplulated that the global CO_2 emissions curve must peak between 2015 and 2020 and decline thereafter. As a further milestone it should be stipulated that by 2050 decarbonization is to be widely acomplished.
2. *National decarbonization road maps and interim targets:* All countries should pledge to develop and present national strategies to manage their own CO_2 budgets ('decarbonization road maps'). These should be based on realistic evaluations of the national emissions reduction potential as a function of time and their plausibility and operability should be verified by an independent international institution. This would reduce the risk that some governments would postpone the necessary action indefinitely and leave it to future generations (Section 5.4). By allowing high flexibility in the choice of transformation pathways, the strengthening of countries' individual responsibility is coupled with accountability to the international community. The decarbonization road maps should include interim targets for national emissions inter alia to 2020, as prompt action is needed to set the course for the restructuring of relevant infrastructures (e.g. electricity and transport networks) towards climate protection (Section 5.3).
3. *Interregional flexibility*: WBGU recommends the unrestricted and efficient management of national budgets via a global CO_2 emissions trading system. As a prerequisite, the national budgets must be declared to be tradable allowances. International emissions trading allows and encourages a very wide range of bilateral and multilateral transactions. For example, trading allows industrialized countries that have used up almost all their CO_2 budget to purchase allowances, but also boosts the incentives for countries to reduce their own emissions. Substantial capital flows are generated for the developing countries and here too, incentives are created for emissions reductions, as CO_2 budget surpluses can be traded and monetized.

5.2.2
Calculating national emissions budgets

For the proposed budget approach, the total available global emissions budget of CO_2 from fossil sources that allows compliance with the 2°C guard rail is calculated for a specific period. This amount is then allocated among the individual countries, based on equal cumulative per-capita emissions over a fixed period.

It is then very easy to determine the national budgets because the model only contains *four* – political, i.e. negotiable – parameters; beside the period for the total budget with a *start* and *end* year, the *probability* of achieving compliance with the 2°C guard rail must be determined, and finally, a *demographic reference year* for the population figure must be fixed. WBGU proposes that the year 2050 be selected as the end point for the budget period, as there is no doubt that most of the requisite emissions reductions will need to have been achieved by that date (Chapter 3).

The other three parameters determine the overall budget amount and its relative distribution. They are therefore parameters of the utmost political relevance.

- The *start year* determines the point at which globally equitable emissions management – in other words, the proposed distribution formula – should come into effect. If the start year is backdated (i.e.

a year in the past is defined as the starting point), the budget to be distributed will include emissions that have already been produced. This inevitably means that countries with high historical per-capita emissions will have a proportionately smaller emissions budget in future.

- Due to the complexity of the climate system, it is not possible to calculate exactly what additional amount of CO_2 can still be absorbed by the Earth's atmosphere without breaching the 2°C guard rail. However, with the help of so-called ensemble calculations and using the best simulation models available worldwide, as well as sophisticated statistical methodologies, it is perfectly possible to calculate *probabilities* that a specific total amount of emissions will remain 'sub-critical' and will thus be compatible with restricting warming to 2°C (Chapter 3). The global budget amount that is available for distribution can thus be calculated directly on the basis of a global political risk assessment: the higher the probability of compliance with the 2°C guard rail that is chosen, the smaller the available budget in the relevant period must be. It is important to note at this juncture that probabilities of averting damage that fall within the 50–90%-range – i.e. the range generally discussed in relation to the climate problem – would be considered completely unacceptable in an every-day context (e.g. traffic safety, infectious diseases, etc.). Unfortunately, however, global environmental change has already progressed too far for a genuinely appropriate precautionary policy.
- The *demographic reference year* determines the national share of the global budget based on the country's relative demographic weight for the given year. The later the reference year selected, the more this will benefit countries with rapidly growing populations when it comes to emissions budget allocation, as their relative demographic weight is steadily increasing. Instead of taking the population figure in a single year, allocation could also be based on the (mean) population trend over a longer period. The argument in favour of using a fixed reference year is that in countries with high population growth rates, it could serve as an incentive for demographic change, since unabated population growth after the reference year would stretch the allocated budget, effectively reducing emissions per capita.

The mathematical formula describing the budget approach is presented in Box 5.2-1. In Section 5.3, WBGU illustrates the significance and effect of the individual parameters and presents two policy options for the implementation of the budget approach. In Section 5.4, it then shows how this proposed solution for protecting the global climate must be flanked by institutional arrangements in order to make optimum use of its advantages (particularly flexibility) without jeopardizing the essential goal, i.e. preserving tolerable climatic conditions.

Box 5.2-1

Mathematical formula describing the budget approach

The key parameter is the global CO_2 emissions budget from fossil sources $C_{glob}(p)$, i.e. the maximum emissions from fossil sources which may be released/produced within a specific period T_1 to T_2 if the 2°C guard rail is to be obeyed with probability p. Once p has been defined (based on precautionary factors), then $C_{glob}(p)$ can be determined from model studies within the bounds of specific uncertainties (Meinshausen et al., 2009). The global emission pathway $E_{glob}(t)$ must be compatible with this constraint, i.e. it must fulfil the following equation

Of course, 'under-utilization' of the resource 'atmosphere' is also conceivable, but it can be assumed that, in reality, the leeway for global emissions will be fully exhausted. It is important to bear in mind that equation 1 only fixes the area below the global emissions curve but otherwise allows full freedom to determine the reduction schedule.

$$\int_{T_1}^{T_2} E_{glob}(t)dt = C_{glob}(p) \qquad (1)$$

The national emissions budget C_{nat} is the total amount of CO_2 that a specific country is allowed to emit in the time period T_1 - T_2. It is calculated as a proportion of the global emissions budget $C_{glob}(p)$, based on the relative demographic weight of the given country in the demographic reference year T_M. The coefficient is therefore the quotient from the national population figure $M_{nat}(T_M)$ at time T_M and total world population $M_{glob}(T_M)$ at the same point in time.

A country's emission pathway $E_{nat}(t)$ must thus be managed in such a way that it matches the allocated budget:

Equation 2 can be regarded, to some extent, as the global 'climate formula' within the budget approach's philosophy.

$$\int_{T_1}^{T_2} E_{nat}(t)dt = C_{nat} = C_{glob}(p)\frac{M_{nat}(T_M)}{M_{glob}(T_M)} \qquad (2)$$

5.3 Two policy options for implementing the budget approach

In this section, two possible options for the implementation of the WBGU budget approach are presented, along with a proposal for the definition of milestones, in the form of medium-term emissions reduction targets. In both options, WBGU has selected 2050 as the final year of the budget period (Section 5.2), as current understanding of the relevant system dynamics indicates that the fossil fuel era must be brought to an end as swiftly as possible. The precautionary principle and the responsibility to future generations, in turn, necessitate a total budget which keeps global warming below 2°C with the maximum possible probability. In view of the considerable risks associated with global warming above the 2°C guard rail (Chapter 2), the probabilities applied here, i.e. 75% and 67%, reflect the need for compromise between what is scientifically necessary, on the one hand, and politically and economically feasible, on the other.

5.3.1
Option I: 'Historical responsibility'

Adopting 1990 as the start year for the budget period can be justified in order to take account of the polluter pays principle and the industrialized countries' historical responsibility: 1990 was the year in which the IPCC published its first assessment report. In other words, by this point in time, all the world's countries were fully informed about the climate problem, its causes and effects. Table 5.3-1 lists examples of the national emissions budgets that would result from equal per-capita distribution of the global cumulative CO_2 budget between 1990 and 2050. A 75% probability of compliance with the 2°C guard rail has been selected; based on the relevant analyses by climate scientists, this yields a total budget of 1100 Gt CO_2 from fossil sources (Box 5.3-1). 1990 is also taken as the demographic reference year.

In this way an emissions budget is derived for each country, which it may utilize over a total period of six decades. Deducting from this budget the emissions already produced between 1990 and 2009 yields the residual amount available to countries for the period from 2010 to 2050. In this option, the USA, Germany and Russia would have a *negative* emissions budget to 2050 (Fig. 5.3-1) – in other words, they are already 'carbon-bankrupt'. Japan, too, would already be close to exhausting all the emission allowances available to it for the period 1990–2050. This would force these nations to acquire substantial quantities of emission allowances from countries which are unlikely to utilize all their allocated emissions budgets now or in future. Such emissions trading would undoubtedly trigger substantial North-South financial transfers.

This option obeys the polluter pays principle retroactively as well, since it takes account of emissions already produced by the industrialized countries. Politically, however, it appears difficult to carry through as it would greatly limit the industrialized countries' scope for action. In order to maintain the momentum that is currently emerging in global climate policy, WBGU recommends Option II, presented below, which looks forward from today's status quo and is thus oriented to the responsibility of all countries for future emissions. However, in this option too, account can be taken of historical responsibility via lump-sum compensation payments by the industrialized countries to newly-industrializing and developing countries, e.g. to support adaptation to climate change.

5.3.2
Option II: 'Future responsibility'

In light of the current proposals on the table for the climate negotiations, it would seem constructive to choose a later start year than 1990. WBGU therefore recommends that the residual permissible quantity of CO_2 emissions for the future should be allocated to the world's population on an equal per-capita basis, and that this allocation be calculated as of now

Box 5.3-1

The global emissions budget under Option I

According to Meinshausen et al. (2009), a cumulative total of 1000 Gt CO_2 emissions from anthropogenic sources (fossil sources and land use/ land-use change) for the period 2000–2050 yields a 25% probability of warming exceeding the 2°C guard rail. Assuming that around 350 Gt CO_2 have already been emitted from *anthropogenic sources* between 2000 and 2009, and that emissions from land-use change between 2010 and 2050 can be limited to around 50 Gt CO_2, that leaves a budget of 600 Gt CO_2 from *fossil sources* for the period 2010–2050. At present, emissions from land-use change exceed 5 Gt CO_2 per year (Le Queré, 2008), and postulated scenarios for the future span a wide range. WBGU is assuming a relatively optimistic scenario in which the current high emissions from progressive deforestation in developing countries can be reduced rapidly (Section 5.7); failing that, an even smaller budget for CO_2 emissions from fossil sources would be available.

Together with the CO_2 emissions from fossil sources of approx. 500 Gt CO_2 between 1990 and 2009 (Le Queré, 2008, and WBGU's own estimate), this results in a total global budget of 1100 Gt CO_2 *from fossil sources* for the period 1990–2050, which permits a 75% probability of compliance with the 2°C guard rail. After the year 2050, only a small amount of CO_2 may be emitted, which must be less than approximately one-fifth of the available global CO_2 amount up to 2050.

Table 5.3-1
Option I: 'Historical responsibility', 1990–2050; 75 % probability of compliance with the 2 °C guard rail; 1990 as the reference year for population data. Only includes CO_2 emissions from fossil sources. CO_2 emissions for 2008 are estimations.
Source: WBGU, using data from: Meinshausen et al., 2009; WRI-CAIT, 2009; U.S. Census Bureau, 2009

	Share of world population in 1990 [%]	Total budget 1990–2050 [Gt CO_2]	Emissions to date 1990–2009 [Gt CO_2]	Budget 2010–2050 [Gt CO_2]		Estimated emissions in 2008 [Gt CO_2]	Reach of the budget lifetime, assuming annual emissions as in 2008 [years]
				Total period	Per year		
Germany	1.5	17	17	-0.90	-0.022	0.91	-1
USA	4.7	52	108	-56	-1.4	6.1	-9
China	22	239	75	164	4.0	6.2	26
Brazil	2.9	31	6.1	25	0.62	0.46	55
Burkina Faso	0.16	1.7	0.0090	1.7	0.042	0.00062	2810
Japan	2.3	26	23	2.4	0.058	1.3	2
Russia	2.8	31	31	-0.29	-0.0071	1.6	0
Mexico	1.6	18	6.9	11	0.26	0.46	23
Indonesia	3.4	38	4.8	33	0.81	0.38	88
India	16	175	19	156	3.8	1.5	103
Maldives	0.0041	0.045	0.0098	0.035	0.00086	0.00071	50
EU	8.9	98	81	18	0.43	4.5	4
World	100	1,100	500	600	15	30	20

