A Global Contract on Climate Change

Policy paper prepared for the conference

A Global Contract Based on Climate Justice: The Need for a New Approach Concerning International Relations

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Executive Summary

Climate Change represents an unprecedented challenge to global society. Unmitigated climate change will introduce large-scale risks to ecosystems and human societies, while its mitigation represents a major task for the world economic system. Ultimately, managing the problem of climate change will require the weighing of different kinds of risks arising from climate change, adaptation, and mitigation.

Climate change is already under way and can lead to an increase of global mean temperature of up to 5°C or more relative to pre-industrial levels, implying large-scale shifts in global and regional climates, ecosystem patterns, and human activities. Global warming could push components of the climate system (‘tipping elements’) past critical thresholds so that they switch into qualitatively different modes of operation, resulting in considerable consequences for human and ecological systems. The Arctic sea-ice, where summer minima have been decreasing at alarming rates in recent years, and the Greenland ice sheet, which stores ice masses equivalent to a sea level rise of seven meters, are highly sensitive tipping elements. Other, more uncertain tipping elements include the West-Antarctic Ice Sheet, boreal forests, the Amazon rainforest and the Indian summer monsoon. The current state of research suggests, however, that the EU target of limiting the rise in global mean temperature to 2°C above pre-industrial levels will likely be sufficient to avoid most of these effects. It will probably be insufficient to avoid the loss of Arctic summer sea-ice.

Key impacts of climate change include flooding of coastal areas and river deltas, more intense droughts and desertification, increased occurrence of weather extreme events, and water scarcity due to melting glaciers and changing precipitation patterns. Particularly vulnerable regions include Africa, small islands, Asian megadeltas, and the Arctic. In general, developing countries are more vulnerable to climate change. While no level of climate change is inherently “safe”, stabilization of global climate change at 2°C above pre-industrial level is expected to prevent the most severe impacts.

Climate change raises serious questions regarding global equity. Most of the carbon emissions historically occurred in the industrialized countries, and there is a strong link between capital accumulation and historic emissions. At the same time, developing countries as well as low-income groups in the industrialized world are particularly vulnerable to climate change. Due to high exposure to climate risks and limited adaptive capacity, they are projected to feel the bulk of impacts. Unmitigated climate change will further increase global inequalities.

Concerning the cost of mitigating climate change, an economic consensus has emerged in recent years that they will be relatively low at the order of magnitude of 1-2% of global GDP. However, this requires that action is taken quickly and effective institutions and technologies are put into place on a global scale.

Given that the costs of limiting the rise of global mean temperature to 2°C are relatively moderate, and that major impacts of climate change regarding tipping elements and ecosystem changes may be avoided when limiting global warming to 2°C, this appears to be a reasonable target for international climate policy in a Global Contract on Climate Change.

Achieving this target will require an institutional framework that can deliver on the criteria of environmental effectiveness (reducing emissions in accordance with the 2°C limit), economic efficiency (doing so at least costs), and equity (taking into account different responsibilities and capabilities in mitigating and responding to climate change). Along these lines, we propose that a Global Contract should focus on four major issues: establishing a global carbon market, fostering the development and sharing of low carbon technologies, reducing emissions form deforestation and land degradation (REDD), and setting up a framework for addressing adaptation. Such a Global Contract represents a guiding vision that can be implemented via a set of policy roadmaps that eventually merge into an integrated climate policy architecture.

A *global carbon market* achieves environmental effectiveness by setting a cap for global emissions; realizes efficiency through trading of permits; and allows addressing equity considerations through international allocation rules. The emerging price for emissions should stretch across all sectors and countries. A global trading system may be implemented via UNFCCC negotiations, or bottom-up by linking of regional schemes in the context of the International Carbon Action Partnership (ICAP). Ideally, these approaches will complement each other, but bottom-up linking can be a fallback option if a more comprehensive approach turns out to be politically not feasible in the 2009 Copenhagen negotiations. In an international carbon market, developing countries should at least participate by means of one-sided trading mechanisms such as a reformed Clean Development Mechanism (CDM).

A large-scale transformation of the global energy systems will be needed to achieve the deep emission reductions required to avoid dangerous climate change. In this context experience learning has a large potential to reduce the costs of the transition towards *low-carbon technologies*. However, market failures where e. g. innovators cannot fully capture the benefits from developing a new technology because others will imitate them can lead to an undersupply of research and developments. Thus, policy intervention is required in addition to carbon pricing. Policy instruments on the national level include enhanced R&D funding for low-carbon technologies, publically supported demonstration projects for complex technologies such as Carbon Capture and Storage (CCS), and market introduction programmes for renewable energies. The industrialized countries should agree on a burden sharing for the introduction of renewable energy. In addition, sustainable energy provision for developing countries is of key importance for a long-term and global solution of the climate problem and comes with numerous ancillary local and regional benefits. Mainstreaming low-carbon development into development policy, promoting sharing of technologies, and setting up a low-carbon fund for least developed countries and regions are important policy options to foster leapfrogging of developing countries into a low-carbon future.

Deforestation and forest degradation accounts for roughly 20% of global anthropogenic greenhouse gas emissions. According to most estimates, these emissions can be reduced at low costs. Also, reducing deforestation comes with significant ancillary benefits due to the preservation of ecosystems and their services. Important challenges in establishing an environmentally effective REDD regime lie in ensuring permanence of forest conservation and limiting leakage. Options for providing incentives for REDD are full-scale integration into the global carbon market, fund-based schemes, or hybrid approaches.

Finally, it is clear that to solve the climate problem mitigation and *adaptation* must go hand in hand to meet the principle of "avoiding the unmanageable and managing the unavoidable". The funding required to finance adaptation to climate change in the developing world is significant. As the adaptation fund set up under the Kyoto Protocol is inadequate in meeting these needs, a broadened funding mechanism should provide a sufficient and reliable financial basis for adaptation activities in developing countries.

There are several areas where we need to improve our knowledge to ensure that the challenge of climate change can be managed in an effective, efficient and equitable manner. First, a better understanding and management of the risks and uncertainties surrounding the problem is required. For example, given our current knowledge the 2° C-limit is a reasonable target for climate policy, but further research is required to understand the implications of this target for mitigation and impacts. Second, the climate problem gives rise to multiple and overlapping public goods: mitigating climate change may require an extensive use of biomass for energy production, for example, but this may interfere with other public goods such as food security or biodiversity. We need to understand how to tailor policies that avoid solving one public good problem at the expense of another. Third, climate change mitigation and adaptation require a concerted global effort entailing global burden-sharing in various areas. Designing climate policies involves explicit and implicit judgments between the interests of (a) different generations, (b) different countries and regions of the world, and (c) different economic sectors and stakeholders. We need to better understand the distributive effects on these groups when using climate policy instruments. Fourth, the long-term nature of climate change gives rise to credibility problems in policy making. We require a better understanding of how to design institutions and instruments that can translate long-term targets into effective short- to mid-term policies.

While fundamental challenges for science and policymaking remain, we know enough to justify action that should aim at limiting global warming to 2°C. In view of the scale of the challenge, the historic responsibility of the industrialized countries, the vulnerability of the developing world and the rapidly increasing energy demand in the emerging economies, it is evident that international cooperation is vital for a sustainable solution of the climate problem. Implementing a global price on emissions, fostering low-carbon technology research and development, reducing emissions from deforestation and land degradation, and supporting adaptation in poor vulnerable countries should form the central pillars of an environmentally effective, economically efficient, and equitable Global Contract on Climate Change.

Introduction

Tackling climate change is one of the most significant challenges to the global society in the 21st century. In his 2006 report, Nicholas Stern referred to the climate problem as the “greatest market failure that the world has seen”. Indeed, climate change is unique due to the extreme temporal and spatial decoupling of its causes and consequences: Greenhouse gas emissions affect the climate on a global scale, no matter where they occurred, and our actions today affect the state of the planet for centuries to come.

In view of the pressing global climate problem and its implications for development, members of the European Parliament from different political groups together with the Ecosocial Forum Europe and the Potsdam Institute for Climate Impact Research (PIK) will host the conference “A Global Contract Based on Climate Justice – The Need for a New Approach Concerning International Relations” in the European Parliament in Brussels on 11 November 2008. The goal of this conference is to provide a forum for discussions among parliamentarians and stakeholders, and to foster their involvement in shaping the future international climate policy architecture. A ‘Global Contract’ does not necessarily imply the ratification of a uniform, all-compassing agreement, but could also refer to a set of policy roadmaps, either top-down or bottom-up, that will eventually merge into an integrated architecture.

The objective of this background paper is to provide an integrated and science-based perspective on the future international climate policy architecture. Economically speaking, climate protection is a global public good, i. e. its provision leads to benefits to the human society as a whole. The situation is complicated by interactions with other public goods such as development, ecosystem goods and services, or technology development. Hence, a holistic analysis and careful weighing between various policy objectives is essential.

The paper is structured as follows: The first part provides an overview of the climate change problem, reviewing the state of knowledge on human interference with the climate system, climate change impacts, equity implications of climate change, current emission trends, and the economics of climate stabilization. In the second part, principles, key elements and design options for the various components of a “Global Contract” are discussed. Besides summarizing the state of research and presenting various design options, we aim at identifying future challenges for research on sustainable solutions to the climate problem, potential conflicts and trade-offs between various policy objectives as well as barriers to implementing climate policy.

I. The climate problem

I.1 Human interference with the climate system

- **Climate change is already under way, and the bulk of it is due to anthropogenic emissions of greenhouse gases. If climate change continues unmitigated, global warming can reach as much as 5°C or more until 2100.**
- **Global warming could push components of the climate system past critical thresholds so that they tip into qualitatively different modes of operation, thus resulting in large-scale consequences on human and ecological systems.**

In its Fourth Assessment Report, the IPCC has formulated a clear message: Climate change is already under way, and the bulk of it occurs due to anthropogenic activities. As depicted in Figure 1, there is a strong empirical warming trend on all continents that has accelerated during the past decades. The chart also shows that the same models that are used for predicting future climate change can accurately reproduce the spatial and temporal pattern of the past warming, if man-made emissions are included. By contrast, if the models are run taking into account only natural changes such as changes in solar irradiance and volcanic eruptions, but without considering the human factor, there will be a substantial deviation between model results and observations. This is only one piece of evidence among many that demonstrates that global warming is caused by humans.

Due to our past activities and because of the inertia in the climate system, we are already committed to more changes: Even if the atmospheric greenhouse gas concentration were stabilized at current levels, the world would face 0.5 °C of global warming on top of the 0.7 °C that have already occurred. The IPCC reckons that the cumulative warming by the end of the century would be approximately in a range of 1.7-7.0°C relative to pre-industrial levels, depending largely on the future development of anthropogenic emissions.

The climate system is extremely complex and highly non-linear, and therefore small changes in certain control parameters can result in some components of the climate system changing to a qualitatively different mode of operation. Such components are referred to as tipping elements (Lenton et al., 2008). The Arctic sea ice is one example of a tipping element: As the highly reflective ice and snow cover at high latitudes retreats in response to warming, an increasing portion of the incoming sunlight is absorbed by the dark ocean surface rather than being reflected back to space, thus giving rise to additional regional warming. Due to this positive feedback, Arctic sea ice becomes unstable already at low levels of global warming. In fact, the ice cover in the Arctic Ocean has shrunk rapidly over the last three decades, and this trend has dramatically accelerated in recent years (NSIDC, 2007). Arctic sea ice is only a few meters thick and therefore responds quickly to changes, thus serving as an early warning system for the effects of climate change in the Arctic.

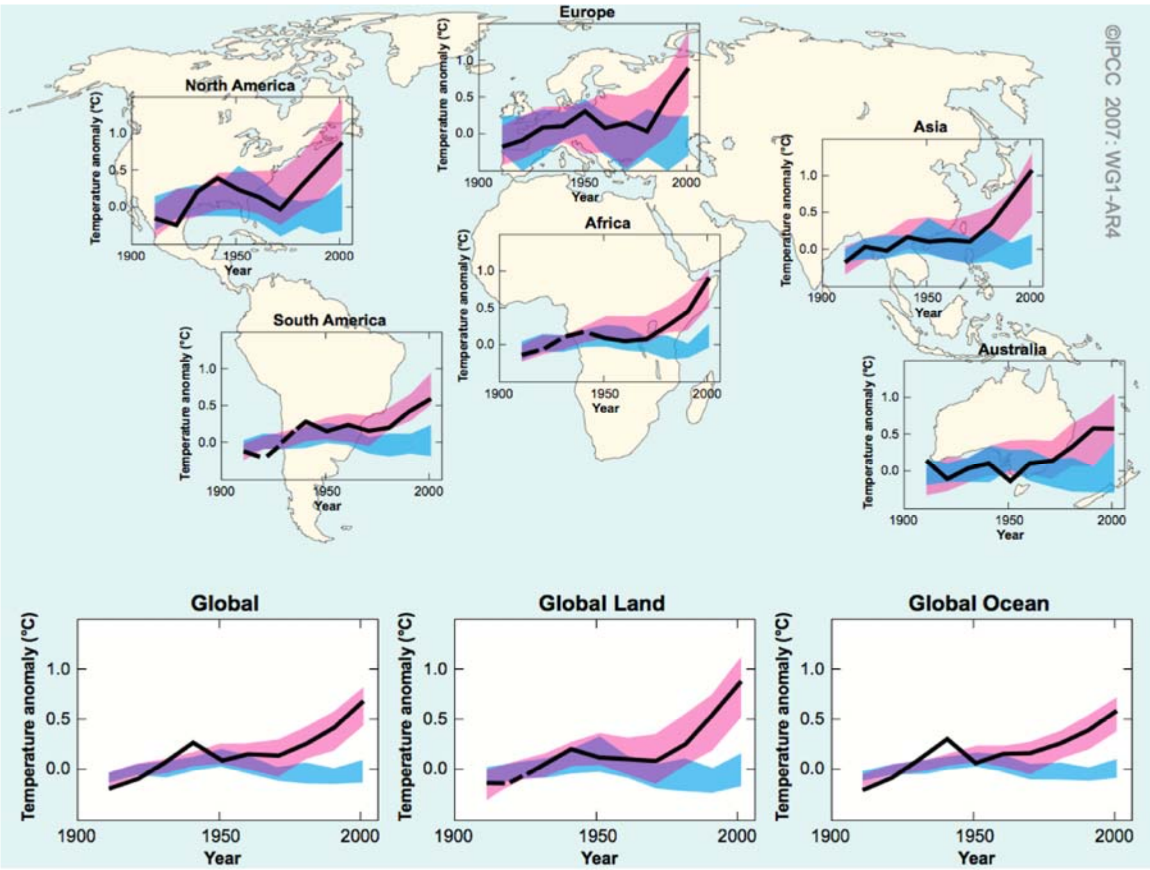

Figure 1: Comparison between observed continental-scale surface temperature trends (black lines), model results using natural and anthropogenic forcings (pink range) and model results using only natural forcings due to volcanoes and changes in solar activity (blue bands). Source: IPCC (2007a).

Other significant tipping elements include the ice sheets of Greenland and West Antarctica. For both these land-borne ice masses melting results in several meters of sea level rise and would therefore have dramatic impacts on human societies. In contrast to sea ice, these continental ice sheets are several 1000 m thick and will therefore take centuries to millennia to react to the global warming signal. While the destabilization of these ice sheets can be triggered in the course of this century, the bulk of the impacts will occur later.

As laid down in Article 2 of the United Nation’s Framework Convention on Climate Change, the ultimate goal of the convention is to achieve a “stabilization of greenhouse gas emissions at a level that would prevent dangerous anthropogenic interference with the climate system”. In line with this goal, the European Union has formulated the objective to limit global warming to 2°C above pre-industrial levels. Tipping elements in the climate system are a particularly important aspect for the assessment at which level global warming can be considered dangerous. In their study, Lenton et al. (2008) identified eight tipping elements in the climate system whose fate is determined by human activities over the next hundred years (Figure 2). Their estimates of the temperature thresholds for triggering the tipping elements ('tipping points') suggest that the EU's 2°C-target will be sufficient to avoid triggering intermediately sensitive tipping elements such as the West-Antarctic ice sheet, El Niño / Southern Oscillation, Indian summer monsoon circulation, Amazon rainforest and Boreal forests. The 2°C–target, however, bears the risk of being insufficient for avoiding a collapse of the Greenland ice sheet. For the highly sensitive Arctic sea ice, the tipping point may even have been passed already.

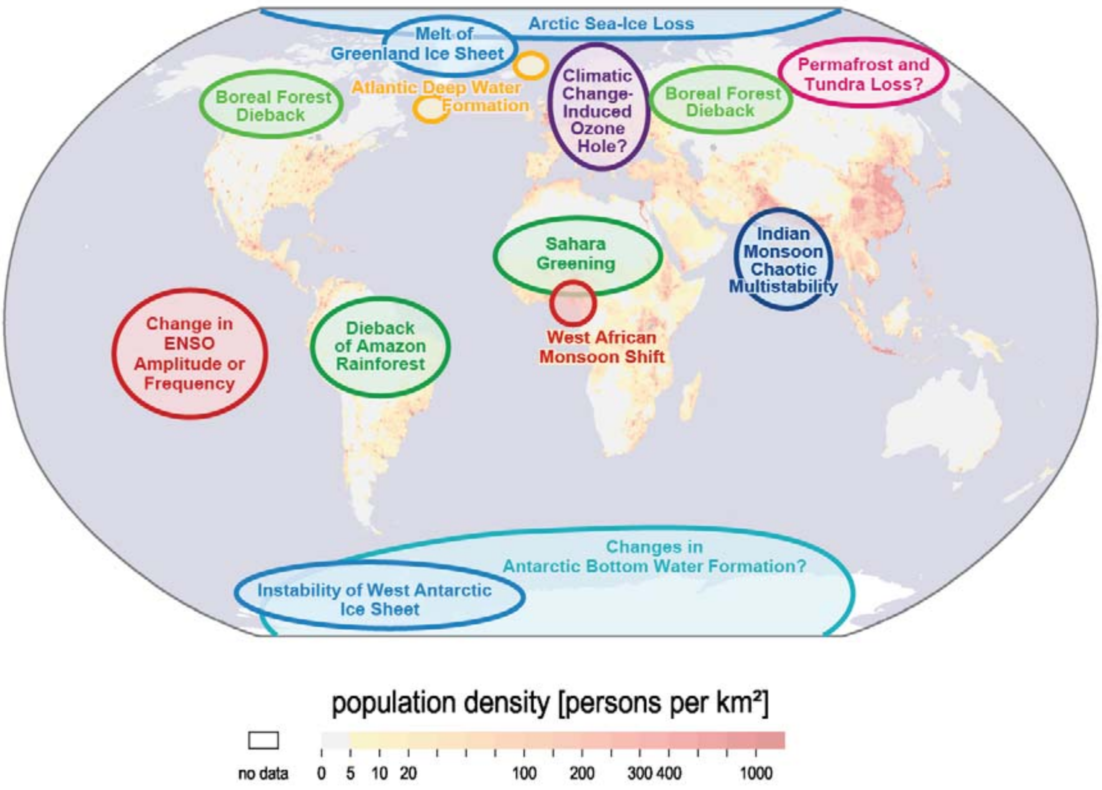

Figure 2: Tipping elements in the Earth system. Source: adopted from Lenton et al. (2008).

Key challenges for further research on the physical basis of climate change are to reduce uncertainties about future changes in climate variables such as temperature and precipitation, to foster knowledge on regional patterns of climate change, and to promote the understanding of instabilities and tipping elements, particularly towards a more quantitative assessment of critical thresholds.

