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The Economic Costs of Climate Change

Claudia Kemfert

International experts agree that the emission of greenhouse gases by mankind is rising further and further, and causing climate change. This can clearly be seen in the rise in the average global temperature and sea level. It is also evident in the increase in extreme weather events and natural catastrophes, which are causing enormous economic damage. If the global temperature changes by 1 degree Celsius economic damage of up to 2 billion US dollars is possible in 2050. If greenhouse gas emissions are not reduced enough to prevent such a rise in temperature, altogether damage from natural catastrophes amounting to 137 billion euros could be caused in Germany by the year 2050. With optimal cooperation from the main emitters – Europe, Russia and the United States – the costs of reducing greenhouse gas emissions could be minimised. By offering emission rights for sale Russia would gain from climate policy, its participation could bring a revenue of up to 20 billion US dollars over a period of four years (2008 to 2012). So Russia is well advised to ratify the Kyoto Protocol.

Mankind can influence the climate

The influence of mankind on the natural climate has never been greater than today. Far-reaching changes to the environment, like the increasing emission of greenhouse gases, have become a major part of life today. It is foreseeable that this will cause irreversible long-term damage which will jeopardise the natural bases of life. The report by the Intergovernmental Panel of Climate Change (IPCC) summarises the main facts and consequences of climate change.[1]

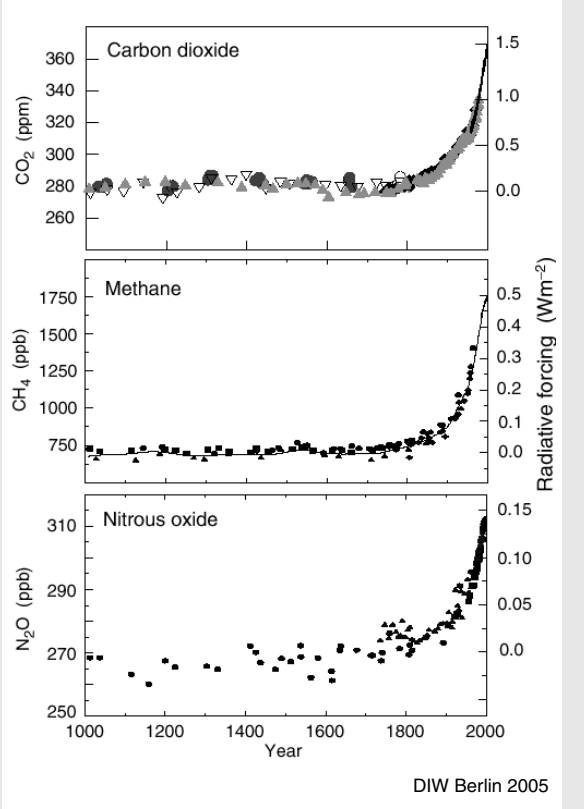
In the 20th century the global surface temperature rose by 0.2° C (± 0.6°). The rise in the surface temperature in the northern hemisphere was greater during that period than in the previous 1000 years. 1990 was the warmest year globally in the 20th century, and 2002 was the warmest year since weather records began. The number of hot days has increased and the num-

[1] Intergovernmental Panel of Climate Change (IPCC): 'Climate Change 2001: Third Assessment Report', Synthesis Report, Cambridge 2001.