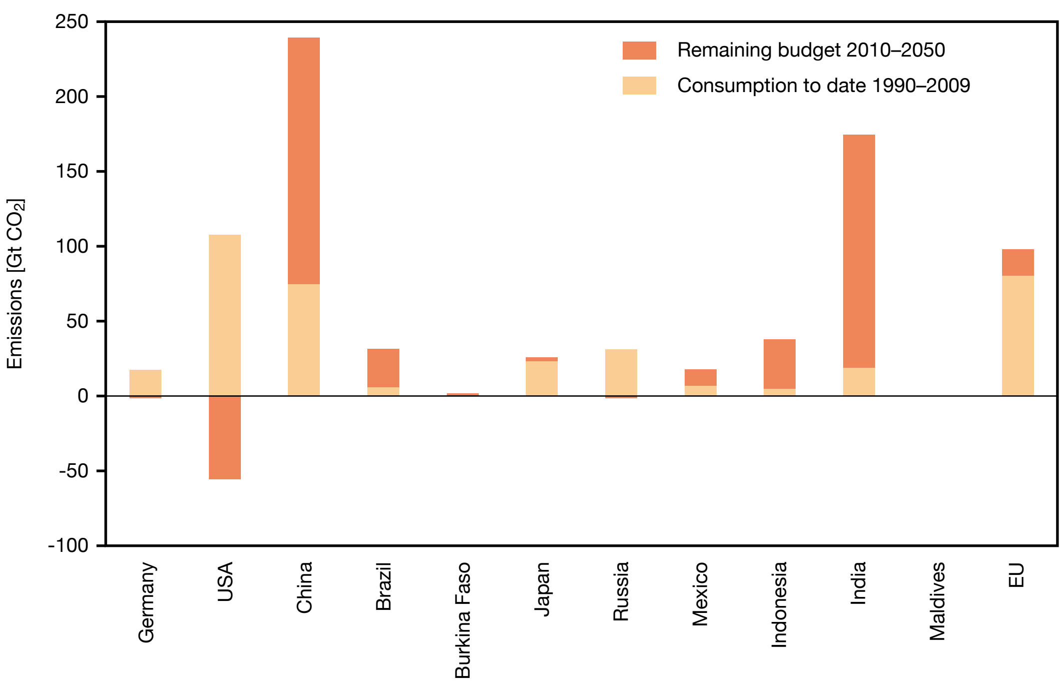

Figure 5.3-1
Total CO_2 emissions from fossil sources, 1990–2009 (i.e. consumption to date) and residual CO_2 budget to 2050 based on Option I: 'Historical responsibility' (Table 5.3-1). The USA, Germany and Russia have already emitted more than they would be entitled to, in this option, for the period 1990–2050.
Source: WBGU

or from the year when a new climate treaty comes into force. In order to create more political leeway, in this option a greater climate risk is consciously accepted, and a probability of just two-thirds, i.e. 67 %, of achieving compliance with the 2 °C guard rail is postulated. Table 5.3-2 shows examples of the ensuing national emissions budgets, based on a permissible global budget of 750 Gt CO_2 from fossil sources between 2010 and 2050 (Box 5.3-2) that is allocated to the countries on an equal per-capita basis.

In this option, the start year 2010 would appear to be a suitable demographic reference year. Under Option II, every person (based on the 2010 world population) would be allocated a budget of around 110 t CO_2 emissions for the next 40 years, equivalent to average annual per-capita emissions of approx. 2.7 t CO_2. However, in order to safeguard the transition to the low global emissions that are permissible post-2050, global mean per-capita emissions at the end of the budget period must lie well below this average: by 2050, global CO_2 emissions must be around two-thirds lower than the 1990 baseline despite a growing world population. This would result in an entitlement to annual per-capita emissions of around 1 t CO_2.

Figure 5.3-2 shows selected countries and the mean annual budget to which they would be entitled under Option II, as compared with emissions in 2005.

All figures refer to fossil CO_2 emissions (i.e. without land-use changes), but deforestation and other sources of persistent greenhouse gases could also be included in the budget approach. Specifically in relation to land-use changes, however, WBGU considers that a separate regime is likely to be more successful (Section 5.7). The key issue is that allocating the national emissions budgets creates a shared responsibility for climate change mitigation. It is not possible or necessary for mitigation to be tackled solely through countries' own domestic emissions reductions. The allocation scheme proposed is equitable and should be regarded, not least, as the basis for effective and efficient burden-sharing. This can take place in a variety of ways: alongside domestic emissions reductions, the trading of emission allowances is likely to play a key role, but other flexible mechanisms for international climate cooperation, along with financial and technology transfers, can help to speed up progress towards low-carbon development all over the world.

Countries can be classified broadly in three groups according to the number of years their allocated budget can be expected to last (excluding emissions trading):

- Group 1: Countries whose budget – at their current rate of emissions – would be exceeded in *less than 20 years*. Under the assumption of a linear reduction trajectory, these countries would therefore have to achieve zero emissions before 2050 if they are to stay within budget.
- Group 2: Countries whose budget – at their current rate of emissions – would last for *20–40 years* at most, i.e. to the end of the global budget period in 2050.
- Group 3: Countries whose budget – at their current rate of emissions – would last for *more than 40 years*, i.e. beyond the end of the global budget period.

For all calculations, assumptions for 'current rate of emissions' are based on estimated values for 2008.

Group 1: 'Comprehensive decarbonization before 2050'

Assuming the above-mentioned global budget of 750 Gt CO_2, this group comprises around 60 countries, i.e. all countries which currently emit more than 5.4 t CO_2 per capita per year. Besides the industrialized countries (almost all Annex I countries), it includes some Arab states, as well as Venezuela, South Africa and Iran. In terms of their per-capita emissions, the USA and Australia top the league in this group (apart from a handful of very small countries such as Qatar or Kuwait). If the USA and Australia continue along the present emission pathway, their budgets would last for barely 6 more years. Assuming a linear reduction trajectory from 2010, these two countries would, theoretically, need to achieve zero emissions within just 11 years. Due to their extraordinarily high per-capita emissions of 19 t CO_2 per year, the USA and Australia would have to shoulder an extremely heavy mitigation burden in future as an inescapable consequence of any globally equitable model.

The CO_2 budgets available for Germany and the EU to 2050 – assuming that the current level of emissions is maintained (Germany: 11 t CO_2 per capita per year; EU: 9 t CO_2 per capita per year) – would

Box 5.3-2 The global emissions budget under Option II

According to Meinshausen et al. (2009), cumulative total CO_2 emissions of 1160 Gt from *anthropogenic sources* between 2000 and 2050 would give a 33 % probability of warming exceeding the 2 °C guard rail. As described in box 5.3-1 (option I), it is assumed that approx. 350 Gt CO_2 have already been emitted from anthropogenic sources between 2000 and 2009. The emissions from land-use changes between 2010–2050 are estimated at around 60 Gt CO_2. This yields a total global budget of 750 Gt CO_2 from *fossil sources* for the period 2010–2050, which permits a 67 % probability of achieving compliance with the 2 °C guard rail. After the year 2050, only a small amount of CO_2 may be emitted, which must be less than approximately one-fifth of the available global CO_2 amount up to 2050.

Table 5.3-2
Option II: 'Future responsibility', 2010–2050; 67 % probability of compliance with the 2 °C guard rail; 2010 as the reference year for population data. Only includes CO_2 emissions from fossil sources. CO_2 emissions for 2008 and population numbers for 2010 are estimations.
Source: WBGU, using data from: Meinshausen et al., 2009; WRI-CAIT, 2009; U.S. Census Bureau, 2009

	Share of world population in 2010 [%]	Budget 2010–2050 [Gt CO_2]		Estimated emissions in 2008 [Gt CO_2]	Reach of the budget lifetime, assuming annual emissions as in 2008 [years]
		Total period	Per year		
Germany	1.2	9.0	0.22	0.91	10
USA	4.6	35	0.85	6.1	6
China	20	148	3.6	6.2	24
Brazil	2.8	21	0.52	0.46	46
Burkina Faso	0.24	1.8	0.043	0.00062	2892
Japan	1.8	14	0.34	1.3	11
Russia	2.0	15	0.37	1.6	9
Mexico	1.6	12	0.29	0.46	26
Indonesia	3.4	25	0.62	0.38	67
India	18	133	3.2	1.5	88
Maldives	0.0058	0.043	0.0011	0.00071	61
EU	7.2	54	1.3	4.5	12
World	100	750	18	30	25

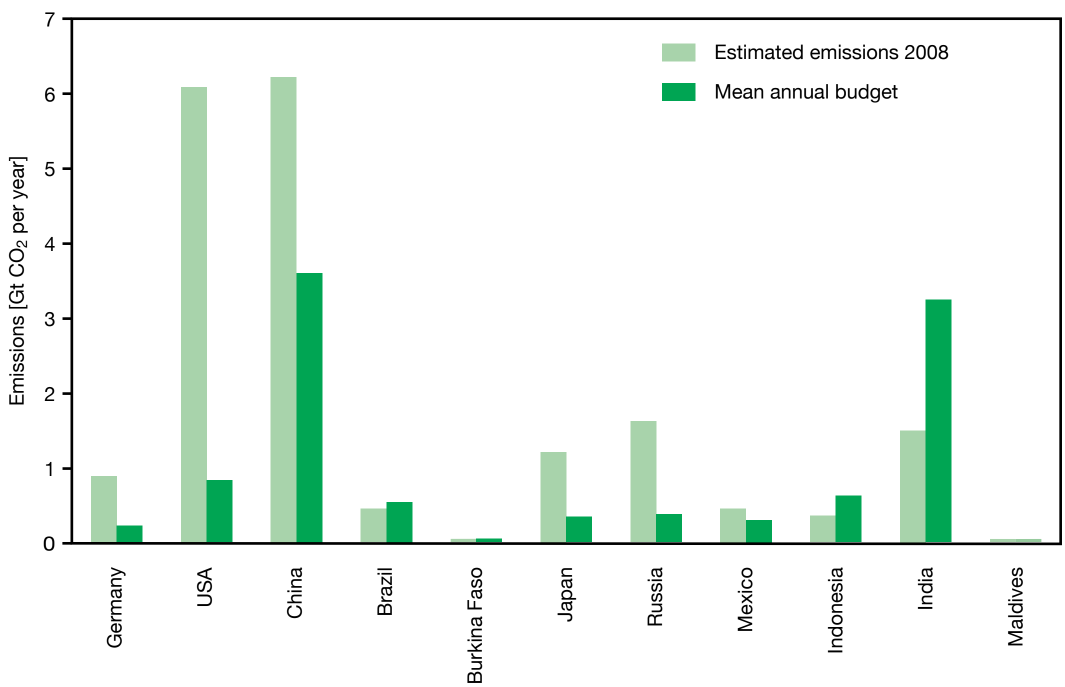

Figure 5.3-2
Fossil CO_2 emissions in 2008 (estimated figures) and permissible average annual budgets under Option II: 'Future responsibility' (Table 5.3-2) for selected countries.
Source: WBGU

be exhausted within 10 and 12 years respectively. In light of this situation, it is clear that the industrialized countries must carry out rapid and comprehensive decarbonization of their economies by 2050 if they wish to present themselves as credible advocates of global climate protection. However, even drastic domestic reduction efforts will not be enough to keep them within budget. They are therefore reliant on extensive cooperation with developing countries which still have leeway to contribute to international emissions trading.

Group 2: 'Stabilization of emissions and transition to decarbonization'

This group comprises around 30 countries, i.e. all those which currently release between 2.7 and 5.4 t CO_2 per capita per year to the atmosphere. By far the largest emitter in this group is China, which accounts for 75% of the group's total emissions. With 4.6 t CO_2 per capita per year, China's current CO_2 emissions from fossil sources (estimated for 2008) are almost equivalent to the global average of 4.4 t CO_2 per capita per year. If China maintains its emissions at a constant level, its budget would only last for another 24 years – similar to the world as a whole, where the budget would last for 25 years. According to the logic of the budget approach, it is manifestly clear that China must stabilize its emissions very quickly and then reduce them substantially. If its CO_2 emissions were to continue on an upward trajectory to around 2020, China would then have to reduce its emissions to virtually zero by 2050 in order to remain within budget.

Other newly-industrializing countries such as Mexico, Argentina, Chile and Thailand are in a similar situation. Their budgets, too, would only last for 24-27 years if their emissions remain constant.

At the 'lower' end of Group 2, there are countries such as Cuba, Tunisia and Syria with emissions of 2.7–3.0 t CO_2 per capita per year, whose budgets – if their emissions remain at a constant level – would last for 36-40 years. They could thus continue to emit CO_2 at a more or less constant level. However, like every other country, they only have a very limited budget for the second half of the century (post-2050). As dramatic emissions reductions are generally not feasible, these countries too would have to achieve substantial reductions in their CO_2 emissions to around 1 t CO_2 per capita per year by 2050. A typical pathway for one of these countries under the budget approach would be a gradually declining rate of emissions growth to a peak in 2025, when the level of emissions could be around one-third higher than at present. This would be followed by decarbonization to 2050, i.e. around a decade later than the industrialized countries. If an ambitious decarbonization pathway is pursued, involving massive cooperation with industrialized countries, some Group 2 countries might even be able to sell a proportion of their emission allowances and thus generate additional revenue to fund the transformation to a sustainable economy. However, it seems plausible that this group of countries as a whole will have to purchase emission allowances (Fig. 5.3-5).

Group 3: 'Trading power through avoided carbonization'

This group comprises all the other countries (some 95 in total), which emit less than 2.7 t CO_2 per capita per year. In total, these countries only account for 12% of current global CO_2 emissions but by 2010, they will be home to more than 50% of the world's population and will thus hold more than half the global emissions budget. Under Option II, some of these countries would still have considerable leeway to increase their emissions. In view of the required trend towards global convergence at around 1 t per capita per year by 2050, however, this does not give them carte blanche indefinitely. A typical pathway for this group of countries would therefore be a kind of 'hump trajectory', with emissions increasing to 2030 and falling again thereafter.

At the 'upper' end of Group 3 are countries such as Brazil, Egypt and Peru, whose budgets – assuming that emissions remain at a constant level – would last for 46, 57 and 59 years respectively. These countries therefore need to start decoupling their desired economic growth from greenhouse gas emissions soon, if they are to remain within their CO_2 budget with ease. At the 'lower' end of the group are 45 countries (mainly in sub-Saharan Africa but also including Afghanistan and Nepal) which currently emit less than 0.5 t CO_2 per capita per year, meaning that their budgets – assuming that emissions remain at a constant level – would last for more than 250 years.

