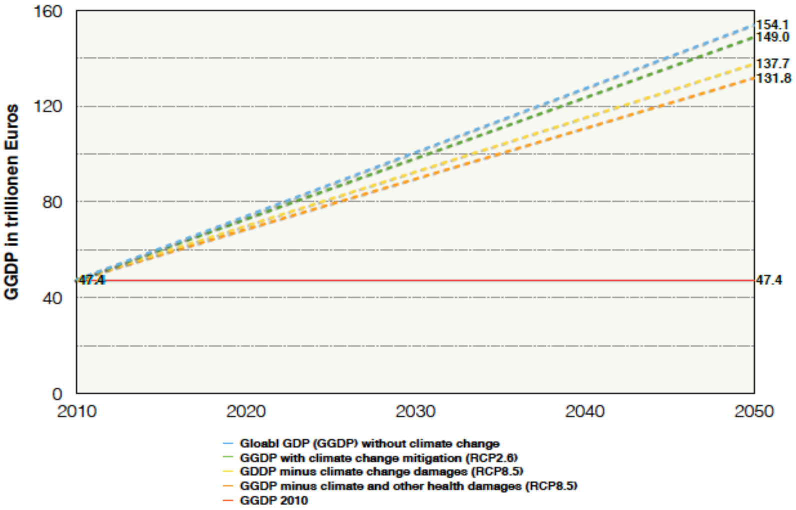
CENTER FOR SUSTAINABLE ENERGY SYSTEMS (ZNES)
Department for Systems Integration

The Benefit of Climate Protection

Why the 5th Progress Report of the IPCC falls short



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Content

1 Executive Summary

In autumn 2013 and spring 2014, the Intergovernmental Panel on Climate Change (IPCC) submitted the first three sub-reports of its fifth major progress report. In this, the IPCC reported on the scientific state of the art in the top three sets of problems of human-made climate change. In the sub-report Working Group I of the IPCC, the findings from the field of physical climate science are summarised (IPCC 2013), which showcase how strongly humankind alters global climate through the emission of greenhouse gases. The sub-report by Working Group II of the IPCC demonstrates the most recent findings on the impact of human-made climate change in relation to the multi-faceted areas of life and the various regions of the world, as well as highlighting the opportunities to soften the impact of climate change through targeted adaptive measures. The sub-report by Working Group III summarises the latest level of knowledge about the options to avoid the most incisive consequences of climate change by means of more or less drastic reductions of human-made greenhouse gas emissions (IPCC 2014a). In autumn 2014, the summary of all three sub-reports was passed by the plenary of the IPCC in a so-called synthesis report.

The quintessence of the new IPCC report is to indicate that humankind is rapidly approaching the "point of no return", after which it will become almost impossible to limit climate change through adaptive measures far enough to yet avoid catastrophic consequences (IPCC 2013, p. 19). The report thus underlines the pressing need for a drastic, global decrease of human-made greenhouse gas emissions (IPCC 2013, p. 27f).

1.1 The Issue

Although the authors of the three sub-reports make a sincere effort to collate and demonstrate in a focused manner the scientific state of the art pertaining to their sub-question, the presented overall picture becomes skewed in a major way because of a fundamental omission: The economic costs of neglecting ambitious climate protection are not described. This leaning results from the content structure which was determined by the IPCC for the three sub-reports. While the report of Working Group III discusses and illustrates the costs of the different strategies for *mitigating* greenhouse gas emissions, and Working Group II also covers the *adaptive* measures pertaining to climate change in detail, the *benefit of climate protection by means of avoiding the grave consequences* of climate change is usually treated by Working Group II only by discussing qualitative aspects or quantifying physical effects. Indications which scale economic damage would reach, if climate change is not detained, are rarely found in the over one thousand pages of the report by Working Group II. Similar to the fourth progress report of the IPCC, the impression is easily gained that climate protection costs "X" percent of growth, that the adaptation to climate change leads to high economic costs and that these costs markedly surpass the not further specified benefits of climate protection. This impression is definitely false and should result under no circumstances, since it can lead to the situation that politicians do not decisively act to inhibit climate change and, furthermore, that substantial parts of the public cannot be convinced of the necessity of climate protection.