I.2 Impacts of climate change: The threat of dangerous climate change

- **Both human societies and ecosystems are affected by climate change in many different ways.**
- **Key impacts of climate change include flooding of coastal areas and river deltas, increased occurrence of many extreme weather events, stronger droughts in many regions, and water scarcity due to melting glaciers and changing precipitation patterns.**
- **Particularly vulnerable regions include Africa, small islands, Asian megadeltas, and the Arctic. In general, developing countries are more vulnerable to climate change because of their limited adaptive capacities.**
- **While limiting global warming to 2°C would still result in significant impacts, it is expected to prevent the most severe impacts of climate change, such as deglaciation of ice sheets leading to several meters of sea level rise.**

Anthropogenic emissions of greenhouse gases perturb the global climate system, resulting in increasing temperatures and rising sea levels across the world, changes in precipitation patterns, and increases in climate variability. There will be significant regional variability in climate change and its impacts. In general, warming will be stronger over land areas than over the oceans, and it will be particularly strong in polar regions. Current differences in the distribution of precipitation are generally amplified, i. e. wet regions generally will become wetter and dry regions will become drier. A shift in the mean climate in combination with an increase in climate variability will have important effects on extreme weather events. It is very likely that the frequency and intensity of heat waves will increase across the world, and that heavy precipitation events become more frequent. Furthermore, it is likely that the area affected by droughts increases, that intense tropical cyclone activity increases, and that the incidence of storm surges increases (IPCC, 2007a).). Increases in these extreme events have already been observed during the last decades. In addition to the risks from climate change, carbon dioxide emissions are increasing the acidity of the oceans for millennia, which is a major threat to marine ecosystems.

Climate change can affect ecosystems and societies in many different ways. It will cause large-scale shifts in vegetation, major losses of plant and animal species, significant shifts in the geographic ranges of disease vectors and pathogens, and it will have wide-ranging effects on agriculture, water supply, human health and tourism (IPCC, 2007b). A major fraction of species are likely to be at increasingly high risk of extinction due to climate change (IPCC, 2007b). Ecosystem impacts are particularly severe, since healthy natural ecosystem an important role in mitigation (due to their function as carbon sinks) and adaptation (e. g. local climate regulation, flood protection).

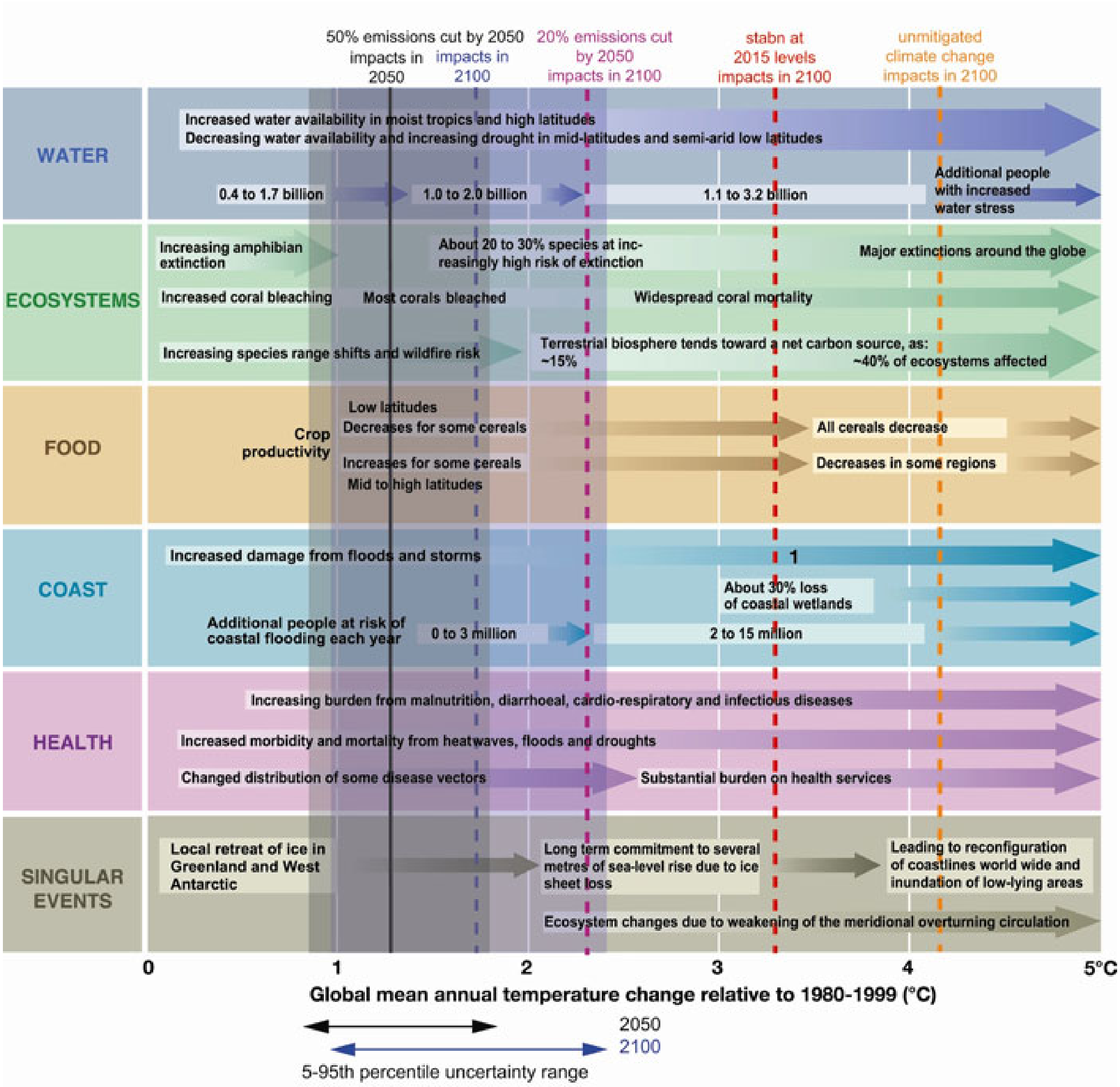

Figure 3: Expected impacts of climate change as a function of global mean temperature change. Vertical lines indicate the warming expected to result from indicated emissions scenarios, with shadings indicating the uncertainty range for the 50% emissions reduction scenario. Source: Parry et al. (2008).

The regional impacts of climate change are not only influenced by regional changes in climate and weather patterns but also by the current climate, by social and economic factors, and by the presence of non-climatic risks and stresses. The impacts of decreasing precipitation are for instance most severe in regions that are already water-scarce, and any change in climate is particularly threatening for societies dominated by climate-sensitive livelihood strategies, such as rain-fed agriculture, forestry, fisheries, and weather-dependent tourism. Furthermore, societies with limited economic resources, with limited technical and institutional capacity, and with urgent non-climatic problems, such as high disease levels and malnutrition, will be in a much weaker position to prepare for and cope with the impacts of climate change than affluent societies with effective institutions. The unequal vulnerability of regions to climatic risks is highlighted by the fact that more than 98% of the casualties caused by floods, droughts and storm surges in the last four decades have occurred in developing countries (EMDAT, 2008).

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Initially, anthropogenic climate change will often exacerbate existing climate risks, e. g., leading to stronger droughts in already drought-prone regions and to stronger floods in already flood-prone regions. For that reason, it is sometimes difficult to state whether a particular weather event has already been influenced by anthropogenic climate change or not. Over time, however, societies will increasingly experience climatic risks that have never occurred in a particular region. For instance, 2004 saw the first-ever hurricane to form over the South Atlantic. This hurricane caused significant damage in southern Brazil, which had no experience at all in mitigating hurricane losses. Similarly, the summer heat wave 2003 subjected many regions in Europe to temperature levels far beyond those experienced in the past, leading to more than 70,000 deaths in Western Europe (Robine et al., 2003).

Box I.1: Climate Change as a Security Risk

The last decade has seen growing scientific and political interest in potential security risks caused by global warming. It is conceivable that the dramatic impacts of climate change may move societies beyond their adaptive capacity and cause regional destabilisation, threatening national and international security. In a recent report, the German Advisory Council on Global Change (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, WBGU) has investigated this issue in detail (WBGU, 2008). Its findings suggest that climate-induced interstate wars are unlikely to occur. However, climate change could well trigger national and international distributional conflicts and intensify problems already hard to manage such as state failure, the erosion of social order, and rising violence. These dynamics threaten to overstrain the established global governance system, thus jeopardizing international stability and security.

Four conflict constellations for climate-induced security problems can be identified in which critical developments can be anticipated as a result of climate change and which may occur with similar characteristics in different regions of the world. These conflict constellations define typical causal linkages at the interface of environment and society, the dynamics of which can lead to social destabilization and, finally, to violence:

- *Degradation of freshwater resources:* Today, more than a billion people are without access to safe drinking water. Climate change is likely to worsen this situation by increasing the variability of precipitation and by melting glaciers, which provide a large fraction of humanity with water.
- *Decline in food production:* Global warming is expected to have a negative impact on the world's food production mainly by lowering productivity and more frequent droughts. As already more than a billion people are suffering from malnutrition today, additional food crises might lead to violence and destabilisation.
- *Increases in storm and flood disasters:* More frequent heavy-precipitation events, sea-level rise and a higher intensity of tropical cyclones make it likely that some regions of the world will suffer from additional and more intense disasters. Events like these have already led to violence and conflict in the past.
- *Environmentally induced migration:* Climate-induced impacts on water and food supply as well as storm and flood disasters will substantially raise the number of environmental refugees. Experience shows that conflicts in transit and target regions are to be expected.

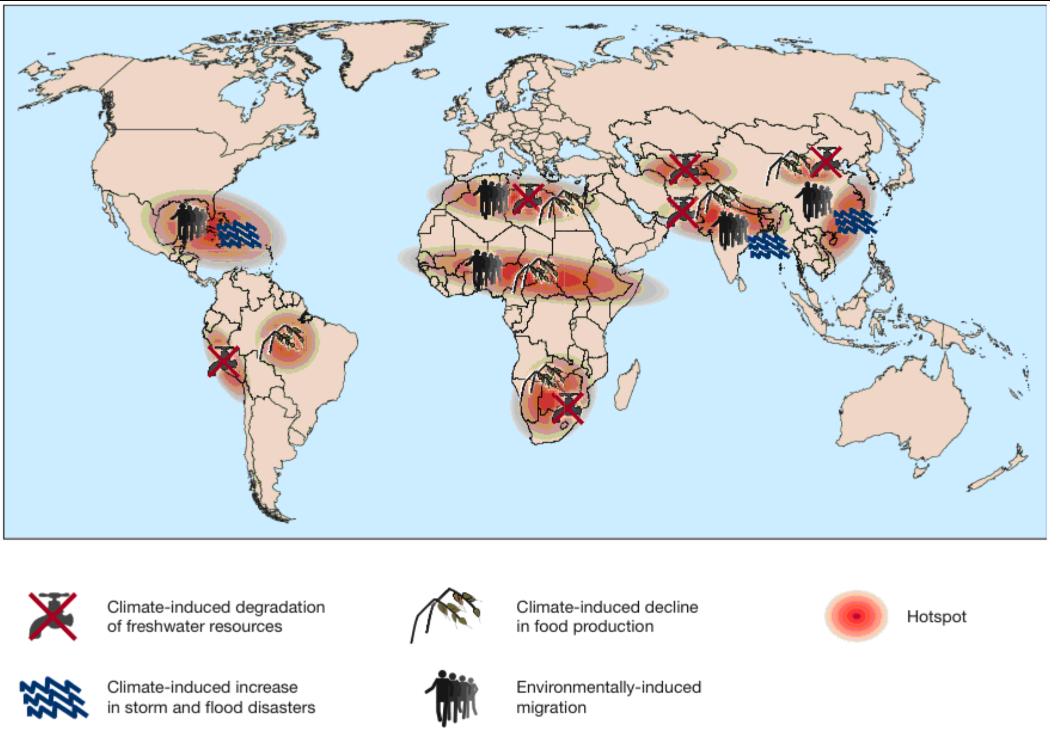

Figure 4: Conflict constellations in selected hotspots. Source: WBGU (2008).

Regional hotspots of security risks induced by global warming can be identified based on the regional distribution of climate impacts associated with these conflict constellations and on an analysis of political stability in different world regions. The world map below shows the hotspots identified in the WBGU report.

Climate change can be expected to jeopardise security not only on the regional level. Threats to international security are based on a number of issues, including a growing number of fragile or failing states, climate impacts on the global economy, distributional conflicts between the main drivers of climate change and the most affected countries, and an intensification of migration. Classic instruments of security policy are likely to fail in the face of these challenges, especially during a time when the current world order with the United States of America as the only superpower is likely to be replaced my a multi-polar world, where rapidly growing countries like China and India gain significance. Global politics over the next two decades will therefore have to master two challenges in parallel: the shift in the centres of power of the political world order, and the global turnaround towards effective climate policy.

The impacts of climate change can threaten basic human needs, in particular food and safe shelter. Climatic risks can destroy the livelihoods of many people, trigger large-scale migrations, and induce or exacerbate national and international conflicts (Box I.1). Climate change is therefore identified as a major obstacle to poverty reduction objectives and achievement of the Millennium Development Goals (IPCC, 2007b; Stern, 2006).

Comparing climate impacts across regions and sectors is difficult due to remaining uncertainties about regional impacts but also to the necessity of making normative judgments, e. g., on the relative importance of the loss of the traditional hunting culture of the Inuit in the Arctic Circle vs. risks to irrigated agriculture in the Central Valley in California. Nevertheless, after a careful review of the available literature, the IPCC has recently identified several regions and systems that are considered particularly vulnerable to climate change (IPCC, 2007b).

According to the IPCC, the most vulnerable ecosystems are the tundra, boreal forests, mountain ecosystems and Mediterranean-type ecosystems, mangroves and salt marshes, coral reefs and the sea-ice biome, which includes iconic species such as the polar bear. Other vulnerable systems and sectors include low-lying coasts and river deltas, due to the threat of sea-level rise and storm surges; water resources in some mid-latitude and dry low-latitude regions, due to decreases in rainfall and higher rates of evaporation and transpiration; agriculture in many low-latitude regions, due to reduced water availability; and human health, especially in areas with low adaptive capacity. The particularly vulnerable regions identified by the IPCC comprise Africa, especially the sub-Saharan region, because of already high temperatures, the importance of climate-sensitive activities such as rain-fed agriculture, and generally low adaptive capacity; small islands, due to the high exposure of the population and infrastructure to sea-level rise and increased storm surges; Asian mega-deltas, due to large populations and high exposure to sea-level rise, storm surge and river flooding; and the Arctic, because of the very high rates of observed and projected warming. In all world regions, some people can be particularly at risk, such as the poor, young children and the elderly.

The IPCC report emphasizes that climate impacts become more severe the larger the magnitude of climate change, and the faster its pace (Figure 3). Recent climate change has already caused significant impacts in many regions, including 70.000 premature deaths and major economic damage during the 2003 summer heat wave in Europe. While no level of climate change is inherently “safe”, stabilisation of global climate change at 2°C above the preindustrial level is expected to prevent the most severe impacts of climate change.

In particular, stabilisation at this level would

- likely prevent deglaciation of the Greenland and West Antarctic ice sheets, which would eventually raise sea levels by several meters;
- limit the increase of floods, droughts and forest fires in many regions, including in Europe;
- limit the increase of death and disease from infectious diseases, diarrheal diseases, and extreme heat;

- prevent mass extinction of more than a quarter of all known species, including many Alpine species;
- and prevent significant decreases in global food production.

Climate stabilisation at 2°C above the preindustrial level would, however, still cause significant impacts, including

- more and stronger extreme weather events, including heat waves;
- increasing water stress in many world regions;
- decreasing food production in most tropical regions; and
- damage to many ecosystems, including widespread loss of coral reefs.

There is still considerable uncertainty about the many regional impacts of climate change, which is an important focus of further research. Studies on regional impacts are essential for planning adaptation measures as well as the evaluation of climate damages. Estimations of climate impacts should include monetary evaluation as well as quantitative metrics that can account for damages in non-market goods and services.

I.3 Climate change and equity

- **Historically, most of the carbon emissions occurred in the industrialized countries, and there is a strong link between capital accumulation and carbon debt.**
- **Developing countries as well as low-income groups in the industrialized world are particularly vulnerable to climate change and are projected to feel the bulk of impacts.**
- **Due to the discrepancy between historical responsibility and vulnerability, climate change tends to increase global disparities.**

The historical responsibility for climate change is distributed unequally across the world, and so are its impacts. As depicted in Figure 5, present climate change was caused mainly by greenhouse gas emissions from industrialized countries in the Northern hemisphere whereas most developing countries have contributed very little to the greenhouse effect. For instance, average CO_2 emissions from fossil-fuel burning in the period 1950 to 2003 were 5.2 tons per person and year in the US, 2.7 tons in Russia, 0.4 tons in China and less than 0.2 tons in India. As argued above developing countries are, however, disproportionally affected by the consequences of climate change.

Put simply, rich countries are responsible for the bulk of the problem because their wealth was to a large extent built on the expense of emitting substantial amounts of CO_2. Furthermore, they continue to have large per-capita emissions simply because they can afford to consume large amounts of fossil fuels. On the other hand, poor countries are generally most affected because they lack the technological and financial means to adapt to climate change. Furthermore, future climate change tends to be more uncertain in low-latitude developing countries than in industrialized countries. The discrepancy between those who are most responsible and those who are most vulnerable poses the key moral dilemma of climate change and needs to be addressed as part of a fair Global Contract on Climate Change. It has thus long been recognized that the developed world bears a special responsibility in helping poor regions to adapt to and cope with the consequences of climate change.

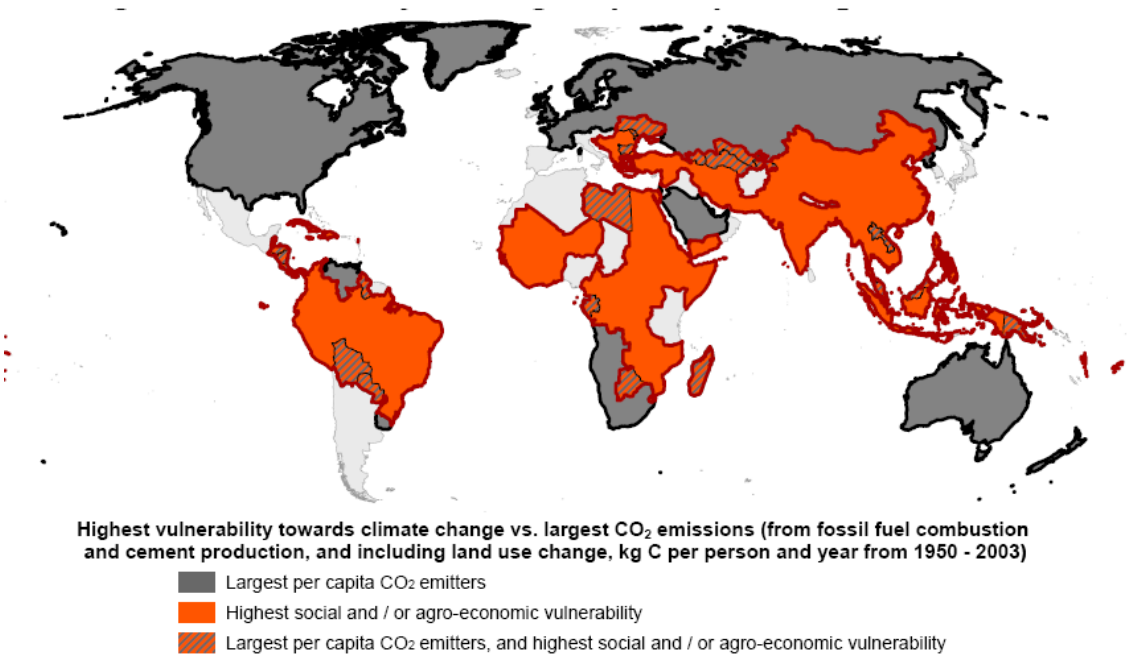

Figure 5: The moral dilemma of climate change – there is only little overlap between the countries with highest historical per-capita greenhouse gas emissions (grey) and countries that are most vulnerable to climate change (red).

