WBGU
German Advisory Council on Global Change
Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen

policy paper

5

New impetus for climate policy: making the most of Germany's dual presidency

Contents

SUMMARY FOR POLICY-MAKERS

If dangerous climate change is still to be avoided, a reversal of current trends must be achieved within the next ten years, and greenhouse gas emissions worldwide must be halved by 2050 compared with a 1990 baseline. However, there is a widening gap between the action that is urgently needed and current climate policy. The German Advisory Council on Global Change (WBGU) is therefore convinced that a new climate policy dynamic is required worldwide. Currently, all eyes are on Germany: its Presidency of the Council of the European Union and Presidency of G8 offer a dual opportunity to drive climate protection forward. The Council's core messages are as follows:

- *Climate protection is both worthwhile and feasible:* Investing in climate protection is economically efficient, as the costs of effective climate protection are far lower than the costs of inaction. The longer we delay, the more expensive climate protection will become. For successful climate protection, a transformation of the world's energy systems is key. Such a transformation is technologically feasible, marking a shift away from fossil towards renewable energy sources, and requires rapid utilization of the high efficiency potentials.
- *Further development of the UN climate convention:* A consensus on the mitigation target must be forged and enshrined in the convention. To this end, the Council recommends the adoption of a global temperature guard rail limiting the rise in near-surface air temperature to a maximum of 2 °C relative to the pre-industrial value – equivalent to stabilizing the concentration of greenhouse gases below 450 ppm CO_2eq. The Kyoto Protocol must be developed further and offer effective incentives for the transformation of energy systems. The industrialized countries should commit to ambitious reduction targets, while mechanisms must be established for the progressive, but differentiated integration of the newly industrializing and developing countries into commitment regimes. The issue of adaptation must also be given appropriate priority. This must include firm pledges from the industrialized countries on technological cooperation and financing.
- *Making the most of the G8 Summit at Heiligendamm:* Fresh initiatives from the heads of state and government are required to inject new life into the faltering climate process. The G8 countries and the five major newly industrializing countries, as the world's leading political and economic nations, should now send out clear signals and agree an 'innovation pact on decarbonization'. By adopting joint parameters for efficiency and CO_2 emissions standards, developing a Road Atlas for the decarbonization of energy systems, and promoting technological cooperation, the G8+5 countries have the potential to become the driving force in international climate policy.
- *Reaffirming the European Union's leading role:* The European Union should expand its leading role in international climate protection. To maintain its credibility, it must achieve its agreed emissions reduction targets. The EU must demonstrate the viability of climate protection and provide fresh impetus for energy efficiency and renewables worldwide. The European Union's Emission Trading Scheme should be developed further and improved as a matter of urgency.

1 Climate protection: Swift action is essential

The scientific evidence is clear

The scientific debate about the fact and causes of global warming is over. Decades of research have resulted in a substantial body of scientific evidence demonstrating that humankind is primarily responsible for the current process of climate change. It is undisputed among climate researchers that human activity has increased the concentration of carbon dioxide in the atmosphere by more than one-third, from 280 parts per million (ppm) to the current level of 380 ppm. Today's atmospheric carbon dioxide levels are the highest in at least 650,000 years (i. e. as far back as the CO_2 record from ice cores goes), but may well be the highest level for millions of years. The atmospheric lifetime of carbon dioxide is often assumed to be around 200 years, but this is a considerable underestimate. Indeed, the oceans absorb emitted CO_2 on a time scale of centuries, but a substantial proportion will remain in the atmosphere for tens of thousands of years (Archer, 2005).

It is also undisputed that carbon dioxide is a greenhouse gas whose atmospheric enrichment inevitably causes climate warming. The physical mechanism underlying this process was identified as early as in the 19th century, is well understood and is backed up by substantial evidence in the form of measurements.

Globally averaged surface temperatures have increased by 0.8 °C over the last one hundred years. This corresponds with the figure that physicists would expect to obtain from theoretical calculations based on the above-mentioned increase in the atmospheric concentration of carbon dioxide and other greenhouse gases. It takes into account that air pollution through aerosol particles ('smog') partly counteracts the warming caused by greenhouse gases and that the heat capacity of the oceans causes a delayed reaction by the climate system. There is no other scientific explanation for the warming that is being observed. This is confirmed by the statement issued by the science academies of the G8 countries, which notes: 'The scientific understanding of climate change is now sufficiently clear to justify nations taking prompt action' (Joint Science Academies, 2005).

The impacts of climate change can already be seen and felt in every region of the world. Around the globe, mountain glaciers are retreating. Arctic sea ice cover has shrunk by 20 % in recent decades – recent studies suggest that the Arctic Ocean may be ice-free during the summer as early as 2040. Global sea level rose almost 20 cm during the last century, with a 3 cm increase occurring in the last ten years alone. The intensity of tropical cyclones has increased over recent decades. Extreme weather conditions, such as the European heat wave in summer 2003, are becoming more frequent. According to NASA, 2005 was the hottest year across the globe since records began.

Unabated climate change would radically alter the lives of people in industrialized and developing countries alike. It would contribute to the destabilization of societies, cause international security problems, trigger migration flows worldwide, and have a massive and detrimental impact on the global economy. In the United Nations Framework Convention on Climate Change (UNFCCC) of 1992, the international community pledged to avoid 'dangerous climate change'. As the upper limit to tolerable climate warming, the Council has recommended the adoption of a global temperature guard rail which limits the rise in near-surface air temperature to a maximum of 2 °C relative to the pre-industrial value. This guard rail has now been adopted as official EU policy and is increasingly recognized outside the EU as well.

With warming above 2 °C, extreme events such as flooding, heat waves or tropical storms would likely exceed tolerable limits. This temperature increase would inflict irreversible damage on ecosystems such as coral reefs and perhaps the Amazon rainforest and would greatly accelerate biodiversity loss. Global warming of 3 °C and above would be likely to trigger irreversible melting of the Greenland ice cap, and could thus result in sea-level rise of several metres within a few centuries, threatening the survival of coastal towns and cities worldwide.

If the concentration of greenhouse gases in the atmosphere can be permanently stabilized below 450 ppm CO_2eq, there is a realistic chance – based on current scientific knowledge – of achieving compliance with the 2 °C guard rail (450ppm CO_2eq denotes an atmospheric concentration of all greenhouse gases that has a radiative impact equivalent to that of 450 ppm CO_2). A stabilization target of 550 ppm CO_2eq, which has occasionally been dis-

cussed, notably by Stern (2006), is likely to result in global warming of around 3 °C, and is thus incompatible, in the Council's view, with the commitment to avoid 'dangerous climate change' enshrined in the UNFCCC.

To achieve compliance with the 2 °C guard rail, a reduction of around 50 % in greenhouse gas emissions worldwide by 2050 compared with a 1990 baseline is required as an interim target.