The largest emitter in Group 3 is India, a special case which will be looked at in more detail below. Within its budget allocation under Option II, India (with current CO_2 emissions of 1.2 t CO_2 per capita per year; estimated for 2008) could theoretically continue along a business-as-usual pathway and increase its emissions by 300% during the budget period (Fig. 5.3-3). In this case, however, India would fall short of future viability when the post-fossil age dawns in 2050. In order to ensure the success of this transition, India should have reversed its CO_2 emissions trend by 2030. In Fig. 5.3-3, the green curve shows the example of an emissions trajectory in which India sells one-third of its budget via international emissions trading and uses the revenue to implement a decarbonization road map to bring its emissions back down to today's level by 2050.

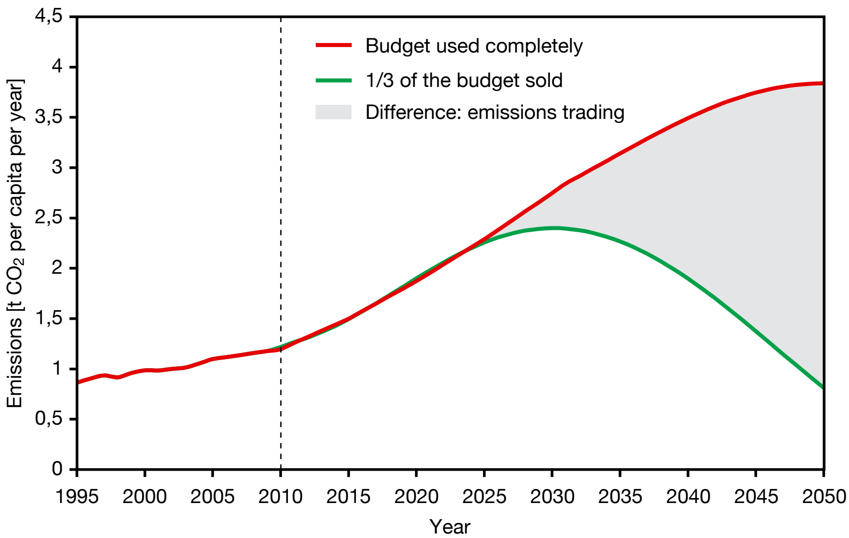

Figure 5.3-3
Examples of budget-compatible CO_2 emissions trajectories per capita for India. Per-capita emissions shown are based on the 2010 population and do not take account of population growth. The figure shows a theoretical pathway with full utilization of the budget (red), and a pathway along which India sells one-third of its budget to other countries and thus retains a smaller budget for itself (green). Up to 2030, the red emission pathway continues along the projected business-as-usual pathway (IEA, 2007).
Source: WBGU

As the particular example of India shows, the allowances to balance out the industrialized countries' budget excesses will have to be supplied primarily by this third group of countries. However, the balance should largely be achieved through concrete climate change mitigation efforts so that countries with low emissions do not simply sell 'hot air' via an unregulated emissions trading scheme, which would result in massive financial transfers without any mitigation effect (Section 5.4). A properly structured emissions trading system would provide strong incentives for climate partnerships between countries with high and low emissions. In these partnerships, industrialized countries – in their own interests – would typically support poorer countries' endeavours to reach their emissions peak as soon as possible while keeping it as low as possible. The industrialized countries would thus utilize the purchased emission allowances to balance out their own budget deficits, whereas the developing countries could use the transactions in order to set a course towards a sustainable, low-carbon economy. In this way, the budget approach makes climate change mitigation attractive to all countries immediately – even to those countries whose own per-capita emissions are still very low as yet.

Cooperation between the groups

Figure 5.3-4 shows theoretical trajectories, over time, of the per-capita emissions of selected countries under Option II *without emissions trading*. These curves depict a dramatic state of affairs for the USA, and paint an alarming picture even for Germany, despite the country's previous mitigation successes. It is notable that in this scenario, even China would have to achieve complete decarbonization by 2040 at the latest. This shows just how much the climate problem has linked the world's countries in a 'community of fate'. At this juncture, however, we cannot emphasise enough that the actual per-capita emissions profiles of the countries will deviate substantially from the trajectory shown here, not least due to the use of flexible market instruments and engagement in bilateral and multilateral partnerships. While the high-emission countries have the chance to increase their emissions budgets by purchasing emission allowances, countries whose emissions lie on average below the plotted curves stand to benefit from the sale of their allowances.

Figure 5.3-5 shows theoretical per-capita emissions trajectories for the three groups of countries overall. First, it presents sample trajectories which could arise without emissions trading; secondly, it shows the trajectories which could result if the Group 1 and 2 countries were to boost their budgets by purchasing emission allowances from Group 3 countries.

If the world succeeds in setting a course towards a global low-carbon economy via the budget approach, then the national actors will need to stick closely to the following script: More than 100 countries will have to initiate, as urgently as possible, a transformation process which allows them to stabilize their emissions swiftly and then move towards almost complete decarbonization. Only 65 countries have economies whose emissions are currently below 1–1.5 t CO_2 per capita per year and are thus climate friendly. The CO_2 budgets of the industrialized countries are extremely limited. These countries should therefore combine strategies for the radical restructuring of their 'fossil' economies with the use of flexible mechanisms (such as technology transfer to reduce greenhouse gas emissions in developing countries) and the purchase of substantial quantities of emission allowances. Many newly-industrializing economies also need to make substantial decarbonization efforts if they are to stay within budget by mid-century without having to purchase additional emission allowances. The majority of emerging economies are therefore highly unlikely to become suppliers of tradable allowances. This gives developing countries with consistently low levels of emissions strategic importance, as owners – and sellers – of such emission rights. The budget approach offers them the opportunity to accelerate their future development through technology and financial transfers, and to move onto a low-carbon footing from the outset.

From the above clusters of interests, it becomes apparent, *firstly*, that an historic climate partnership between Group 1 countries (essentially the industrialized countries) and Group 3 countries (essentially today's poorest countries) is vital in solving the climate problem. They will operate on the principle of technology and financial transfers in exchange for 'budget surpluses'. The 'donors' and 'recipients' who have traditionally been the key actors in development cooperation thus become partners with mutual interests. International climate change mitigation must thus go hand in hand with a global development partnership between 'high emission' and 'low emission' countries. For many developing countries, these transfers hold the key to a zero-emissions future, as the development of their sustainable energy systems could largely be funded through emissions trading. The dual benefit is that these countries can avoid the burden of fossil path dependency without forfeiting their opportunities for development.

A more detailed analysis of the potential suppliers of emission allowances reveals the following scenario: sub-Saharan Africa is the region with the largest number of countries that could sell their surpluses. However, many of the suppliers in Group 3 are small economies which – from a potential purchaser's perspective – have only very modest amounts of greenhouse gas emissions available to sell. From the perspective of the Group 1 countries, the more attractive potential suppliers with large volumes of emission allowances are India (population: 1.2 billion; budget would last for 88 years if emissions remain constant, Table 5.3-2), Bangladesh (population: 164 million; 384 years), Pakistan (population: 185 mil-

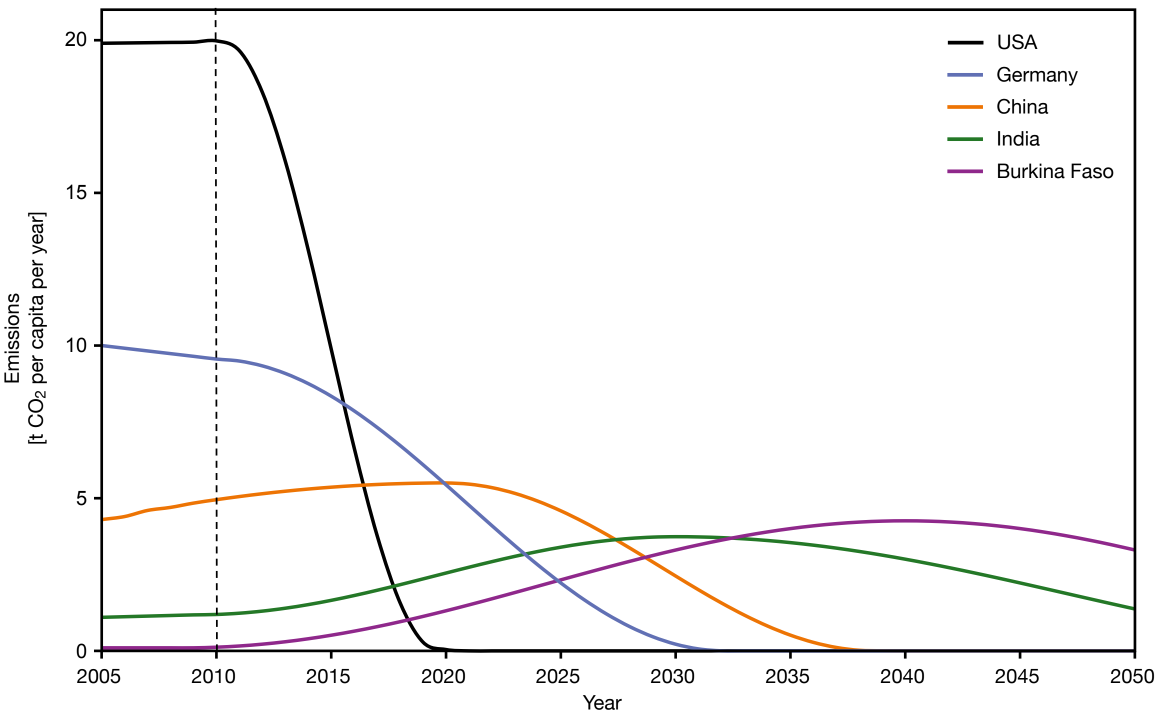

Figure 5.3-4
Examples of theoretical trajectories, over time, of the per-capita emissions of selected countries under the WBGU budget approach, without emissions trading, based solely on CO_2 emissions from fossil sources and assuming a constant population (2010). Starting from current emissions (estimated for 2008), theoretical per-capita emissions trajectories over time were calculated that would allow compliance with the national budgets. However, for some countries (e.g. the USA), the trajectory presented would be unrealistic in practice. Each country is entitled to a total of 110 t CO_2 emissions per capita over the period from 2010 to 2050, based on population data for 2010. Actual per-capita emissions will deviate, sometimes substantially, from these trajectories due to the sale and purchase of emission allowances.
Source: WBGU

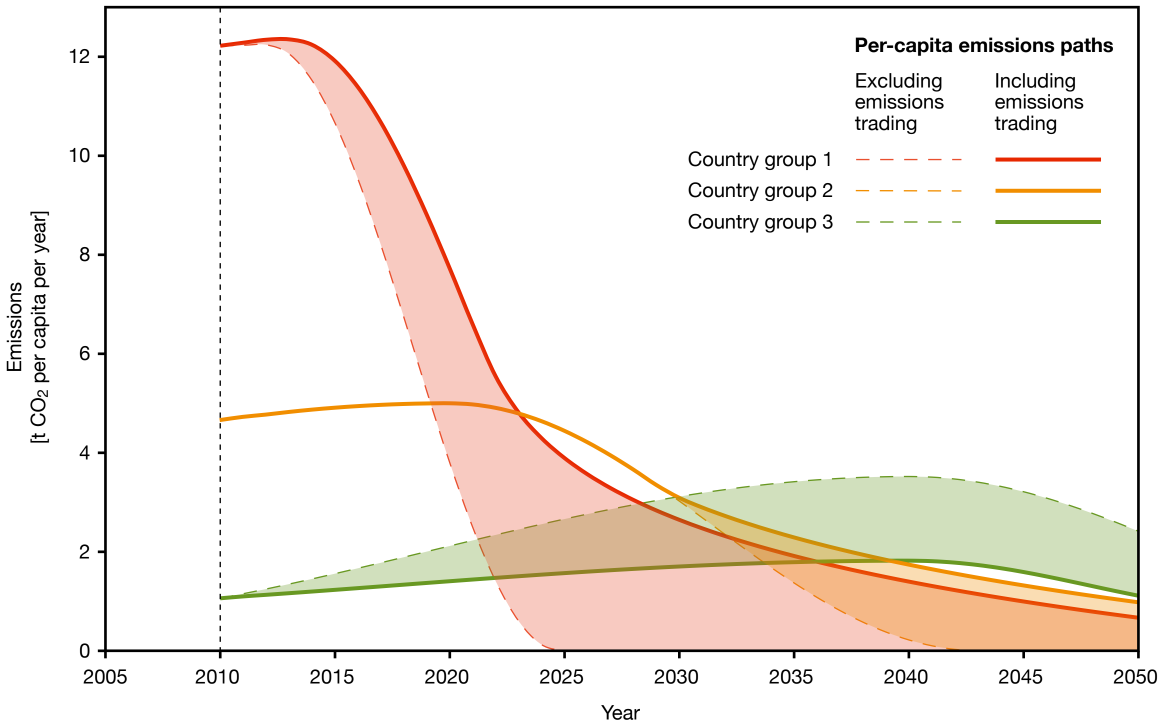

Figure 5.3-5
Examples of per-capita CO_2 emissions trajectories from fossil sources for three country groups under the WBGU budget approach. The *broken curves* show theoretical per-capita CO_2 emissions trajectories without emissions trading. These would allow compliance with the national budgets, but would be partly unrealistic in practice. The *unbroken curves* show emissions trajectories that could result from emissions trading. It is assumed that Group 1 countries increase their budget by 75% by purchasing emission allowances for 122 Gt CO_2. Group 2 countries purchase emission allowances totalling 41 Gt CO_2. The suppliers of the sum total, i.e. 163 Gt CO_2, are the Group 3 countries, resulting in a decrease of around 43% in their own emissions budget. Towards the end of the budget period, convergence of real CO_2 emissions occurs at around 1 t per capita per year (based on the population in 2010). The areas between the curves represent the traded quantities of emission allowances. As this is a per-capita presentation and the country groups have different populations, the total of the areas between the curves for the buying Groups 1 and 2 is not equal to the area between the curves of the selling Group 3.
Country groups are organized according to CO_2 emissions per capita per year from fossil sources, whereby CO_2 emissions are estimates for 2008 and population figures are estimates for 2010. *Red:* country group 1 (>5.4 t CO_2 per capita per year), mainly industrialized countries (e.g. EU, USA, Japan), but also oil-exporting countries (e.g. Saudi Arabia, Kuwait, Venezuela) and a small number of newly-industrializing countries (e.g. South Africa, Malaysia). *Orange:* country group 2 (2.7–5.4 t CO_2 per capita per year), which includes many newly-industrializing countries (e.g. China, Mexico, Thailand). *Green:* country group 3 (<2.7 t CO_2 per capita per year), above all developing countries (e.g. Burkina Faso, Nicaragua, Vietnam), but also some large newly-industrializing countries (e.g. India, Brazil).
Source: WBGU