At the same time, emerging economies are set to become major emitters themselves. Due to their large population and rapid economic growth, China and India will account for a substantial fraction of future global emissions, while they will continue to be highly vulnerable to climate change. This puts them in a special position and may, on the medium term, make it easier to reach a comprehensive international agreement.

While the moral dilemma of climate change is generally discussed in the context of inequity across regions, it is important to note that climate change also affects equity within societies (e. g., decreasing summer precipitation in a region may be beneficial for the tourism industry but detrimental for agriculture) and across generations (e. g., the current population of small islands may benefit economically from intercontinental tourism but the emissions caused by long-distance flights are threatening the very existence of these islands in the future).

It is a crucial challenge for international climate policy to address this moral dilemma. A fair solution to the climate problem will have to account for vulnerability to climate change and historic responsibility. Equity implications and ways to incorporate equity considerations into climate policy instruments are discussed in Part II.

I.4 Current emission trends

- **Despite efforts to curb greenhouse gas emissions, current emission trends track along the high end of the spectrum of IPCC emission scenarios.**
- **Recent increases have been spurred by the robust growth of the world economy. Most industrialized countries struggle to achieve significant reductions, while emerging economies have seen rapid emission growth.**
- **An issue of particular concern is the increase in the carbon intensity of energy use: With rising prices for oil and gas, coal becomes, in the absence of carbon pricing, an increasingly attractive energy carrier.**

With a few exceptions, anthropogenic greenhouse gas emissions have been steadily increasing ever since the onset of the industrialized revolution in the 18th century. In recent years, this trend has even accelerated. While the CO_2 emissions from fossil fuels increased by 1.0% per year during the 1990s, their growth rate accelerated to almost 3% per year from 2000 to 2005. If current trends continue, future emissions will exceed even the highest of the emissions scenarios used by the IPCC for simulations of future climate change (Sheehan, 2008). The situation is aggravated by the fact that an increasing fraction of emissions remains airborne due to a decreasing oceanic uptake of CO_2 (Canadell et al., 2007). In a warming world, also the land biosphere, the second major natural sink, is projected to become less efficient in absorbing CO_2. In combination, the emissions increase and the declining sinks result in rapidly growing atmospheric CO_2 concentrations.

For the further analysis, it is helpful to decompose emission trends in the key underlying factors as identified in the Kaya-identity distinguishing population growth, labour productivity (i. e. GDP per capita), as well as energy and carbon intensity. Energy intensity describes the amount of primary energy needed for producing one unit of economic output, while carbon intensity refers to the CO_2 emissions per unit of primary energy consumption (Raupach et al., 2007; Nakicenovic and Grübler, 2000). The historic global development is shown in Figure 6.

Recent increases in emissions have largely been spurred by the robust growth of the world economy since 2000 (Figure 6a). Emerging economies like China and India encountered a highly energy and carbon-intensive boom, resulting in a rapid increase of their CO_2 emissions (Figure 6b). Partly, their surge in emissions is due to the relocation of energy intensive activities away from the traditional industrialized countries. At the same time, most industrialized countries struggled to keep on track towards reaching their Kyoto reduction targets or, as in the case of the USA, declined to ratify the Kyoto Protocol. Per capita emissions in industrialized countries are still substantially higher than those in developing countries, including China and India.

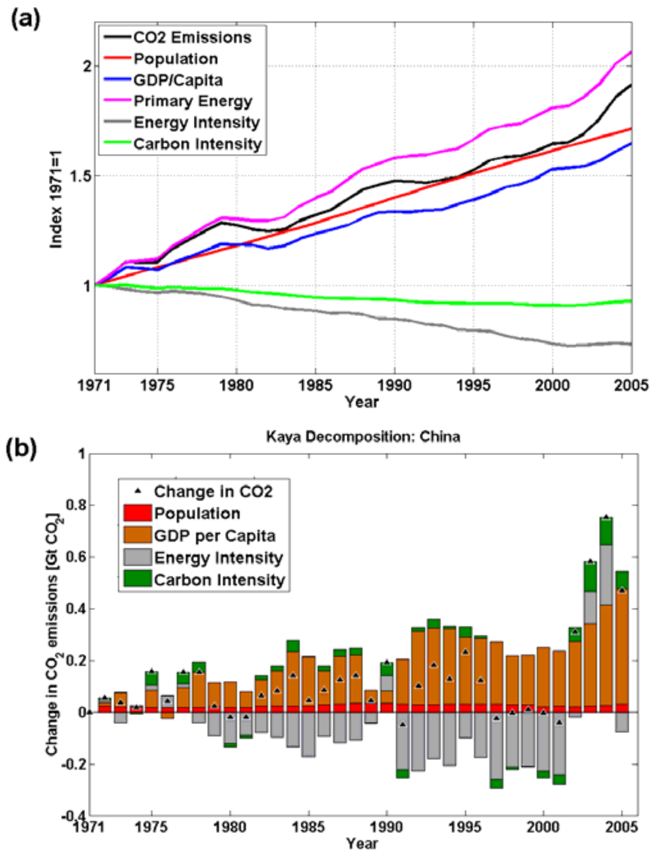

Figure 6: (a) Development of global CO_2 emissions, population, productivity, energy and carbon intensity 1970-2005. (b) Decomposition of driving factors for emission growth in China. Source: Own calculations based on IEA (2007).

The scope of the challenge to reverse global emissions trends is underlined by current developments on the world energy markets. Supply of oil barely keeps pace with demand, giving rise to rapidly increasing prices. However, the effect of high oil and related gas prices on CO_2 emissions is ambivalent. On the one hand, high prices provide incentives for energy conservation and efficiency improvements and make investments into renewable energies more attractive. After three years of almost zero efficiency improvements from 2001-2004, global efficiency has improved again in 2005. China, for example, has formulated the goal of improving energy efficiency by 20% from 2005 until 2010. On the other hand, high oil prices result in a substitution to carbon-intensive alternatives. Prices for coal increase at a much slower pace than those for oil and gas, because coal reserves are substantially higher and will last several times longer than oil and gas reserves. The consequences are twofold: First, the current situation of high gas prices results in a switch towards coal, e. g. in power generation and fuel production (coal-to-liquid technologies). Recent trends confirm that we are in the midst of a renaissance of coal: Worldwide coal consumption expanded by almost 30% from 2001-2005, and its share in global primary energy supply increased from 22.7% to 25.3 % (IEA, 2007). Second, high oil prices trigger the exploration of new reserves and new technologies. The current price-surge results in increased investments in difficult to access oil fields and enhanced oil recovery techniques. Furthermore, at current prices, highly emission-intensive oil production from oil shale and oil sands becomes competitive, and so does coal liquefaction (Rogner, 1997).

The shift towards coal is already reflected in the recent trends of carbon intensity. As depicted in Figure 6a, global carbon intensity almost continuously decreased from 1971 to 2001, but increased markedly afterwards. It will not be possible to reach ambitious mitigation targets unless this trend is reversed.

The understanding of the energy-economical mechanisms underlying the current emission trends is still limited. The fossil resource basis is a key source of uncertainty. Providing projections of the future energy mix under various assumptions of fossil resource availability and for different relative prices between oil/gas and coal will be essential for providing a sound basis for decisions in energy and climate policy. The on-going process of expansion of energy systems in emerging economies and their restructuring in industrialized regions is a challenge, but it also bears opportunities. Policy should establish strong incentives for climate-friendly investments in order to avoid locking into carbon-intensive technologies.

I.5 The economics of climate stabilization: Is there a risk of dangerous emission reductions?

- **Stabilizing climate will require a large-scale transformation of the world energy system.**
- **Model-based assessments show that stabilization can be achieved at moderate costs of about 1-2% of the world GDP, albeit only in the case of immediate action, efficient climate policies and international cooperation.**
- **A broad portfolio of low-carbon technologies is required, which all come with their own set of risks and opportunities. An integrated evaluation of mitigation potential as well as non-climate related ancillary benefits and adverse effects is essential for forming an optimal and sustainable technology mix.**

In economic history, the accumulation of physical capital stocks and the accumulation of carbon emissions in the atmosphere have gone hand in hand. The combustion of fossil fuels has been at the heart of the model of economic growth that was developed in Europe some 200 years ago. Figure 7 illustrates this historical nexus between accumulation of capital and emissions.

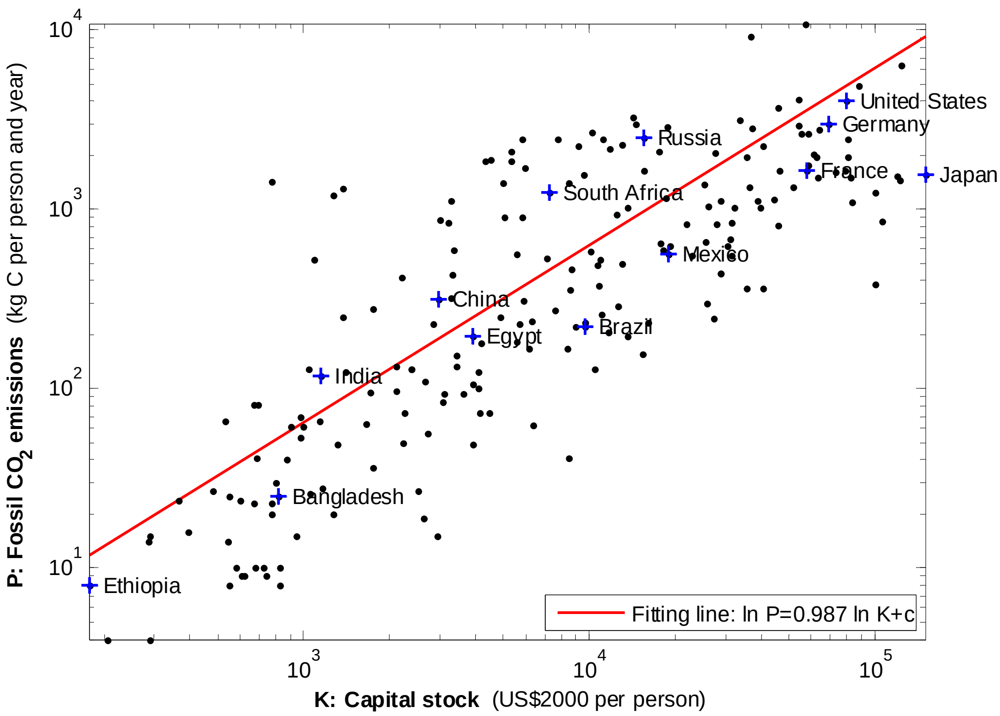

Figure 7: Correlation of capital stock and cumulated per capita emissions.

The economic challenge of climate change lies in developing an economic growth paradigm that decouples the growth in carbon emissions and capital stock. It is necessary to overcome the tragic choice between economic growth at the expense of dangerous climatic change on the one hand, and climate protection sacrificing economic growth on the other. Developing countries cannot be asked to forego economic growth for climate protection, in particular given their low historic use of the atmosphere as a deposit for greenhouse gas emissions. At the same time, significant reductions in developed countries growth rates will be difficult to accept.

But is it possible to stabilize the climate at reasonable economic cost? In recent years, modelling exercises with integrated economy-energy-climate models that feature an improved formulation of endogenous technological change show that the cost of climate stabilization are modest. In a comparison of several leading integrated assessment models, the Innovation Modelling Comparison Project (IMCP) found that the costs of mitigation do not exceed 2% of the global GDP until 2100 (Edenhofer et al., 2006).[1] The results of IMCP were central for both the Stern Review (Stern, 2006) and the IPCC Fourth Assessment Report (IPCC, 2007c). These results show that the conflict between economic growth and environmental protection can indeed be overcome. There are two decisive factors: Technologies and institutions. Before we discuss institutions in Part II, we turn to technological options that enable low-carbon economic growth.

Figure 8 displays the portfolio of mitigation options (“mitigation wedges”) as calculated by the energy-economy-climate model REMIND (Edenhofer et al., 2008). The upper curve in the diagram represents business-as-usual emissions that would occur in absence of any climate policy. The challenge lies in reducing emissions to the lower curve, which shows a global emissions trajectory that is consistent with limiting global warming to 2°C above pre-industrial levels.

[1] The costs of climate protection are calculated as the difference between the path of the GDP with no climate protection policy (business-as-usual) and the path of GDP with climate policy. This difference expresses the total costs of climate protection without considering the damages caused by climate change. This difference is discounted to take into account the time at which costs arise. Costs in the remote future are weighed less than costs that arise in the near future. In IMCP, a 5% discount rate was applied. This present value is expressed as a share of the present value of GDP that would be achieved if there was no climate policy.

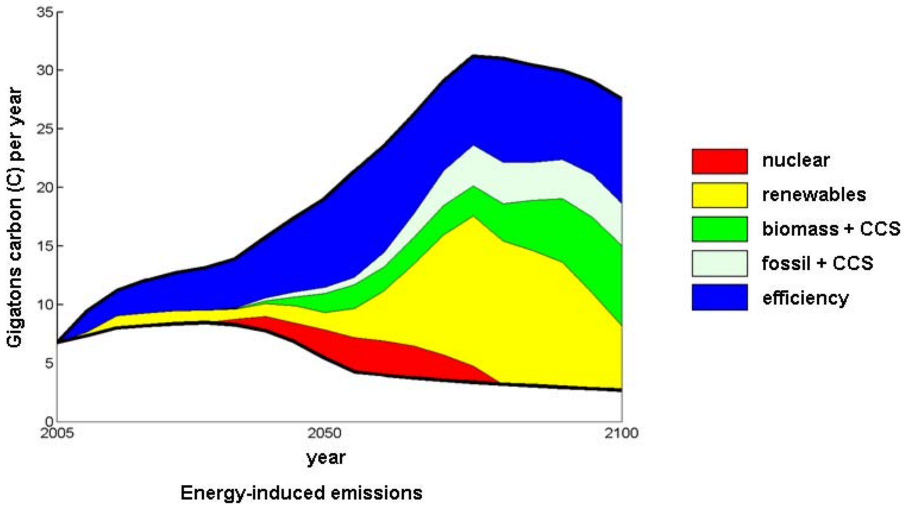

Figure 8: Contribution of mitigation options to global emission reductions in the energy sector for a scenario with cheap fossil fuels. Source: Edenhofer et al. (2008).

There are four key types of mitigation options:

- *Energy efficiency and fuel switch*: Efficiency improvements and switching to fuels with low carbon content, e. g. by replacing coal by gas, are projected to play an important role and to contribute substantially already in the near future. There are, however, limits to the switch of coal to gas: While USA, China and India only have limited gas resources, coal is rather abundant. Many major emitters are reluctant to increase the share of in primary energy because of concerns over energy security. There is, however, significant potential for energy efficiency: results from bottom-up analyses suggest that there is a large potential for mitigation options at low or even negative costs, e. g. in the building sector (e. g., IPCC 2007c; Enqvist et al., 2007).

- *Carbon capture and storage (CCS)*: Fossil fuel combustion in combination with CCS – the technology of capturing CO_2 and storing it in geological formations such as oil and gas fields or saline formations instead of releasing it into the atmosphere – is another potentially important mitigation option. It might become particularly significant for emerging economies with substantial resources of coal, such as China and India. Combining biomass energy with CCS even bears the possibility to generate negative atmospheric CO_2 emissions, since the carbon is absorbed by plants during their growth, but ends up sequestered underground after the combustion. However, CCS technologies are not expected to be available for large-scale implementations before 2020. There are significant concerns about adverse side-effects of CCS deployment and a number of uncertainties need to be resolved. The extra processes involved in CCS result in decreased overall efficiency of power plants, i. e. more fuel is consumed for a given amount of electricity production. The most important environmental concern is the permanence of the underground reservoirs. If a significant fraction of the CO_2 is found to leak back into the atmosphere, the desired mitigation is foiled. Key future challenges include the specification of economic costs and of the scale and measurability of leakage from geological reservoirs.

- *Renewable energies*: Currently, many renewable energy technologies are not competitive compared to fossil fuels, particularly in absence of carbon pricing. However, there is a significant cost reduction potential due to learning effects. Renewable energies are projected to become competitive at a large scale in the future. Thus, they have the potential to be an important factor for energy production and are projected to contribute substantially to curbing emissions particularly in the second half of the 21st century. Issues concerning the grid integration of renewable energies and handling fluctuations in energy supply require further research. Given the competition for land and water with food production, the use of bioenergy is particularly controversial (see Box I.2).
- *Nuclear energy*: Nuclear energy has low specific CO_2 emissions, even if the energy requirement for extraction and processing of uranium is taken into account. The role of nuclear power is, however, constrained by uranium availability unless large-scale investments into closed fuel-cycle reactor designs such as the fast breeder reactor are undertaken. The fast breeder concept, however, relies on plutonium as fuel and therefore comes with its own set of risks. Moreover, significant concerns persist with respect to the long-term safety of geological storage of waste and control of nuclear proliferation for military use (Deutch and Moniz, 2003).

Another central insight arising from the model-based analyses is that there is no silver bullet reduction technology, but rather a mix of technological approaches is needed. Model simulations tell us also, that some mitigation options are more important for achieving ambitious mitigation targets at moderate costs than others. We can identify these technologies by asking energy-economy models “how much more would it cost to reach a particular climate stabilization target without using a certain technology”? The difference in mitigation costs in the ‘all options’ scenario employing all technological options and the ‘all but one option’ scenario provides us with the so-called option value for a technology (Figure 9). For example, our results show that fixing nuclear energy at the business-as-usual level would only result in marginally higher mitigation costs. The option value of expanding nuclear power for mitigation is thus small. Solar power and CCS, by contrast, have greater option values. Depending on the assumptions on fossil fuel prices, climate stabilization without using CCS can even result in almost a doubling of mitigation costs.

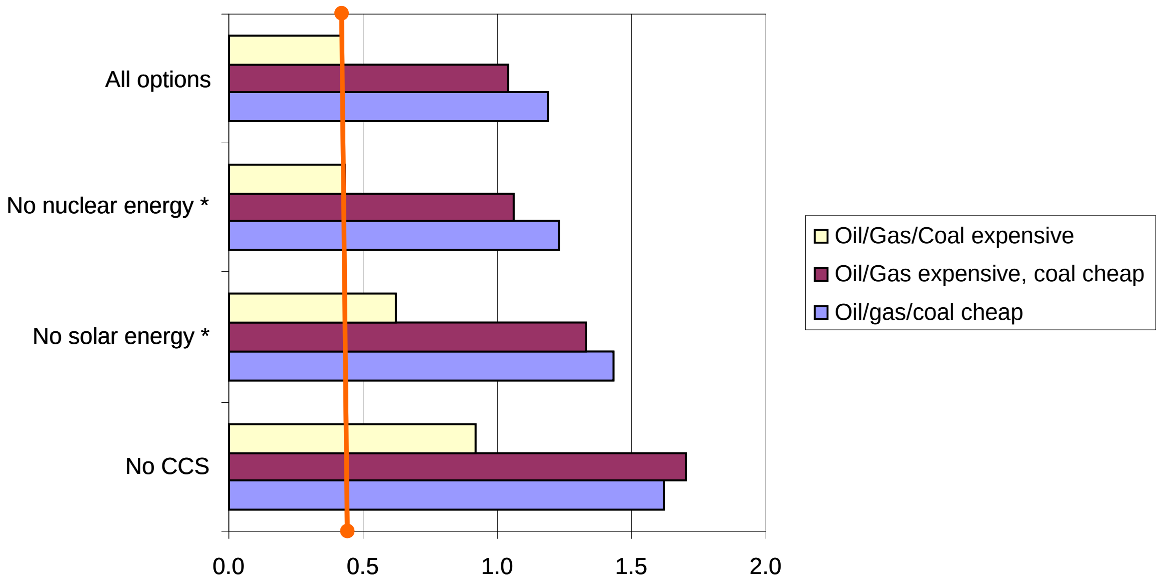

Figure 9: Option values of mitigation options for various fossil fuel price scenarios. Source: Edenhofer et al. (2008).