Compliance with the 2 °C guard rail is worthwhile

Global CO_2 emissions have increased by more than 20 % since 1990 and are continuing to rise. This trend must, if possible, be reversed within the next ten years. As greenhouse gases are accumulating in the atmosphere, any delay will mean that higher emission reduction rates will be required in subsequent years in order to achieve the desired stabilization level. Delaying the reversal of this trend by just ten years could mean that future reduction rates will have to be doubled. Longer delays will ultimately make it impossible to achieve the desired stabilization level at all.

Another reason why there should be no delay in taking action is the risk of 'locking into' CO_2-intensive technological structures. This would delay the time-consuming process of developing low-emission systems, with the result that appropriate technologies would not be available in time. The earlier the political course is set and technological innovations and learning processes are initiated, the lower the cost of emissions reduction.

Failing to achieve the necessary emission reductions, the consequent unabated climate change would cost – according to Stern (2006) – at least 5 % of annual global GDP, now and into the future. These costs could increase to as much as 20 % if damages caused by extreme and abrupt natural events, 'non-market' impacts (e. g. impairment of human health, biodiversity loss) and potentially larger biophysical feedbacks are factored in, and if the relatively high welfare losses in poorer regions of the world are weighted more strongly in the appraisal. Since Stern, in view of the large uncertainties, purposely includes plausible but extreme scenarios in his analysis, his figures lie at the upper end of the spectrum of the estimates published to date. The adoption of a pro-active climate policy could avoid most of the costs of climate change. These avoided costs are therefore equivalent to the benefits associated with such a policy.

Stern estimates that the costs of a pro-active climate policy aimed at stabilizing greenhouse gas concentration at 550 ppm CO_2eq by the year 2050 will manifest themselves through a reduction of annual global GDP by 1 % against the reference case during the next one hundred years. However, to achieve compliance with the 2 °C guard rail, the target must be stabilization at 450 ppm CO_2eq or below (Meinshausen, 2006). Estimates show that the ambitious stabilization target of around 450 ppm CO_2eq can be achieved at costs of less than 1.5 % of global GDP (WBGU, 2003). However, these estimates are based on the assumption that a stringent and reliable climate policy will indeed be adopted, thus initiating dynamic technological development, and that in addition to a transformation of energy systems, a significant reduction in emissions of long-lived greenhouse gases from land-use changes, notably deforestation, and from other sources will be achieved. Overall, these estimates demonstrate that compliance with the 2 °C guard rail is worthwhile from a macro-economic perspective as well.

There is an emerging consensus within the international community about the need for resolute action to counteract climate change, but the practical agenda is still trailing far behind. The gap between the need for urgent action and the faltering international climate process is becoming increasingly apparent. In presenting this policy paper, the Council aims to draw urgent attention to this discrepancy and make recommendations to the German Federal Government on how it can use the EU Presidency and the G8 Presidency to generate a new climate policy dynamic.

2 Transforming the world's energy systems: The cornerstone of climate protection

The energy sector currently contributes more than 60% to global greenhouse gas emissions. The International Energy Agency (IEA), in its 'business as usual' scenario, assumes a 53% rise in global energy demand by 2030 compared to 2004. There are four main reasons for the soaring energy demand: the continued rise in consumption in the industrialized countries, the rapid catch-up development taking place in the economies of populous newly industrializing countries, the slow implementation of efficiency measures in commerce and industry, and poor demand for eco-efficient products and services.

Key drivers of consumption in the industrialized countries, but also in China, are rising per capita consumption as average household size decreases and people's changing – and increasing – demand. A further factor is major backlog consumption in the industrializing and developing countries. This cancels out the advances made so far in the energy efficiency of technologies and products. Furthermore, in many industrialized countries and populous newly industrializing countries such as China, India or Brazil, long-term investments in energy infrastructure are due to take place in the next 10–15 years, notably to expand the power plant network. In the worst-case scenario, this could lock in climate-damaging structures for decades and beyond, so a fundamental change of strategy aimed at the transformation of the world's energy systems is required today. At the same time, access to modern forms of energy must be safeguarded for 2.4 billion people living in developing countries. Overcoming energy poverty will make a real contribution to achieving the Millennium Development Goals.

In its 2003 Flagship Report, the Council mapped out an exemplary path for the transformation of the world's energy systems, which is guided not only by climate protection but also by other environmental and socio-economic guard rails (WBGU, 2004). The vision of a future global energy supply charted in that report is still relevant today and provides the frame of reference for many of the recommendations presented in this policy paper. The key elements are the vigorous expansion of renewables and improved energy efficiency, both in generation and use.

The energy portfolio for the future

In light of the latest technological developments, it is becoming increasingly apparent that renewables have the potential to secure the entire global energy supply in the long term. Particularly wind power and the use of biomass for energy generation can make substantial contributions already in the short and medium term. At present, wind power contributes 1% to the global energy supply. Assuming that the growth witnessed over the past decade continues, this could increase to 20% within 20 years. To some extent, wind power is already competitive compared with conventional electricity, so there is scope for rapid further development of wind power at negligible additional cost. A similar contribution to the energy supply could be made by bioenergy if its share were to increase by 20% per annum in future. Together with existing hydropower, these three renewables have the potential to generate two-thirds of the world's electricity within 20 years. In the long term (i.e. post 2030), the direct use of solar energy with its virtually unlimited potential will play a more significant role in meeting the steadily rising demand. Table 1 compares and evaluates renewable energy sources in terms of their sustainable potential and availability.

To facilitate a successful transition away from fossil fuels towards renewables, a massive increase in research into renewables is required. In the Council's view, a ten-fold increase in direct public spending on research and development in the energy sector by 2020 in the industrialized countries is entirely justified. The German Government's High-Tech Strategy (BMBF, 2006) points in the right direction. Ultimately, however, the expansion of renewables must be based on sustainability criteria such as those proposed by the Council. Hydropower, for example, can only be expanded gradually and to a limited extent, and when exploring the potential of bioenergy, due consideration must be given to competition with land use for food security and nature conservation.