lion; 125 years) and Ethiopia (population: 85 million; 1251 years). Although their geostrategic role is negligible at present, climate change issues in future could make them major players with whom the industrialized countries should maintain particularly constructive relations.

Secondly, it is clear that emissions trading between the Group 1 and Group 2 countries is likely to be very limited due to the minimal or modest budgets available. Nonetheless, the industrialized countries are likely to have great interest in technology partnerships on equal terms in order to reduce the greenhouse gas intensity of the newly-industrializing countries (especially China) and thus prevent these countries from becoming major purchasers of emission allowances themselves. Competition between Group 1 and Group 2 countries for Group 3's limited supply of emission allowances would undoubtedly drive up prices. This insight could encourage the formation of climate alliances between China, the EU and the USA, for example. Despite such common interests, however, there is likely to be intense competition between the industrialized countries and China in particular in future over global technological leadership during the phase of global decarbonization.

Thirdly, WBGU's analysis shows that the two most important emerging economies in Asia, namely China and India, will be confronted with very different challenges under the budget approach. China, due to its impressive economic growth dynamic and already relatively high level of per-capita emissions, will need to implement a comprehensive decarbonization strategy with great urgency (McKinsey, 2009c). India by contrast, due to its still relatively low per-capita emissions, has the chance to pursue a gentler transformation pathway towards a low-carbon economy, despite its high economic growth potential; in other words, it will face far less time pressure than China in starting to decouple economic development from greenhouse gas emissions. The sooner India recognizes this opportunity to avoid 'catch-up' carbonization, the greater its prospects of becoming a major supplier of emission allowances in future (Fig. 5.3-3). India could thus greatly ease its path towards a low-carbon future through partnership with the industrialized countries. Equally, climate cooperation with India would be of great strategic interest for the North as well, in terms of securing its own access to India's emission allowances. In sum, India could become a key actor and major winner if a world climate treaty is adopted in line with the budget approach. This illustrates that decoupling economic development prospects from fossil energy generation is crucial to the destinies of industrialized, newly-industrializing and developing countries alike.

Compensation for historical responsibility

Since Option II: 'Future responsibility', sketched out above, does not take account of the emissions produced in 1990–2010 in the allocation of future emission allowances, the high-emission countries' historical responsibility for global warming is not reflected in the resulting national budgets. In WBGU's view, a separate method could be adopted to take account of historical responsibility, provided that political agreement could be achieved on such a modality. Compensatory financial transfers (especially for adaptation measures) would be a most appropriate method, with the amounts of these transfers depending on the high-emission countries' different per-capita emissions during the period 1990–2009 (Section 5.5).

Short-term targets for CO_2 reductions to 2020

Besides the total budget to 2050, verifiable interim targets are essential for climate policy, and these should also be agreed at Copenhagen. Otherwise, there is a temptation for politicians to put climate change mitigation measures 'on the back burner' and possibly avoid pursuing measures that are likely to be unpopular, pledging instead that they will be initiated in future legislative terms. What is more, countries cannot act in isolation where climate change mitigation is concerned, as their decarbonization pathways intersect in many ways – via emissions trading, technological development and the need to reverse the collective global CO_2 emissions trend during the period 2015–2020 in order to maintain a credible prospect of keeping global warming below the 2°C guard rail. For all these reasons, agreements on short-term targets (i.e. for 2020 etc.) are essential.

For the USA, due to the considerable amount of time lost to climate change mitigation under the two terms of the previous Administration, it is unrealistic to set a reduction target for 2020 that comes close to matching the scale of the problem. For that reason, and in view of the USA's massive potential for innovation, the establishment of a 'separate milestone' for the USA is worth considering at Copenhagen: one option is to agree a target for the USA to reduce its domestic emissions to 4 t CO_2 per capita per year by 2030, for example.

Short-term targets for Option II: 'Future Responsibility'

Based on, and having studied, the national CO_2 budgets resulting from Option II, WBGU proposes the systematic setting of milestones, in the form of short-term targets to be reached by the year 2020. According to the country group, either reduction targets or upper limits on budget use could be established to 2020.

The approach proposed here can be used to derive not only budgets to 2050 but also the short-term targets in a transparent and equitable manner. The budget approach, if applied correctly, is therefore extremely helpful for the specific negotiating process in the run-up to, and in, Copenhagen. To develop the short-term targets, the three groups of countries, discussed above, are considered separately.

Group 1: These countries – assuming linear emissions reductions from 2010 – must achieve zero emissions before 2050. For this group, the 2020 interim target is a point on a straight line linking the present level of emissions with the zero level in year X in compliance with the budget allocated. Germany, for example, would need to reduce its CO_2 emissions to zero within 20 years. The interim target would therefore be minus 50% by 2020, relative to the present level.

Very similar figures apply to the industrialized countries as a group; in this case, the group target would at the same time be a 50% reduction of CO_2 emissions against the 1990 baseline, as this group's current emissions are approximately equal to the 1990 level. Therefore the 2020 milestone that could be set for the industrialized countries as a whole, for example, could be a 35–40% reduction in their domestic emissions, with the rest coming from measures undertaken in, or via cooperation with, developing countries. The EU as a whole would have to reduce its CO_2 emissions to zero within 25 years –

which corresponds directly to a target of minus 40% by 2020. In theory, the USA would need to achieve zero emissions within 11 years, so this method does not offer a realistic reduction target for 2020. The USA should therefore set itself the most ambitious target possible for domestic emissions reductions to 2020, and meet the substantial remainder of its climate commitments progressively through the purchase of emission allowances and mitigation projects abroad, with a view to compensating all its emissions by 2020.

Group 2: The rule that should apply to these countries is that they should be permitted to emit a maximum of 44% of their total budget by 2020. This figure automatically arises for a hypothetical country that is aiming to reduce its emissions by 100% on a linear trajectory to 2050: during the four decades to 2050, it will utilize 44%, 31%, 19% and 6% of its budget. The milestone established will then fit in seamlessly with the interim targets for Group 1 – but allows ever greater flexibility the lower the current per-capita emissions of a country are. Conversely, this rule allows a country which is only required to reduce its emissions by 10% under the budget to increase its emissions substantially at the start. For Tunisia, for example, with 2.9 t CO_2 per capita per year, emissions growth of 135% for 2010–2020 is permissible, enabling it to continue along a 'business as usual' pathway at first. Due to the limited budget up to 2050, however, there would still be a strong and direct incentive to engage in climate change mitigation. For China, whose current emissions of 4.6 t CO_2 per capita per year place it mid-range in this group, a 10% emissions rise between 2010 and 2020 would be permitted; this represents a substantial reduction compared with a 'business as usual' scenario and would therefore entail major mitigation efforts.

Group 3: This group would manage without short-term milestones but should commit to submitting verifiable decarbonization road maps. These would then also form the natural basis for these countries to benefit from joint climate change mitigation projects with industrialized countries via emissions trading.

5.4 The institutional architecture: A world climate bank and advanced flexible instruments

When implementing the budget approach proposed by WBGU, care needs to be taken that no individual countries or groups of countries postpone the requisite emissions reductions to such an extent that the global budget for 2050 is exceeded after all, resulting in the 2°C guard rail being breached. In particular, it is essential to ensure that individual countries do not make wasteful use of their CO_2 emission allowances in early phases of the budget period and thus become 'carbon-bankrupt' later – a process that can be further strengthened by technological lock-in effects. National decarbonization road maps are an effective means of preventing such misguided development trajectories.

These road maps should be guided not only by the allocated CO_2 budgets, but also by national capacities to reduce emissions, as in order to comply with the 2°C guard rail it will be essential to make maximum use of all globally available abatement options (McKinsey, 2009b). The decarbonization road maps would, however, need to be scrutinized regularly as to their plausibility and feasibility by an international, independent and central institution. For that purpose, WBGU proposes the establishment of a *world climate bank*.

The world climate bank would have several other important tasks, including the monitoring of the actual emissions of countries or country groups and the imposition of sanctions. To ensure in a systematic manner that budgets are not exceeded, it would be helpful to set national milestones referenced to manageable time periods (e.g. five or ten years). As a general principle, these interim targets should be included in the national decarbonization road maps. In the event that a milestone is missed, the world climate bank would undertake an intensive review of the road map in cooperation with the respective national institution, and would set new targets or corridors for emissions reductions.

When implementing the budget approach, the industrialized countries in particular would need to decide to what extent they wish to undertake the necessary greenhouse gas reductions at home or would rather make use of flexible mechanisms (emissions trading, Joint Implementation) which permit cost-efficient fulfilment of national reduction commitments.

To allow inter-country emissions trading, the national budgets would need to be divided into tradable allowances. Group 3 countries would be the main suppliers of allowances, as even Group 2 countries would probably only be able to generate small emissions surpluses over the entire budget period. Emissions trading would present novel prospects for income generation for the suppliers of emission allowances.

For climate policy to succeed, it will be essential that those Group 3 countries that do not fully exploit their emissions budget even while experiencing rapid economic growth invest their revenue from the sale of allowances in low-emission technologies, rather than remaining on fossil trajectories. Thus not only national decarbonization milestones should be set; there schould also be a partial earmarking of revenues from inter-country emissions trading. In such a scheme, a substantial proportion of this revenue should be invested in low-emission technologies, especially for energy production from renewable sources.

Joint Implementation (JI) is a further flexible mechanism established by the Kyoto Protocol. JI allows countries subject to reduction commitments to create additional domestic emission rights by carrying out emissions reduction projects in other countries that have also entered into commitments to limit emissions. Within the budget approach proposed by WBGU, Joint Implementation creates incentives for industrialized and other high-emission countries to invest in mitigation technologies in developing countries and emerging economies, i.e. Group 2 and Group 3 countries. For Group 2 and 3 countries that are unable to sell emission rights, JI is a promising mechanism by which to finance their transformation processes. The basis for this mechanism would be substantially broadened compared to the Kyoto Protocol, as national CO_2 emissions budgets would be allocated to all states, with the Clean Development Mechanism (CDM) being merged into Joint Implementation.

Moreover, the budget approach creates a variety of incentives for North-South partnerships. Such partnerships are based on bilateral agreements pledging mutual support in the implementation of decarbonization road maps. The world climate bank could play an extremely important role here, notably in identifying such partnership projects and in finding suitable partners.

Both flexible mechanisms should be administered by the world climate bank. In its capacity as global budget administrator, the bank would register transfers and would need to verify these against strict criteria. The world climate bank would thus coordinate national emissions budgets that are linked via the flexible mechanisms and at the same time monitor compliance with the global budget. Not least, the bank would need to monitor the development over time of national and thus global emissions, in order to ensure compliance with the 2°C guard rail. In particular, it is important to ensure that global CO_2 emissions start to decrease at some point during the period from 2015 to 2020 (Sections 3, 5.3) and reach very low levels towards the year 2050. In order to ensure that global CO_2 emissions actually peak prior to 2020, it would be expedient to structure the use of the flexible mechanisms by introducing trading periods.

In addition, through the granting of loans for abatement measures, the world climate bank could perform an important role in financing the implementation of national decarbonization road maps. It is possible that – depending upon the start year set for the budget period – some states, especially Group 2 countries, will require financial support, as they can only generate limited revenue from emissions trading. Furthermore, the world climate bank could also administer a fund established to finance adaptation and forest conservation measures (Section 5.5).