Figure 1

Indicators of the Human Influence on the Atmosphere during the Industrial Era

Global atmospheric concentrations of three well mixed greenhouse gases

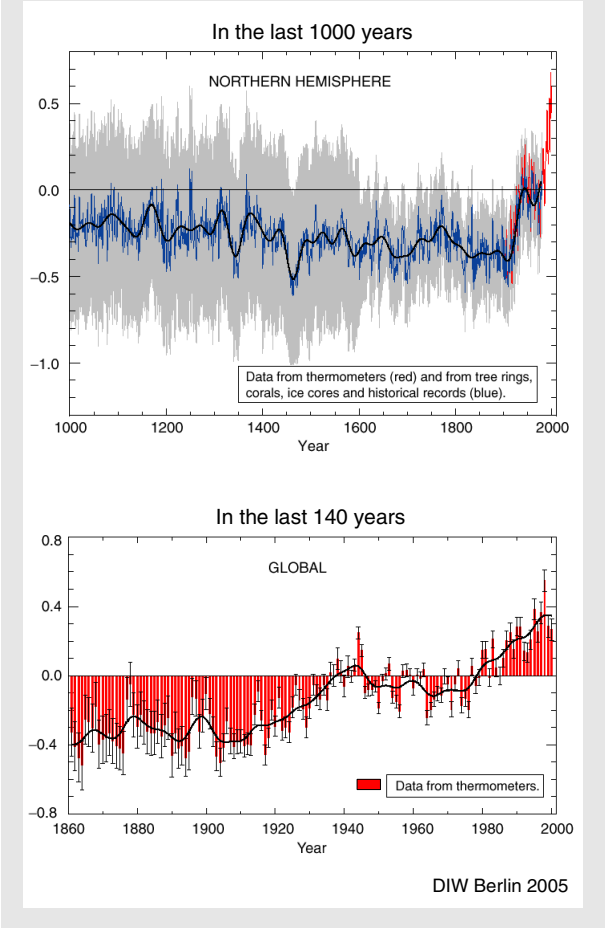


Source: Intergovernmental Panel of Climate Change (IPCC 2001).

Figure 2

Earth Surface Temperature

Deviations from the average in degrees Celsius



Source: Intergovernmental Panel of Climate Change (IPCC 2001).

ber of cold days has decreased. The anthropogenic (that is, caused by human activity) concentration of greenhouse gases, carbon dioxide (CO_2), methane (CH_4 and nitrous oxide (N_2O) has increased exponentially in the 20th century (cf. figures 1 and 2). Depending on assumptions on future developments, temperature increases of between 1° and 3.5° Celsius are to be expected in 2100 (cf. figure 3). The concentration of carbon dioxide alone in the atmosphere has risen since weather records began by 31% (± 4%).[2] CO_2 emission comes mainly from burning fossil fuels. As the emission of greenhouse gases increases and the temperatures rise the global sea level will also continue to rise. Again depending on the assumptions and scenarios on which the prognosis is based the figure is put at between 10 cm and 90 cm by the year 2100.

Growing number of extreme natural catastrophes

The number and severity of natural catastrophes, like flooding caused by extremely heavy rainfall, will continue at growing intensity, as will heat waves and storms. Table 1 shows the extreme weather events that are possible, how likely they are to occur and their possible impacts. Many regions in the world are already more affected by climate change than others, and this will also be the case in future. In North America worse storms and tornadoes are to be expected, while floods are more likely in Asia. In Europe as well as extreme

[2] Today there are 150 gigatonnes (Gt) more of carbon dioxide emissions in the atmosphere than before industrialisation. The quantity is growing by 3% a year and in 2050 it will have reached 300 Gt if this growth rate continues unchanged.

heat waves and flooding the storms like tornados and hurricanes are also likely in future.

Extreme heat phenomena and rainfall have been a striking feature in Europe in recent years, especially Germany. In 2002 Middle and Eastern Europe suffered catastrophic floods. In the east and south of Germany, the southwest of the Czech Republic and Austria and Hungary the rivers Danube, Elbe, Moldau, Inn and Salzach burst their banks. The millennium flood hit Germany hard, causing damage amounting to about 9.2 billion euros.[3]

In 2003 the whole of Europe suffered from an extreme heat wave. The economic damage of such catastrophes include those who died of heat stroke (particularly in France), increased ill-health from the greater risk of disease, as well as harvest losses, disruptions to energy provision and more forest fires.[4] Altogether it is estimated that the heat wave in 2003 caused damage of between 10 and 17 billion euros in Europe.[5]

Hundredfold increase in economic costs – what is to be done?