1.2 Goal of this Discussion paper

This discussion paper aims to indicate that it is possible, in spite of the considerable uncertainties in the monetary estimation of the benefits of climate protection (and of the potential or averted costs respectively), to outline these and contrast them with the costs of climate protection.

In this, it will not be disregarded that such a monetisation of the benefits of climate protection cannot include many of the qualitative aspects of the information on the subsequent damage of climate change which have been collected by the IPCC. Furthermore, it should be noted that in a monetisation of this damage, social value judgements are unavoidably included. This can lead to a wide range of monetary valuations for one and the same damage type, or for the same number of human casualties in developing or industrialised countries respectively.

Thus, the economic assessment of the expected losses from climate change massively depends on which systemic delimitation is being made in the analysis (for instance, whether only increased grain prices or also the victims of famine are rated); if – and to which extent – future casualties are "discounted" and devalued in contrast to contemporary casualties; it is also very relevant whether those affected in developing countries – for example according to their purchasing power – are rated as a smaller loss than those in industrialised countries. Since neither the general public, nor the active politicians, process complex qualitative information about climate change and compare it with basic monetary results, a monetary valuation of possible climate damage is nonetheless necessary. That ambitious climate protection, which avoids the most serious consequences of climate change, is economically sensible, only becomes clear in a direct comparison of the costs of climate protection with the costs of climate damage which are avoidable by means of these climate protection measures. A direct monetary comparison very clearly demonstrates that a loss of a few percent of economic growth because of the expenditure for climate protection is contrasted with a significantly higher benefit resulting from prevented climate damage.

1.3 Findings of the Study

This study demonstrates that, given agreement on fundamental value judgements, it is possible to assess the monetary benefit of decisive climate protection equally well as the costs of the required measures for climate protection. For Germany, a scientifically well-founded proposal on agreeing about such essential value judgements exists with the methodological convention for the assessment of external environmental costs (UBA 2012). This integrates the prevailing convictions in the German and West European societies with the principle of equality of the UN Convention on Human Rights – every human is valued equally – and deduces resulting costs for climate damage from uninhibited climate change. For the year 2050, the Umweltbundesamt (UBA[1]) arrives at a mean value of 260 $€_{2010}/tCO_{2eq}$, while the developing costs for climate damage up until the shorter deadline in 2030 are estimated at approximately 145 $€_{2010}/tCO_{2eq}$ (UBA 2014, p. 7).

Based on the monetary value suggested by the Umweltbundesamt and on the statements by the IPCC about expected greenhouse gas emissions for the year 2050 after uninhibited development (RCP8.5), ambitious climate protection which meets the two-degree limit (according to the scenario RCP2.6) can prevent climate damage costs of approx. 16 Trillion Euro. According to the statements by

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[1] The "Federal Environmental Agency of Germany", which is the equivalent of the American EPA.

Working Group III of the IPCC, such an ambitious climate protection strategy would cost circa 5 Trillion Euro (calculated from the IPCC's specifications, IPCC 2014a, p. 47).

As figure 1 indicates, the costs for pervasive climate protection specified by Working Group III of the IPCC are subject to an economic development which is based on an expected Global Gross National Product (GGNP) for the year 2050 without any climate change of approx. 154 Trillion Euro. Due to the necessary climate protection measures for meeting the two-degree limit, this hypothetical Global Gross National Product would be reduced to approx. 149 Trillion Euro. If, however, these climate protection measures are foregone as a consequence of the resultant climate damage, the GGNP is reduced to almost 138 Trillion Euro. If it is additionally taken into consideration that without the climate protection measures significant additional damage results, particularly due to the emission of air contaminants, without climate protection, a further 6 Trillion Euro have to be expected as further environmental and health costs. Hence, the GGNP without climate protection would reach only 132 Trillion Euro for 2050 and thus would be more than 10 % under the GGNP with consistent climate protection. In this, an eventual increase of the Gross National Product because of the repair of climate damage is included.

From the *perspective of European values* and on the basis of the values of the UN Convention on Human Rights about equality and justice, pervasive climate protection is urgently recommended from an economic point of view as well, since its benefit can exceed the costs by the year 2050 in triplicate.