The world climate bank will only be able to perform the tasks set out above if it is equipped with sufficiently far-reaching powers and is also able to impose effective sanctions, for example in the case of impending or actual exceedance of allocated national emissions budgets. The sanction rules should be publicized at the beginning of the budget period and should be sufficiently effective to create strong incentives to remain within budget.

The advantages of a world climate bank in the context of the budget approach can be summarized as follows:

- The monitoring, regulatory and sanctioning activities of the world climate bank allow *temporal and regional flexibility*, thus ensuring that the global CO_2 budget is not exceeded.
- Transfers of emission allowances not required by their holders are coordinated in a way that generates substantial *revenue and development potential* for the selling countries.
- The existence of verified, mandatory decarbonization road maps and national milestones, in conjunction with monitoring and sanctions, greatly enhances the *credibility* of the individual countries with regard to their willingness to engage in transformation.

5.5
Financial transfers under the budget approach

Substantial financial resources will need to be mobilized in order to implement countries' decarbonization road maps. In Group 1 countries, large amounts of capital will be required for radical innovations, investment in low-emission technologies and the installation of sustainable infrastructures. The developing countries and emerging economies in Groups 2 and 3 will also need substantial financial resources if they are to embark upon low-carbon development pathways. These resources are required in order to deploy appropriate technologies, but also to prevent deforestation (Reducing Emissions from Deforestation and Degradation, REDD). Furthermore, extensive measures need to be financed worldwide in order to adapt to the already inescapable climatic changes and their significant impacts within the 2°C guard rail.

The following sections examine financial transfers for mitigation, adaptation and REDD, mainly in the form of allowance trading and mandatory payments arising from historical responsibility for emissions.

5.5.1 Financial transfers for climate change mitigation: Emissions trading

The most recent estimates of global mitigation costs per annum – i.e. the additional investment required to avoid dangerous climate change – arrive at several hundreds of billions of US dollars. For instance, the UNFCCC Secretariat estimates that in the year 2030 up to US$ 350 billion in additional investment funding will be necessary, of which around half will be required in developing countries (UNFCCC, 2008). Other estimates also arrive at sums – rising year on year – of a similar magnitude over the period from 2010 to 2030 (IEA, 2008; McKinsey, 2009b).

Emissions trading

It can be assumed that even if all short-term emissions reduction potentials are identified and exploited, Group 1 countries are unlikely to succeed in remaining within their allocated budgets. The industrialized countries' demand for additional emission rights will therefore presumably be very large. This will result in extensive capital and technology transfers via emissions trading (and also through intergovernmental agreements on the exchange of emission allowances) or Joint Implementation. The sample transactions outlined in Figure 5.3-5, which show the industrialized countries purchasing emission rights totalling 120 Gt CO_2 between 2010 and 2050, are an entirely plausible thought experiment. Making the conservative assumption that allowance prices are € 10–30 per t CO_2, this would be a financial transfer amounting to € 1200–3600 billion over the entire period, thus an average monetary flow of € 30–90 billion per year. A major contribution could thus be made via emissions trading to the requisite future investments in developing countries and emerging economies. The world climate bank should coordinate and support such market-based processes in such a way that the less developed countries, in particular, can also participate.

Private-sector resources

Emissions trading can only generate part of the required mitigation funding. It follows that those states which generate substantial revenue from emissions trading should use this as leverage to mobilize further private resources. A ratio of 3:1 to 4:1 for the deployment of private to state resources appears appropriate and realistic (Capoor and Ambrosi, 2008). Low-interest loans and guarantees, financed largely from revenues generated by emissions trading, could be used to attract private investors, especially in developing countries and emerging economies, to participate in the transformation process. 'Matching funds' are a further option, in which funds deployed by the private sector to finance mitigation measures are matched by government funds amounting to a certain percentage of the private investment.

Loans and grants

If revenues from emissions trading and other flexible mechanisms should not suffice to implement the decarbonization road maps of certain countries (presumably those in Group 2 in particular, which will profit minimally or not at all from emissions trading), the world climate bank should be able to access a fund for loans and grants. This would become all the more relevant the less the historical responsibility of high-emission countries is taken into account, i.e. the further the start year of the budget period is shifted from the past into the future (Section 5.2). This fund could be resourced in various ways.

One option under the budget approach would be to provide resources, in line with the polluter pays principle, from compensation payments made for historical emissions. The start year of the budget period (T_1) determines to what extent past CO_2 emissions have an impact on national budgets. This start year must be set through political compromise. In Section 5.3, WBGU discusses two options for designing the budget approach, whereby Option II does not include emissions arising before 2010. A possible method to determine corresponding compensation payments would be as follows: first of all, the historical emissions not included in the budget calculation – for instance CO_2 emissions between 1990 and 2009 under Option II (Section 5.3.2) – are added up (Table 5-3.1). Then this sum is compared to the fictitious overall emissions which the country would have generated over the same period assuming that per-capita emissions were identical worldwide. This fictitious sum is obtained by multiplying actual global emissions over the period from 1990 to 2009 with the country's share of the global population (Table 5-3.1). The difference between the fictitious and actual emissions would be priced with a monetary value per tonne CO_2. This price must be determined politically and should be guided by the marginal damage costs or allowance prices of CO_2 emissions. Collecting such annual compensation payments from the high-emission countries would be a further important task of the world climate bank. In terms of international efforts to generate financial resources, the bank would need to be in a position to impose effective sanctions on those countries which do not meet their payment commitments. Various sanction mechanisms are conceivable: joint-and-several liability rules for certain groups of countries, temporary exclusion from participation in the flexible mechanisms, or explicit penalty payments such as those already applied in the EU.

Another option of generating resources for this fund would be the international sale (fixed price or auctioning) of a share of the global emissions budget by the world climate bank. One variant of this option would be to retain from the outset a part of the global budget so that the emissions quantity to be allocated globally would be reduced. A different variant would be to withdraw a part of the national budget from Group 3 countries that are particularly well endowed with emission rights (a part corresponding roughly to the volume of emissions that could not be exhausted even if high levels of 'fossil' economic growth occur) and to redistribute it via the world climate bank. In all variants, the bank would need to sell suitable tranches at regular intervals in order to generate a steady revenue stream. Countries in Groups 1 and 2 would be the purchasers of these emission allowances. Both variants would, however, result in certain problems of equity, as the ability-to-pay of the affected countries is likely to diverge widely. Poorer countries would thus be disadvantaged when purchasing allowances. Moreover, Group 3 countries could feel disadvantaged, as they would not be able to dispose of the emission rights allocated to them with complete freedom.

A third option for the generation of resources would be to impose a levy on the use of the flexible mechanisms. Such a levy is already being imposed on the Clean Development Mechanism (CDM) in the first commitment period of the Kyoto Protocol, by retaining 2% of the certified emissions reductions generated and channelling them to the Kyoto Adaptation Fund. Under the budget approach, this method could be applied to emissions trading and to JI, and the revenue utilized for the world climate bank fund mentioned above. One disadvantage, however, is that it could constrain the flexible mechanisms – mechanisms which would need to be expanded greatly under the budget approach.

In addition, WBGU proposes a levy on international shipping and aviation. Deploying these levies to replenish the world climate bank fund would be a straightforward process. The greenhouse gas emissions arising from international shipping and aviation are not yet subject to any restrictions, and their attribution to individual states is problematical. In aviation, for instance, payments could be collected in the form of a ticket levy (WBGU, 2002).

5.5.2
Financial transfers for adaptation and forest conservation: Funds with mandatory contributions

Adaptation to climate change

Various estimates indicate that adaptation measures will require annual investment, rising over the years, in the region of several tens of billions of US dollars. As it is the developing countries which will be particularly severely affected by the impacts of climate change, it is in these countries that the greatest need for adaptation arises. The UNFCCC Secretariat expects annual adaptation costs of US$ 28–67 billion in developing countries around 2030 (UNFCCC, 2007, 2008). According to the Stern Review, adaptation costs of US$ 4–37 billion per year are already arising today in the corresponding regions (Stern, 2006).

In order to finance such adaptation measures, WBGU proposes establishing a binding mechanism under international law. All new and existing funds for adaptation should be brought together within the existing Kyoto Adaptation Fund, in order to ensure transparency of funding streams and thus the efficiency of resource deployment. Under the budget approach, the financing of this fund could be placed on a far more robust basis: *firstly*, it would be replenished with mandatory contributions whose overall level would, *secondly*, need to be determined by actual adaptation requirements. Without enlarging on the second point at this stage, WBGU notes that an independent, international scientific commission supported by the world climate bank could identify, at regular intervals, the global and national funding requirements for adaptation measures and for compensation for climate damage. The estimates produced by this commission should build upon the extensive preliminary work performed within the UNFCCC process (e.g. the Nairobi Work Programme, and the National Adaptation Programmes of Action). When determining adaptation requirements, the commission should take particular account of those climate impacts that will occur even if the 2°C guard rail is not breached. The assessments should include both the investment costs for an optimal adaptation strategy, and the costs of damage caused by climate change that cannot be prevented by even the best adaptation measures.

The mandatory contributions from individual states that would result under such a scheme would then be based on the historical responsibility of countries for CO_2 emissions. Under Option II (Section 5.3.2) this refers to the period between 1990 and 2010, whereby the method for assessing contributions set out above could also be applied. All those countries whose emissions exceed their 'fair' amount in the period under review would then have to make a corresponding financial contribution. The total volume of payments, however, would correspond to the overall requirement determined, whereby each country would make a contribution in proportion to the difference between its released and fictitious emissions.

These contributions could be generated within the countries from the revenues from a national CO_2 tax or from the auctioning of national emission rights. As part of the international scheme for generating financial resources, the world climate bank would need to be in a position to sanction those countries which do not make their mandatory contributions.

The above-mentioned levies on international shipping and aviation could also be deployed for the adaptation fund.

Reducing emissions from deforestation

An independent fund, binding in international law and designed to provide financial compensation for reducing emissions from deforestation and degradation (REDD) in developing countries, should be established in a manner similar to that set out above for the adaptation fund (Section 5.7). The level of mandatory contributions could also be determined using the method set out above. This fund should, firstly, reward any reduction of deforestation rates beyond agreed targets and, secondly, support the establishment of protected areas for the sustained preservation of natural carbon reservoirs (Box 5.7-1).

WBGU advises, for several reasons, against including land-use-related CO_2 emissions in the budget approach – and thus in CO_2 emissions trading (Box 5.7-1). Developing countries could, however, deploy the revenues generated from emissions trading under the budget approach to reduce their deforestation rates, to the extent that this is envisaged in the earmarking of revenues. However, an independent source of funding for forest conservation is essential: firstly, because there is no direct link between revenues from emissions trading and the costs of forest conservation and, secondly, because funding must start to flow soon and reliably in order to reduce deforestation as swiftly as possible.

5.6 Ten arguments for the budget approach

The following arguments support applying the WBGU budget approach in international climate policy:

1. *Global responsibility, equity and precaution:* Linking the 2°C guard rail with a corresponding global CO_2 emissions budget, and with national budgets derived from it, places the international climate policy debate on a transparent and rational basis. Moreover, the approach rests on simple and credible principles of *equity*. This makes it easier for the Copenhagen decision-makers to present the summit outcomes convincingly in their national policy arenas.
2. *Radical simplification of climate negotiations:* Through its simple distribution formula for calculating national emissions budgets, the approach reduces the complexity of the climate negotiations. Decision-makers only have to agree once on the few parameters of the formula, instead of negotiating reduction commitments separately for each individual state.
3. *Foundation for an historical climate compromise:* The budget approach makes it possible to reconcile interests fairly and globally, because the states in all country groups have to accept responsibility for the future and make concessions. The principle of equality, together with the polluter pays principle, requires industrialized countries to enter into major reduction commitments and provide extensive transfers of technology and finance to developing countries. The developing countries and emerging economies need to accept that economic development based on fossil energy carriers is no longer viable and that they, too, will need to decarbonize their economies over the medium and long term, with the support of the industrialized nations. Their advantage is that they can avoid the drawbacks of fossil path dependency in a cost-effective manner.
4. *Transparent emissions budgets:* The budget approach creates major transparency worldwide concerning the (global and national) CO_2 emissions budgets still available. This makes it clear that many countries need to develop emissions reduction strategies without further delay, and underscores the speed with which action needs to be taken. It also becomes evident that economic development based on the use of fossil energy no longer has a future. For the private sector, this transparency results in stability, anticipatory certainty, and a clear system of incentives for investments in the future.
5. *Leeway at national level is linked with accountability at international level:* The budget approach improves the legitimacy and underscores the necessity of climate policy, because plausible, sustainable and internationally verifiable decarbonization road maps need to be developed on the basis of national budgets. National responsibility, flexibility to adopt solutions appropriate to con-

ditions on the ground and international accountability are linked.