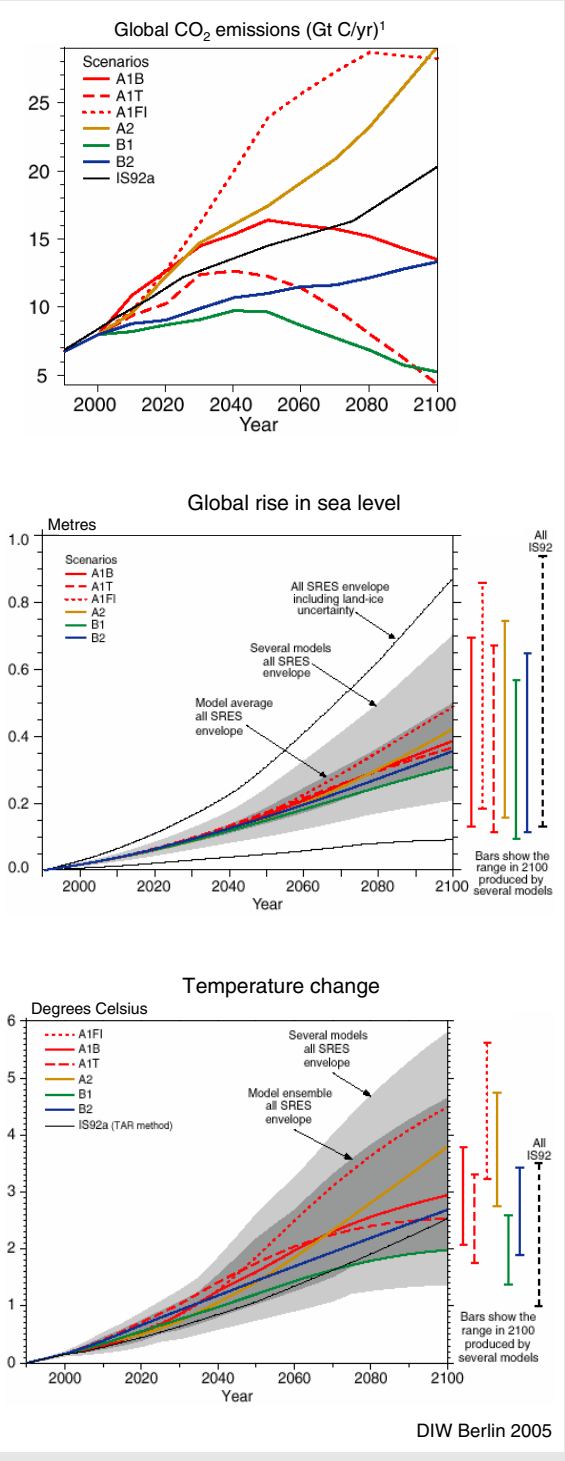
The economic damage from extreme weather events has increased by the factor 15 in the last three decades (cf. figure 4).[6] In 2002 the insurance company Münchner Rück put the global damage at 55 billion US dollars.[7] The strong rise in damage is partly due to the fact that coastal regions that are particularly affected by climate change are becoming increasingly densely populated.

An extrapolation of the economic trend in the data from Münchner Rück shows the damage increasing tenfold by 2050, to 600 billion euros (cf. figure 5). Insurance companies will be less and less willing to offer insurance

Figure 3

Projections of Various IPCC Scenarios

Global carbon dioxide emissions[1]



1 A1: High growth rate in GDP and population; A1F1: Intensive use of fossil fuels; A1B: Balance between use of fossil and alternative energies; A1T: Little use of fossil fuels; A2: Low per capita growth; B1: As A1, but higher growth rate in services and IT sectors; B2: Sustainability scenario, as A and B; 1992a TAR method: scenario from the Second Status Report.

Source: Intergovernmental Panel of Climate Change (IPCC 2001).

[3] That is the figure for the damage given by the insurance industry. See Münchner Rück: 'Jahresrückblick Naturkatastrophen 2002', Munich 2002.