Fossil fuels must continue to be used for a transitional period. There is probably no option but to combine the utilization of these energy carriers with technologies for the capture and safe final storage

Table 1: Assessment of renewable energy carriers: relevance and temporal dynamics.
*EJ/a = exajoule per annum = 10^{18} joules per annum. As a comparison: global electricity production currently amounts to around 58 EJ/a. * For sustainable potential, see WBGU, 2004*

	Bioenergy	Wind power	Hydropower	Solar thermal power plants	Photovoltaics	Geothermal energy	Marine energy
Share of global electricity production	Today: 1.5 % By 2025: 30 %	Today: 1 % By 2025: 20 %	Today: 17.5 % By 2025: 16 %	Today: 0.05 % By 2025: 1 %		Today: 0.3 % By 2025: 0.6 %	Today: 0 % By 2025: 0.1 %
Relevance and dynamic of energy contributions	Combustion and fermentation can be deployed immediately on a large scale Gasification still under development	Can be deployed immediately on a large scale Offshore requires further development	In some countries, major importance in the electricity sector; technology already mature	First power plants already up and running Globally relevant from around 2030	Currently still niche markets Globally relevant from around 2030	Local importance for electricity Use in district and neighbourhood heating Technology largely mature	Still under development
Climate compatibility	High Negative emissions possible with CO_2 sequestration	High	High Need to take account of greenhouse gas emissions from reservoirs	High	High	High	High
Sustainable potential*	around 100 EJ/a	around 140 EJ/a	around 15 EJ/a	Practically unlimited	Practically unlimited	30 EJ/a	20 EJ/a
International competitiveness	Already exists for combustion and fermentation Gasification from around 2020	Already exists at good sites Generally from 2010	Exists	From around 2020 for large-scale application	Already exists for niche applications For broad applications from around 2030	Already exists in some areas	From around 2020
Potential environmental risks	Land-use competition with nature conservation Environmental problems arise in intensive cultivation (soil degradation, water consumption, pesticides)	Very low Impacts on fauna (e. g. bird migration and reproduction) are being investigated	Complex and often substantial impacts on ecosystems	Very low	Very low	Avoid waste heat and polluted wastewater	Impacts on marine ecosystems require further study
Acceptance	Limited Land-use competition with food production	Limited Problems with aesthetic appearance and tourism	Low Major conflicts over many large-scale dams	Limited (land take)	High	High	High

of CO_2 at appropriate sites. Storage in geological formations should only be permitted if an annual maximum leakage rate of 0.01 % can be guaranteed or if the storage is secure for at least 10,000 years (WBGU, 2006).

Hydropower already makes a larger contribution to the global energy supply than nuclear energy. As stocks of uranium are finite, however, nuclear power could only play a substantial role in the future energy supply if breeder technology is used, but this technology is not mature. It would also entail a switch to a plutonium economy and would increase the risk of nuclear technology being misused for military or terrorist purposes. Furthermore, although nuclear power has been in use for 50 years, there is still no accepted strategy for safe final storage of radioactive waste anywhere in the world. As the use of nuclear power involves unacceptable risks, the Council recommends a nuclear phase-out.

A new generation of energy technologies

A further key building block in the transformation of the world's energy systems is improving efficiency in energy production. The efficiency of supply systems is highest if many different energy carriers can be converted with high efficiency into a wide range of useful energy forms. In future, gasification technologies and gas grids will play a major role in this context. With advanced gasification techniques, coal, almost all forms of biomass and even plastic waste can be

Lighthouse Project 1
A European Supergrid

A trans-European high-capacity power grid is proposed as a technological lighthouse project. This grid, with a transmission capacity of around 10 GW, would carry power to wherever it is needed in Europe and thus help safeguard an affordable supply in line with the Lisbon Strategy. This high-capacity grid is also needed in order to smooth the substantial fluctuations in feed-in, e. g. from wind farms, and to make the output of Norway's large hydro storage power plants available to the rest of Europe. It would also provide links to other grids (e. g. in North Africa) and make a major contribution to European grid stability. The connection to major offshore wind farms and high-capacity marine energy systems in Northern Europe could thus be achieved at affordable cost; the same applies to hookups to on-shore wind farms in regions of Africa with very high wind speeds or to solar thermal plants in regions with intense solar irradiance.

used to generate electricity very efficiently in combined-cycle power plants. These technologies allow the production of synthetic natural gas (methane), which can then be supplied via the gas grids for use in a wide range of applications, e. g. in small-scale combined heat and power (CHP) plants or as fuel in the transport sector (gas propulsion). A further benefit of this technology is that it easily offers the opportunity for CO_2 capture. Later on, this type of infrastructure, combined with methane reforming, could pave the way for a hydrogen economy. Feeding synthetic natural gas into the grids on a decentralized basis changes the nature of the gas grids – away from a straightforward supply function towards an interactive system. High-capacity continental gas grids will therefore play a key role in facilitating the introduction of new energy technologies in the future.

The expansion of power plants should therefore focus now on high-efficiency combined-cycle plants which allow retrofitting CO_2 sequestration techniques and offer the opportunity for integrated gasification of coal and biomass. Alongside major power plants, there should be a greater reliance on local CHP plants as they substantially increase energy efficiency through the cogeneration of heat and power. Microturbines and fuel cell technology will come on-stream in the medium and long term respectively. Both conversion principles allow a prompt response to electricity demand and will play an important role in the stabilization of the electricity grids and the supply of balancing energy. The hitherto untapped potential of small local producers can thus be harnessed in future, thanks to the rapid and continued development of information and communication technologies (ICT) combined with the introduction of 'virtual' power plants or online energy markets. Even if wind power is expanded substantially, this approach will remove the need for additional energy storage systems or back-up power plants to smooth the fluctuations in feed-in from wind farms. The same ICT infrastructure will also permit better management of energy demand. Through active management of time-flexible consumers, demand peaks can be levelled out, thus allowing power plant capacity to be reduced by as much as 20 %.

Furthermore, the rapid expansion of high-capacity electricity grids with decentralized feed-in is very important for the integration of renewables into the grid. Compared with conventional systems to supply balancing energy, 'horizontal balancing' – i. e. balancing over long distances – is the cheapest method by far. For wind energy in particular, balanced capacity provision can be achieved by establishing suitable sites across large distances. Furthermore, the integration of major capacity from hydropower dams in mountain regions is extremely important in order to smooth the fluctuations in feed-in of power from major sources such as offshore wind farms. A strategy based on continental transmission grids is suited for Europe (see Lighthouse Project 1) and could be extended to other continents as well.

Innovations in energy infrastructure are an indispensable element of a transformation of the world's energy systems towards sustainability. Germany should therefore lobby pro-actively within the frameworks of the EU and the G8 to drive forward cooperation in this area.

Mobilizing untapped efficiency potential

The far-reaching restructuring of global energy systems, outlined above, is likely to take several decades, even if considerable efforts are made. Therefore in order to reduce global emissions before it is too late, it is essential to curb the growing energy demand as soon as possible by improving the efficiency of energy use. In the short term, energy saving has the greatest potential to reduce greenhouse gas emissions.