6. *Incentives for long-term action:* The obligation to implement national decarbonization road maps, together with budget transparency, makes the long-term perspective an integral part of the logic guiding the actions of policy-makers and private-sector players.
7. *Scarcity increases efficiency:* The global and national CO_2 emissions budgets create scarcities that generate incentives for low-carbon patterns of production and consumption, and contribute to the creation of sustainable employment.
8. *Climate protection strengthens competitiveness:* Under the budget approach, every success in reducing emissions and improving energy efficiency is rewarded equally, regardless of the country in which it is achieved. CO_2 emissions reductions become a form of capital. This generates mitigation incentives in industrialized countries, emerging economies and developing countries alike. Climate protection becomes a key factor in boosting competitiveness.
9. *New prospects for international cooperation:* Industrialized countries whose emissions budgets are small or exhausted have an interest in climate technology partnerships with developing countries that have untapped mitigation potential. The 'carbon deficit countries' possess the financial resources, technology and knowledge that are urgently needed in the less-developed 'carbon surplus countries'. The complementary interests of individual states result in incentives for bilateral, multilateral and regional climate and decarbonization partnerships that assist developing countries through technology and financial transfers between partners of equal standing.
10. *Definite framework for a low-carbon world economy:* Quantitative limitations on both global and national CO_2 emissions budgets create clear incentives for the transition to a low-carbon age. A global frame of reference is provided for emissions trading, technology and financial transfers and decarbonization partnerships. The budget approach thus points the way forward beyond the climate negotiations in Copenhagen and outlines the future course towards a low-carbon world economy.

5.7 Options to accelerate climate protection and extend the budget approach

The WBGU budget approach presented above covers and administers CO_2 emissions from fossil sources, and thus takes account of around 60% of total greenhouse gas emissions. The CO_2 quantities released by other activities, such as land use, land-use change and forestry (LULUCF), should not be addressed under the budget approach, but should be covered by sep-

Box 5.7-1

Reducing CO_2 emissions from deforestation and land-use change

Emissions from land use and land-use change should be treated separately from the emissions generated by fossil energy use, and therefore should not fall under the budget approach. The CO_2 dynamics associated with the terrestrial biosphere differ substantially in many fundamental aspects – such as measurability, reversibility, long-term controllability, interannual fluctuations – from the CO_2 fluxes associated with the industrial use of coal, mineral oil or natural gas (WBGU, 2008). There is thus a strong scientific argument for restricting the opportunities for reciprocal offsetting of emissions from the two sectors.

WBGU thus recommends the negotiation of a comprehensive, separate agreement on the conservation of the carbon stocks of terrestrial ecosystems (WBGU, 2003), which should replace the previous rules on land use, land-use change and forestry (LULUCF). Such an agreement could become effective very rapidly and could lead to substantial CO_2 emissions reductions worldwide.

Under this agreement, all countries should commit to preserving their carbon reservoirs effectively. The greatest priority should be given to rapidly reducing emissions from deforestation and degradation in developing countries (REDD). These currently account for around 17% of global emissions of persistent greenhouse gases (IPCC, 2007c). WBGU takes the view that a REDD agreement within the UNFCCC should be designed in such a way that it generates rapid real emissions reductions and at the same time creates incentives for the sustainable protection of natural carbon reservoirs (such as tropical primary forests) from deforestation and degradation.

Combining national reduction targets and designating protected areas is a suitable strategy. For instance, the participating developing countries could commit to reducing their future national emissions from land-use change by specific absolute or relative values. When emissions are reduced beyond the agreed extent, financial transfers would be made from a fund (Section 5.5). This would create a strong incentive to accelerate the reduction of LULUCF emissions, which are considerable at present; at the same time, such a scheme would underscore the joint responsibility of developed and developing countries for climate change mitigation. In addition, participating developing countries should receive financial support when they give nature conservation status to areas of acknowledged relevance. The agreement would therefore need to mobilize a sufficient volume of international financial transfers (Section 5.5).

arate rules (Box 5.7-1). In order to accelerate emissions reduction, the fluorinated greenhouse gases (industrial gases) regulated under the Kyoto Protocol could be treated in a manner modelled on the Montreal Protocol (Box 5.7-2). The other persistent greenhouse gases regulated under the Kyoto Protocol could in principle be integrated within the budget approach.

In addition, there are several short-lived radiative forcing substances such as ground-level ozone and soot particles that are not regulated at all under the Kyoto Protocol. It is extremely important that states commit at the Copenhagen climate summit to drastically cut, through national-level regulations, the ground-level concentration of ozone and the emissions of soot (Box 5.7-3).

As WBGU has shown, if the 2°C guard rail is to be obeyed with acceptable probability, radical fossil CO_2 emissions reductions will be required. The speed with which reduction measures need to come into effect gives particular cause for concern. Minimizing the above-mentioned short-lived radiative forcing substances would be extremely cost-effective with the present state of knowledge – and would deliver valuable climate relief.

Box 5.7-2

Fluorinated greenhouse gases

Beside carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), the Kyoto Protocol also regulates fluorinated greenhouse gases, namely sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). Considering the success achieved by the Montreal Protocol and its mechanisms in protecting the stratospheric ozone layer, treating PFCs and HFCs differently from CO_2, CH_4 and N_2O merits consideration. Separate regulation of these gases under the UNFCCC, inspired by the relevant provisions enacted under the Montreal Protocol, could deliver a simpler and far more rapid reduction of these radiative forcing substances. As for the gases causing depletion of the stratospheric ozone layer, substitute substances and alternative technologies are already available on the world market for fluorinated greenhouse gases with a high warming potential (Molina et al., 2009). This makes such a narrowly defined approach possible and attractive. A combination of rapid emissions reductions in industrialized countries at manageable cost and transitional periods for developing countries, which would require support from a multilateral fund to make the necessary transition, would greatly simplify the UNFCCC architecture while delivering rapid reduction of industrial gases at the same time. The latter is all the more important as the Montreal Protocol could in fact trigger a steep rise in HFC emissions (Velders et al., 2009): HFCs are often used as substitutes for gases whose production has already ended or will soon be phased out under the terms of the Montreal Protocol.

Box 5.7-3

Short-lived radiative forcing substances

There are a number of components of the atmosphere which are short-lived but can generate a substantial radiative forcing effect. These include, in particular, soot particles (black carbon) – with an atmospheric residence time of a few days – and ground-level ozone, which is formed in the atmosphere from precursor substances such as nitrogen oxides (NO_X), carbon monoxide (CO) and hydrocarbons and has a lifetime of a few months. Climate policy has not yet taken account of these components. The IPCC (2007a) notes, however, that atmospheric soot particles currently make a direct warming contribution of around 0.2 W per m^2 (Chapter 2), while soot deposited on snow surfaces contributes an additional 0.1 W per m^2 radiative forcing. More recent estimates even posit a contribution of up to 0.8 W per m^2 (Wallack et al., 2009), which may be equivalent to 20–50% of the warming effect of CO_2. Regionally, above all in glacier and ice-covered areas, the contribution of soot to warming may even be greater than that of CO_2. Ground-level ozone contributes 0.35 W per m^2, which is around 20% of the warming effect of CO_2.

Due to the short lifetime of these components, their atmospheric concentration (and therefore also their contribution to global warming) is not determined by historical emissions as in the case of persistent greenhouse gases, but is almost entirely attributable to their release in the very recent past. Policy-driven reduction measures can therefore have a much more rapid effect, as they would not only limit accumulation but rapidly reduce the concentration itself. This would make it possible to attenuate human-induced global warming by a significant amount as a one-off measure. Wallack and Ramanathan (2009) estimate that reducing tropospheric ozone by 70% and soot particles by 50% could reduce global warming almost instantaneously by 0.5°C. This could compensate for the cumulative effect of 30 years of CO_2 emissions at their present level.

The overall picture is, however, very much more complex: many aerosols with an overall cooling effect on the atmosphere (e.g. sulphate droplets) come from the same sources as soot particles. If, then, improved capture of the soot coming from power plant emissions removes sulphate aerosols at the same time, this also removes a part of the desired climate-stabilizing effect.

Furthermore, the relative cooling effect delivered by the atmospheric reduction of soot particles can only be achieved once. It follows that the general warming trend can only be halted if the emissions of CO_2 and other long-lived greenhouse gases that accumulate in the atmosphere are also reduced greatly. The future world climate treaty should therefore contain a separate commitment concerning the national-level reduction of the above-mentioned short-lived radiative forcing substances. This would be a useful and important complement to the budget approach for CO_2 emissions. It should not, however, be mistaken for an alternative.

Making the transition to a low-carbon society 6

The budget approach developed by WBGU not only offers a way out of the negotiation dilemma set out above (Chapters 1, 4), but also charts the course towards a low-carbon world society. Whether the essential 'Great Transformation' (Polanyi, 1944; Nobel Cause Symposium, 2007) can succeed within the narrow remaining window of opportunity will depend upon the ability of the relevant players (especially the USA, China, the EU and India) to work together and upon our societies' capacity for technological innovation and political reform. The urgency of effecting a transformation is countered at all levels by cognitive blockages and institutional path dependencies, a lack of long-term perspective, an unwillingness among individual and collective decision-makers to tolerate losses, and the power of stakeholder groups to block processes. The following sections outline ways to remove these barriers and exploit available transformative potential.

6.1 Accelerating technological change

Achieving the greenhouse gas emissions reductions called for by the 2°C guard rail will require a technological quantum leap on an historically unprecedented scale. Electricity generation, which presently contributes around 40% of global energy-related greenhouse gas emissions, plays a key role in this regard. Worldwide electricity demand is expected to double by 2030 compared to the 2000 level. This trend is due only in part to the rapidly rising levels of demand in newly-industrializing countries (IEA, 2008). Further factors driving worldwide demand for electricity upwards include the broad-scale introduction of electric vehicles, the further spread of electric heat pumps and air-conditioning systems, but also the rapidly expanding use of information and communication technologies.

Because of the long operating lives of power plants – typically 40–60 years – innovations need time to become established in practice. Decisions on which power plant technologies to use therefore have strategic character, for they set future emission pathways on systemic trajectories. This makes technology, knowledge and policy transfer particularly important in this field (Boxes 6.1-2, 6.1-3 und 6.1-5). Calculations using integrated assessment models, in which the economic and climate system are dynamically linked, show that if dangerous climate change is to be prevented no more than 25% of global investment in generating plant should go to conventional fossil systems from the year 2010 onwards. Indeed, this share must drop below 20% by 2020, by which time more than 80% of investment would go to new, practically zero-emission power plants (IIASA, 2009). There are essentially three options for this transformation of the generating mix towards low-carbon structures: firstly, the utilization of fossil energy carriers with carbon capture and storage (CCS); secondly, nuclear power; and, thirdly, the massive expansion of renewables (wind, solar, hydro, biomass, geothermal etc.).

Carbon Capture and Storage

CCS technology is still at an early stage of development worldwide. Its broad-scale deployment is not anticipated before 2015 or 2020. In some countries there is considerable resistance to this technology, not least because the actual potential for long-term storage of CO_2 in underground repositories is still highly uncertain. The IPCC estimates the global storage potential in oil and gas fields and coal seams to be 700–11,000 Gt CO_2, and has identified an additional potential of 1000–10,000 Gt CO_2 in aquifers (IPCC, 2005). In previous reports, WBGU has identified a secure global storage potential amounting to around 1100 Gt CO_2 (WBGU, 2004). WBGU's special report on the oceans has shown that the retention period in CO_2 repositories needs to be at least 10,000 years (WBGU, 2006). WBGU further recommended that while CCS technologies should continue to be developed, their deployment should be limited both in time and in quantity in order to mitigate the risk of uncontrolled returns of carbon dioxide to the atmosphere (WBGU, 2006). For these reasons, CCS-capable power plants fired with fossil fuels are considered – even in a global perspective – to be at best

Box 6.1-1

Transforming energy systems – a labour market opportunity

Transforming global energy systems towards more efficient end use and renewable energy sources also improves general employment prospects. In many cases, investments in the relevant fields lead to macroeconomic growth in employment in net terms – i.e. taking account of all the adjustments triggered by the investments. One adjustment commonly to be expected is that if renewable energies are increasingly promoted jobs will be lost in fossil energy production (substitution effect). Similarly, the still relatively high market price for some forms of renewable energy supply may lead to temporarily reduced disposable household income (income effect), with a negative impact on consumer demand and thus on employment. Both effects, however, are outweighed by additional jobs in sustainable energy generation and in the sectors concerned with energy efficiency. One reason for the positive overall employment effect is that supplying renewable energies and carrying out efficiency improvement measures is often relatively labour-intensive. Furthermore, many jobs at component suppliers are linked to the expansion of renewables. Cost savings are also generated by reduced energy consumption and fewer imports of expensive energy carriers from abroad; these resources can then be reinvested domestically (BMU, 2006; Jochem et al., 2008).

It is not yet possible to make any precise forecasts of anticipated employment growth. For the German labour market, for instance, Jochem et al. (2008) expect that implementation of the German federal government's Integrated Energy and Climate Programme, adopted in August 2007 (the Meseberg Programme), may create around 500,000 new jobs by 2020 in gross terms, i.e. before taking account of possible job losses in other sectors. If Germany were to gain a clear competitive edge on the world market as a pioneer of climate change mitigation technologies, a further 200,000 jobs could be created between 2015 and 2025. McKinsey (2009a) even anticipates 850,000 new jobs by 2020 in gross terms if Germany maintains and further expands its leading position in the renewable energy and energy efficiency sectors. A study by the German Environment Ministry (BMU) finds that vigorous expansion of renewable energies alone could create more than 130,000 jobs in Germany in gross terms by 2020, of which 70,000 would be net additional jobs (BMU, 2006).