As elaborated above, each mitigation technology comes with its own set of opportunities, drawbacks and uncertainties. An integrated assessment of the greenhouse gas mitigation potential on the one hand and non-climate related benefits and risks is a crucial exercise for forming a sound basis for decisions relating to the future energy mix. Developing a broad technology portfolio is of key importance to hedge against uncertainties and yet unidentified risks.

Box I.2: Land-use conflicts: Bioenergy vs. food production and forest conservation

Currently, human society appropriates about one quarter of the total net primary production of the terrestrial biosphere (Haberl et al. 2007). Rising food, energy and material demand, climate change and ambitious mitigation policies exacerbates the competition for land and water especially in tropical developing countries.

The supply of agricultural products in the second half of the 21st century will be constrained by global climate change (IPCC, 2007b). Global warming and shifts in precipitation patterns will alter the regional patterns of plant growth and yields. While regional impacts of climate change vary significantly, agro-economic vulnerability is particularly high in tropical countries.

The growing world population is demanding more and different kinds of food. Rapid growth in emerging economies has pushed up consumers' purchasing power, generated rising demand for food, and shifted food demand away from traditional staples and toward higher-value foods like meat and dairy products. This dietary shift leads to an increased demand for grains used to feed livestock.

At the same time, growing energy demand, concerns about climate change and security of energy supply makes bioenergy attractive. Modern bioenergy is projected to be an important contributor to future sustainable energy supply in both developing and industrialized countries, particularly as a renewable fuel for transport. Moreover, bioenergy use in combination with carbon capture and storage (CCS) results in negative CO_2 emissions to the atmosphere, thus making it an interesting mitigation option for very low stabilization of atmospheric CO_2 concentrations.

However, as the expansion of bioenergy will increase the competition for land, water, and other inputs, they also raise the price of food over the long-term and negatively impact the landless and poor in developing countries, while landowners benefit. The most prominent concerns about bioenergy expansion include (e. g. Farrell et al. 2006, Searchinger et al. 2008):

- *Indirect greenhouse gas emissions from bioenergy:* While bioenergy combustion is carbon-neutral due to the CO_2 absorbed during plant growth, bioenergy use can result in significant indirect emissions. Bioenergy production may result in the expansion of cultivated land, putting additional pressure particularly on tropical forests, and releasing vast amounts of carbon stored in these natural ecosystems. Moreover, N_2O emissions from cultivation of maize or rapeseed, which is commonly used for biofuels, may offset or even completely negate the positive effect of the carbon savings. Likewise, fossil fuel use in agriculture and for fertilizer and pesticide production must be taken into account. Intensification on existing cropland, on the other hand, will require increased fertilizer use.
- *Food prices and food security:* Bioenergy production increases competition for land. This translates into increased food prices or food scarcity.
- *Water:* Agriculture already accounts for 70% of global freshwater use. The expansion of biofuels will increase the pressure on water supply and quality. Water constraints thus will have to be considered in the framework of a sustainable bioenergy strategy.

It is important to distinguish between different sources and processing pathways. Studies show clear differences in environmental performance and energy yield per unit area for various bioenergy crops. More advanced and efficient bioenergy concepts that do not rely on food crops are currently under development and could significantly reduce both costs as well as land need and environmental side-effects (Hill et al., 2006).

Nonetheless, the above listed socio-economic and environmental concerns are likely to heighten as production grows and as biofuels are increasingly traded internationally, not least, because for some of these issues, the impact may grow disproportionately as fuel production increases in scale. It will be impossible to avoid all of the negative impacts of bioenergy production but whether the impact is positive or negative will be determined, in great part, by political decisions (Worldwatch Institute 2007).

II. Principles and core elements of a Global Contract

The climate problem poses a threefold challenge: To avoid dangerous climate change, to avoid excessive economic losses due to too stringent or ill-designed climate policy, and to avoid an increase of global poverty due to climate change. A Global Contract should thus have the goal to address the problem along the following principles:

(1) ***Environmental effectiveness:*** The first priority of international cooperative action on climate change is to stabilize the climate, i. e. to limit man-caused global warming to a level that is acceptable and manageable in terms of the impacts. By identifying a temperature or concentration target, the division of labour between adaptation and mitigation is defined. Thus it is important that this target takes account of the limits of adaption. At the same time, too ambitious mitigation targets can have adverse environmental and economic side-effects, such biodiversity effects from excessive biomass use. It is important to ensure that mitigation and adaptation measures are environmentally sound in terms of non-climate related side-effects in order to avoid solving one problem at the expense of creating new problems.

(2) ***Cost-efficiency:*** In view of the scale of the problem, limited resources and other challenges to the global community, it is imperative to achieve the stabilization target in a cost-efficient way. Climate policy needs to ensure that the stabilization target is reached at minimal cost, in order to mitigate the conflict of objectives between climate protection and economic growth. This requires a wise choice of policy instruments on national and international levels. Putting a price on greenhouse gas emissions is a precondition for cost-efficiency. In order to be cost-efficient, action must be comprehensive, i. e. broad coverage of emitting sectors and regions will be required.

(3) ***Equity and justice:*** Industrialized countries are responsible for the bulk of historic CO_2 emissions. Many low-income developing countries that contributed least to the problem are by contrast among the most vulnerable to climate change, and people there will be hit hardest. It will be a key challenge for international climate policy to confront this dilemma and to ensure a fair distribution of the costs of curbing greenhouse gas emissions and adapting to climate change.

A central task for climate policy is to define a stabilization level that is in accordance with these principles. Clearly, a conventional cost-benefit analysis is inadequate for the context of climate policy for several reasons: Many of the climate change impacts affect non-market goods and thus are difficult to quantify in monetary terms. Moreover, it is possible that a significant share of impacts is still unknown – thus they would not be accounted for. Furthermore, there are numerous uncertainties in the climate system and and mitigation costs, which are very difficult to incorporate in a cost-benefit analysis. Finally, due to the global nature of the problems and the long timescales involved, a monetary assessment requires regional and intertemporal aggregation – this requires implicit value judgements by weighing the welfare of one world region against that of others, or the welfare of the current generation against that of future generations. A more promising approach is thus to derive a global stabilization target in terms of a broader risk analysis.

There is growing evidence that suggests that global warming in excess of 2°C above pre-industrial levels would entail a high risk of triggering major components of the earth system to switch to qualitatively different states and to result in substantial impacts on human well-being despite all feasible efforts at adaptation. Studies using economy-energy-climate models, on the other hand, show that stabilizing climate at 2°C is within reach at moderate cost of about 1-2% of GDP (Edenhofer et al., 2006; Stern, 2006; IPCC, 2007c). This is substantially less than the damage that can be expected from unmitigated climate change. Thus, limiting global warming to 2°C above pre-industrial levels appears as a reasonable target for a Global Contract on climate change.

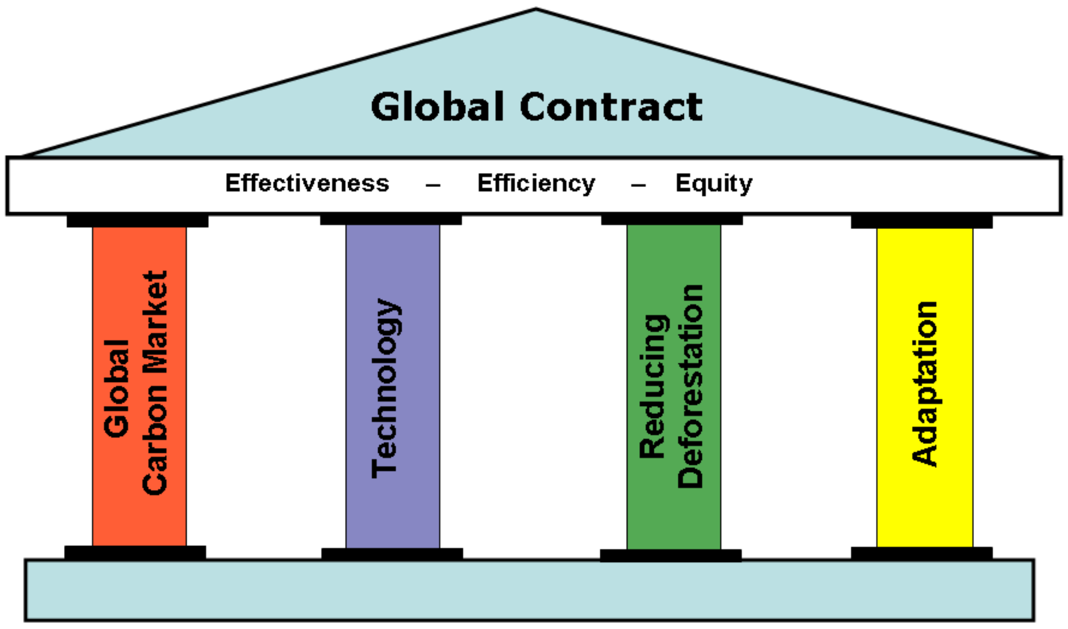

Figure 10: The Global Contract on Climate Change should embrace four major components: a global carbon market, technology, action for reducing deforestation, and adaptation.

We propose grouping the elements that the international climate architecture should embrace four major components (Figure 10). These include (a) the setup of a global carbon market[2], (b) cooperation for developing and spreading low carbon technologies, (c) a mechanism for reducing emissions from deforestation and forest degradation (REDD), and (d) adaptation. These components are discussed in the following sections.

II.1 A global carbon market

- **A global carbon market should be at the centre of the human response to climate change: It achieves environmental effectiveness by setting a cap for global emissions, realizes efficiency through trading of permits, and allows addressing equity considerations through international allocation rules.**
- **Top-down and bottom-up approaches to emissions trading are complements in building a global carbon market. A government-level trading system setting the overall environmental target and international allocation principles can be supplemented by linked domestic company-level systems that enhance market liquidity and performance.**
- **In the long-term, developing countries should fully participate in an international emissions trading system with fair absolute emission caps. During a transition phase, one-sided trading mechanisms suiting national and sectoral circumstances can integrate developing countries into the emerging international carbon market.**

Putting a price on greenhouse gas emissions is a pre-requisite for cost-effectiveness in reaching a given stabilization target. It is central to the effort of mitigating climate change as it addresses the market failure relating to the adverse effects caused by greenhouse gas emissions. Ideally, the carbon price signal should be global, covering all sectors and regions, to ensure emissions are reduced where this is cheapest.

The concept of a global carbon market is already present in the Kyoto Protocol's flexible mechanisms. The Kyoto Protocol defines emission caps for industrialized countries and allows the trade of emission allowances at the government level. Under the Clean Development Mechanism (CDM), emission reductions from projects implemented in developing countries can be credited towards the reduction obligations of industrialized countries. With its domestic emissions trading system (EU ETS) the European Union has demonstrated that setting up a company-level

[2] The term "Carbon Market" is commonly used to describe a market for greenhouse gases. In addition to CO_2 it may also include non- CO_2 gases such as methane (CH4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and Sulfur hexafluoride (SF_6).

trading system in the context of the Kyoto trading system is a feasible climate policy option.

Allocation in a global carbon market is the key lever to control the distributional effects of an international effort to tackle climate change. A global trading system allows the flexible management of uncertainty as emission trajectories can be adjusted to new information on key parameters such as climate sensitivity.

Pricing emissions

In general, instruments for introducing a price for emissions include emissions trading, taxes and regulation (Stern, 2006). Regulation is an important tool where price signals fail to be effective due to specific barriers, but in some contexts there is risk of considerable inefficiency.

Regarding the choice between taxes and trading, there is a long-standing debate in economics which of the approaches is superior. Clearly, the two instruments are equivalent under perfect market conditions and complete information, and research efforts have focused on comparing their relative performance inter alia under uncertainty, long and short time periods, and political economy considerations. While one of the main arguments in favour of taxes is the administrative ease of implementation and predictability of prices by economic agents, taxes would need to be periodically adjusted to ensure that emission reduction targets are met. Also, harmonizing taxes across a number of countries has proven to be difficult. For example, EU efforts for coordinated eco-taxation in the 1990s failed. Regarding international compensation for mitigation costs, tax schemes require explicit transfers across regions. Another argument often put forward in favour of taxes is that they raise revenue, and appropriate recycling of these revenues can enhance the efficiency of carbon pricing.

On the other hand, emissions trading systems may appear complex to implement but enable the control of absolute emission volumes. Trading systems also generate revenue, but only if allowances are auctioned. Caps may need to be revised as new information emerges. Banking provisions will reduce price volatility, and forward markets enable agents to hedge against price uncertainties. Transfers to compensate some parties for mitigation costs occur automatically through the trading mechanism, depending on allocation rules. The 1997 Kyoto Protocol introduced an emissions trading system for Annex-B countries, and domestic emissions trading systems are currently emerging all over the world. Against the backdrop of the economic debate and these political developments we consider a global carbon market with a single price on greenhouse gas emissions the instrument of choice for pricing emissions (see also Stern, 2006).

General principles and policy objectives

While Kyoto is an important intermediate step for setting up a global carbon market, it is, in its current design, insufficient for reversing emission trends on a global scale and for achieving reductions necessary for ambitious climate stabilization targets. Key shortcomings of the Kyoto Protocol are the lack of long-term targets, as well as the insufficient and inefficient inclusion of developing countries. It will thus be necessary to further develop the global carbon market along the following objectives:

- *Defining a global reduction trajectory* in line with limiting global warming to around 2°C above pre-industrial levels
- *Reducing uncertainty* for investors by establishing credible short, medium and long-term targets
- *Harmonizing marginal abatement costs* across world regions and sectors to ensure that reductions are performed where this is cheapest
- *Generating revenues* to finance mitigation in developing countries
- *Distributing costs* in a fair manner in line with capabilities and responsibilities

Towards a Global Carbon Market

While the international carbon markets have grown considerably over recent years, compared to the scope and volume of a truly global system, they clearly are in a state of infancy. Of the global value of 64 billion US-$ in 2007, the EU ETS has a value of 50 billion US-$, followed by the market for CDM credits with 13 billion US-$ (Capoor and Ambrosi, 2008). There have been hardly any trading activities for Assigned Amount Units (AAUs) among governments for compliance under the 2008-2012 Kyoto trading system so far, but several governments have been active in the Clean Development Mechanism (CDM) market. Smaller mandatory and voluntary schemes display only a fraction of the value and volume of emissions in existing trading systems. How can the world community move from this patchwork of systems to an environmentally effective, economically efficient and equitable integrated global trading regime?

In general, there are two routes to global trading: Top -down and bottom-up.[3] In the top-down-approach, emissions trading is implemented on the level of governments in the context of multilateral UNFCCC negotiations. Countries may then choose which options they use for achieving compliance, i. e. trading with other countries or domestic abatement induced by a variety of instruments such as standards, taxes, or domestic trading systems. In an idealized setting, a global cap is set and emissions are allocated e. g. to national states, resulting in a comprehensive global trading system. However, several world regions are reluctant to take on binding caps, e. g. because they fear this can impede their economic growth. The Kyoto trading system thus

[3] For a comprehensive treatment of the following issues, see Flachsland et al (2008b)

introduced binding caps for developed Annex-B countries only and set up the CDM to integrate developing countries into the international carbon market.

Bottom-up-approaches to establishing emissions trading entail the implementation of domestic emissions trading systems by governments on the national or sub-national level. Currently, domestic trading systems are emerging all over the world. On the federal level, New Zealand, Australia, Switzerland, USA, Canada, and Japan are implementing or discussing the implementation of trading systems. On the sub-national level, trading schemes are emerging in North America and Japan where the municipalities of Tokyo and Kyoto are planning to introduce this instrument. The initiatives in North America include the Regional Greenhouse Gas Initiative (RGGI), the Western Climate Initiative (WCI) and the Midwestern Greenhouse Gas Accord. Figure 11 summarizes the timelines for these emerging systems.

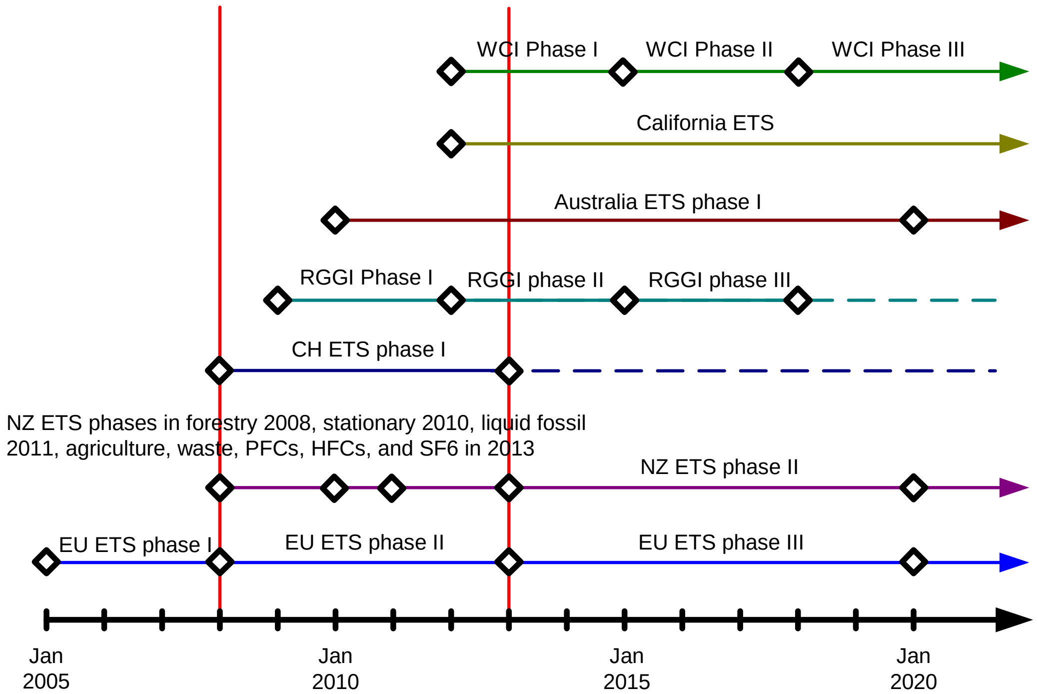

Figure 11: Timelines for emerging Emissions Trading Systems. The two red lines define the time span of the Kyoto Protocol's first commitment period. Source: Flachsland et al. (2008b).

There are broadly three options for organizing the co-existence of domestic trading schemes. First, regulators can refrain from integrating these systems. There would still be indirect linkages via international energy markets.[4] The resulting regional differences in allowance prices will imply efficiency losses and competitiveness

[4] Assume two identical countries with equal emission caps and a common domestic permit price, the trading systems of which are not linked. Now one country adopts a more stringent cap. As a consequence, its domestic permit price rises, and consumption of fossil fuels will drop (neglecting CCS). In as much as that prompts the world market price of fossil fuels to fall, the second country will use more fossil fuels, leading to an increased need for permits and thus a higher domestic permit price.

concerns, enabling less ambitious reduction targets. Second, domestic trading systems are linked indirectly if they commonly accept certain credits e. g. from CDM. This leads to some price convergence across systems. Third, domestic trading systems will formally be linked if they mutually accept their allowances for compliance.