[4] High river water temperatures also bring the risk that nuclear reactors will not be adequately cooled. In 2003 this caused nuclear reactors in Germany and France to be closed.

[5] Claudia Kemfert and Dietmar Pfeifer: 'The Economic Impact Assessment of Extreme Weather Events', in: *Zeitschrift für Versicherungswirtschaft,* in preparation. In a speech the British Prime Minister Tony Blair actually spoke of 26 000 dead and put the damage at 13.5 billion US dollars: Speech given to mark the tenth anniversary of the Prince of Wales' Business & the Environment Programme (abbreviated), London, 14 September 2004 (*www.britischebotschaft.de/de/news/items/04091.4.htm,* 4 October 2004).

[6] Münchner Rück: 'Die Welt der Naturkatastrophen', Munich 2000, and Reimund Schwarze and Gert C. Wagner: 'Mandatory Insurance against Natural Disasters: Why and How?', in: *DIW Economic Bulletin,* vol. 40, no. 5, May 2003.

[7] Münchner Rück, loc. cit.

Table 1
Examples of Extreme Climate Events and their Effects (Positive and Negative)

Extreme climate event	Probability	Effects
Higher maximum temperatures More hot days and heat waves	Very high	Rising number of deaths and serious ill-health of the elderly, particularly in poor regions Rise in heat stress in animals Shift in tourism areas Rise in risk of harvest damage Less certainty in energy supply Rise in demand for energy for cooling purposes
Fewer cold days and fewer cold waves	Very high	Less likelihood of deaths from cold Less risk of harvest loss Rise in spread of tropical diseases Greater spread of pests Less demand for energy for heating purposes
More extreme rainfall	Very high	Rise in damage from floods, landslides and avalanches More soil erosion Higher expenditure by the state on compensation payments Higher risks for insurance companies
Rise in summer dry periods and the risk of drought	High	Lower harvest yields Rise in damage to buildings from changes in ground conditions and contraction (subsidence) Reduction in water resources and poorer quality of water Greater risk of forest fires
Rise in the strength of hurricanes Increase in medium and heavy rainfall (in some regions)	High	Greater risk to human life Greater risk of disease and epidemics Increased coastal erosion and more damage to buildings and infrastructure near to coasts Increase in damage to the eco systems on coasts (like coral reefs and mangroves)
More floods and droughts from El Niño effects	High	Lower agricultural productivity in areas liable to drought and flooding Rise in damage in Central Asia Fewer water resources in drought regions
Greater fluctuation in monsoon rainfalls in Asia	High	More flooding and droughts
Greater severity of storms in equatorial regions	Low	Greater risk to life and health Greater loss of welfare and more damage to infrastructure More damage in coastal areas

Source: Intergovernmental Panel of Climate Change (IPCC 2001)

against possible damage from natural catastrophes in the areas particularly at risk (regions liable to flooding, coastal areas etc.), as such natural disasters become increasingly likely.[8]

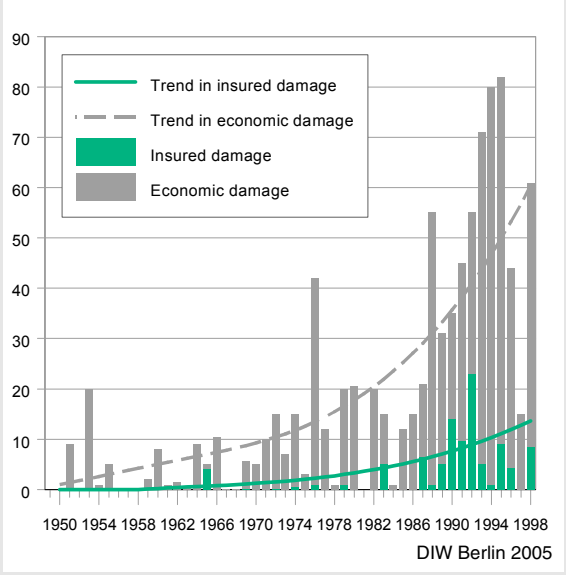
The global WIAGEM simulation model[9] (cf. box) combines a detailed economic and trade model with a climate model, and this enables the economic effects of climate change to be estimated. Beside the direct economic effects on energy production, agriculture and industry the effects on the ecology are also taken into account (e.g. the increase in forest fires, loss of species), as are risks to health and its economy (e.g. spread of disease, changes in mortality rates). A rise of 1° Celsius in the temperature can cause global damage of up to 214 billion US dollars in a period of 50 years (cf. figure 6).[10] In 2050 alone damage worldwide would amount to 2 billion US dollars. These sums will be crowded out of other investments in the economy, so reducing economic growth and causing further loss of prosperity.