Kammen et al. (2004) estimate for the USA as well that the transformation towards renewable energies will deliver higher growth in employment than continued investment in fossil energy use. If renewables and energy efficiency were promoted in tandem, the creation of new employment would accelerate further. Houser et al. (2009) and Pollin et al. (2008) arrive at similar results, based on comparative estimates for the USA of the employment effects of 'conventional' and 'low-carbon' economic stimulus programmes. Over a relatively short study period of one to two years, these studies find that investments in renewable energies, sustainable infrastructure development and energy efficiency lead to around 20% more new jobs than under reference scenarios based on continuation of the present patterns of energy use.

a medium-term and transitional solution, and indeed one that has yet to show that it can compete economically with other low-carbon technologies. CCS may, however, become important in later stages of the climate protection process, if it should become necessary to actively withdraw CO_2 from the atmosphere ('negative CO_2 emissions'), for instance by sequestering CO_2 emissions from biomass use (WBGU, 2009). Such a strategy would only come fully into effect, however, when the industrial energy system has already been largely decarbonized.

Nuclear power

WBGU does not consider the expansion of nuclear power – currently generating around 16% of global electricity demand from some 400 reactors with an average capacity of 0.85 GW – to be a geostrategically viable way out of the climate dilemma. Given the anticipated growth in global electricity demand by 300% by mid-century (IAEA, 2008), generation from nuclear reactors would have to grow by the considerable factor of 6 if nuclear power were to make any significantly larger contribution to the power generation portfolio (e.g. 30%). This would require the additional construction of around 1000 large reactors of 1.6 GW capacity each by 2050. The fuel required for this could presumably only be supplied by introducing breeder technology and thus through large-scale plutonium generation. Quite apart from the problems of proliferation and terrorism and other security issues that would result, there is to this day not a single successful and accepted project for the final storage of nuclear fuels.

Renewable energies

Renewable energies are the option preferred by WBGU. They have the potential to meet global energy requirements now and in the future. On the cost side, they can already compete in certain respects with conventional generating plant (e.g. wind power in favourable locations) and can be introduced at present with still high growth rates (above 20% per year) if suitable incentive structures are in place. Over the coming decades, both sustainable bioenergy use and wind power can make the greatest contributions to transforming energy systems, thanks to their robust competitiveness and the capacities already in place today. Solar energy, with its practically unlimited potential, will then become the dominant technology around mid-century; one reason for this is that other technologies, especially bioenergy use, may be expected to encounter sustainability limits (WBGU, 2009).

Substantially improved network structures that permit transmission and integration across great dis-

Box 6.1-2

Technology, policy and knowledge transfer under the WBGU budget approach

The budget approach proposed by WBGU generates incentives for the international transfer of technology (Sections 5.4 and 5.5). If the 2°C guard rail is not to be breached, it will be essential to rapidly introduce low-carbon processes in developing and newly-industrializing countries. This needs to be accelerated through intense cooperation between the industrialized and developing countries. Protection of intellectual property rights should be considered.

Flexible mechanisms such as emissions trading and Joint Implementation can help to finance technology and knowledge exchange and can foster the global dissemination of low-carbon processes and systems (Chapter 5). A number of conditions determine the success of technology and knowledge transfer. Technology transfer must comprise both the technology and the knowledge needed to maintain and operate it. Furthermore, if low-emission technologies are to operate efficiently, the technology recipient must be placed in a position to adapt the technologies to local circumstances (incremental innovation). In order to reduce costs, local manufacturing capacities need to be established. To ensure the long-term, broad-scale and rapid application of low-emission technologies, dissemination must be fostered by implementing appropriate national environmental and energy policies.

The Top Runner scheme developed in Japan is an example of energy policy that fosters the development and diffusion of low-carbon technologies in a competitive setting (Kikkawa, 2009). It aims to increase energy efficiency by making the most efficient appliance the standard within a given sector.

Establishing joint research and training facilities is a further element of intensified cooperation. This makes it possible to jointly refine and adapt existing technologies to the conditions prevailing in a given partner country.

tances (super-grids) are a key precondition to an integrated electricity system fed essentially from renewable sources. These networks must be able to respond flexibly to fluctuating and distributed feed-in, as well as to changed conditions of use (e.g. through a massive expansion of electromobility), and therefore need to be made ‘intelligent’ with the support of advanced information and communication technologies (‘smart grids’, ‘inter-grids’). ‘Super-smart grids’ are designed to meet both requirements (Box 6.1-4). WBGU takes the view that building such highly advanced structures is the most important precondition for the accelerated use of renewable energies, and also for the comprehensive implementation of efficiency-boosting innovations and measures. Examples of the latter include electromobility, as already mentioned, but also combined heat and power generation (CHP) and electric heat pump systems. It will certainly not be possible to build such novel and comprehensive infrastructures through market-based mechanisms alone. It will further require strategic and proactive action at government level and the creation of an appropriate regulatory framework in both statutory and institutional arenas.

Improving efficiency

Without suitable regulatory and supporting policy measures, in some regions of the world demand for electricity will grow more rapidly than renewable generation capacities. As is the case in processes of technology diffusion in general, the sustainable transformation of the energy system will be the outcome of exponential dynamics, delivering relatively small contributions in the initial phase, but growing very rapidly later on. Transformatory efforts aimed at a low-carbon primary energy supply must therefore be complemented by demand-side efforts, particularly at the beginning of the process. This needs to be done by realizing comprehensive strategies for efficiency improvement in energy use across all sectors of industry and society. Many of the resultant investments in end-use efficiency will also have positive labour market effects and other benefits (Box 6.1-1). In the first decade of the Great Transformation, this efficiency revolution may even make the prime contribution to emissions reduction. Research and promotion programmes such as the ‘high-tech strategy for Germany’ initiated by the German federal government are essential (BMBF, 2006). In tandem, investments in renewable energy systems build the long-term foundations for decarbonization.

Costs

Implemented consistently and intelligently, a combination of the strategies outlined above not only permits sustainable transformation of global energy systems, but is also more cost-effective over the longer term than ‘energy business as usual’: the investments required from 2010 to 2050 to establish global electricity supply systems based on low-carbon sources, including the super-smart grids that need to be constructed, total around 21,000 to 34,000 billion US dollars, depending upon the global development of the population and economy. This sum is only 10–39 % higher than investment costs in conventional scenarios (IIASA, 2009). Savings delivered by efficiency improvements, more efficient energy use and avoided expenditure for fossil energy carriers (especially if solar, wind and hydro sources are used) would largely offset these additional investment costs. Indeed, in some plausible transformation

Box 6.1-3

An example of policy transfer: A worldwide feed-in payment scheme for renewable energies

The successful mechanism established in Germany by the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz – EEG) has triggered strong innovation dynamics in that country and elsewhere: currently more than 30 states use this instrument, including developing and newly-industrializing countries such as Brazil, South Africa, Indonesia and China (REN21, 2009). The limitation, however, is that all the EEG-based schemes support national-level energy supply. No support can be provided for electricity from regions beyond a national boundary, even if the conditions for harnessing wind and solar sources are more favourable there. The creation of a transnational EEG-type mechanism for larger regions such as the EU or the Middle East could mitigate this drawback and deliver a huge innovation impetus. Furthermore, extending the scheme's geographical scope would have the advantage that – in tandem with the growth of the area in which support is given based on uniform criteria – more and more renewable sources would feed into the grid; this could increasingly help to level out fluctuations in power input. Such institutional-technological integration would produce excellent prospects for partnerships among many countries. The integration of national economies would at the same time help to safeguard peace. The costs associated with introducing a transnational or even global EEG-type mechanism could either be shared among by all electricity consumers, as is the case in Germany, or could be covered by an international form of financing.

Box 6.1-4

An example of technology transfer: Transnational 'super-smart grids'

Super-smart grids respond flexibly to the fluctuations in the amount of power fed into the grid by wind and solar generating systems; such fluctuations are often rapid and strong. Super-smart grids also involve consumers in overall energy management, and therefore allow to take account of peak loads when balancing electricity supply and demand. Such grid technologies and structures, combined with a much more far-reaching spatial integration, are key preconditions for the unrestricted integration of fluctuating sources in future power generation portfolios. In contrast to the renewable energy sources themselves, which are decentralized by their nature, the grids of the future are strategic infrastructures that need to be planned and realized centrally. They are comparable in this regard – and with regard to their operation – to road or railway networks. The electricity transmission capacity of modern super-smart grids would be several times greater than that of present networks.

Box 6.1-5

An example of knowledge transfer: Joint research and training

In addition to transferring existing technologies, research cooperation arrangements among industrialized, newly-industrializing and developing countries could also serve to newly develop or refine technologies. The joint research findings should then be made freely available to industry. Research partnerships will also be needed to keep initial and advanced training in developing and newly-industrializing countries at the cutting edge of science and technology. Cooperation should therefore embrace all levels of training, research and industrial cooperation. It is important to ensure that the exchange of information and knowledge takes place between teaching, science and the private sector on the one side, and among the participating countries as well. System analyses would be particularly suitable research themes (production, storage and distribution of renewable energies; electricity grids of the future; electric drives in transport; air-conditioning in buildings; use of biomass as an energy source etc.). Training should encompass Masters courses and doctoral theses.

scenarios costs are lower over the long term than in the fossil reference scenario.

6.2 International revolution in cooperation

The task is global and Herculean

If nations continue their consumption of fossil energy carriers at present levels, there is a real risk that they will cause irreversible damage to the Earth System and lead humankind into an unstable, conflict-laden future (WBGU, 2008). The main emitters are thoroughly capable of accelerating the climate crisis by refusing to cooperate; this applies to the industrialized countries which bear the greatest responsibility, but also to populous emerging economies such as China and India and to nations that have large areas of forest with high rates of deforestation at present, such as Brazil, Indonesia, Malaysia, Myanmar and the Democratic Republic of Congo (Bauer and Richerzhagen, 2007). The negotiation deadlocks encountered on the path to Copenhagen demonstrate this situation. The result is a kind of 'Mikado game': whoever makes the first move appears to have lost (Depledge, 2005; Ott et al., 2008).

International climate policy needs to untie this Gordian Knot and to launch a broad-scale process of ‘carbon disarmament’ in December 2009 in Copenhagen. The acknowledgement by the 16 major economies (Major Economies Forum on Energy and Climate, to which the G8 also belongs) of the importance of the 2°C guard rail at the G8 summit in L’Aquila in July 2009 was a major success that must now be translated into tangible reduction action. As the peak year of global emissions needs to be in the period from 2015 to 2020, cooperation in global climate policy must accelerate and deepen considerably from now on and throughout the coming decades in order to achieve a breakthrough towards a low-carbon world economy.

A global and Herculean task is emerging. This will involve establishing emissions trading for all countries, setting up a world climate bank, promoting global efforts to create an energy system that becomes increasingly independent from fossil energy carriers, engaging in international strategies to develop low-carbon urban structures, adopting international energy and carbon efficiency standards and assisting developing countries in adaptation to climate change. Initiating and managing the exit from the age of fossil energy carriers calls for ‘global climate governance’.

The normal mode of international policy will not suffice

The ‘normal mode’ of international cooperation is too slow for this task, for it tends to narrow agreements down to the lowest common denominator and follows the logic of national interests and competition among nations (Chasek, 2001; Newman et al., 2006). Previous attempts to integrate national and international interests have proceeded too slowly; examples include the poor outcomes from the World Trade Organization (WTO) rounds, the Millennium Development Goals (MDGs) which have remained largely in the realm of rhetoric, and even policy processes within the most advanced arena of transboundary cooperation, the European Union. This means that the conviction – widespread among policy-makers – that in a closely interconnected world the growing number of global problems can be solved only through global governance has not yet been translated into the desired acceleration and routineness of international cooperation. Traditional power structures, unclear amalgamations and divergences of interests and the complexity of negotiation processes have also hampered the Kyoto process involving up to 192 states (Victor, 2007).

Successful climate policy guided by the 2°C guard rail is therefore reliant on a substantive and institutional redesign of international cooperation. There are few precedents for this in history, with the exception of the reform policy launched by Mikhail Gorbachev, which was completely unexpected at the time. The Soviet president had accepted the reality that the real-socialist model was bankrupt and that maintaining the rigid pattern of confrontation between East and West would accelerate the economic and political decline of the Soviet Union and its allies and would heighten the risk of international confrontation (Wassmund, 1993; Checkel, 1997). This opened up the path towards the end of the East-West nuclear conflict. Global climate change displays certain parallels to this: the development model based on fossil energy is also facing a deep crisis. If decision-makers were to refuse to accept this reality and the requisite transformation of economic systems based on fossil energy sources were not to take place, a destabilization of the global economy would be highly likely to occur sooner or later. International negotiation tactics that continue to be driven by short-term interests can lead to dangerous climate change and can thus fuel immense international tension and conflict (WBGU, 2008; Homer-Dixon, 2009). In analogy to the end of the Cold War, WBGU takes the view that it is now essential to recognize this reality and to take resolute climate policy action.