In the World Energy Outlook (IEA, 2006), substantial improvements in energy efficiency worldwide are regarded as attainable. In the Alternative Policy Scenario, around 80 % of emissions avoided come from improved energy production and use; as compared

Lighthouse Project 2
Consumer information on CO_2 emissions

For consumers, the greenhouse gas emissions associated with the consumption of specific products or services are generally not transparent. The Council therefore proposes a consumer information project on CO_2 emissions. As an initial step to raise awareness before personal carbon credits might be introduced, the EU should agree to label products and services with consumer information on their CO_2 emissions. The transport sector lends itself particularly to this approach: here, absolute CO_2 emissions could be stated on airline tickets and filling station receipts, as (average) emissions are relatively easy to quantify in this highly significant sector and the individual consumer can exert considerable influence over his or her personal CO_2 balance sheet. It is important to place the quantified emissions in a context which can be understood by consumers, e. g. by comparing them with the daily amount of emissions that are ‚sustainable', based on an equal global per capita allocation.

to the Reference Scenario as a baseline. According to the European Commission, the estimated savings potential in EU annual primary energy consumption by 2020, above and beyond agreed measures, add up to 20 %. This could reduce annual fuel costs in the EU by as much as € 100 billion (based on an assumed oil price of US$ 48 a barrel).

Very high efficiency potentials exist above all in buildings, transport, manufacturing, and household appliances. Compared with the situation in the 1980s, substantial improvements in efficiency have already been achieved in many flagship products in a wide range of product groups worldwide, notably new building construction, cars, washing machines and dryers, dishwashers, refrigerators, and energy-saving light bulbs. Here, good quality energy-efficient products and services are already available, enabling consumers to reduce their CO_2 emissions by as much as 40 % at no extra cost.

At present, however, the existing energy-efficient products still only account for a small share of the market and even efficiency measures which are cost-neutral or allow savings to be made are often not being implemented. In the past, the main problem was the 'time to market', i. e. the length of time it takes from a product being conceived until it is available for sale, but today, it is the 'time to consumer', i. e. the diffusion of a product in the market place. A massive efficiency backlog has existed for some time, which policy-makers worldwide have failed to recognize fully and address. A key reason for this is the international community's continued fixation with straightforward technology promotion while ignoring systemic innovations and their widespread adoption by society (e. g. energy certificates for buildings to record their energy rating, or an intermodal public transport system with mobility tickets allowing integrated use of rail, local transport and car-sharing). A purely supply-oriented strategy based on more energy-efficient products and technologies is not enough to achieve the ambitious reduction targets for CO_2 emissions. What is required is a radical rethinking within society and a change in behaviour on the part of consumers and companies alike, along with support for price changes via the internalization of external costs, public procurement as a model of best practice (see Section 5), appropriate information measures (see Lighthouse Project 2) and the adoption of regulatory provisions setting limit values.

Until now, such provisions have primarily been used to regulate toxicologically problematical materials and emissions, and have been deployed far less often in relation to energy consumption and CO_2 emissions. In view of the global threat posed by climate change and the high costs to the general public, however, there is no longer any justification for the legislator to ignore the opportunities afforded by regulatory law. This applies all the more as many energy-efficient products and measures do not entail any additional costs for the consumer. To harness the high efficiency potentials, stringent and dynamic limit values should therefore be established (see Sections 4 and 5).

Financing the transformation of energy systems

In order to ensure that adequate financing is available for the transformation of energy systems that is an essential feature of a pro-active climate policy, measures must be adopted at both national and international level. At national level, much of the financial burden must be borne by the private sector. In this context, the public sector's task is to provide appropriate investment incentives. As part of an ecological financial reform, taxes could be imposed or increased on fossil fuels, subsidies for non-sustainable forms of resource use should be reduced, and appropriate funding measures should be made available to promote renewables and energy efficiency. In addition, private capital could be mobilized for foundations whose aim is to promote renewables; this could be achieved through tax incentives (WBGU, 2004).

In developing countries, there is often a lack of adequate financial resources for the restructuring of national energy systems that is required in the interests of climate policy. The industrialized countries should therefore provide financial assistance via existing funds, such as the Global Environment Facility (GEF) or the Global Energy Efficiency and Renewable Energy Fund (GEEREF) established in the EU, and via further debt relief. The budgets currently available for official development assistance could be increased through taxation of climate-damaging behaviour or the introduction of emissions-dependent user charges for aviation and shipping (WBGU, 2002). In addition, the private sector should be involved through Public Private Partnerships and integration into the work of multilateral development banks. Microcredits could empower local actors to make smaller-scale investments to improve energy efficiency (WBGU, 2004).

A new climate policy dynamic

As the above sections show, a transformation of the world's energy systems on a scale and at a pace sufficient to avert dangerous anthropogenic climate change is both technologically feasible and economically worthwhile. If this type of energy turnaround can be introduced successfully in the next 10–20 years and is accompanied by energetic climate protection measures in other areas (e.g. tropical forest conservation), it will still be possible to avoid global warming of more than 2 °C relative to the pre-industrial value. If this fails, climate change may become a source of global economic and political crises. As the country which holds both the EU Presidency and the G8 Presidency in 2007, Germany has a dual opportunity to initiate this energy turnaround. In the following sections, the Council therefore sets out recommendations for practical action in three particularly relevant policy arenas:

1. *The UNFCCC:* In the long term, only a treaty endorsed by the international community can guarantee attainment of climate protection targets. The UNFCCC and the Kyoto Protocol must therefore be developed further as a matter of urgency.
2. *G8+5:* In view of the faltering dynamic of the international climate process, there is a risk that without additional impetus, the necessary transformation of energy systems will not take place in time. In light of the urgency of the problem, those of the world's countries which have the greatest capacity to take political and economic action have a special responsibility to press ahead with the implementation of this energy turnaround and thus serve as models of best practice. They should become the driving force behind a new dynamic in the UNFCCC process.
3. *The European Union:* In order to be a credible negotiating partner within the UNFCCC, the EU should expand its leadership role. It must achieve its agreed emissions reduction targets and demonstrate the feasibility of restructuring energy systems and curbing energy demand through improved efficiency, and it must do so by achieving measurable successes of its own.

3 Implementing and developing the Climate Change Convention

Anthropogenic climate change is a global problem which can only be resolved by the international community as a whole. In the long term, therefore, only an international treaty which is regarded as fair and equitable and is based on the principle of common but differentiated responsibilities can guarantee attainment of the climate protection goals. So as not to jeopardize the objectives of the UNFCCC, global emissions – which are currently still rising – should initially be stabilized and then reduced within the next ten years. However, the current faltering dynamic of the international climate process suggests that this will not be achieved without additional impetus. The aim which must be pursued over the coming months is therefore to generate the necessary willingness to take action also at other political levels. The dual presidency puts Germany in an outstanding position which it can utilize for this purpose.

Making the 2 °C guard rail an international standard

Only a consensus-based climate policy with a long-term focus will initiate the global technological revolution and the shift in attitudes that are necessary to achieve the objective of the UNFCCC. At international level, a consensus must therefore be reached on quantifying the ultimate objective of the Convention as set out in its Article 2. To this end, the WBGU recommends the adoption of a global temperature guard rail limiting the rise in near-surface air temperature to a maximum of 2 °C relative to the pre-industrial value. If the concentration of greenhouse gases in the atmosphere is stabilized at 450 ppm CO_2eq, there is a realistic chance – based on current scientific knowledge – of achieving this goal. This will require a 50 % reduction in global greenhouse gas emissions by 2050 compared with a 1990 baseline. As it is highly unlikely at present that the 2 °C guard rail will be established on a legally binding basis in the UNFCCC, the G8, at least, should commit to this target.