[8] Examples are buildings in coastal areas liable to flooding or severe storms.

[9] Claudia Kemfert: 'An Integrated Assessment Model of Economy-Energy-Climate – The Model WIAGEM', in: *Integrated Assessment,* 4/2002, pp. 281-299; Claudia Kemfert: 'Global Economic Implications of Alternative Climate Policy Strategies', in: *Environmental Science and Policy,* 5/2002, pp. 367-384.

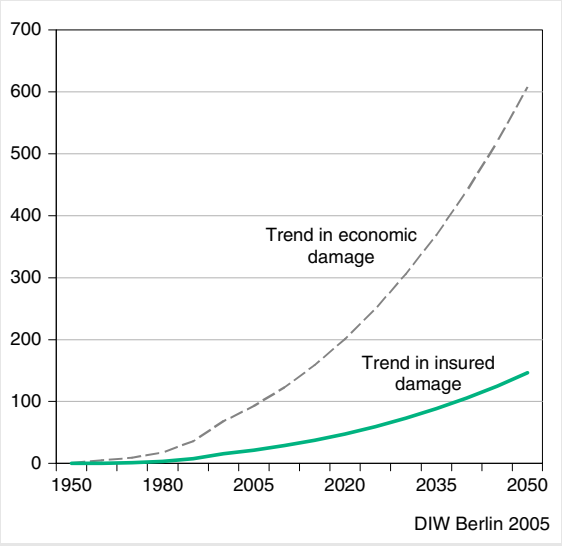
[10] The amount of the damage depends on the assumptions about future developments, but these involve great uncertainties. On an optimistic view the damage could be very much less than this amount, while on a pessimistic view it could easily be double. Cf. Claudia Kemfert: 'Global Economic Implications', loc. cit.

Figure 4
Global Economic and Insured Damage
In billion US dollars at 2002 prices



Source: Münchner Rück (2000).

Figure 5
Extrapolation of Global Economic Damage to 2050
In billion US dollars



Source: Calculations by DIW Berlin based on data from Münchner Rück.

If climate change is to be reduced or prevented total emissions of greenhouse gases must be lowered drastically. Climate experts assume that a reduction of greenhouse gases by 60 to 80% will be needed by the year 2100.[11] In view of the length of time greenhouse gases remain in the atmosphere the states responsible should start on these drastic reductions as soon as possible. The main responsibility lies with the United States, which is the chief emitter of global greenhouse gases; it is followed by China, Europe, Russia and Japan.[12] A climate protection policy must require binding levels of reduction, especially from countries with high levels of greenhouse gas emission.

What would happen without the United States and Russia?

In 1997 the first step was taken to achieve a promising climate protection policy when the Kyoto Protocol was launched. Under this agreement the industrial countries are to reduce global emissions by a total of 6.2%. If the agreement is to become legally binding at least 55 countries, that together account for at least 55% of the emissions by the Annex I countries (the industrial countries), must ratify the Kyoto Protocol.[13] Europe and Japan have already ratified, and in Europe a pilot project to reduce greenhouse gas emissions through a European system of emission certificates trading started on 1 January 2005. In 2002 the United States decided not to ratify the Kyoto Protocol. It is afraid of serious economic loss and is demanding that developing countries like China, which has already moved up to second place as a global greenhouse gas emitter, must also be included in the calculations. Russia has ratified the agreement. The Russian ratification makes the Kyoto probal binding.