There is no historical precedent for the global cooperation that will be required to stay within the 2°C guard rail. The closest parallel (as Al Gore has noted) may be the Apollo programme launched in 1960 by the US government. This set a clear goal (to put a human on the moon) that was to be achieved within ten years; at first this appeared just as utopian. To achieve this goal, previously unheard-of amounts of financial resources (US$25 billion) and human capital (400,000 people) were deployed; the commitment of the Kennedy administration, which set clear targets and time corridors, was equally important. In the completely different circumstances of climate policy, however, a much more wide-ranging combination of political leadership, technological innovation and political dynamic – in both spatial and substantive terms –will be required. The programme of global decarbonization is called for due to the existential threat to humankind posed by dangerous climate change and the urgency of policy action as set out above. In historical terms, turning away from a fossil-based economic and energy policy requires an act of political and moral will similar to that needed to abolish slavery and child labour in the 19th century. Those initiatives were not driven by technological or economic benefits – these only emerged in the further course of the Industrial Revolution – but by the intentional break with an untenable habit.

The L'Aquila paradigm shift

At their July 2009 meeting in L'Aquila in Italy, the heads of state and government of the G8 countries and the forum of the 16 major economies (Major Economies Forum on Energy and Climate, MEF) – which, in addition to the G8, included India, Brazil and China – acknowledged the importance of the 2°C guard rail to prevent dangerous climate change. The task now is to incorporate this guard rail in binding form in international law. To make appropriate reduction commitments enforceable, it is essential to set the global economy on a low-carbon course at the same time. This requires coordinated action by the 'big three' (USA, European Union and China), mainstreaming the climate policy agenda within reform efforts in multilateral multilevel policies (such as in the G20 context), and a low-carbon realignment of international development cooperation (Bauer, 2008; Scholz, 2009). To bring about financial, technological, political and scientific cooperation at a hitherto unknown level and in a spirit of trust, it will be necessary to overcome a stage of international policy development that has been based primarily on national interests and their enforcement through the exercise of power (Müller, 2008). This demands the will and leadership of key decision-makers.

The challenge presented by climate change cannot be tackled using the traditional pattern of international policy, which has been based on the division of risks and the re-distribution of resources. Because unabated climate change is a global and collective threat, the interests of humankind as a whole must in future have absolute priority over short-term national interests. Moves in this direction are already emerging in the shape of the present reconfiguration of global governance structures, characterized by the coexistence of old and new agendas and both hegemonial and multilateral decision-making processes (Cooper and Antkiewicz, 2008; Nuscheler and Messner, 2009). In terms of issues needing to be addressed, the main outstanding characteristic of global climate policy is that it cannot remain focused on sectoral solutions but is instead linked organically to the reorganization of the world financial system, world trade and development cooperation.

In institutional terms, the L'Aquila resolution means two things: firstly, the 2°C guard rail has to be made the global standard of climate policy and, secondly, new formations of global governance are needed. This includes the consolidation of negotiations taking place with equal standing between the old (e.g. USA, EU, Japan) and new hegemonial powers (China), which wield the power of veto in the UN Security Council. These negotiations must also, however, include other emerging nations (Brazil, Russia, India) and, from case to case, must also involve regional powers such as Mexico, Egypt, Turkey and Indonesia.

In this extended arena, the old G7/G8 no longer operates as a hegemonial centre, but rather as a form of relay station and preparatory body. At the same time, within a variable negotiation architecture, links exist to the numerous conference institutions within the UN family, which contribute the combined might of all G192 states (Schechter, 2005; Bauer, 2008). There are also links with political and economic regional and continental groupings such as the EU, Mercosur and the African Union (Debiel, 2009). In addition, within the context of trade in emission rights under the UNFCCC, global climate policy will also be determined by bilateral partnerships. This flexible yet fragile negotiation architecture in an interlocking, multilevel system can only function if it is guided by clear premises for action and is accompanied by sufficient democratic legitimation and participation in national and local arenas.

6.3 Global governance and local action: An alliance of change agents

Path dependencies in politics, industries and technologies pose a major barrier to global governance (Pierson, 2004). The present configurations of institutions (norms, contracts, negotiating and decision-making modes etc.) and of technologies and infrastructures impede far-reaching societal change. In policymaking and industry alike, path dependencies often cause errors to become entrenched and learning effects to fail to materialize. A fundamental path shift – in this case the transition to a climate-friendly and resource-efficient economy as well as society – requires complex learning processes and fundamental innovations. It also involves reconfiguring departments and competences in governments and administrations. Since the 1970s, environment ministries and administrations have emerged in most of the OECD countries and beyond, and have responded to the new challenges. The task today is to integrate policies from the outset in the realms of energy, economy, education, research, finance and labour under the premise of a low-carbon economy. This will involve assessing sustainability and climate effects as a matter of principle when drafting laws and regulations and conducting 'sustainability impact assessments'.

However, the transformation of societies towards sustainability and climate-compatibility cannot succeed through 'top-down' policies alone. Consumers and voters too must take their decisions in such a way that their long-term utility is maximized. They must also do this in situations when short-term utility losses in the form of higher costs are (or appear to be) associated with these decisions. The reasons for insufficient long-term orientation and for loss aversion among decision-makers are diverse. A lack of knowledge combined with uncertainty about the future costs and benefits of the given options play a major role. The greater the uncertainty is, the more decision-makers and consumers will discount future gains and will resist embarking upon projects that involve a 'long haul'. The later the benefit of an action arises, the less apparent it is to the individual. The sooner costs are incurred, the greater the risk of loss is seen to be. It also becomes less likely that individual players will develop enthusiasm for such options and work to further them. Actions based on short-term thinking and the avoidance of losses are all the more prevalent the lower the disposable income or standard of living of those taking decisions is (Lorenzoni et al., 2007). Policy innovations are doomed to fail if they are countered by players whose approval is indispensable under constitutional law or in realpolitik (veto players). The greater the number of collective or individual veto players is and the more heterogeneously and competitively they operate, the more unlikely any change in the status quo becomes (Tsebelis, 2002).

Innovation through change agents

In overcoming this stagnation, 'change agents' are pivotal – these are strategic groups who are the first to engage in social change and spread an awareness of its opportunities. Historically, periods of 'great transformation' have been characterized by the emergence of new technologies and lead sectors of industry, but even more by aspiring social classes who advanced change in institutions and mentalities (Rogers, 2003). Strategic groups and alliances operated as role models and trendsetters across societies and national boundaries; they thus created cultural hegemony for innovation impulses that were isolated or appeared at first to have no prospect of success.

Change agents spread innovations by calling worldviews into question, challenging entrenched attitudes and behaviours and engendering motivation to engage in change among potential allies. Today, change agents can be found in many realms of society, in policymaking and in administrations. They include non-governmental organizations such as environmental and other grassroots groups, churches, foundations, academia, parties, the technical departments of local authority administrations, federal and regional state ministries and the directorates-general of the European Commission. Such change agents are also to be found in energy sector companies, autonomous energy cooperatives, pilot projects and application-oriented research as well as in the most varied professional groups (such as engineers, urban planners, architects). What unites these players is that they see huge opportunities and creative challenges in the decarbonization of industry, cities and mobility. Their work is often isolated and dispersed; they may at first lack an awareness of the opportunities to forge political alliances. Often, however, the elites in leading positions for their part are not aware either that among these pioneers are potential allies in communicating and enforcing supposedly unpopular policies.

The global climate protection negotiations will fail if people only see the technical terms and diplomatic compromises couched in the formal wording of final communiqués and thus come to misconstrue climate protection as a purely 'top-down', state-run operation. At present most people scarcely understand the negotiations, and citizens have plenty of misgivings about the democratic legitimacy of the dispatched climate negotiators. Climate protection requires resolute action at nation-state and supranational level, yet successful climate policy will only be possible once the populations of the main polluting countries come to see that they themselves are responsible. This requires a regionalization of climate protection targets in a manner comprehensible to citizens, down to the level of city districts and individual municipalities, along with an interactive feedback of climate policy up to the highest tiers of state and corporate action. Not least, it is important that the issue is skilfully embedded in a broader perspective. Energy-efficient and climate-friendly behaviour on the part of consumers is more likely to occur if the costs and impositions that are to be expected over the short term can be rendered less prominent in their perception than the benefits arising over the medium to long term.

Citizens of all states must therefore be alerted to the far-reaching actions that are required to avoid dangerous climate change; parliamentary debates and position papers produced by non-governmental organizations are just as important in this regard as campaigns and awareness-raising activities to modify consumer behaviour, and more general political and cultural information and education activities. Because of the extremely long duration of climatic processes, a sense of responsibility needs to be generated that spans several generations. 'Bottom-up' climate policy therefore needs to contain self-reflexive and participatory components, integrating the target groups and 'non-experts' as people who themselves generate knowledge, take action, amplify and propagate relevant messages.

Fostering a culture of participation

The interplay of the proponents of a 'global green deal' in the various spheres of society can lead to the formation of a new, positive culture of participation articulated at all levels of political engagement: during elections, in clubs, associations, parties, non-governmental organizations and in extra parliamentary campaigns and activities for climate protection, energy system transformation and sustainability. Agents include the growing group of strategic consumers who not only seek low-carbon products and patterns of nutrition, mobility, construction and heating, but also call patterns of consumption as such into question and change them in line with sustainability considerations (Lamla and Neckel, 2006).

An appreciable financial incentive, supported by public subsidies, is doubtlessly an important motivation for sustainable forms of energy use and energy-saving. However, a considerable number of consumers are also changing their behaviour on the basis of general sustainability norms, i.e. when outcome utility is accompanied by an additional process utility generated by involvement in a broader civil-society project. This is a reference to a person's awareness of having done something useful and good for the environment and for one's descendants and of having gained recognition from others for having done so (Frey and Stutzer, 2002). In this case, an individual's 'rational choice' acquires a dimension related to collective identity.

The exigencies of climate policy should not be defined and communicated as altruistic actions, but as opportunities to make the shift to a low-carbon world society. The guiding vision of a low-carbon society is not a crisis scenario; rather, it is the vision of liberation from an energy-sector trajectory and an energy-policy pathway that is expensive, risky and crisis-prone. The future lies in a path that promises fewer resource conflicts, greater security, better environmental quality and improved prospects for the future of our children and grandchildren. Many members of society have already been travelling on this path for some time as individual pioneers of transformation. The political elites will find it much easier to aim towards great goals of cooperation if they are supported at national level by civil-society mobilization and positive visions of the future that enjoy broad approval. The courage which policy-makers display in untying the Gordian Knot of climate policy will then be rewarded, for they will be relieved of the burden of sole responsibility for accomplishing the required social transformation.

Epilogue 7

To the 'realists' whose thinking has long dominated the international relations discourse, the transformation pathway portrayed by WBGU may sound naive and unworldly. It is therefore appropriate, at the conclusion of this report, to remind ourselves once again where the 'prevailing realism' – the business-as-usual approach – would inevitably lead us.

In such a scenario, economies and transportation systems would continue to grow unabated worldwide, fuelled by fossil energy carriers and accompanied by rising greenhouse gas emissions. Compliance with the 2°C guard rail would be impossible to achieve, resulting in increasingly manifest, costly and even catastrophic impacts of climate change. As fossil fuels become more expensive, these trends would trigger a belated switch to 'clean' centralized technologies (carbon capture and storage, expansion of nuclear power) and other technological 'solutions' (such as geo-engineering, with the associated risk of uncontrollable changes to the Earth System). The enforcement and control of these measures would entail scaled-up security activities by governments.

The proliferation of weapons-grade nuclear material, for example, would confront international politics with considerable problems. At the same time, countries and supranational regimes would have to massively expand their disaster relief systems in order to cope with the increasing impacts of climate change. More frequent extreme weather events, progressive desertification and water scarcity would exacerbate conflicts over food and basic resources worldwide, intensifying existing conflicts in many countries and societies and also precipitating new conflicts over access to increasingly scarce fossil fuels. In response to the increasing numbers of intra-nationally displaced persons and international refugee flows, the industrialized countries would continue their trend towards ever more restrictive refugee and migration policies. The vital mitigation and adaptation measures would be imposed and enforced by increasingly interventionist regimes wielding emergency powers. The regimes that would emerge would prioritize security and, calling on states of emergency, would greatly curtail the freedoms customarily enjoyed by liberal societies. Channelled through the conduit of supranational systems, this would culminate in the consolidation of authoritarianism and the weakening of democracy.

And yet, this scenario does not have to become reality – for the history of an alternative, low-carbon global politics began long ago. In this climate-friendly scenario, all that was required was a small but crucial shift in perspective, namely the view of climate change as a challenge to humankind, seen through the eyes of the most vulnerable countries and population groups. In June 2009, for example, Indonesia offered refuge to the inhabitants of the Solomon Islands, who could soon fall victim to rising sea levels. This significance of this development lies in the fact that the world community has come to view the situation from the perspective of a small island state – in other words, it is showing cosmopolitical empathy for one of its weakest links.

From the perspective of the countries which belong to the Alliance of Small Island States (AOSIS) – a coalition of small island and low-lying coastal countries – the challenge is obvious: the rest of the world, only seemingly better protected from the impacts of dangerous climate change, must accept that global warming threatens humankind as a whole, that the time to change course is running out, and that only a truly Herculean effort can safeguard the natural life-support systems on which our very survival depends. Humankind must begin to see itself, and conduct itself, as a global interest community.

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