In October 2007, a number of public authorities from several world regions (including the European Union, members of WCI and RGGI, Australia, New Zealand, and Japan) formed the International Carbon Action Partnership (ICAP) with the aim of establishing " (…) an expert forum to discuss relevant questions on the design, compatibility and potential linkage of regional carbon markets " (ICAP, 2007). In spring 2008, the first of a series of public workshops took place exploring requirements for harmonizing domestic ETS when these are linked. ICAP may provide an institutional starting point for organizing the integration of regional trading systems.[5]

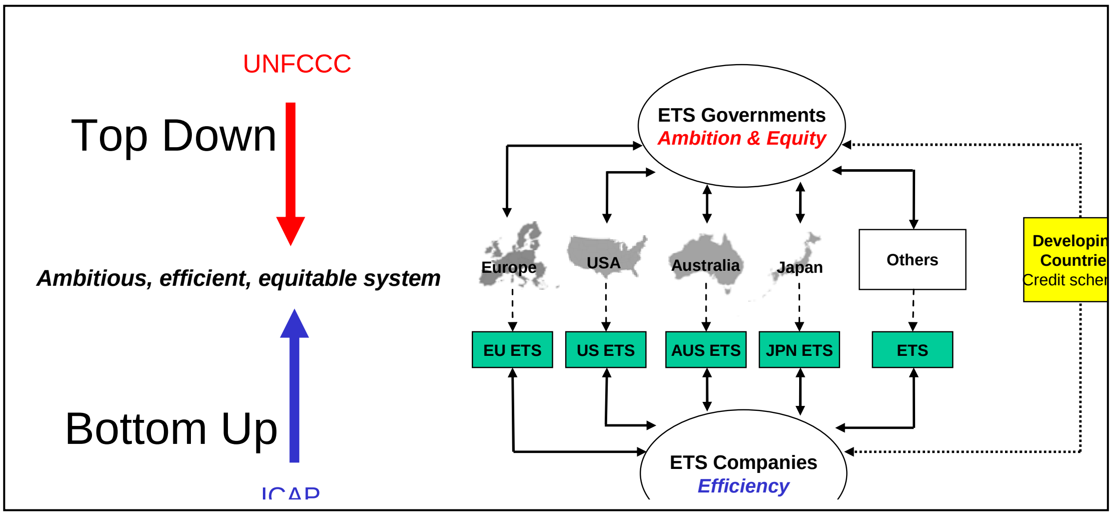

Figure 12: Complementarity of the top-down and bottom-up-approach to international emissions trading.

Clearly, top-down and bottom-up-approaches are complements that can be implemented in parallel (Figure 12). If governments devolve trading activities in the context of an intergovernmental emissions trading scheme to companies that trade allowances in linked domestic trading systems, this will enhance market performance: The information asymmetry between governments and companies regarding marginal abatement costs is overcome, and market power of governments in an intergovernmental trading scheme is reduced. Conversely, the top-down-approach enables the coordination of the overall level of environmental ambition via the global cap, and critical burden sharing issues can be addressed through an international allocation rule. In broad terms, the top-down road to emissions trading enables

[5] See Flachsland et al. (2008a) for a detailed discussion of emerging regional trading systems and the prospect of formally linking these systems, as well as the role of ICAP in this process.

governments to address the issues of environmental effectiveness and equity, while the bottom-up-approach will enhance economic efficiency of a global trading system.

Thus, a global trading system may be constructed by simultaneously implementing an intergovernmental emissions trading scheme with national caps top-down, building on the existing Kyoto trading structure, while linking domestic trading systems bottom-up. The EU ETS exhibits a case study of this approach: Implemented on the company level, allowance transfers across countries are mirrored by transfers of Assigned Amount Units (AAUs) across country registries.

However, the considerable negotiation challenges of top-down-approaches that are reflected in current multilateral climate policy talks create the risk of political stalemate of indeterminate duration. Therefore, in the face of the emergence of regional trading systems all over the world, linking these systems represents a fallback option enabling the construction of a global market bottom-up even if top-down-negotiations under UNFCCC fail.

On the other hand, the bottom-up road to international emissions trading is constantly challenged by the question of whether emission reductions in this context can have a significant environmental impact at all. The fear of emissions leakage and doing too much relative to others (free-riding) – thus hurting the economy without significantly benefitting the global environment – will likely lead to reduction efforts that are less ambitious than in a top-down approach. Therefore, even in a bottom-up linking scenario UNFCCC negotiations should still focus on setting reduction targets for countries to overcome these concerns. However, the available evidence suggests that at least in the short- to mid-term leakage will not play an important role for the vast majority of sectors (e.g. Stern, 2006). Also, regions may adopt ambitious reduction targets in a bottom-up world to foster domestic development of low-carbon technologies in order to profit from a first mover advantage when they expect other regions to join the international climate policy effort later.

Any mandatory emissions trading system requires a regulating authority or a set of regulating authorities for its effective implementation and enforcement, e. g. regarding sound monitoring and reporting, emission registries, compliance and penalties, banking and borrowing procedures, method of allocation or acceptance of credits. Equally, an international trading system will require coordinated regulation, inasmuch as changing regulation in one of several linked systems will impact the others. Therefore, exploration of a suitable governance structure for the international carbon markets is a key task for future research.

Integrating Developing Countries

Integrating developing countries into an emerging global carbon market is of key importance for an effective, efficient and equitable response to climate change for at least three reasons. First, developing (non-Annex-I) countries emitted 50% of global

CO_2 emissions already in 2004 (CAIT, 2008), and this share will increase over the 21st century. Therefore, they will need to participate in a global effort that aims at reducing global emissions significantly below business-as-usual levels. Second, economies of developing countries feature considerable low cost abatement potentials that can enhance cost effectiveness of the global mitigation effort. Third, to prevent emissions leakage that undermines environmental effectiveness, all world regions should implement comparable carbon prices in the long-term.

Today, developing countries participate in international emissions trading via the Clean Development Mechanism (CDM). Under the CDM, individual projects need to demonstrate that emission reductions would not occur without the funds provided by the sales of generated emission reduction credits, a requirement known as additionality testing. Also, CDM projects shall contribute to sustainable development, and promote sharing of technologies. As of July 2008, 1133 projects have been registered with the UNFCCC's CDM Board, with 1.3 Gt of CO_2eq being expected to be abated by these projects until 2012 (UNFCCC, 2008).

Observers have raised several critical points regarding the current CDM. These include the integrity of the additionality procedures (Schneider, 2007), high transaction costs (Michaelowa et al., 2003), limited attainment of sustainable development targets (Wara, 2007), and the lack of incentives for structural transformation towards the decarbonisation of the entire economy (Stern, 2006). Therefore, several proposals for reforming the current CDM and for introducing new mechanisms are being discussed. Generally, given the large differences among non-Annex-I countries and sectors, different instruments may be used that suit regional and sectoral circumstances.

A number of decisions need to be taken when designing mechanisms for integrating developing countries into the global carbon market: Shall the scale of instruments be economy-wide, sectoral, or project-based? Are absolute or relative targets applied? Should targets be binding or non-binding? We briefly discuss some of the options.

Many developing countries reject *absolute binding caps* arguing that these may impede their economic growth. However, depending on the level of the cap, developing countries may gain from full inclusion into a global market, not least because they can sell permits at a price well above their average abatement costs, creating rents (see below). On the other hand, some developed countries fear that developing countries would be allocated 'too many' permits, creating so-called 'hot air'.[6] Both concerns usually arise due to the difficulty of projecting economic growth and related emissions in developing countries: While the first refers to the case where economic growth exceeds expectations and additional permits would need to be

[6] The concept of 'hot air' refers to emission permits that are issued above the actual level of emissions of a country. Sale of 'hot air' permits does not lead to real emission reductions in such a country.

purchased – hampering economic growth –, the second concern relates to the possibility of lower than expected emission levels, creating hot air.

One possibility to address these concerns is to use *country-level intensity targets* that may be implemented instead of absolute targets, e. g. in terms of emissions per unit of GDP. Such targets, however, do not guarantee that certain emission levels are met, because emission entitlements will rise with growing GDP.

Absolute or intensity targets may be implemented for single sectors in developing countries, e. g. the power, aluminium, steel, and cement sectors. *Non-binding sectoral intensity targets* have for example been proposed, where sectors that reduce their emission intensity (e. g. defined in terms of emissions per unit of output) below a benchmark receive credits that are eligible for sale into cap-and-trade markets (Schmidt et al., 2006). Such benchmarks may implicitly take into account own contributions of developing countries. Two main problems are associated with such a mechanism. First, negotiating benchmarks is a formidable task, given the uncertainties on sectoral business-as-usual developments (e. g. regarding fuel prices) and the important role of benchmarks for the volumes of permits that are created under the mechanism. Furthermore, setting intensity targets for specific sectors instead of regarding the whole economy foregoes the mitigation option of substituting emission-intensive sectoral economic activities with an increased production in less emission-intensive sectors.

Sectoral approaches may also take the form of *international sectoral agreements*, where countries with significant shares in international trading of specific products (e. g. steel, aluminium) implement such schemes in a coordinated manner to ensure a level playing field for these industries (Bodansky, 2007). A harmonized emission price signal would prevent international leakage and related concerns about national competitiveness.

Other proposals have been made to improve the CDM in its current form, including *Programmatic CDM* (Figueres et al., 2005), *Policy CDM* (Cosbey et al., 2005), and *Sustainable Development Policies and Measures* which focus on the sustainability aspects of abatement activity (Winkler et al., 2002).

Clearly, more research is required that compares and assesses different mechanisms for integrating developing countries into the emerging global carbon market. However, compared to all alternative proposals, binding absolute caps for developing countries have the advantage that once absolute caps are negotiated, the total environmental outcome is certain, transaction costs are relatively low to other mechanisms, leakage concerns are eliminated, and a structural economy-wide incentive for decarbonisation is introduced.

Therefore, the current and reformed CDM procedures as well as other mechanisms for integrating developing countries into the emerging global carbon market should be regarded as transitory steps towards a full inclusion into a global cap-and-trade system. This is the idea of the ‘multistage approach’ (den Elzen et al., 2006): Countries implement different emission reduction mechanisms according to their state of economic development, with gradually increasing levels of responsibility for contributing to global emission reductions. At the end of this chain of commitments stands the full inclusion into a global cap-and-trade system.

The existing proposals for a CDM reform as well as other mechanisms require further development, and crucial design elements need to be spelled out. For different sectors and regions, different instruments will be suitable during transition periods. Developing countries should play an active role in this process.

Allocation and justice

In the context of a global emissions trading scheme, the discussion of international justice usually focuses on the rules for allocation of emission rights to different world regions. In scientific literature, this approach is usually referred to as allocation-based justice (Rose et al., 1998). However, the distributional outcome of a global mitigation effort crucially depends not only on the allocation and trade of emission rights but also on the costs of emission abatement as well as trade of energy carriers (e. g. fossil fuels, uranium) and energy intensive goods. A comprehensive consideration of global burden-sharing thus needs to take into account the distribution of economic costs *after* the allocation process, abatement activity and global trade in different regions. This perspective is referred to as outcome-based.

In this section, we first set out key principles that are frequently put forward in the discussion of allocation formulas. We then discuss five prominent allocation rules, before presenting modelling results that quantify the impact of these formulas on regional mitigation costs.

Before we begin our discussion, it is fundamental to note that in emissions trading systems there is a difference between the initial endowment (allocation) of emission rights and actual emissions after emissions trading has occurred. Countries that emit less than their endowment can sell permits, while regions with higher emissions can buy these. As an example, Figure 13 displays a projection for the allocation of emission rights and actual regional emissions after trading in a global ETS.

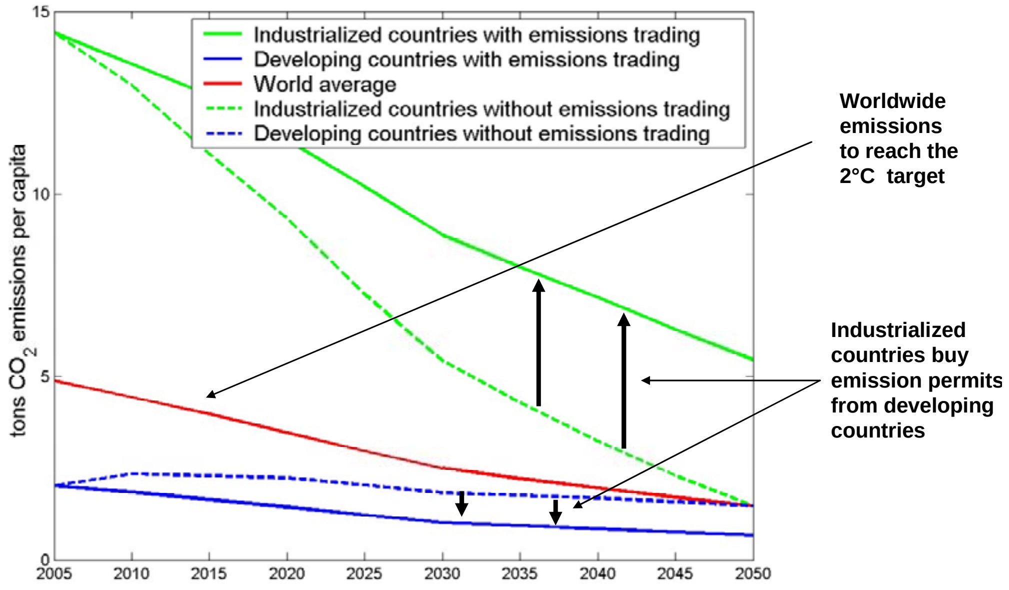

Figure 13: Difference between allocated and actual emissions after emissions trading in a global emissions trading scheme. Annex-I and non-Annex-I regions are allocated emission rights according to the Contraction and Convergence rule (see below). Actual emissions deviate from this distribution as Annex-I countries buy emission permits from non-Annex-I countries. Source: Leimbach et al. (2008).

The following guiding principles are often put forward in the discussion of international allocation rules (e. g., den Elzen and Lucas, 2005):

(1) *Egalitarian*: Every person in the world should have the same right to use the atmosphere.

(2) *Ability to pay*: An allocation rule should ensure that rich countries bear higher mitigation costs than poor countries.

(3) *Historic responsibility (or polluter pays principle)*: Those who have heavily used the atmosphere in the past – accumulating large emission stocks and being most responsible for climate change – should receive less allowances in the future than others.

(4) *Sovereignty*: There is a customary right regarding the status quo of global emission patterns, and an allocation rule should take this into account to avoid distortive consequences for large emitters.

Clearly, contradictions arise between some of these claims. Therefore, specific proposals for allocation rules are characterized by the relative priority they assign to these four principles, and none will equally meet them all.

In our following discussion of five allocation rules, it is assumed that there is a global emissions trading system with a cap on emissions that corresponds to some global climate policy target – e. g. the 2°C-limit. The rules determine how the total amount of emission permits is allocated to different world regions.

The *equal-per-capita rights* proposal emphasizes the egalitarian principle by allocating an equal amount of emissions to each citizen in the world. Dividing the global cap by world population yields per capita allocation, and countries receive emission rights according to their population size. Given the high disparity of per capita emissions today, immediate implementation of this rule means that industrialized countries need to buy large amounts of permits from less developed countries. Therefore, some would object this rule on grounds of the sovereignty principle. Others, in contrast, will find that this approach does not take into account the ability to pay and historic responsibility and that developing countries should indeed be entitled to emit more than rich industrialized countries with high historical emissions.

By contrast, the *grandfathering* approach allocates emissions according to the economic status quo, thus representing an operationalisation of the sovereignty principle.[7] In each period, countries receive permits according to their fraction of global GDP. Countries need to reduce emissions proportionally to the global reduction effort. This rule gives rise to objections based on egalitarian, ability to pay and historic responsibility grounds: Those who are and have been major emitters building considerable economic wealth in this process are entitled to emit more emissions than developing countries, which – in a pure grandfathering approach – will even be asked to reduce their emissions from their low current levels.

The *contraction and convergence (C&C)* rule (Meyer, 2000) combines the previous two approaches. In the beginning, allowances are grandfathered according to the status quo emissions. A long-term equal-per-capita emission target is defined (e. g. by 2050), and as illustrated in Figure 14, the allocation of each region then converges linearly towards the equal-per-capita allocation in a transition phase. This rule is also subject to criticism on grounds of historic responsibility: Rich countries have already used up a disproportional part of the global landfill atmosphere. Distributing the rest of the available resource according to the principle of equal utilization rights and sovereignty appears questionable in a perspective that emphasizes intertemporal equity. From the latter point of view, historic emitters should receive fewer allowances. In this sense, contraction and convergence merely represents a minimum standard from the point of view of equity.

The *historic responsibility* approach takes into account cumulated historic emissions. Countries that already have accumulated high per capita emissions receive proportionally less emission rights than regions with a low historic carbon stock. Critics of this rule will remark that the negative externality of greenhouse gas emissions has been widely recognized only recently and that developed countries cannot be punished for emissions produced in nescience while pursuing the legitimate

[7] See e. g. Vattenfall (2006) for a proposal based on the grandfathering rule, adjusted by the ability to pay considerations.

goal of economic development.[8] Therefore, it is important to define a base year from which on to count historic emissions as relevant for allocation. This need not be the beginning of industrialization, but may be the date of the Rio Earth Summit in 1992, the Fourth Assessment Report of the IPCC (IPCCa, 2007) stating that climate change is anthropogenic with likelihood of more than 90% or the G8 summit in Heiligendamm 2007 where all major economies acknowledged the reality and challenge of climate change.[9]

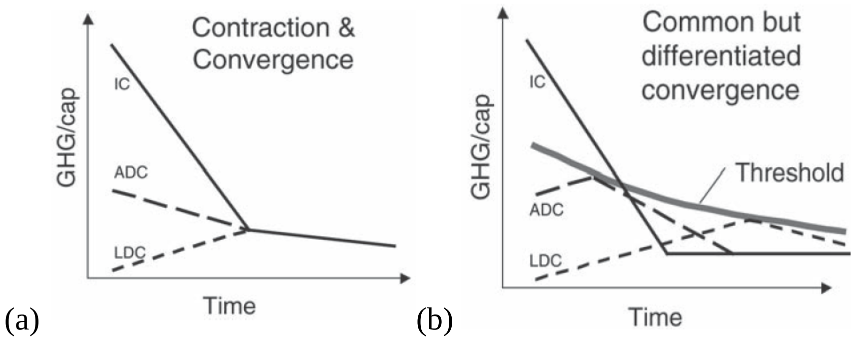

Figure 14: Schematic outline of contraction and convergence and common but differentiated convergence rule. Source: Höhne et al. (2006).

Finally, the *common but differentiated convergence (CDC)* rule (Höhne et al., 2006) represents one of the many compromise proposals combining several of the principles outlined above. Like contraction and convergence, initial allocations are based on grandfathering. Also, there is a long-term equal-per-capita target. The difference is in the transition phase: Developing countries below a certain threshold are enabled to increase their emissions until reaching the gliding threshold (which may be defined relative to the global average of per capita emissions). In turn, developed countries need to adopt more stringent reduction targets to ensure that a global emissions budget in line with the overall climate policy goal is achieved. This alternative transition path may be substantiated both on the grounds of ability to pay and historic responsibility: Economic growth in developing countries shall not be limited by stringent emissions targets, especially given their low ability to pay and low historical use of the atmosphere. On the other hand, developed countries are richer and can afford financing larger shares of emission reductions and have already used up considerable shares of the atmosphere. Thus, the CDC rule incorporates elements of

[8] However, in the case of asbestos, insurances are still paying compensation for the damages that have resulted from the use of asbestos in the past, even though its damaging properties were not widely recognized then.
[9] There are a number of ways for specifying the implementation of the historic responsibility rule. In the model runs presented below, a Contraction and Convergence approach was assumed where historic emissions since 1990 were accounted for. This is based on the assumption that equal-per-capita emissions should have been allowed since 1990; countries that have emitted more than the global average of per capita emissions between 1990 and 2000 have their allocation modified accordingly within a pure C&C approach that stretches from 2000-2100.

all four principles – egalitarianism, ability to pay, historic responsibility and sovereignty. The drawback of this approach is in the complexity of calculating consistent allocation trajectories for developed and developing countries and making sure that it is compatible with a predefined global emission profile.