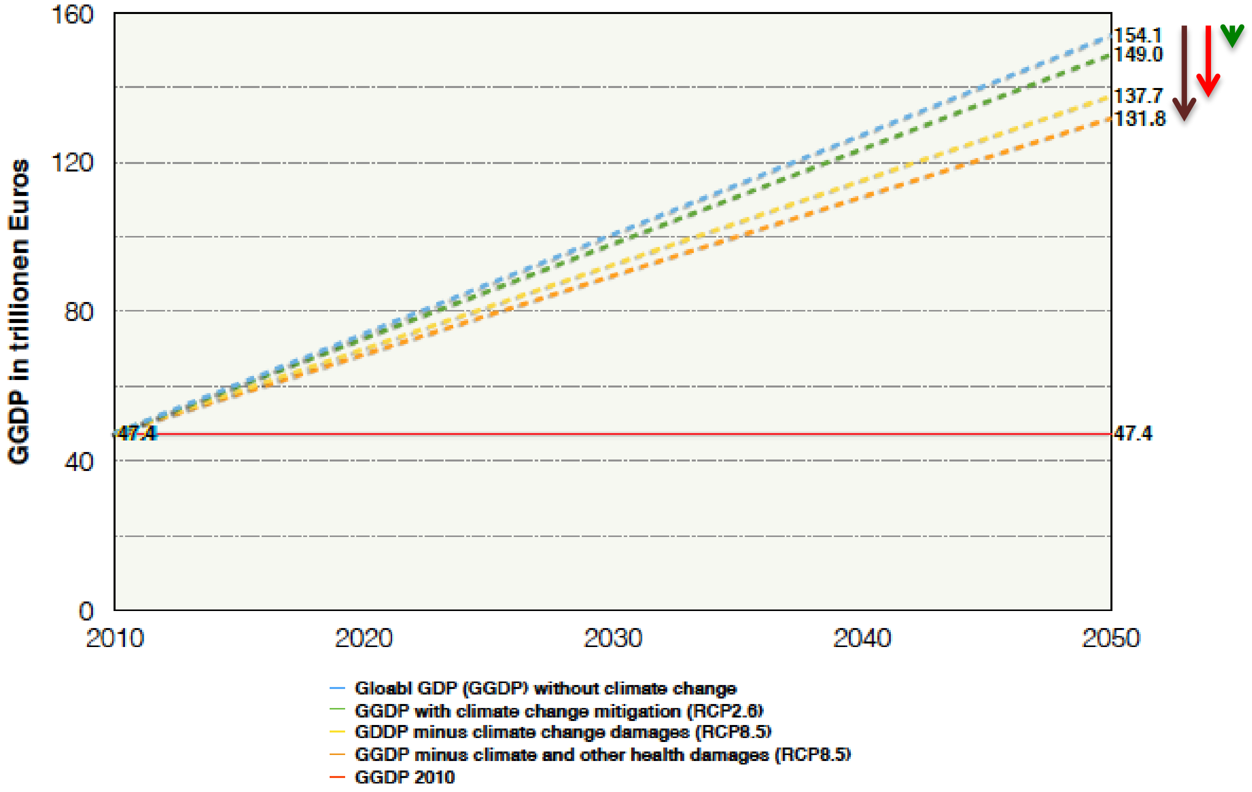


Figure 1: Development of the Global Gross National Product with and without climate protection (own calculation on the basis of the IPCC 2014a and UBA 2012)

Meeting the two-degree limit, particularly in order to avoid the catastrophic consequences of human-made climate change, requires quick and decisive action. Effective climate protection specifically calls for a fundamental transformation of three subareas of our economic framework: in the area of development strategies of fast-growing mega-cities, in the area of land-use and particularly in the area of energy supply. This transformation, which is developed in the reports by the Global Commission on the Economy and Climate (2014) and the Scientific Advisory Board on Global Environmental Change of the Federal Government of Germany, leads to significant positive economic effects and can become a driver for climate-friendly growth over the next decades.

Decisive climate protection is not only profitable, but can also become a key factor for growth in the future. Rigorous climate protection is surely one of the most beneficial investments into our future.