Gearing the Kyoto Protocol towards the long term

The approach pursued in the Kyoto Protocol – combining reduction commitments with tradable emissions certificates – establishes the basis for the necessary transformation of the world's energy systems by providing economic incentives for the development and diffusion of low-emission technologies. The negotiations on the second commitment period should be concluded on schedule in order to close any gap between the commitment periods. In the Council's view, however, it is not simply a matter of renewing the existing commitments with new targets: the measures provided for under the Kyoto Protocol must be aligned with the quantified objective of the UNFCCC. The mechanism established under Article 9 UNFCCC to review the Kyoto Protocol should therefore be vigorously pursued. A shared understanding among all signatory states of the medium- and long-term need for action to achieve the UNFCCC objective must be established. The outcome of this review should form the basis for the further development of the Kyoto Protocol.

In the WBGU's view, equal per capita allocation of emission entitlements on a global basis is the allocation formula which should be aimed for in the long term. The Council considers this formula to be fair and equitable, as well as workable in the second half of this century without overtaxing the capacities of the individual countries or impeding their development opportunities to an inappropriate extent (WBGU, 2003). All countries must ultimately play a part in achieving this goal. This is all the more likely to succeed the more strongly the principles of equal treatment and fair differentiation – according to countries' current and historic responsibility for causing climate change and their economic and technological capacities – are incorporated into the mechanism for allocating shares of the world's total permissible emissions budget.

Agreeing ambitious reduction targets for industrialized countries

In view of their high per capita emissions, their historic responsibility for climate change and their substantial economic and technological capacities, the industrialized countries must commit to substantial emissions reductions; otherwise, dangerous climate change can not be avoided. For the second Kyoto commitment period, they should adopt ambitious and effective targets in the order of 30 % effective greenhouse gas emissions reductions by 2020 compared with the 1990 baseline. The targets must be pegged higher as

Lighthouse Project 3
Developing an international compensation and adaptation regime

At the UNFCCC Seventh Conference of the Parties (COP 7) in Marrakesh, international policy measures were initiated to help the developing countries in particular to adapt to climate impacts which are no longer avoidable. This approach was developed further at the Conference of the Parties in Nairobi, albeit in a manner which failed to do justice to the gravity of the problem. In view of the speed at which climate change is already occurring, and in the light of the increasing pressure on nature and societies, there is an urgent need to develop a globally coordinated adaptation strategy based on precautionary considerations. This strategy should address the impacts of climate change on the basis of compliance with the 2 °C guard rail, as this is a realistic and acceptable target for mitigation policy.

This strategy must include an international compensation and adaptation regime whose primary task is to generate adequate funding to compensate for climate damage and to finance adaptation strategies. This is a completely new type of political and institutional challenge which presents socio-economic research with a range of innovative tasks. The Council therefore proposes that the Federal Government launch an initiative for an international lighthouse project aimed at developing this regime. It must answer the question as to what amount of money is required – likely to reach thousands of billions of euros in accumulated payments by the end of the century. Furthermore, enforceable rules must be proposed for payments into the regime, as well as provisions for an allocation formula which guarantees the effective, efficient and equitable use of these financial resources. A further issue to be clarified is the regime's integration into existing structures of global governance.

more opportunities for flexible mechanisms and goals are created. Germany should serve as a role model here: in the Council's view, a 40 % reduction target for Germany is appropriate.

However, the global climate protection goals can only be achieved if the USA also substantially reduces its greenhouse gas emissions. In addition, effective climate protection means that emissions from aviation and shipping outside a country's sovereign territory must also be included very soon in national reduction commitments within the UNFCCC negotiations. This could happen in line with the efforts currently under way to integrate aviation into the European Union's Emission Trading Scheme (ETS), for example.

Integrating newly industrializing countries on a differentiated basis

In order to integrate newly industrializing and developing countries into climate protection to a greater extent, the WBGU recommends the adoption of a more flexible approach to the setting of reduction commitments. The prospects of involving the newly industrializing and developing countries will improve if these countries have the option of committing to flexible targets instead of fixed emissions limits. Possible options in this context are sectoral targets or no-lose targets, which are only transformed into fixed and binding cross-sectoral targets once specific indicators – such as per capita income or per capita emissions – have been exceeded. Here, it is important to determine how countries with flexible targets can be integrated into emissions trading and how the associated problems can be resolved.

Furthermore, a clear differentiation must be made within the group of newly industrializing and developing countries. In view of the high and/or rapidly rising total emissions produced by some newly industrializing countries, integrating them into a commitment system should be a priority. China and India in particular are now playing a far more significant role in the world economy and international arena and are taking on global responsibility, and this should also be reflected in climate protection. By progressively adopting appropriate commitments, they could also act as a role model for other developing countries and – in line with the principle of common but differentiated responsibilities – contribute to effective global climate protection. In the medium term, all the newly industrializing and developing countries, as far as possible, should commit to flexible targets, with fixed targets being the long-term objective. However, for the poorest developing countries with low overall emissions, an opt-out should also be possible over the long term.

Recommendations

- Make the 2 °C guard rail an international standard
- Agree new and ambitious emissions reduction targets for industrialized countries
- Agree differentiated commitments for newly industrializing countries
- Safeguard adequate funding for adaptation

Giving adaptation high priority

In an effective climate regime which is recognized by the international community as fair and equitable and has long-term viability, appropriate priority must be given to adaptation to climate change. As well as implementing specific adaptation projects, the primary focus must be on strategies and measures to improve the adaptive capacity of those countries – generally the poorer ones – which are hardest hit by climate change. At present, neither the specific adaptation funds nor the development budgets are equipped with sufficient financial resources for this purpose. To cover the funding gaps, substantial additional financial commitments are required from the Annex I countries in line with the 'polluter pays' principle. One of the conceptual challenges facing the international community is to develop a workable regime which generates enough international transfers to compensate for climate damage and fund adaptation strategies (see Lighthouse Project 3). This regime must also guarantee the equitable allocation and effective use of financial resources.

4 Agreeing an innovation pact with Road Atlas at the G8 summit

'There remains a frightening lack of leadership', said UN Secretary-General Kofi Annan in November 2006 in his speech to the Climate Change Conference in Nairobi. In view of the urgency of the climate problem, far greater political will and leadership is required. Climate protection must feature on the immediate agenda of the heads of state and government of the world's leading nations. They must now assume responsibility and inject a fresh dynamic into international climate policy.