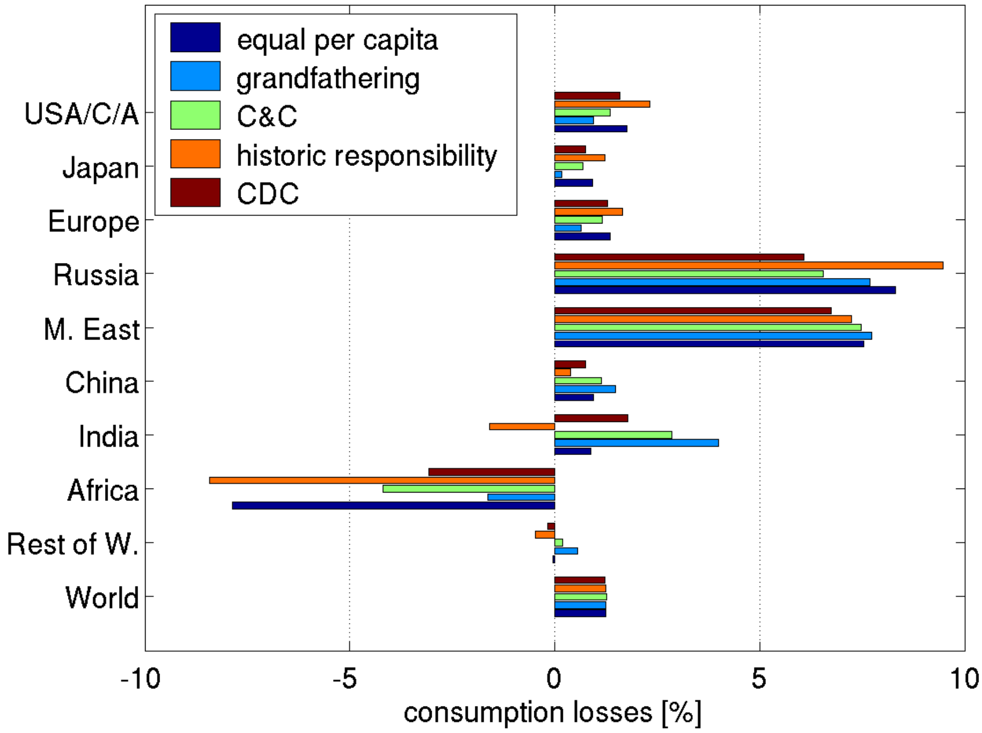

Figure 15: Comparison of the regional distribution of mitigation costs for different allocation rules. The cumulated consumption losses until 2100 relative to the business-as-usual scenario are shown. Source: Knopf and Lüken (2008).

Figure 15 shows the results from the integrated energy-environment-economy model Remind-R, assuming a 2°C-limit. Regional mitigation costs are displayed for the five allocation rules outlined above. A first result is that the variance of mitigation costs is higher between regions than between most allocation rules. Interestingly, the differences in the distribution of costs vary for different allocation schemes, but are not as large as one may expect for the very different rules of equal-per-capita and grandfathering. This can be attributed to the fact that the value of trade in allowances is an order of magnitude lower than that of trade in goods, limiting the impacts of emission trading on regional economies. Another key result is that Russia and the Middle East suffer the largest consumption losses in each allocation scenario, which is due to the devaluation of their fossil resources under climate policy. Africa, by contrast, has much to gain from a global trading system. However, as Collier (2007) argues, large revenue streams from resources such as oil – or emissions permits – can have a detrimental impact on economic development due to Dutch disease, revenue volatility and erosion of governance practices. Therefore, a careful institutional design for administering revenues from international permit trading will be necessary.

Except for the historic responsibility rule, the qualitative bias of results (i. e. whether a region suffers or benefits from mitigation) is quite stable. In general, these results suggest that there is some leeway for political bargaining in the negotiations of allocation rules and international burden-sharing within a global emissions trading system, in the sense that slight modifications across a certain set of allocation rules will not lead to major changes in distributional outcomes.

It is important to note that the relative distribution of mitigation costs may also depend on the stabilization target, particularly for allocation schemes that foresee a gradual transition from status quo to equal-per capita emissions. For contraction and convergence, for instance, the more stringent the global target, the less emission allowances will be available once the equal-per-capita stage is reached. Thus, more ambitious reductions on a global scale will result in disproportionately higher reduction requirements for countries with presently low per capita emissions. At the same time, stringent targets imply the use of a different technology portfolio. For instance, atmospheric stabilization at 400ppm would require large amounts of biomass in combination with CCS to generate negative emissions, hence favouring countries with a large biomass potential such as Russia. Integrated analyses of mitigation costs as a function of the stabilization level, taking into account allocation effects as well as energy system characteristics and trade, are yet to be performed.

Uncertainty and flexibility

There is significant scientific uncertainty regarding several parameters that are key determinants for optimal reduction targets. First and most importantly, uncertainty prevails about climate sensitivity, i. e. the mean global warming to be expected for a doubling of atmospheric CO_2. The higher the climate sensitivity, the more stringent reduction targets need to achieve stabilization at a given temperature level. Second, there is limited knowledge about the response of the climate system and its potential tipping points to global warming and impacts of climate change as a function of temperature increase (cf. Section I.1). If impacts turn out to be more severe than initially expected, or if previously unforeseen impacts emerge, it will be necessary to move to a more stringent temperature target. Vice versa, evidence of less severe than expected impacts or higher adaptive capacity could result in a relaxation of the temperature target.

While fix short and medium targets are central, it is important to allow for adjustments in long-term reduction obligations in line with an improved understanding of the climate system. Therefore, long-term reduction levels should be prescribed in terms of a corridor of possible emission pathways along with a well-defined mechanism for review and adjustment of the cap in a global trading system. Policy-makers need to strike a delicate balance between flexibility on the one hand, and credible long-term targets on the other hand.

Further research is needed about the optimal hedging strategy against the backdrop of the various uncertainties. Clearly, a ‘wait-and-see policy’, i. e. political inaction until uncertainties are removed, is not an option as it will render certain low-stabilization levels impossible.

II.2 Technology development

- **A large-scale transformation of the global energy systems will be needed to achieve the deep emission reductions required to avoid dangerous climate change.**
- **Experience learning has a large potential to reduce the costs of the transition towards low-carbon technologies.**
- **Due to multiple market failures, policy intervention to induce sufficient investments into innovative low-carbon technologies is required in addition to carbon pricing.**
- **Sustainable energy for developing countries is of key importance for a long-term and global solution of the climate problem and comes with numerous ancillary local and regional benefits. Mainstreaming low-carbon development into development policy, promoting sharing of technologies, and setting up a low-carbon fund for least developed countries and regions are important policy options to foster leapfrogging of developing countries into a low carbon future.**

Technical change towards low-carbon technologies will be central to stabilizing the climate. Limiting global warming to 2°C above pre-industrial levels will require curbing global emissions by some 60-80% relative to present levels by 2050. Reaching such deep reductions without compromising the standard of living in the industrialized countries and the right of economic development in the developing world will require a comprehensive global effort aimed at decarbonising the world economy. This effort will have to involve both transforming the energy supply of industrialized countries and assisting developing countries to become low-carbon economies.

Broadly, technological change can be divided into two steps. First comes innovation, the process from invention to the development of a commercially available product. Innovation is of key importance for broadening the portfolio of low-carbon options that could potentially contribute to the transformation towards a climate-friendly economy. Continued innovation is necessary to increase the diversity of technologies in order to hedge against uncertainties in technical and economical performance as well as unintended side-effects of individual technologies. The second step, diffusion, is equally important. It refers to the process of gradual adaptation and replacement of old technologies by new ones.

Hence, in the long-term, an important challenge for climate policy will be (a) to induce innovation of carbon-free technologies and (b) to foster the diffusion of technologically mature concepts to the markets.

Market failures and barriers related to technology

Pricing emissions is very important in harvesting near-term reduction potentials and can provide strong incentives for technology development if reduction targets are long-term and credible. The carbon market alone, however, will not be sufficient for inducing the socially optimal level of innovation and market penetration. This is largely due to market failures related to technology that exist in addition to the external effects of greenhouse gas emissions.

Learning effects are at the core of several technology-related market failures: While many low-carbon technologies are not competitive initially, there is significant cost-reduction potential with increased adoption due to (a) learning by using and accumulation of experience, and (b) economies of scale as production is increased and complementary goods (such as low-voltage appliances for photo-voltaic systems) become more readily available (Figure 16). Learning effects are particularly important for renewable energies. The cost of producing electricity from wind power, for instance, has decreased by a factor of seven from 1980 through 1995 (IEA, 2000). Overall, there are several barriers to optimal deployment and development of new technologies:

- The positive side-effects of introducing new technologies are not limited to the innovating firm, because technology development typically also creates benefits for others, e. g. in the form of knowledge spillovers. By the same token, countries investing in low carbon technologies create positive side-effects for other countries. The positive externality of innovation derives from the public good nature of knowledge, and without additional policies addressing this externality explicitly, investments are very likely to be less than would be socially desirable.
- Due to the learning effects and network effects, multiple equilibria are introduced to the energy-economy system: In the status quo, marginal additional investments in low-carbon technologies are not profitable even in presence of a price on carbon, because many alternative technologies are still at the beginning of their learning curves, hence this state is a stable equilibrium. On the other hand, once the learning curve of a technology has been passed through, there may be another stable state of the energy system with a high deployment of low-carbon technologies that is cost-optimal even if

the R&D and learning investments are taken into account. This bistability creates a strong path-dependency of future structures.

- For solving the climate problem, it is important to take a long-term perspective and to weigh the interests of future generations against those of the current generation. Most firms and economic agents, by contrast, expect high returns on their investments, thus planning on a shorter time scale than such an ‘ethical’ long-term perspective implies. Investments into the energy system compete for capital with other investment opportunities in the private sector, and thus will be considered attractive only if they provide similar returns. Therefore, investment projects that would be profitable in the decadal perspective will not be undertaken by private actors with a shorter time horizon and higher expectations about returns on investment.
- There are large uncertainties concerning the future development of energy and climate policy, availability and prices of fossil fuels, as well as the speed of innovation in low-carbon technologies. An economic analysis shows risk aversity and the threat of stranded investments results in a strong tendency to delay investments. This is particularly adverse for many low-carbon technologies, since they are rather capital intensive and require substantial up-front investments.

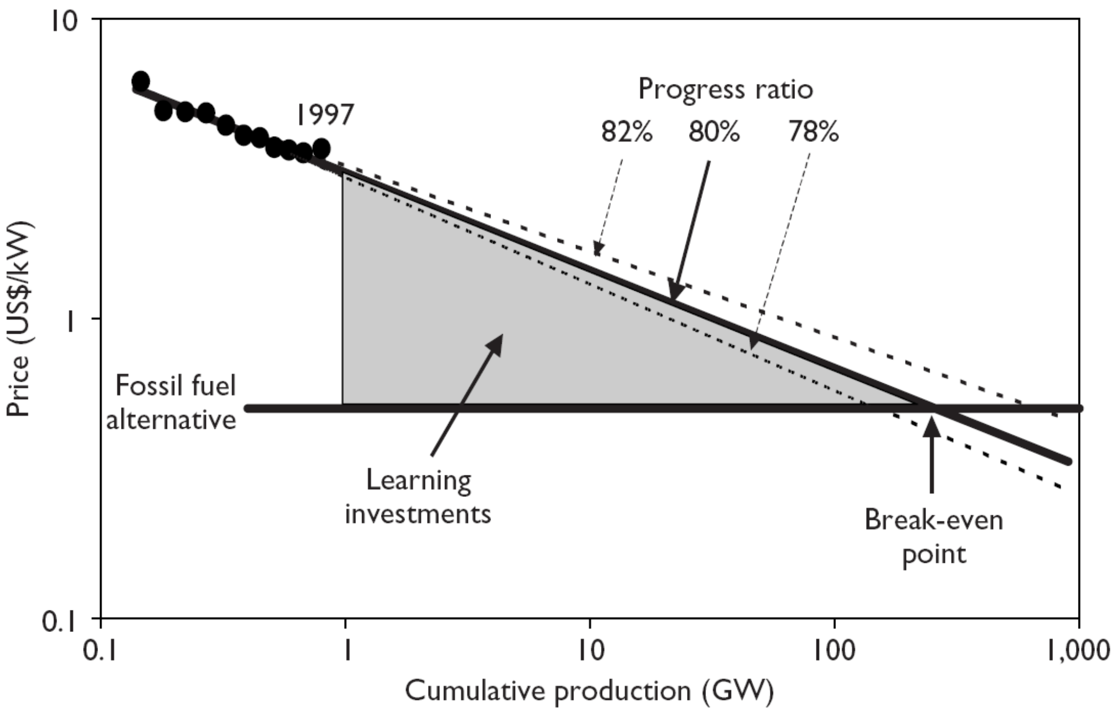

Figure 16: Illustration of learning effects for the example of photovoltaics. The progress ratio, indicating costs after a doubling of cumulative installed capacity, is a measure of the learning potential. Empirical evidence shows that renewable energy carriers have high learning potential. Source: IEA (2000).

General principles and policy objectives

In view of these market imperfections and barriers to technological change, explicit policies complementing carbon pricing need to be put in place on both national and international levels to foster the transformation towards a low carbon economy. To coordinate efforts internationally, a technology protocol may be required that explicitly addresses these issues.

Technology policy should have the following objectives:

- *Mainstreaming* mature low-carbon innovative technologies to the markets with the goal of decoupling emissions from economic growth;
- *Cost efficiency* in inducing technological change towards low-carbon technologies;
- *Broadening of the technology portfolio,* i. e. basic research and development with the goal of developing new technologies and making them commercially available;
- *Equitable sharing* of the costs of technology development and market introduction among industrialized nations;
- *Sharing technology* with developing countries to avoid a lock-in into carbon intensive technologies:
- *Avoiding adverse impacts* of new technologies on the environment, international security, or food production.

Elements of a technology protocol

Policy options for fostering innovation

At early stages of technology development, public R&D funding plays an important role. The knowledge created by R&D exhibits the characteristics of a public good. Despite the increasing challenges of meeting the growing global energy demand and mitigating climate change, public energy R&D funding in OECD countries has remained on a rather low level compared to the early 1980s (Figure 17). Increased resources for R&D will be required to deliver a diverse and effective portfolio of low-carbon options. The relative shares of technologies should reflect their relevance in a future sustainable energy mix (see Section I.5). Historically, much of the R&D expenditure was spent on nuclear technologies. For the future, it will be of key importance to shift the focus to renewable technologies, CCS, and energy efficiency. In this context, it will be central to maintain ‘techno-diversity’ to reduce the risk of reaching a dead end by premature lock-in into one or a few designs. Policy-makers have to strike a delicate balance between efficiently supporting promising developments while avoiding picking winners prematurely.

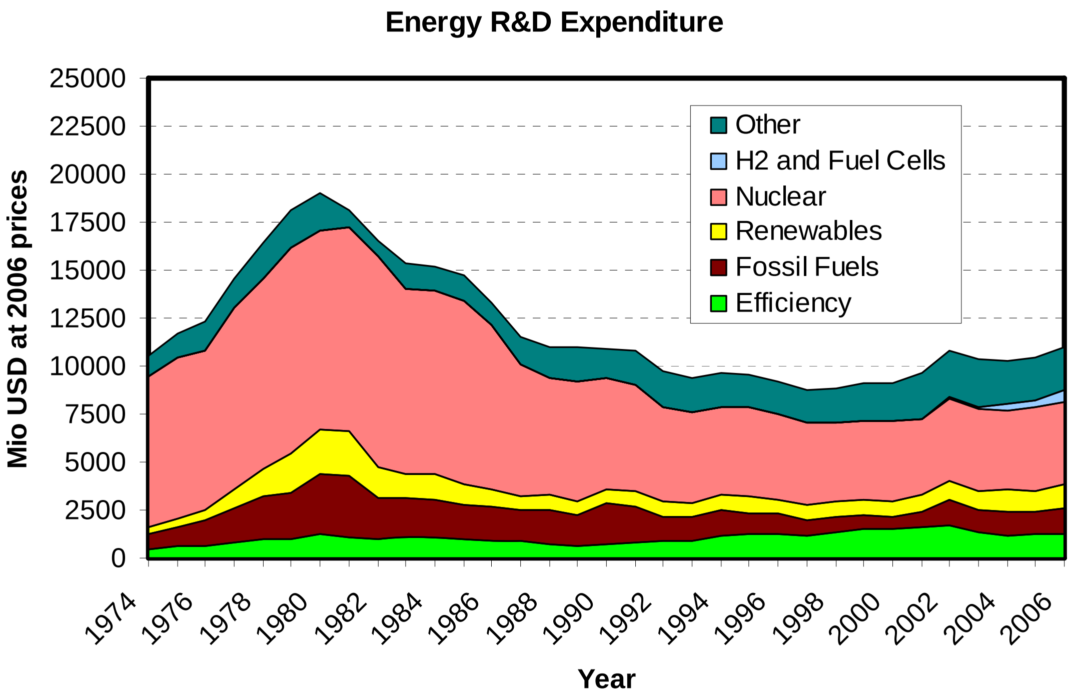

Figure 17: Expenditure for Research and Development of various energy technologies in the industrialized countries at 2006 prices and market exchange rates. Source: IEA (2008).

In general, the more advanced the stages of development and deployment, the larger is the role of private investors. To reduce uncertainty, governments need to provide a stable framework of incentives. For complex and large-scale approaches, such as CCS or centralized power production using concentrating solar power (CSP), demonstration projects can prove viability and reduce risks and thus are an important intermediate step towards commercialisation. A cost-efficient way towards realizing demonstration plants would be to tender such projects publicly (Held and Edenhofer, 2008).

The benefits of R&D are not limited to national states. Trans-national R&D is essential to avoid a duplication of efforts and to enhance the diffusion of ideas. Industrialized countries should agree on devoting a minimum share of GDP to R&D. This would avoid a free-riding of some countries on the effort of others.

Policies for fostering diffusion of low carbon-technologies

A principal choice for deployment incentives is between price (e. g., feed-in tariffs) and quantity instruments (e. g., renewable quotas) (Stern, 2006, Ch. 16.6.). If implemented well, such market introduction programs are an ample tool for increasing the market share of new technologies and in reaching cost-reductions through experience learning and economies of scale. Experience, such as the renewable energy law in Germany, suggests that price-based mechanisms are particularly effective in achieving growing deployment at moderate societal costs, largely due to long-term price guarantees (Butler and Neuhoff, 2004).

Internationally tradable quota systems (e. g. Green Energy Certificates) could be an important option for distributing the cost of learning investments among industrialized countries and for ensuring that new technologies are deployed where they are most cost-effective. Eventually, these learning investments will prove beneficial for the entire global community. At the same time, on a national level, governments should be aware of the first-mover advantages resulting from investing early into innovative low-carbon technologies, as it helps local businesses to establish technological leadership in promising industries of the future.

Box II.1: Carbon Sequestration Bonds

Carbon Capture and Storage (CCS) is an important option for reaching deep cuts in atmospheric CO_2 emissions. A major concern regarding CCS is the potential leakage of CO_2 from geological storage sites. It is obvious that the CCS leakage rate will be a strong function of the regulatory framework: If the authorities require operators to ensure safe storage and bear the risks of unintended leakage, much less CO_2 will re-enter the atmosphere than in the absence of such a regulation. In this context, Held et al. (2006) propose to establish Carbon Sequestration Bonds (CSB) as a means of internalising the risk of leakage. The bond scheme functions as follows: For each ton of CO_2 sequestered, the operator is required to purchase a CSB from a governmental authority equal in value to the potential damage if leakage occurred at a high rate. The bond owner is eligible for interest payments from the authority. After regular checks of the storage site, the bond is partially devalued according to the leakage rate and the owner is required to purchase CO_2 emission certificates for the amount of CO_2 that entered the atmosphere. Once the long-term stability of the site has been proven, the bond can be cashed. An important feature of the proposed CCS bonds is that they can be traded. Hence, operators can, depending on their trustworthiness, retrieve a large fraction of the expenses for CCS bonds at the financial markets.