1.4 Recommendations

From the results of the study it can be concluded that, aside from humanitarian and moral reasons, economic reasons also make it highly commendable to implement a decisive climate protection strategy as quickly as possible, in order to avoid extreme economic damage and to ensure to meet the two-degree limit adopted by the global community. The scenario RCP2.6, which was developed by the IPCC and specifies a budget for global emissions and the connected possible amounts of emissions until the year 2100 of about 290 Gt C_{eq} (IPCC 2013, p. 103), can and should be the foundation for all further environmental policy. This has to be the benchmark for the projected climate treaty in Paris and the hoped-for mobilization of environmental policy in the coming years – even if this initially will proceed from the self-commitment of the countries.

In light of this background, it becomes imperative to take effective measures for a drastic reduction of greenhouse gas emissions as soon as possible, and to utilize the economic and technological opportunities which present themselves for a fundamental transformation of the global economy, in order to bring the necessary reductions of emissions in line with the economic growth needed by many countries. Particularly the area of energy efficiency and the transition to a renewable supply of energy present many opportunities which offer great potential to reduce emissions and to subsequently reduce the damage caused by climate change and its adherent costs as well. An EU policy which is geared towards human rights and the principles essential in the EU would take the required measures by itself and increase the mobilization in other countries and regions through intelligent policies.

2 Findings of the IPCC about the Cost of Climate Protection

The core of the following section summarises which costs the IPCC derives for climate protection and the adaptation to climate change in its 5th Assessment Report (AR5) for climate protection and the adaptation to climate change. In addition, this section reflects on how the AR5 discusses foreseeable climate damage.

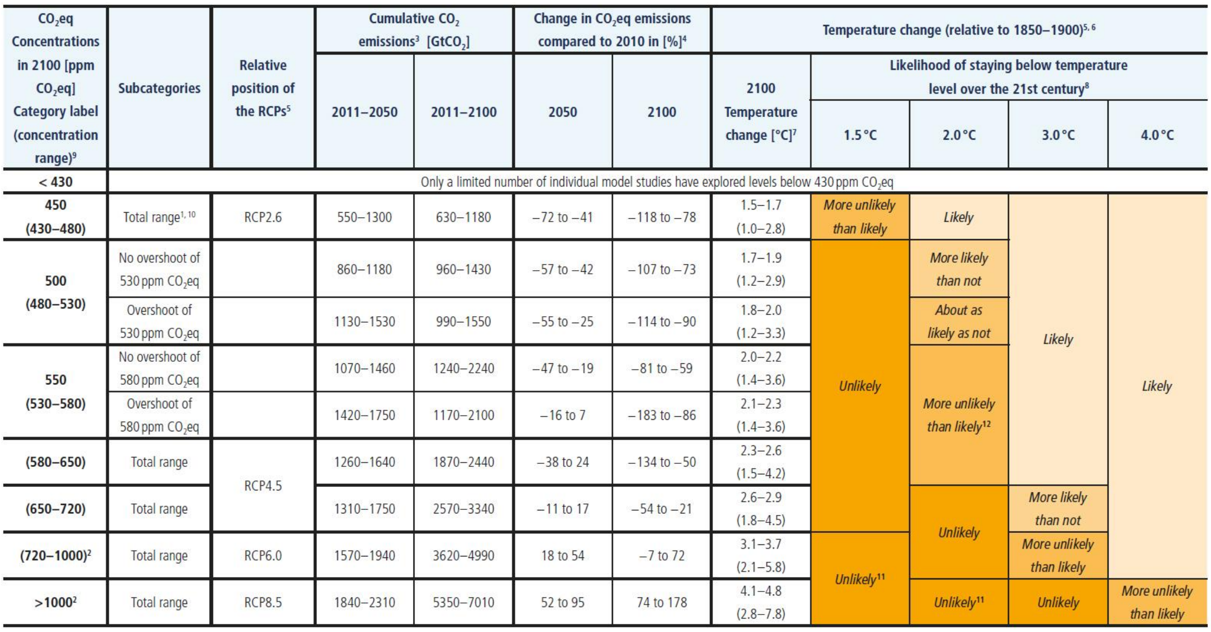
2.1 The Emission Scenarios used by the IPCC

The IPCC assumes (cf. IPCC 2014a, p. 19) that the atmospheric concentration of greenhouse gases, which was 400 ppm CO_{2eq} in 2010, would, without climate protection measures, climb to over 450 ppm by the year 2030 and to between 750 and over 1300 ppm CO_{2eq} by the year 2100. This means that the cumulative greenhouse gas emissions from 2010 onwards until the year 2030 will be at over 700 Billion tons (Gt CO_{2eq}), until 2050 at over 1.500 Gt CO_{2eq} and until 2100 at markedly over 4.000 Gt CO_{2eq} (IPCC 2014a, S. 19). This emissions development would lead to a temperature increase of 4-5 °C more than pre-industrial levels until the year 2100 (cf. table 1 below).