An appropriate forum is the Group of Eight (G8 – Canada, France, Germany, Italy, Japan, UK, USA and Russia, as well as the European Commission) and the five major newly industrializing countries (Brazil, China, India, Mexico and South Africa), known as the G8+5. This group represents the heavyweights in the global political arena and accounts for around two-thirds of global greenhouse gas emissions. All its countries have ratified the UNFCCC and – with the exception of the USA – the Kyoto Protocol. The dialogue on energy and climate change which was launched at the Gleneagles Summit in 2005, offers a viable basis for this process with scope for further development.

The G8 Summit at Heiligendamm must use this as a basis to decisively push forward the climate process. The political signals being sent out are positive: Germany is committed to its leadership role in climate protection and is receiving strong support from the EU. Moreover, there are growing signs that a change of heart over climate policy is taking place in the USA. Major newly industrializing countries, especially China, recognize that their own regions will be affected to a disproportionate extent by climate change. And finally, the Stern Review has clearly identified the long-term economic benefits of a global energy tranformation.

As the country which holds the G8 Presidency, Germany is in a good position to provide positive and practical impetus for climate protection at Heiligendamm. The Summit's final declaration should therefore contain the following messages: climate protection is one of the key challenges facing humankind. In order to avoid the dangerous impacts of climate change, compliance with the 2°C guard rail is essential. To this end, the course towards the transformation of the world's energy systems must be set today. As regards global greenhouse gas emissions, the current trend must be reversed within ten years and emissions must be cut by 50% by 2050. Energy systems must be largely decarbonized by 2100.

The Gleneagles action plan emphasized the importance of technological innovations and substantially increased investment in climate-compatible energy systems. The WBGU proposes that at Heiligendamm, this be developed further into an 'innovation pact on decarbonization'. The pact should be seen as a G8+5 process but be open to accession by any interested country. Two conditions can bring the five major newly industrializing countries on board:

1. The pact has characteristics of a 'club good' for these countries. As members, these countries enjoy specific benefits such as better access to information, technologies and technological cooperation, and financial support.
2. The diverse socio-economic development goals and the specific economic and technical capacities of the newly industrializing countries are taken into account on a differentiated basis.

The innovation pact proposed by the Council should include the following three elements.

1. Agreeing parameters for climate-compatible technologies

The signatory states would commit to promote climate-compatible technologies and products. To this end, they would agree parameters for energy efficiency and sector/product-specific CO_2 emission standards. Such standards would act as innovation goals, establishing quantitative guidelines and a timeframe for the introduction of the requisite technologies. The innovation pact should focus on the following strategic areas: power plants with integrated gasification technologies, technologies for CO_2 capture and storage, buildings and air conditioning, the automotive industry, and high-capacity electricity and gas grids to facilitate the integration of renewables (see Lighthouse Project 1). Initially, improving energy efficiency should take priority, as this can make significant contributions to reducing emissions in the short term at minimal cost and allow economic benefits to be achieved through energy savings.

Lighthouse Project 4
Decarbonization partnerships with newly industrializing countries

The Council proposes the launch of strategic decarbonization partnerships with those newly industrializing countries that are likely to play an important role in the future world's energy sector. These partnerships, over the coming decade, would aim to move the participating actors' energy systems and energy efficiency towards sustainability, thus providing innovative impetus and acting as a role model on a worldwide basis. China and India should be priority partners. The joint development of a strategic Road Map could build on existing or planned partnerships and activities. Within the EU framework, Germany could assume a leadership role in this energy policy dialogue.

2. Developing a joint Road Atlas

The signatory states would also commit to present national Road Maps within an ambitious timeframe, containing proposed measures and a timetable in which to achieve interim goals. These Road Maps would chart the transformation of national energy systems in the interests of climate protection. Every opportunity must be utilized for this purpose, both on the energy production side and on the demand side. A joint 'Road Atlas for the Decarbonization of Energy Systems' can then be produced on the basis of the national Road Maps. The compilation of the Road Atlas would reveal whether the Road Maps are sufficiently ambitious, both individually and as a whole, to achieve the objective of global climate protection, or whether additional efforts are required. This appraisal could be undertaken by a high-level commission. A credible agreement among the world's leading countries on viable parameters and national Road Maps would greatly accelerate the international diffusion of low-emission products and technologies.

3. Offering technological cooperation as an incentive

The offer of better access to technologies could be the crucial incentive for newly industrializing and developing countries to participate in the innovation pact. Without such access, most of the energy systems developed in these countries are likely to be non-sustainable, creating lock-in effects which are very difficult to change. The G8 countries should therefore support the development of national Road Maps, e.g. through decarbonization partnerships (see Lighthouse Project 4). In addition, cooperation arrangements with newly industrializing and developing countries in the fields of business and research should be encouraged through the establishment of reliable legal frameworks and the provision of government support. Specific technologies and innovations for adaptation to unavoidable climate change must be a key element of such arrangements. An appropriate mix of different instruments can help to avoid problems relating to the protection of intellectual property rights: such instruments include public subsidies and compensation, but also commitments to technology transfer under legally regulated conditions.

Harnessing impetus for the Climate Change Convention

The innovation pact could encourage countries which have been dragging their feet on combating climate change to show greater commitment to the UNFCCC negotiations and the Kyoto Protocol. It would also allow to conceive and try out models of technological cooperation, which could later be elaborated within the UNFCCC framework and established on a broader basis. The production of a national Road Map free from externally imposed obligations, combined with technological support from the G8 or other industrialized countries, would make it easier for newly industrializing and developing countries in particular to assess the task of transforming their energy systems and to recognize the benefits, as well as the costs. For innovative companies in industrialized and newly industrializing countries which supply climate-compatible technologies and goods, attractive future markets could emerge under these conditions.

Through these positive approaches for innovation and technology, the G8 Summit at Heiligendamm can send out a strong message: that the major industrialized and newly industrializing countries are determined to achieve the crucial progress that is needed to solve the climate problem. This impetus should flow into the forthcoming climate conferences and be translated into practical agreements as soon as possible.

Recommendations

- Agree, within the G8+5 framework, an 'innovation pact on decarbonization' with joint parameters, a Road Atlas and measures to promote technological cooperation
- Harness this impetus for the UNFCCC

5 Strengthening the EU's leading role

In order to be a credible negotiating partner within the climate process, the European Union should fulfil its leading role. To this end, it must first achieve its Kyoto commitments and then set more far-reaching and ambitious reduction targets. In the Council's view, a 30% reduction target for greenhouse gas emissions by 2020 compared with the 1990 baseline and an 80% reduction target by 2050 are appropriate. At the same time, the EU must demonstrate the feasibility of restructuring energy systems and curbing energy demand by achieving measurable successes of its own. This is the only way to convince other countries that such a policy is viable and effective.