The CSB scheme has the advantage of (a) ensuring the integrity of an overall reduction target in the context of CCS, (b) providing a strong incentive for operators to select well-suited storage sites and to use best practice in running CCS facilities through the internalisation of the risk of leakage, and (c) exploiting the investigative power of the market to search the most trustworthy combinations of CCS-operators and geological storage formations.

Another decisive factor for alternative energy technologies is infrastructure. Power supply based on renewables requires highly performing electricity grids for adjusting regional fluctuations of production. Granting renewables priority access to electricity grids and reducing administrative barriers as well as connection costs is important to encourage microgeneration, which can contribute significantly to sustainable energy supply. CCS will require transport infrastructure to carry the CO_2 to appropriate storage locations. Appropriate regulatory frameworks, legal certainty and public support will be essential for establishing the infrastructure required for low-carbon economies.

- Harmonization of standards and removal of trade barriers (technical as well as tariffs) are important to create larger markets and benefits from economies of scale.
- Risk management: Life-cycle assessment and internalisation of all major externalities associated with technologies are important for minimizing the risk of adverse effects and maximizing benefit. Technology choices matter not only in terms of the carbon balance, but also in view of their non-climate related co-benefits as well as shortcomings and risks. Replacing conventional energy technologies with alternative ones can have a positive impact on the air quality and enhance energy security. On the other hand, certain options (e. g. biomass, nuclear) bear new risks for adverse impacts. An example for internalising the risk of new technologies are CCS bonds that address the risk of CO_2 leakage from geological formations (see Box II.1).

Non-energy related greenhouse gas emissions:

While CO_2 related to the combustion of fossil fuels accounts for the bulk of man-made emissions, several other sources and compounds also contribute significantly to global warming. Currently, CO_2 release due to deforestation, mostly in tropical countries, accounts for almost 20% of the emissions (IPCC, 2007c). In terms of CO_2 equivalents, emissions of methane and nitrous oxide from agriculture make up 14% of the global total. Agricultural emissions have risen continuously and are particularly difficult to reduce. Other significant sources are nitrous oxide and fluorinated gases from industrial processes. Many of these emissions can be reduced at low costs. Another often neglected global warming agent is black carbon particulate matter, mostly originating from the combustion of fossil fuels and traditional biomass use. Despite being short-lived in the atmosphere, black carbon accounts for about 20% of the current anthropogenic climate forcing. Emission reductions would translate directly into a reduction of the atmospheric burden and thus greenhouse forcing.

Policy options for reducing non-energy related emissions include integration into the carbon market, regulatory measures, and voluntary commitments.

Sharing technologies with developing countries

Experience suggests that technologically relatively backward countries can quickly catch up with the world technology frontier by adopting the latest technologies without going through intermediate stages first. This ‘technology leapfrogging’ should set developing countries on a low-carbon growth path and prevent the reproduction of some of the unsustainable development patterns observed in industrial countries. However, it is of crucial importance to act quickly and decidedly in order to prevent locking in fossil fuel based energy sources (e. g. newly constructed coal-fired power plants without an option to be retrofitted with CCS), which typically have average lifetimes of several decades. As many of those related measures (like reducing energy subsidies) entail considerable co-benefits, such as reducing ambient air pollution or increasing energy security, they might constitute ‘no-regret’ policies in the sense that they would be desirable even in the absence of climate policy.

The objectives of the CDM under the Kyoto Protocol are “to assist Parties not included in Annex I in achieving sustainable development […] and to assist Parties included in Annex I in achieving compliance with their […] reduction commitments”. While the CDM was partly successful in realizing cheap abatement opportunities for industrialized countries and providing additional finance for mitigation projects in advanced developing countries, it largely failed in inducing sustainable development particularly in least developed countries. The vast majority of CDM-credits (certified emission reductions, CERs) are generated in emerging markets, with China, India, Brazil, and Mexico accounting for more than 75% of the total CERs expected by 2012 (UNFCCC, 2008). An upscaling of the CDM and further integration into the global carbon market is crucial for ensuring that emerging markets become low-carbon economies (cf. Section II.1). Triggering low-carbon development in less advanced regions, by contrast, requires separate targeted policies.

Initial capital costs for renewables are substantially higher than for conventional energy. At the same time, many developing countries are plagued by the scarcity of investment capital. Provision of access to investment capital is therefore crucial for fostering the expansion of renewables in the developing world. A low-carbon development fund for financing would help to overcome this financing gap. Microcredit schemes have proven to be useful instruments and could ensure effective broad access to the benefits and an effective use of the resources from such a low-carbon development fund. A crucial issue that the low-carbon development fund shares with other climate-related development policies is the question of how to raise adequate finance (Box II.3, p. 57).

Low-carbon development cooperation comes with a multitude of opportunities for both in the North and in the South. While urban centres in many emerging economies are already electrified, the challenge for rural areas and many less developed countries is to setup elementary electrical supply in the first place. Renewable energies are well-suited for such countries and regions, as in many cases local conditions are favourable for either solar and wind, or biomass is readily available. Renewable off-grid systems can provide power in rural areas as an intermediate step towards full electrification. Due to the large share of energy costs in LDC’s household incomes, LDCs are especially affected by rising prices for fossil fuels. Renewable energies can significantly decrease vulnerability with regard to increasing fuel prices.

In order to create an environment conducive to technology transfer, it is of crucial importance to strengthen absorptive capacities in receiving countries. This will require capacity building in the form of cooperation in education as well as establishing stable business environments and institutions to spur investments from the private sector. Where credit constraints prevent otherwise beneficial investments from being undertaken, appropriate funding schemes will have to be developed and put in place. Finally, deep integration of the corresponding policies as cornerstones of official development assistance will be a useful approach to promote technology transfer and the adoption of low-carbon energy sources in developing countries.

Box II.2: A Euro-Mediterranean cooperation on solar thermal power

On a global scale, the technical potential for solar power is almost unlimited: Already 1% of the World's desert area would suffice to cover the entire primary energy demand of the world in the form of electricity. Energy from concentrating solar power (CSP) has the potential to play a significant role in a sustainable future energy mix for several reasons. In solar thermal power plants, incoming sunlight is concentrated and used to heat water, which subsequently can be converted into electricity. This technology requires a strong direct insulation and works particularly well in the deserts of North Africa, but also in places that are rather close to centres of electricity demand such as the South West of the US, Australia, the Gobi desert in China, or the province of Rajasthan in India. CSP has the advantage over intermittent sources of renewable energy such as wind power of photovoltaics that the energy can be stored and used to produce electricity at times of strong demand or low insolation. According to a recent study, at well suited locations and with current technology, CSP plants can currently produce electricity at about 0.10 USD/kWh, with a further cost reduction potential to 0.04-0.06 USD/kWh (MED-CSP, 2005). This is already in the range of electricity generation costs from fossils. With increasing fossil fuel and carbon prices in the future, CSP will likely become competitive in the future.

There are several barriers that need to be overcome to make a Euro-Mediterranean solar cooperation work. First, large-scale import of solar energy into the EU requires substantial public investments into a high-capacity electricity grid. The HVDC (High Voltage Direct Current) technology allows for large-distance power transmission. A trans-European HVDC supergrid with a connection to North Africa would have the additional benefit of fostering the integration of domestic renewable energies (such as wind and hydropower) and increasing competition on European energy markets. Second, in the initial phase of experience learning, policies are required to foster market diffusion. A suitable approach would be publically co-funded demonstration projects. Moreover, it would be advisable to make renewable energy imports eligible towards the EU's renewable energy targets.

A trans-Mediterranean cooperation on solar thermal power has an enormous win-win potential for both Europe and North Africa. The possible benefits are manifold: For Europe, virtually zero-carbon electricity from North Africa is an important low-cost option that could, on the long-term, contribute substantially towards decarbonising the economy. It will also diversify Europe's energy supply and thus contribute to energy security. For North African states, CSP can provide cheap and reliable electricity supply, and render the electricity sector independent of fossil fuel imports. Moreover, heat and power from CSP plants can also be utilized to provide cheap and sustainable freshwater supply – an important option to overcome the freshwater deficit in the Mediterranean region. Large-scale solar thermal power in North Africa for export would entail substantial investments in the order of tens to hundreds of billion Euros. It would bring many jobs and prosperity to the unemployment-struck countries of North Africa. Economic prosperity and political stability in its southern neighbourhood is also in the best interest of the European Union, since it fosters cohesion and peace.

II.3 Deforestation

- **Deforestation and forest degradation account for roughly 20% of anthropogenic greenhouse gas emissions. Addressing them in the framework of a comprehensive Global Contract on Climate Change is of key importance.**
- **According to most estimates, deforestation and forest degradation (REDD) can be reduced at low costs. Reducing deforestation comes with significant ancillary benefits due to the preservation of ecosystems and their services.**
- **Options for providing incentives for REDD are full-scale integration into the global carbon market, fund-based schemes, or hybrid approaches.**

Large amounts of carbon is stored in tropical forests' biomass and soils. Deforestation causes the emission of most of the stored carbon into the atmosphere in the form of CO_2, either by burning of slashed wood, or gradual decay. Selective logging and man-caused fire also result in a severe degradation of standing tropical forest, producing additional emissions of CO_2, destabilizing ecosystems and making the forests prone to further degradation by fire (Nepstad, 1999). Therefore, activities should not only focus on avoiding deforestation, i. e. preventing the loss of area under forest cover, but also on reducing emissions from forest degradation by sustainable forest management practices.

The global forest area is about 4 billion hectares (~30% of the land surface), half of which is found in the tropics and subtropics (FAO, 2005). Tropical forests contain about 25% of the carbon in the terrestrial biosphere, account for about 33% of terrestrial net primary production (NPP), and can sequester large amounts of carbon annually (Bonan et al. 2008). Currently, land use changes in the tropics are a massive source of carbon emissions and contribute significantly to global warming and atmospheric change (Malhi and Phillips, 2005; Laurance and Peres, 2006). Tropical deforestation (as high as about 150,000 km^2 per year during the 1990s) accounted for at least a quarter of all anthropogenic carbon emissions in the 1980s and 1990s (Malhi and Grace, 2000; Houghton, 2003) and almost 20% (8 $GtCO_2$/year) of current total greenhouse gas emissions (Stern, 2006).

Deforestation is a process resulting from mainly three global drivers (Geist and Lambin 2002). First, agricultural activities are transferred from developed to developing countries with lower manpower costs, weaker legal environmental constraints and less legal rights on available forest area. Second, due to unsustainable practices, fertility and productivity of existing agricultural land decreases and agricultural activities are shifted to forests. Finally, the growing world population demands more and different kinds of food, wood and pulp.

In addition to storing carbon and acting as sinks for atmospheric CO_2, tropical forest ecosystems provide essential goods and services to human society. They guarantee the protection of biodiversity, the regulation of local and regional climate, the conservation of soil and water and act as sources for timber and other forest products. To maximize the benefits of REDD and to reduce risks, it is important to prioritise investments both among and within countries. A simple approach would be the identification of areas with high values for carbon and other ecosystem services such as biodiversity at both international and national scale (Miles and Kapos, 2008).

Concerning the costs of REDD, different methodologies have been applied, making direct comparisons difficult. Nevertheless, most studies suggest that costs tend to be significantly lower (initial carbon prices of \$3/tCO_2 or less) than the marginal abatement costs projected in energy and industry. Most prominently, a study carried out for the Stern Review applying a bottom-up-approach revealed that eliminating deforestation in eight countries, responsible for about 50% of global deforestation, would result in opportunity cost of around \$5-10 billion annually (approximately \$1-2/tCO_2 on average) (Grieg-Gran, 2006).

The opportunity cost in terms of national GDP could be higher than this, as the country would also forego added value from related activities, including processing agricultural products and timber. The size of the opportunity cost would then depend on how easily factors of production could be re-allocated to other activities. On the other hand, these estimates may overstate the true opportunity cost, as sustainable forest management could also yield timber and corresponding revenues.

Sohngen and Beech (2006) apply a global timber model for their top-down approach and project marginal costs as high as \$15/CO_2 to eliminate about 50% of global deforestation and \$30/tCO_2 to eliminate all deforestation, but initial carbon prices are much lower. In contrast, the McKinsey report (Enkvist, Naucler et al. 2007) found that reducing deforestation by 50 percent in Africa and 75 percent in Latin America could be achieved for about \$50/tCO_2 and abate 3 $GtCO_2$ emissions.

General principles and policy targets

The scale of emissions from REDD and the threat of major and irreversible loss of forest ecosystems make it imperative for the international community to take action. Therefore, REDD must be considered as a *complement* rather than a *substitute* for curbing emissions in the energy-related sectors. However, a mechanism to address deforestation should be designed in line with the overarching principles of environmental effectiveness, cost efficiency and equity of the Global Contract.

Environmental effectiveness

In order to be environmentally effective, the REDD mechanism will need to

- Ensure *additionality,* i. e. only emission reductions that would not have occurred otherwise should be eligible for crediting or compensations. This requires specific design features and implies well functioning Monitoring, Reporting and Verification (MRV) of emissions reductions.
- Guarantee *permanence,* i. e. it must ensure that benefits from emission reductions in one period are not lost through even more excessive deforestation in later periods. This will also require managing risks of unforeseen losses of forest biomass, e. g. by wildfires. Such risks can be reduced by establishing insurances that withhold a proportion of REDD credits from sale. In a national system, these would be held in the national registry and used when necessary to replace lost credits.
- Avoid *leakage,* i. e. it must be ensured that emissions are not merely shifted from one region to another.
- Take into account *ecosystem co-benefits,* i. e. forest systems that have high biodiversity or provide important ecosystem services in addition to carbon storage should be granted priority.

Cost-efficiency

Since the available financial resources are limited, it will be important to reach the environmental goals in a cost-efficient way. This implies:

- *A large-scale approach:* All mitigation potential that is available at costs that are lower than the marginal abatement costs in the energy sector should be captured. This will also ensure delivering enough emissions reductions to contribute substantially to the overall climate stabilization target.
- *The minimization of administrative costs:* The costs for MRV and allocation of funds should be held as low as possible. To reduce administration costs and to guarantee sophisticated monitoring of carbon and land use changes, any REDD program is best addressed at the national level. At the same time,

institutions for developing the methods and technology for MRV (e. g., remote sensing of deforestation rates) should be established on an international level.

Equity

Fair sharing of the benefits and costs of avoided deforestation both among countries and within rainforest nations will be essential for the long-term success of REDD. This requires:

- *Equitable distribution* of REDD proceeds within countries: Ensuring benefit flows to all relevant stakeholders, including the poor, will be essential for the effective and long-term success of REDD strategies. It will also require well-defined land and carbon rights. National efforts will need dispersed funding, which may have to include up front payments for host countries.
- *Fair method of defining baselines*: Any REDD scheme will require the definition of baseline emissions against which the success of forest protection will be measured and on which compensation or crediting will be based. Baselines should be defined so that (a) no 'hot air' is generated, i. e. baselines that are higher than emissions would be in the absence of REDD should be avoided, (b) sufficient incentive for rainforest nations to participate are provided, (c) countries with excessively high historic deforestation rates are not unduly privileged, and finally (d) early action is rewarded.
- *Targeted approaches* for specific groups: As deforestation and degradation of forests has multiple economic, socio-political, demographic and environmental drivers and is unevenly distributed across the globe, any politically viable scheme will have to be flexible enough to address a wide variety of issues and to avoid non-compliance by developing countries. It will be specifically important to support groups that rely on forest resources, such as subsistence farmers, in switching towards sustainable practices.

On the national level, an additional prerequisite for the functioning of REDD are *well-performing governance* structures. This includes well-defined property rights. Without clear land and carbon rights, REDD could present a high risk for the poor as they might be evicted or cannot profit from payments. Furthermore, poorly defined property rights and land tenure issues might result in open-access forests that are overexploited. At the very least, there need to be binding arrangements for assessing and negotiating benefit distribution.

As the highest deforestation rates tend to be in weak governance countries not capable to implement REDD projects, national policies and processes will need to be strengthened in order to address the root causes of deforestation, to design systems for transferring payments from international funds to individuals on the ground and to develop specialized national institutions for monitoring and accounting.

Political framework and design options

The Kyoto Protocol and the subsequent Marrakesh Accords failed to provide incentives for avoiding tropical deforestation. While reforestation and afforestation projects in developing countries are eligible under the Clean Development Mechanism, no such crediting is possible for emissions reductions from avoided deforestation. This is largely due to concerns about additionality, permanence, and leakage (Schlamadinger et al., 2007). Since the 'Conference of the Parties' (COP) 11, held in Montreal in 2005, there has been increasing interest in including avoided deforestation (AD) under the UNFCCC and its Kyoto Protocol. Today, greater awareness and political pressure have initiated a process that could result in the recognition of emission reductions from avoided deforestation. Several proposals have been tabled on how to implement and frame policy instruments that provide incentives to reduce deforestation and degradation in a future international climate policy framework. They can be grouped into two basic types: Those favouring integration into the global carbon market and those favouring compensated reductions from a separate fund. A third category of schemes proposes a hybrid approach, blending elements of the carbon market and fund-based schemes.

(1) Integrated Market approach

An integrated market approach such as the Compensated Reductions (CR) (Santilli et al. 2005) or the Joint Research Centre (JRC) proposal (Achard et al., 2005) could be established by a separate annex to the Kyoto Protocol. Developing (non-Annex I) countries may, on a voluntary basis, agree on a national target to reduce emissions from deforestation. A historical baseline would be constructed on the basis of forest cover or carbon emissions from deforestation, primarily from remote sensing, and extrapolated to the future. National baselines could be either related to a global rate and be traded-off and compensated between countries, or left open to negotiations. Reductions in emission from deforestation during the commitment period could then be credited and sold to governments or international carbon investors at the end of the relevant period. A country that has been credited for reducing emissions from deforestation would agree to stabilizing, or further reducing, deforestation rates in the subsequent commitment periods. There could be various mechanisms to ensure the compliance to this rule, for example some part of the credits could be banked till the subsequent commitment period or an insurance policy could be taken out to ensure the permanence of the carbon credited.

(2) Fund-based schemes

The main alternative to market mechanisms are payments from an international fund as incentives to reduce deforestation. Such transfer payments could be used to buy off commercial interests that drive inappropriate deforestation by making it more profitable to keep forests. However, such payments would need the establishment of a new international fund. Possible sources of funding are proceeds from auctions of emissions allowances under a global carbon market regime (see Box II.3, p. 57). An international fund would compensate countries for reducing emissions from deforestation below a certain baseline.

(3) Partial market integration: Hybrid / dual market scheme:

Partial market integration concepts such as the Dual Market Scheme (CCAP, 2007) or the TDERM scheme (Greenpeace, 2007) are based on the idea of setting up a separate market for deforestation REDD units. Industrialized countries would commit to meeting a certain fraction of their reduction obligations by purchasing REDD units. Industrialized countries would be allowed to use more than the predefined minimum of REDD units towards meeting their reduction targets, however, the international community would also agree on a maximum amount of REDD units to be used. Thus, the substitutability between regular emission allowances and REDD units would be constrained by upper and lower limits to demand. While the CCAP foresees that industrialized countries purchase REDD credits directly from the rainforest nations, Greenpeace (2007) proposes a supra-national institution that pays countries for verifiable reduction in emissions and, in turn, sells REDD credits to industrialized countries to raise the required funds. CCAP (2007) considers the dual market as an intermediate step towards separate carbon markets and reduction commitments from industrial countries for reduced deforestation.

The main advantage of an integrated market approach is that a major source of carbon emissions would be included in the market mechanisms for mitigation and thus could contribute significantly to combat climate change in accordance with the ultimate objective of the UNFCCC. Furthermore, the reduction of emissions from deforestation would provide a means for non-Annex I countries with significant deforestation emissions but a limited industrial base to take on real, sectoral commitments and reduce emissions on a voluntary basis.