In order to systematically examine the consequences of different, future developments of greenhouse gas emissions, the IPCC has defined a set of emission scenarios, which form the basis of all analyses of the 5th progress report. These so-called “representative concentration pathways” (or RCPs) are termed after the energy increase in the climate system (radiative forcing) in W/m^2 of the earth’s surface, which will be caused until the year 2100 when compared to the level before the industrial revolution. Until 2010, the human-made increase amounted to approx. $2{,}3 W/m^2$ (cf. IPCC 2013, p. 12). The scenarios that have been examined range from RCP 2.6 to RCP 8.5. These scenarios correspond to greenhouse gas emissions of between 450 to over 1.000 ppm CO_{2eq}. Table 1 from the report by Working Group III of the IPCC shows which temperature increases will be effected by different scenarios with a certain probability until the end of the 21st century.

In order to avoid the drastic consequences of climate change, experts usually assume that the temperature increase compared to the pre-industrial level needs to be limited to approx. 2 °C. Since these consequences are comprised of hundreds of different effects, the IPCC employs a diagram which demonstrates how, in connection with the global temperature change, the damage increases in different areas (cf. figure 2). Just from this diagram alone can be concluded that, starting with an increase of approx. 2°C, drastic consequential damage from climate change has to be expected. Simultaneously, the illustration shows through the scenarios RCP2.6 and RCP8.5, how dramatically different the consequences will be until the end of this century, by contrast of a development without climate protection measures (RCP8.5) compared to a decisive climate protection policy (RCP2.6). The development illustrated in RCP8.5 also demonstrates that the temperature at such a development would not become stable at a solid plus of 4 °C, but continue to climb precariously. In contrast to this, a development according to securing RCP2.6 would already lead to an end of the temperature increase around the middle of the century.

Table 1: The most important features of the scenarios by the IPCC with regard to greenhouse gas concentration levels (IPCC 2014a, p. 54)



CO_2eq Concentrations in 2100 [ppm CO_2eq] Category label (concentration range)[9]	**Subcategories**	**Relative position of the RCPs**[5]	**Cumulative CO_2 emissions**[3] **[$GtCO_2$]**		**Change in CO_2eq emissions compared to 2010 in [%]**[4]		**Temperature change (relative to 1850–1900)**[5, 6]				
			2011–2050	**2011–2100**	**2050**	**2100**	**2100 Temperature change [°C]**[7]	**Likelihood of staying below temperature level over the 21st century**[8]			
								1.5 °C	**2.0 °C**	**3.0 °C**	**4.0 °C**
< 430	Only a limited number of individual model studies have explored levels below 430 ppm CO_2eq										
450 (430–480)	Total range[1, 10]	RCP2.6	550–1300	630–1180	−72 to −41	−118 to −78	1.5–1.7 (1.0–2.8)	*More unlikely than likely*	*Likely*	*Likely*	*Likely*
500 (480–530)	No overshoot of 530 ppm CO_2eq		860–1180	960–1430	−57 to −42	−107 to −73	1.7–1.9 (1.2–2.9)	*Unlikely*	*More likely than not*		
	Overshoot of 530 ppm CO_2eq		1130–1530	990–1550	−55 to −25	−114 to −90	1.8–2.0 (1.2–3.3)		*About as likely as not*		
550 (530–580)	No overshoot of 580 ppm CO_2eq		1070–1460	1240–2240	−47 to −19	−81 to −59	2.0–2.2 (1.4–3.6)		*More unlikely than likely*[12]		
	Overshoot of 580 ppm CO_2eq		1420–1750	1170–2100	−16 to 7	−183 to −86	2.1–2.3 (1.4–3.6)				
(580–650)	Total range	RCP4.5	1260–1640	1870–2440	−38 to 24	−134 to −50	2.3–2.6 (1.5–4.2)				
(650–720)	Total range		1310–1750	2570–3340	−11 to 17	−54 to −21	2.6–2.9 (1.8–4.5)		*Unlikely*	*More likely than not*	
(720–1000)[2]	Total range	RCP6.0	1570–1940	3620–4990	18 to 54	−7 to 72	3.1–3.7 (2.1–5.8)	*Unlikely*[11]		*More unlikely than likely*	
>1000[2]	Total range	RCP8.5	1840–2310	5350–7010	52 to 95	74 to 178	4.1–4.8 (2.8–7.8)		*Unlikely*[11]	*Unlikely*	*More unlikely than likely*