The WBGU regards the European Commission's proposals on climate and energy – the Green Paper on Energy Efficiency and the Energy Efficiency Action Plan (European Commission, 2005, 2006) – as a good basis for further progress. The Strategic EU Energy Review that is to be put forward by the Commission in January 2007 should establish ambitious policy criteria for achieving the objectives of sustainability, innovation and security of supply. These proposals must then be endorsed and implemented consistently by the Member States. A key factor here is the elaboration of binding targets, parameters and timetables.

During the German Presidency, decisions will be taken on the key elements of the EU's energy policy for the coming years. The Federal Government should use its influential position to drive forward an ambitious global energy and climate policy.

Triggering an efficiency revolution

The proposals set out in the Energy Efficiency Action Plan, as well as existing directives and regulations, provide a sound basis for the necessary improvements in energy efficiency. The potential energy savings of more than 20% by 2020, cited in the Action Plan, should be increased substantially through binding European rules, ambitious national targets and the rigorous enforcement of existing legislation. The WBGU recommends that the following measures and standards be adopted as mandatory in the implementation of the Action Plan:

– a rapid revision of Directive 2002/91/EC on the Energy Performance of Buildings, with the aim of bringing it into line with the passive house standard (15 kWh/m²/yr), and far more stringent provisions to speed up efforts to upgrade the energy performance of existing buildings;
– for new cars, beyond the existing voluntary commitment from car manufacturers' associations to achieve average fleet emissions of 140 g of CO_2 per kilometre for new cars by 2008, binding European rules on further emission reductions (120 g CO_2 per km by 2012, 100g CO_2 per km by 2015 and 80g CO_2 per km by 2020);
– the introduction of dynamic product standards through the adoption of implementing measures based on Directive 2005/32/EC on the Eco-design Requirements for Energy-using Products so that the best energy efficiency ratings (A or A++) will apply to all energy-intensive products after four years.

Expanding renewables

In order to promote renewable energies, the Member States should commit to ambitious innovation targets and practical activities to achieve them. To this end, the targets agreed in 2001 for the share of renewables in electricity production (21% by 2010) and primary energy (12% by 2010) should be increased on the basis of further agreements. The WBGU proposes that a binding target of 40% of renewables in electricity production by 2020 be adopted, along with a figure of 25% for primary energy, supplemented by further sector-specific targets. However, renewables expansion should not take place at the expense of other dimensions of sustainability (this applies especially to bioenergy or hydropower; WBGU, 2004). A key prerequisite for the integration of renewables is the completion of the EU's internal market for electricity and gas, combined with high-capacity trans-European grids (see Lighthouse Project 1). These grids would also enable the EU to engage in energy partnership with North Africa.

Fostering international cooperation in the energy sector

The EU should utilize its international position and technical know-how to a greater extent to develop and deploy renewables and promote energy effici-

ency worldwide. Within the G8 framework, the EU should drive forward the targets and components of the 'innovation pact' (see Section 4). Within the United Nations Commission on Sustainable Development and in bilateral cooperation with newly industrializing countries and international financial institutions, too, a clear message should be sent out about the need to expand renewables and increase energy efficiency. The increase in the budget of the Global Energy Efficiency and Renewable Energy Fund (GEEREF) to promote efficiency and renewables technology in developing countries sends out an important signal in this context.

Making the Emission Trading Scheme efficient and effective

The EU's Emission Trading Scheme (ETS) is a key element of the European climate protection strategy. To ensure that it offers effective incentives for economically efficient climate protection and low-emission technologies, it must be developed further and improved (SRU, 2006). The European Commission's initiative to demand more ambitious reduction targets for the second trading period is a first step towards inducing the level of scarcity of allowances which is essential for effective trading. The planned integration of aviation into the ETS also points in the right direction; other sectors should follow suit. In the National Allocation Plans, however, the allocation of allowances should be decoupled from previous emissions to a far greater extent. During the second trading period, the EU should make much more use of the option of auctioning allowances than is currently the case (at present, Member States can allocate up to 10% of allowances by auctioning). Indeed, in the medium term, rather than setting a ceiling, a minimum limit on the allowances to be auctioned should be set.

For sectors which cannot be integrated into the ETS for practical reasons or due to the high costs involved, and which are currently not regulated effectively, minimum emission charges or, if appropriate, ambitious minimum standards should be imposed to a greater extent on an EU-wide basis. The ETS's potential to promote efficient climate protection can be increased through the involvement of third countries, provided that appropriate institutional arrangements are in place in these countries and their integration does not just inject 'hot air' into the scheme. An efficient ETS will ultimately set standards for the development of emissions trading schemes outside Europe as well. The WBGU recommends identifying the conditions which must be in place for the development of a transregional network of compatible trading schemes in the long run and defining the role that the ETS could play in this context – perhaps even as the nucleus of such a network.

Strengthening the function of the public sector as a role model

Society will accept a shift towards sustainable consumption more readily if that shift is actively supported and practised by those initiating it. In order to increase the demand for energy-saving or low-emission products and processes, and thus create incentives for innovation, the EU Member States should prioritize these products and processes in public procurement, the award of construction contracts, and buildings use. Directive 2006/32/EC on Energy End-Use Efficiency and Energy Services provides a good basis here. However, the major energy-savings potential in the field of public procurement can only be harnessed if in practice, the Member States go beyond the minimum requirements of the Directive. In particular, the WBGU recommends that in the context of public procurement and funding programmes, the EU Member States adopt criteria which ensure that only high-efficiency products may be purchased, e.g. products with an energy efficiency rating of A or A++ or cars with maximum emissions of 100 g CO_2 per km. The economic basis for decision making for procurement should be the total costs over the product's life cycle, not the purchase price. If this approach fails to produce substantial savings, the adoption of further binding provisions by the EU should be considered.

Implementing the programme of action on 'sustainable consumption'

So far, the climate protection measures adopted by the EU have not taken appropriate account of private consumption and transport. The 'ten-year framework of programmes on sustainable consumption and production' adopted by the United Nations in Johannesburg and elaborated in Marrakesh in 2003 calls for the establishment of sustainable production and consumption patterns worldwide. In line with the principle of common but differentiated responsibilities, the industrialized countries are called upon to take on a leading role in establishing sustainable consumption patterns. The EU's Energy Efficiency Action Plan should therefore be adopted and implemented swiftly and effectively by the Member States, also in light of

the objectives set in the UN Action Programme. A key aim, in this context, is to harmonize the many different product labelling and certification schemes in the EU and launch a major campaign to promote eco-efficient products.