A further 20 billion US dollars in revenue for Russia from ratification

The Kyoto Protocol lays down explicit measures to minimise the costs of reducing emissions, like global trading

[11] Intergovernmental Panel of Climate Change (IPCC), loc. cit. The IPCC puts the costs of so great a reduction in emissions at up to 150 billion US dollars worldwide.

[12] Hans-Joachim Ziesing: 'Worldwide Climate Protection Policy – Still No Visible Success', in: *DIW Economic Bulletin,* vol. 41, no. 10, October 2004.

[13] Information on the countries that have already signed the Kyoto Protocol can be downloaded from *unfcc.int/resource/kpstats.pdf* (as per 24 September 2004).

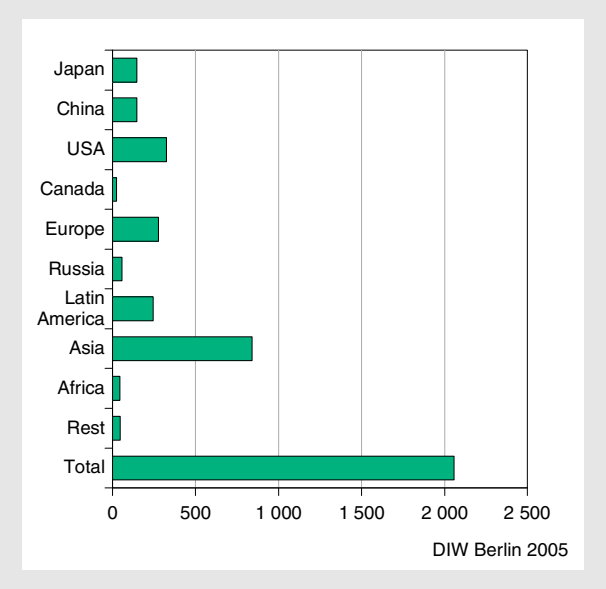
Box 2

The WIAGEM model

The WIAGEM model was designed to determine the long-term economic effects of climate change and climate policy. It combines a dynamic trade model with a simplified climate and eco systems model.
The model simulates the economic developments over a time scale of 100 years (until 2100) for Africa, Asia, Europe, Japan, Latin America, the Middle East and the United States. Linking the economic model to a climate and eco systems model enables the repercussions of changes in temperature and sea level to be quantified in economic terms. An exact reflection of the energy markets for fossil fuels, and the possible replacement of these with renewable energy sources, enables a change in the energy system to be evaluated.
The economic damage of changes to human health, eco systems and expenditure on climate damage before and after the occurrence of extreme climate events is also included. This enables a detailed estimate to be made of the economic loss from climate change.

in emission rights. If it engaged in this trading Russia would be in a position to sell emission rights, owing to the strong fall in its emissions following the economic collapse of recent years. It would thus earn considerable revenue. Participation in emission rights trading would bring Russia additional revenue of up to 20 billion US dollars within the obligatory period (2008 to 2012, cf. table 2).[14] Unlike the United States, which according to model simulations to date would have little economic incentive to rejoin the climate agreement, Russia will profit considerably from ratification.[15] It would earn even more if the United States were to participate in emission trading, as the United States is likely to account for a large part of the demand for emission rights, so raising the price of the permits.[16] Other countries could also reduce their compliance costs by participating in global emission rights trading.

Figure 6
Regional Economic Damage from Climate Change in 2050
In billion US dollars at 2002 prices



Source: DIW Berlin calculations using the WIAGEM simulation model.

Table 2 shows the costs of meeting the climate protection targets in the Kyoto Protocol, with and without trading in emission rights and with and without the participation of the United States and Russia. However, if the United States and Russia do not participate in emission trading, and if the other countries only pursue the reduction targets they have accepted, the basic Kyoto target could not be met.