Notes:

[1] The 'total range' for the 430–480 ppm CO_2eq scenarios corresponds to the range of the 10th–90th percentile of the subcategory of these scenarios shown in Table 6.3.

[2] Baseline scenarios (see TS.2.2) fall into the >1000 and 720–1000 ppm CO_2eq categories. The latter category also includes mitigation scenarios. The baseline scenarios in the latter category reach a temperature change of 2.5–5.8 °C above preindustrial in 2100. Together with the baseline scenarios in the >1000 ppm CO_2eq category, this leads to an overall 2100 temperature range of 2.5–7.8 °C (range based on median climate response: 3.7–4.8 °C) for baseline scenarios across both concentration categories.

[3] For comparison of the cumulative CO_2 emissions estimates assessed here with those presented in WGI AR5, an amount of 515 [445–585] GtC (1890 [1630–2150] $GtCO_2$), was already emitted by 2011 since 1870 [WGI 12.5]. Note that cumulative CO_2 emissions are presented here for different periods of time (2011–2050 and 2011–2100) while cumulative CO_2 emissions in WGI AR5 are presented as total compatible emissions for the RCPs (2012–2100) or for total compatible emissions for remaining below a given temperature target with a given likelihood [WGI Table SPM.3, WGI SPM.E.8].

[4] The global 2010 emissions are 31 % above the 1990 emissions (consistent with the historic GHG emissions estimates presented in this report). CO_2eq emissions include the basket of Kyoto gases (CO_2, CH_4, N_2O as well as F-gases).

[5] The assessment in WGIII AR5 involves a large number of scenarios published in the scientific literature and is thus not limited to the RCPs. To evaluate the CO_2eq concentration and climate implications of these scenarios, the MAGICC model was used in a probabilistic mode (see Annex II). For a comparison between MAGICC model results and the outcomes of the models used in WGI, see Sections WGI 12.4.1.2, WGI 12.4.8 and 6.3.2.6. Reasons for differences with WGI SPM Table.2 include the difference in reference year (1986–2005 vs. 1850–1900 here), difference in reporting year (2081–2100 vs 2100 here), set-up of simulation (CMIP5 concentration-driven versus MAGICC emission-driven here), and the wider set of scenarios (RCPs versus the full set of scenarios in the WGIII AR5 scenario database here).

[6] Temperature change is reported for the year 2100, which is not directly comparable to the equilibrium warming reported in WGIII AR4 [Table 3.5, Chapter 3; see also WGIII AR5 6.3.2]. For the 2100 temperature estimates, the transient climate response (TCR) is the most relevant system property. The assumed 90 % range of the TCR for MAGICC is 1.2–2.6 °C (median 1.8 °C). This compares to the 90 % range of TCR between 1.2–2.4 °C for CMIP5 [WGI 9.7] and an assessed *likely* range of 1–2.5 °C from multiple lines of evidence reported in the WGI AR5 [Box 12.2 in Section 12.5].

[7] Temperature change in 2100 is provided for a median estimate of the MAGICC calculations, which illustrates differences between the emissions pathways of the scenarios in each category. The range of temperature change in the parentheses includes in addition the carbon cycle and climate system uncertainties as represented by the MAGICC model [see 6.3.2.6 for further details]. The temperature data compared to the 1850–1900 reference year was calculated by taking all projected warming relative to 1986–2005, and adding 0.61 °C for 1986–2005 compared to 1850–1900, based on HadCRUT4 [see WGI Table SPM.2].