Redirecting energy subsidies

According to the European Environment Agency, two-thirds of the energy subsidies in the EU-15 (approx. € 22 billion) still go to support fossil fuel production and consumption. Just one-sixth of the EU's energy subsidies goes to support renewable energies (EEA, 2004). This situation is incompatible with a sustainable energy policy (WBGU, 2004). The same applies to the subsidies for nuclear power. For that reason, subsidies for fossil fuels and nuclear energy should be gradually reduced. Existing initiatives launched by the European Commission or the EU's Environment Ministers, but also by the OECD, are a starting point for this process. However, they must be driven forward far more resolutely, e. g. through binding phase-out plans.

Boosting adaptation within the framework of development cooperation

The funding of specific projects and strategies to promote adaptation to the impacts of climate change should be guaranteed through binding commitments by the industrialized countries (see Section 3 and Lighthouse Project 3). In addition, greater priority should be given to promoting adaptation as an integral element of development cooperation. The aim must be to link the Poverty Reduction Strategy Papers – drafted and implemented by almost all the developing countries as part of their efforts to achieve the Millennium Development Goals – with the adaptation measures that are necessary to control the impacts of climate change, and to do so swiftly. The European Union's development policy could play a leading role in this context, and the EU could use its influence to ensure that the link between poverty reduction strategies and adaptation features prominently on the agenda of the major multilateral organizations such as the World Bank, the regional development banks, and the UN system.

Recommendations

- Adopt ambitious dynamic product standards for cars and energy-intensive consumer appliances
- Make the EU's Emission Trading Scheme efficient and effective through the adoption of more ambitious reduction targets and the introduction of auctions for allowances
- Create a pioneering role for public procurement policy in the diffusion of low-emission, energy-efficient products and services
- Redirect energy subsidies within the EU

References

Archer, D. (2005):
The fate of fossil fuel CO_2 in geologic time. Journal of Geophysical Research, doi:10.1029/2004JC002625.

BMBF – Federal Ministry of Education and Research (2006):
The High-Tech Strategy for Germany. Berlin: BMBF.

EEA – European Environment Agency (2004):
Energy Subsidies in the European Union: A Brief Overview. EEA Technical Report 1. Copenhagen: EEA.

European Commission (2005):
Doing More With Less. Green Paper on Energy Efficiency. EU Document COM (2005) 265 final. Brussels: European Commission.

European Commission (2006):
Action Plan for Energy Efficiency: Realising the Potential. Communication from the Commission. EU Document COM (2006) 545 final. Brussels: European Commission.

IEA – International Energy Agency (2006):
World Energy Outlook 2006. Paris: IEA.

Joint Science Academies (2005):
Statement: Global Response to Climate Change. Washington, DC: Joint Science Academies.

Meinshausen, M. (2006):
What does a 2°C target mean for greenhouse gas concentrations? A brief analysis based on multi-gas emission pathways and several climate sensitivity uncertainty estimates. In: Schellnhuber, H. J., Cramer, W., Nakicenovic, N., Wigley, T. und Yohe, G. (eds.): Avoiding Dangerous Climate Change. Cambridge, NY: Cambridge University Press, 265–279.

SRU – German Advisory Council on the Environment (2006):
National Implementation of the EU Emissions Trading Scheme: Market-based Climate Change Mitigation or the Continuation of Energy Subsidies by Other Means? Statement. Berlin: SRU.

Stern, N. (2006):
The Economics of Climate Change. The Stern Review. London: HM Treasury.

WBGU – German Advisory Council on Global Change (2002):
Charging the Use of Global Commons. Special Report. Berlin: WBGU.

WBGU – German Advisory Council on Global Change (2003):
Climate Protection Strategies for the 21st Century: Kyoto and beyond. Berlin: WBGU.

WBGU – German Advisory Council on Global Change (2004):
World in Transition. Towards Sustainable Energy Systems. London: Earthscan.

WBGU – German Advisory Council on Global Change (2006):
The Future Oceans – Warming Up, Rising High, Turning Sour. Special Report. Berlin: WBGU.

Scientific staff

It would not have been possible to produce this policy paper without the committed and untiring efforts of the scientific team of the German Advisory Council on Global Change (WBGU):

Prof Dr Meinhard Schulz-Baldes (Secretary-General), Dr Carsten Loose (Deputy Secretary-General), Dipl-Phys Jochen Bard (ISET Kassel), Steffen Bauer, MA (DIE Bonn), Dipl-Volksw Julia E. Blasch (ETH Zurich, from 16.10.2006), Dr Karin Boschert (WBGU Secretariat), Dr Oliver Deke (WBGU Secretariat), Dr Georg Feulner (Potsdam Institute for Climate Impact Research), Dipl-Umweltwiss Tim Hasler (WBGU Secretariat), Dipl-Volksw Kristin Hoffmann (ETH Zurich), Dr Sabina Keller (ETH Zurich), Dipl-Geogr Andreas Manhart (Institute for Applied Ecology, Freiburg), Dipl-Volksw Markus Ohndorf (ETH Zürich), Dr Benno Pilardeaux (WBGU Secretariat), Dr Martin Scheyli (Universiy Fribourg, Switzerland), Dr Astrid Schulz (WBGU Secretariat), Dipl-Pol Joachim Schwerd (University of Applied Science Mainz).

MEMBERS

OF THE GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE

Prof Dr Renate Schubert (chair), economist
Director of the Institute for Environmental Decisions at ETH Zurich, Switzerland

Prof Dr Hans Joachim Schellnhuber CBE (vice chair), physicist
Director of the Potsdam Institute for Climate Impact Research and
visiting professor at Oxford University (Christ Church College)

Prof Dr Nina Buchmann, ecologist
Professor of Grassland Science, Institute of Plant Sciences at ETH Zurich, Switzerland

Prof Dr Astrid Epiney, lawyer
Director of the Institute for European Law, Université de Fribourg, Switzerland

Dr Rainer Grießhammer, chemist
Member of the management board of the Institute for Applied Ecology, Freiburg

Prof Dr Margareta E. Kulessa, economist
Professor of International Economics at the University of Applied Sciences, Mainz

Prof Dr Dirk Messner, political scientist
Director of the German Development Institute, Bonn

Prof Dr Stefan Rahmstorf, physicist
Head of the Climate System Department at the Potsdam Institute for Climate Impact Research
and Professor for Physics of the Oceans at Potsdam University

Prof Dr Jürgen Schmid, aerospace engineer
President of the Institute for Solar Energy Technology, Kassel and Professor of Electrical
Engineering and Information Technology at the University of Kassel

German Advisory Council on Global Change (WBGU)
Secretariat
Reichpietschufer 60–62
D-10785 Berlin, Germany

Phone +49 30 263948 0
Fax +49 30 263948 50
E-Mail wbgu@wbgu.de
Internet http://www.wbgu.de

Copy deadline 21 December 2006
Translation by Christopher Hay, Seeheim-Jugenheim, ecotranslator@t-online.de

This policy paper can be downloaded through the Internet from our website.
WBGU uses certified eco-friendly paper for this publication.

ISBN 978-3-936191-16-6