Altogether, according to this model simulation global costs of about 730 billion euros could be incurred to prevent emissions in the obligatory period 2008 to 2012.[17] That is if the necessary reductions are exclusively in CO_2. If all the greenhouse gases are included (like nitrous oxide and methane) the costs would be lower, because reducing methane emissions is much less costly than reducing CO_2 emissions. With global emission rights trading this could save 272 billion US dollars during the compliance period. If the United States does not participate in emission permits trading the costs of preventing emissions in Europe and Japan would be

[14] At a price of 35 US dollars per certificate, see Claudia Kemfert: 'International Climate Coalitions and Trade – Assessment of Cooperation Incentives by Issue Linkage', in: *Energy Policy 4/2003,* pp. 455-465; Erik Haites, Faja Yamin, Odile Blanchard and Claudia Kemfert: 'Implementing the Kyoto Protocol without Russia', sent to *Climate Policy*.

[15] Claudia Kemfert, Erik Haites and Fanny Missfeldt: 'Can Kyoto Protocol Parties Induce the United States to Adopt a More Stringent Greenhouse Gas Emissions Target?' In: *Interdisciplinary Environment Review,* 2/2003, pp. 119-141.

[16] Without the United Staes the emission certificate price would fall to as little as 1 US dollar, loc. cit.

[17] For comparison: the IPCC report also calculates costs totalling between 305 billion and more than 1 billion US dollars by the year 2050 for reducing emissions. If the aim is reduction of 60% to 80% this amount could reach up to 10 billion US dollars worldwide by the year 2100, see IPCC, loc. cit, p. 547.

Table 2

Regional Costs of Reducing Emissions in the Obligatory Period 2008 to 2012

In billion US dollars at 2002 prices

	Kyoto all GHG[1]	Kyoto CO_2	Kyoto GHG trading	Kyoto CO_2 trading	Without USA	Without Russia
Japan	18.99	31.64	10.55	16.88	15.81	20.82
China	3.30	5.77	1.65	3.71	–2.88	0.76
USA	170.72	204.86	58.53	92.68	16.52	–15.35
Africa	0.39	0.20	0.59	0.20	0.64	0.67
Rest	7.95	10.22	2.84	4.54	2.59	2.60
Canada	2.56	3.20	1.60	2.24	1.35	1.96
Europe	107.14	149.24	68.88	91.84	57.12	51.89
Of which: Germany	28.48	39.66	18.31	24.41	15.18	13.79
Russia[2]	3.49	5.24	–20.56	–17.26	–1.62	–0.94
Latin America	2.18	1.09	1.09	1.09	4.67	4.98
Asia	17.11	25.67	12.84	15.69	9.13	9.40
Middle East	198.39	289.96	122.09	152.61	35.71	22.26
Total	532.22	727.08	260.09	364.21	139.04	99.05

1 GHG: Greenhouse gases. — 2 Negative values are yields.
Source: DIW Berlin calculations using the WIAGEM simulation model.

lower (the United States would buy a large part of the emission rights, so raising the price of the certificates). With trading in emission rights throughout the EU Germany would have to spend 24 billion US dollars; if Russia participates and the United States does not that amount would fall to 15 billion US dollars. As seller of emission rights Russia, on the other hand, could expect its revenue to fall. The costs would be lower for Europe and Japan without the United States, but it would be more difficult to meet the global reduction target. With their measures Europe and Japan could only reduce global emissions by 1.2%, and failure to meet the target by a considerable amount would be inevitable.

Conclusion

The climate change due to human activity is a major cause for concern. The extent of the damage largely depends on how quickly and to what extent climate policy measures can bring relief. The economic damage could amount to up to 2 billion US dollars worldwide by 2050; the costs to Germany alone would be 137 billion US dollars. Flexible climate policy instruments, like emission rights trading, could slow down that development. Participation by Russia would have a further positive effect. To enable implementation of the international climate protection policy to start as soon as possible and prevent further economic damage from climate change Russia's ratification of the Kyoto Protocol is exceedingly welcome.