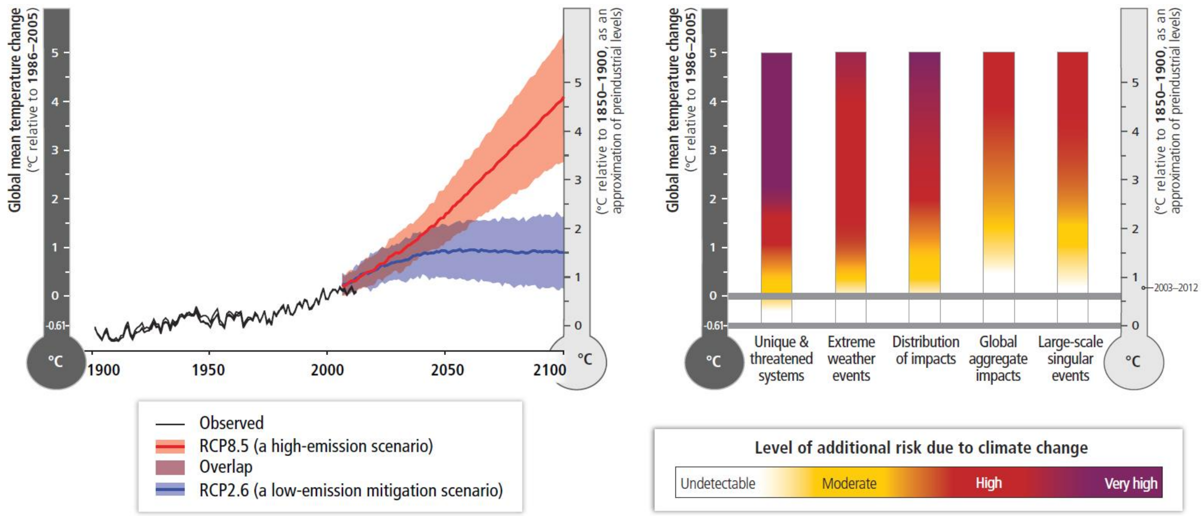
[8] The assessment in this table is based on the probabilities calculated for the full ensemble of scenarios in WGIII AR5 using MAGICC and the assessment in WGI AR5 of the uncertainty of the temperature projections not covered by climate models. The statements are therefore consistent with the statements in WGI AR5, which are based on the CMIP5 runs of the RCPs and the assessed uncertainties. Hence, the likelihood statements reflect different lines of evidence from both WGs. This WGI method was also applied for scenarios with intermediate concentration levels where no CMIP5 runs are available. The likelihood statements are indicative only [6.3], and follow broadly the terms used by the WGI AR5 SPM for temperature projections: *likely* 66–100 %, *more likely than not* >50–100 %, *about as likely as not* 33–66 %, and *unlikely* 0–33 %. In addition the term *more unlikely than likely* 0–<50 % is used.

[9] The CO_2-equivalent concentration includes the forcing of all GHGs including halogenated gases and tropospheric ozone, as well as aerosols and albedo change (calculated on the basis of the total forcing from a simple carbon cycle/climate model, MAGICC).

[10] The vast majority of scenarios in this category overshoot the category boundary of 480 ppm CO_2eq concentrations.

[11] For scenarios in this category no CMIP5 run [WGI Chapter 12, Table 12.3] as well as no MAGICC realization [6.3] stays below the respective temperature level. Still, an *unlikely* assignment is given to reflect uncertainties that might not be reflected by the current climate models.