There are, however, major concerns put forward over integrating REDD into the global carbon market (Scholz and Schmidt, 2008). First, without tightening the short to medium-term reduction targets, it would crowd out other mitigation activities and thus delay the transformations in the energy sector that are necessary for long-term cost efficiency in stabilizing the climate. Second, some forests are more valuable in terms of biodiversity than others. An integrated market scheme would not account for external effects other than CO_2 emissions – thus no incentives for environmental integrity and consistency with sustainable development targets would be provided. Third, as monitoring and verification of emissions is significantly more difficult and less accurate for deforestation than for energy systems, a market integration of REDD would introduce substantial uncertainties and may thus jeopardize the environmental integrity of a global cap-and-trade system.

In contrast to the integrated market approach, fund-based schemes could also account for non-climate objectives such as biodiversity conservation or poverty alleviation. In addition, de-coupled financing from the international carbon market will guarantee that mitigation activities in the energy sector will not be undermined. On the other hand, fund-based schemes require that policy-makers define the relative contribution of fossil fuels and decreases in land-use emissions explicitly rather than relying on the power of the market to establish cost-efficiency. Nevertheless, they represent an attractive option in situations where it is difficult to implement market mechanisms because of institutional constraints or where market mechanisms have undesirable distributional effects. Although such payments could be an effective mechanism to halt deforestation due to its ‘directness’, critics argue that the weakest actors are often marginalized, property rights are often not well defined, and transaction costs are high. Fund-based schemes would allow for flexibility in dealing with local circumstances and particular causes of deforestation and the different actors involved. An interesting variant of fund-based schemes that would effectively address permanence problem are forest protection bonds that entitle land owners to regular payments if the forest remains. According to this scheme, rather than receiving one-time payments for avoided deforestations, land owners would receive annual compensations equal to the opportunity costs for managing forests sustainably rather than converting it into farmland. Such regular payments would provide a strong incentive for long-term protection of forests and their carbon stocks.

Partial market integration schemes aim at combining the strengths of both approaches. By keeping partly separate markets for emission allowances and REDD units and defining upper bounds for offsetting domestic emissions, crowding out of domestic reductions can be limited. At the same time, commitments for minimum contributions of REDD towards industrialized country’s reduction targets would ensure demand for REDD units and establish a broad funding basis. In the hybrid scheme, it would also be conceivable to specifically address permanence and ecosystem co-benefits by adjusting the financial flows accordingly. Transaction costs for partial market schemes are likely to be higher than for other schemes due to the increased complexity.

Outstanding challenges

Challenges include, first, to ensure that sufficient funds are available and, second, that transfer payments do not only benefit the central government and national elites, but that livelihoods and environmental conditions at the local level are improved. Major institutional and policy challenges have to be overcome before implementing a comprehensive, economically and environmentally sound REDD crediting scheme. Policies need to be designed to address both, deforestation drivers and co-benefits.

II.4 Adaptation

- **Mitigation is necessary to avoid unmanageable climate change and and adaptation is necessary to manage unavoidable climate change.**
- **The funding needs for adaptation to climate change in the developing world are significant. The adaptation funds established under the Kyoto Protocol and the UNFCCC fall far short of meeting these needs. Therefore, a broadened funding mechanism is required to provide sufficient and reliable financial resources for adaptation activities in developing countries.**
- **Adaptation on the ground needs to be closely integrated with existing poverty reduction strategies, sustainable development programmes, and sectoral policies. At the same time, it needs to be ensured that resources for adaptation are additional to existing funds for official development assistance.**

Managing the unavoidable

Mitigation of climate change is the most effective option for limiting the long-term risks of climate change. Strong mitigation efforts limit the magnitude and pace of climate change, thus reducing the necessity for adaptation and the residual impacts. While most societies and ecosystems are expected to be able to adapt to a 2°C warming, higher levels of climate change increasingly exceed the adaptive capacities of human societies and ecosystems (IPCC, 2007b).

Adaptation and mitigation are sometimes seen as alternative policy options, suggesting that it suffices to implement either of them. This view, however, neglects some fundamental differences between mitigation and adaptation in terms of their spatial and temporal scales and other policy-relevant criteria. Mitigation of climate change can reduce the impacts of climate change on all systems across the globe and it is certain to be effective. Due to the inertia of the climate system, however, the climatic benefits of mitigation take several decades to fully manifest. Many mitigation activities have immediate side benefits, such as reducing air pollution or protecting biodiversity. Adaptation to climate change is the only option to reduce climate impacts in the near future, it can be implemented locally or regionally, and it can have important synergies with the reduction of current climate-sensitive risks. The benefits of adaption, however, are limited to the targeted regions and sectors, its scope is limited (e. g., it is hard to imagine how to protect the Maldives, with a maximum elevation of 2 m, against a 5 m sea-level rise), its effectiveness is less certain (e. g., dykes and levees can break), and it puts the burden on those most vulnerable to climate change, which is in stark contrast to the polluter-pays principle. As a consequence, both mitigation and adaptation are required to reduce the impacts of climate change to an acceptable level (IPCC AR4 SYR, 2007). In the wording of

UNSEG (2007), mitigation is necessary to avoid unmanageable climate change, and adaptation is necessary to manage unavoidable (or unavoided) climate change.

Most adaptation actions yield short to mid-term benefits for those implementing them. Therefore, adaptation often occurs autonomously, i. e., without the need for policy interventions. Insurance companies adjust their premiums in response to changing weather risks, farmers adjust their practices in response to failing harvests, water managers invest in additional water storage capacity in response to decreasing precipitation, and health managers adjust vaccination recommendations in response to changing disease patterns. However, it would be premature to conclude that adaptation to climate change can largely be left to market-driven actions of self-interested actors.

The role of governments and international organizations

There are three main reasons why governments and international organizations have an important role to play in adaptation:

1. **International and intranational equity: "Governments fund adaptation abroad"**

   Adaptation by self-interested actors pays no attention to equity issues, such as differential responsibility for climate change and capacity to adapt (see Section 1.3). If adaptation were left to the markets, wealthy communities would be able to prepare themselves against the detrimental impacts of climate change but poor societies would have to bear the unmitigated impacts of climate change that was largely caused by others. Such an unjust situation has been denoted as "climate apartheid" by Nobel Peace Laureate Bishop Desmond Tutu.

2. **Provision of new public goods: "Governments facilitate adaptation at home and elsewhere"**

   Effective adaptation at global, regional and local levels often depends on the accessible information about current and future climate change and its likely impacts, on guidelines for the inclusion of climate change risks into current decision procedures, or on the availability of technologies that are robust against a wide range of climate conditions. Many of these goods are most effectively supplied by governments or international organizations. Examples for international public good are the IPCC, whose reports and main datasets are freely available on the World Wide Web and the Nairobi work programme under the UNFCCC, whose objective is to assist all Parties, in particular developing countries, to improve their understanding and assessment of impacts, vulnerability and adaptation to climate change; and to make informed decisions on practical adaptation actions and measures to respond to climate change. An example for a national public good is the United Kingdom Climate

Impacts Programme (UKCIP), which provides climate and climate impact projections as well as adaptation guidelines to a diverse community of users in the country, and which has influenced similar programs in other countries.

3. **Climate-proofing of current government activities: "Governments adapt themselves"**

   Governments are engaged in many climate-sensitive activities. They build and operate transport and water-related infrastructure, they run weather services and agricultural outreach agencies, they establish poverty reduction strategies, building norms and water-allocation rules, they regulate food processing and insurance industries, they run national parks, public health services and disaster preparedness agencies, and they provide international development assistance. These climate-sensitive activities are generally governed by direct regulation rather than by market forces. Hence, decision-making bodies and executive agencies need to explicitly assess and consider the significance of climate change for their activities.

Each of the three points mentioned above is relevant for a Global Contract on Climate Change. The political debate about adaptation in the context of the UNFCCC and the Kyoto Protocol has been largely concerned with the first topic, which implies substantial resource transfers from rich countries with high emissions to poor countries with low emissions to prepare for climate change and cope with its consequences. Several funds have been established under the UNFCCC and the Kyoto Protocol to implement this resource transfer but most of them operate on completely insufficient voluntary contributions. It is generally agreed that adaptation in rich industrialized regions does not need to be addressed in a Global Contract on Climate Change. As for the second point, several international organizations (such as UNEP, UNDP, WHO and the World Bank) as well as individual governments have provided technical and other resources to assist developing countries in adapting to climate change. Nevertheless, developing countries are generally disadvantaged in terms of public goods and services that would reduce their vulnerability to climate change. Thirdly, governments need to ensure that international institutions adjust their activities to account for climate change. A Global Contract on Climate Change is likely to contain provisions for international institutions to assist developing countries in adapting to climate change.

Adaptation in the framework of the Global Contract

The consideration of adaptation in a Global Contract on Climate Change faces several challenges. Such a contract needs to ensure that the collection and distribution of resources consider the different historical responsibility for and vulnerability to climate change in a fair manner. While there is general agreement that developing countries, in particular least developed countries, will be disproportionally affected by the impacts of climate change, science cannot provide definitive assessments of countries' vulnerability to climate change due to large scientific uncertainties as well as methodological difficulties (see Sections 1.2 and 1.3). For the same reasons, quantification of the needs for adaptation funding in developing countries is challenging. Current estimates range from several billion dollars per year to several tens of billion dollars (Stern, 2006; 2008). Compared to these numbers, the resources available in the adaptation funds under the UNFCCC and the Kyoto Protocol are negligible. Thus, broadening the funding base to ensure adequate and reliable funding for developing countries' adaptation needs is a central challenge for international policy. Auctioning of emission rights in emissions trading systems and levies on international transport can be one source of international adaptation funds (see Box II.3, p. 57).

A Global Contract also needs to balance the interests of payers to ensure the effective and targeted use of the resources provided by them, considering that national governments have exhibited different levels of interest in addressing the needs of particularly vulnerable population groups with the interests of recipient countries to establish their own adaptation priorities in line with existing development priorities. To be effective, adaptation policies in least developed countries should be aligned with ongoing development efforts (Stern 2006; 2008). Hence, a Global Contract needs to ensure that adaptation is integrated ("mainstreamed") with international and national development activities. At the same time, it needs to ensure that funding for adaptation is in addition to official development assistance (ODA). This additionality is crucial for developing countries given that most industrialized countries are still far from providing 0.7% of their GNP for ODA as agreed by the UN General Assembly in 1970 and repeated ever since. Finally, a Global Contract should provide incentives for governments to identify efficient and cost-effective adaptation options and avoid perverse incentives that may arise from requirements to demonstrate incremental adaption value of development projects to become eligible for funding.

Specific examples for adaptation in least developed countries include capacity building (e. g. regarding regional climate impact and weather forecasting), access to capital and insurance markets (e. g. through microfinance), technology research and development as well as transfer (e. g. climate-adjusted crop varieties), and consideration of climate change in infrastructure projects.

Box II.3: Financing of climate-related development activities

An overarching issue in the context of tackling the climate problem is the question of financing climate-related activities in developing countries. Significant financial resources are required in the following three policy areas:

(1) Financing of low-carbon development

(2) Reducing emissions from deforestation and forest degradation (REDD)

(3) Adaptation to climate change in developing countries

All three policy areas have in common that substantial sums on the order of several billion to several tens of billion US$ per year are required, and that new sources of funding have to be identified. One option is direct linkage to the global carbon market. Low-cost mitigation options in advanced developing countries can be effectively reaped by up-scaling the current CDM and stepwise integration of emerging economies and middle-income countries into the global carbon market (Chapter II.1). Similarly, certain proposals favour financing REDD by making deforestation credits eligible for the carbon market. There are, however, limits to the power of the carbon market. Purely market-based approaches have proved much less effective in promoting sustainable development in poorer developing countries. A dedicated low-carbon fund to provide finance may therefore be a more effective approach for low-income developing countries (Chapter II.2). There are also valid concerns about full-scale integration of REDD into the carbon market, mostly because of uncertainty, ecosystem co-benefits, and worries about the permanence of emission reduction (Chapter II.3). The benefits of adaptation are to a large extent independent from those of mitigation, and therefore separate adaptation funds are required.

Low-carbon development, REDD and adaptation may be addressed in a uniform funding framework. Providing sufficient finance out of national budgets, however, is notoriously difficult, as witnessed by the failure of most industrialized countries to meet the UN target of spending 0.7% of their GDP on ODA. Approaches related to proceeds from sales of emission allowances rather than national funding sources may thus be more promising. One approach involves earmarking a predefined fraction on the order of a few percent of total emission allowances to be auctioned internationally, with the proceeds to be used for climate-related development activities. Such a scheme is akin to the Norwegian proposal for financing adaptation. Also, a levy on emissions from aviation and shipping, which are not covered by the Kyoto Protocol's reduction obligations, can result in substantial proceeds.

Outstanding challenges for policy and research

The open challenges for policy-makers on the path towards a sustainable solution of the climate change problem can broadly be grouped into four categories: Risk management, multiple public good problems, equity and fairness, and the design of long-term policies. This should also be in the focus of further research.

Management of risks and uncertainties:

Mitigation and adaptation are surrounded by many uncertainties. We do not know when and where particular impacts, technologies or institutions will materialize in the future. These uncertainties have a crucial impact on the design of mitigation and adaptation options. To some extent, they also define the division of labour between mitigation and adaptation: Identifying an appropriate climate stabilization target that avoids socially unacceptable impacts that exceed societies' capabilities for adaptation, while not harming the economic development in industrialized and developing nations, is a major challenge. Given the current knowledge base, the 2°C-target set by the European Union is a reasonable response. However, further research is required to broaden knowledge on the implications of this stabilization level, both in terms of climate change impacts and mitigation. For example, further assessment is required on the risk of passing tipping points in the Earth system if climate stabilization at 2°C is successful. Moreover, it is important to improve the understanding of the carbon cycle and climate sensitivity to reduce the uncertainty on the emission pathway required to meet the 2°C target. The development of robust mitigation strategies also requires an in-depth analysis of risks associated with various mitigation options.

Multiple public good problems and overlapping externalities:

Both mitigation and adaptation involve public goods where the free market alone does not induce the socially optimal quantities. In fact, the climate problem is characterized by a multitude of partly overlapping and interlinked public good problems for which synergies or trade-offs between policy objectives arise:

- Mitigation and adaptation are strongly interlinked: There are limits to adaptation, and therefore it crucially relies on ambitious mitigation to ensure that climate change impacts remain manageable.
- The development of innovative low-carbon technologies is a public good that strongly interacts with the public good of climate change mitigation. Performing innovations and bringing technologies to the markets requires significant up-front investments, but once they are competitive, all countries will benefit from their availability. New infrastructure that will be required for renewables as well as CCS represents another climate policy related public good.

- Virtually all low-carbon technologies come with ancillary benefits and risks, some of which are public goods or bads. They can for instance significantly contribute to curbing local air pollution. By contrast, the extensive use of biomass interferes with public goods such as food security, conservation of ecosystems and intact hydrological cycles. The risks of massive biomass use are as little explored as the requirements for power supply systems in case of an ambitious expansion of intermittent renewable energy sources. The risks of nuclear energy accidents and proliferation endanger the public goods of health and (international) security, and the problem of long-term storage of nuclear wastes is still unresolved. A careful and integrated assessment of these interlinked impacts is of key importance for an optimisation of mitigation strategies.

Equity, fairness and sustainable development:

Public good problems can only be solved if the solution is considered as fair and based on adequate equity principles. In general, the equity principle has to be applied to inter- and intragenerational justice. Designing climate policies involves explicit and implicit judgments between the interests of (a) different generations, (b) different countries and regions of the world, and (c) different economic sectors and stakeholders.

It is a delicate task to balance the interests of these various groups in deciding on climate protection and adaptation efforts and distributing costs. Science should take the position of an ‘honest broker’ in this process by exploring and communicating the implications of various scenarios and by identifying optimal strategies for various normative settings.

A strong focus should be put on the consequences of climate policy for developing countries. Developing countries are particularly vulnerable to both climate change and hikes in energy prices. At the same time, well-designed climate policy has great potential of fostering sustainable development by supporting the setup of a low-carbon energy infrastructure, tackling deforestation, and promoting adaptation to climate change. Considering the historical responsibility of the industrialized countries, it is crucial to ensure that they shoulder the costs of tackling the climate change problem.

Long-term vs. short-term policies:

Translating long-term stabilization goals into short and medium reduction targets, and implementing credible corresponding policy instruments is a major challenge for climate change policy. Policies need to be credible even in the presence of changing governments and modifications in political priorities. If investors anticipate future changes of climate policies, they will be reluctant to deploy low-carbon technologies at a large scale because they fear that they will not recover their investment costs in the future. Well-designed climate policy requires the implementation of stable policies that persist over several decades in order to create a reliable framework for investors to encourage long-term and risky investments like in CCS or renewables.

Climate research has had a strong emphasis on long-term stabilization levels. However, real world decision-makers are confronted with short-term concerns of their industries or lobby groups fearing to loose their competitiveness on the world markets. In general, a convergence of the top-down long-term perspective (‘what is necessary to achieve climate stabilization’) and short-term policy planning (‘what can be done now’) is required. Similarly, in future quantitative top-down modelling efforts need to be complemented by sectoral bottom-up analyses of technical and institutional limits. The relevant barriers that impede the implementation of ambitious climate policies, e. g. vested interests, misplaced incentives such as fuel subsidies, lock-in to carbon-intensive infrastructure etc., need to be identified and addressed.

Conclusions

Ultimately, tackling the climate change problem boils down to the challenge of managing different kinds of risks. The risk of climate change is a substantial threat for industrialized and developed nations alike. Continued, unmitigated emissions of greenhouse gases will likely be associated with large-scale and possibly abrupt changes in climate patterns that will be beyond the historic experience of our civilizations. These changes will have substantial adverse impacts for many sectors and throughout the world's continents. Climate change is already a major threat for the UN's Millennium Development Goals. On the other hand, large-scale emissions reductions may commit us to the risk of exposing economies to a massive strain, particularly in the developing world, and causing adverse distributional effects. The recent development has demonstrated that there is a strong coupling between energy markets and food production. As expenses for food and energy make up for a large portion of their dispensable budget, low-income groups and the poor are particularly vulnerable to escalating energy prices. Current scientific evidence suggests that global warming in excess of 2°C above pre-industrial levels would lead to a number of severe impacts on human welfare and natural systems. On the other hand, in-depth energy-economic analyses suggest that limiting global warming to 2°C is feasible at rather moderate costs, albeit under the condition of an appropriate political framework.

Averting dangerous climate change is a monumental challenge and will, in the long term, require a full-scale transformation of the global industrial metabolism. Suitable political instruments, most importantly a global carbon market and pro-active technology policy, are required to encourage innovation of and investments into low-carbon technologies. In the EU, crucial climate policy elements are already in force or planned: The EU ETS has been in operation since 2005 and increasingly strict emission caps are envisaged. The climate and energy package tabled by the EU Commission earlier in 2008 proposes to increase the share of renewable energies to 20% by 2020. If implemented as planned, these initiatives are important steps towards a cost-efficient low-carbon transformation and may inspire other industrialized countries to follow.

Climate change is characterized by an extreme decoupling of causes and impacts. While sources of emissions are localized, their effect is global and extremely long-term. There is also a notable discrepancy between the geographical distribution of historic responsibility and that of vulnerability to climate change: While the bulk of the past emissions have been caused in the industrialized countries, developing countries will be hit hardest by climate change. The moral dilemma arising from this fact is central to the problem and underlines the responsibility of the developed countries to take the lead in the effort to a solution. At the same time, as emissions rise in conjunction with rapid development in emerging economies, industrialized nations, which only make up for a fifth of the world population, will not be able to solve the climate problem alone. This constellation along with the global nature of the climate change problem underlines the need for international cooperation – a Global Contract on Climate Change with a special focus on justice and development. The problem can be solved – but only if we start to act immediately and on a global scale.

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