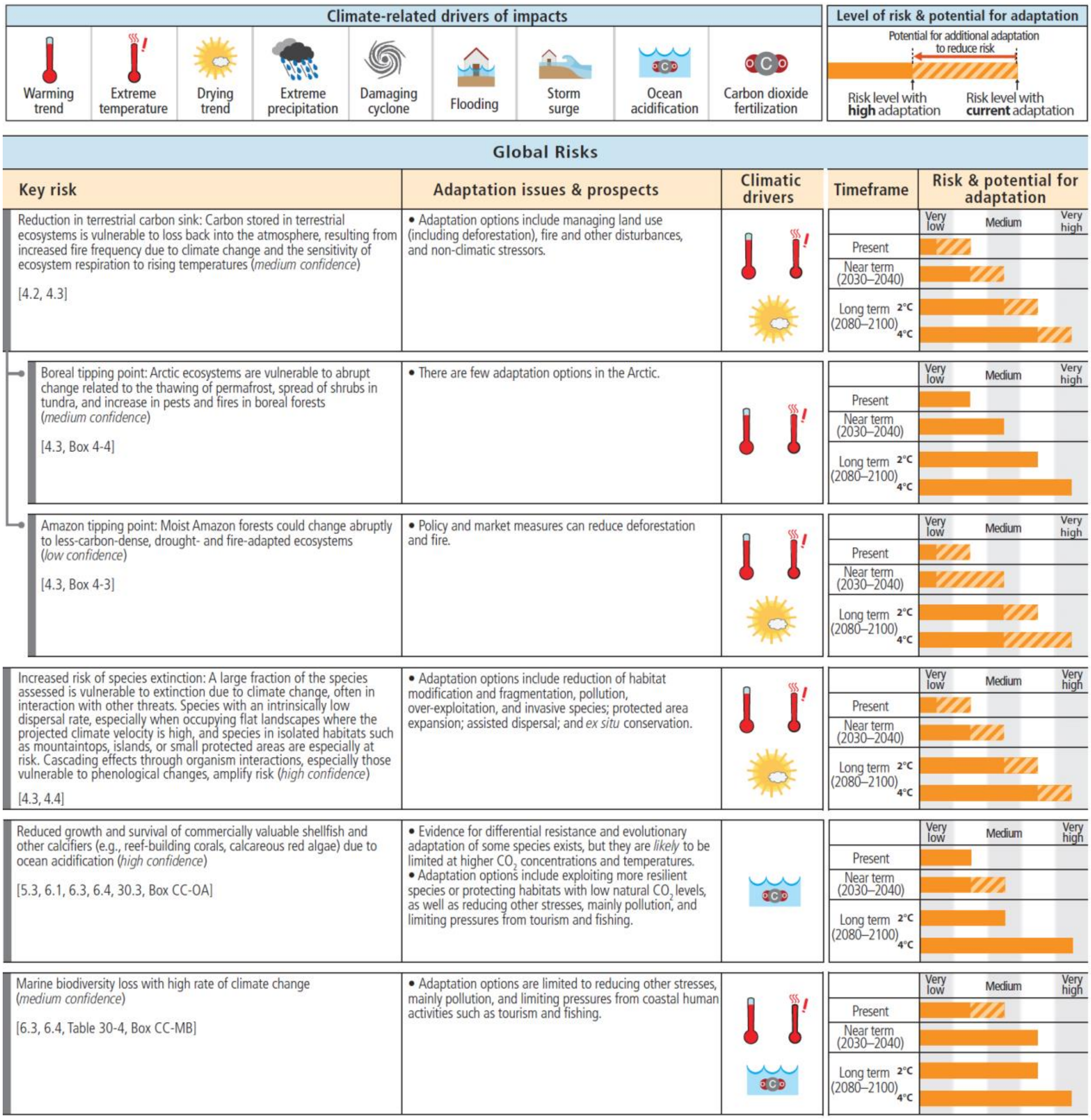
[12] Scenarios in the 580–650 ppm CO_2eq category include both overshoot scenarios and scenarios that do not exceed the concentration level at the high end of the category (like RCP4.5). The latter type of scenarios, in general, have an assessed probability of *more unlikely than likely* to stay below the 2 °C temperature level, while the former are mostly assessed to have an *unlikely* probability of staying below this level.



Assessment Box SPM.1 Figure 1 | A global perspective on climate-related risks. Risks associated with reasons for concern are shown at right for increasing levels of climate change. The color shading indicates the additional risk due to climate change when a temperature level is reached and then sustained or exceeded. Undetectable risk (white) indicates no associated impacts are detectable and attributable to climate change. Moderate risk (yellow) indicates that associated impacts are both detectable and attributable to climate change with at least *medium confidence*, also accounting for the other specific criteria for key risks. High risk (red) indicates severe and widespread impacts, also accounting for the other specific criteria for key risks. Purple, introduced in this assessment, shows that very high risk is indicated by all specific criteria for key risks. [Figure 19-4] For reference, past and projected global annual average surface temperature is shown at left, as in Figure SPM.4. [Figure RC-1, Box CC-RC; WGI AR5 Figures SPM.1 and SPM.7] Based on the longest global surface temperature dataset available, the observed change between the average of the period 1850–1900 and of the AR5 reference period (1986–2005) is 0.61°C (5–95% confidence interval: 0.55 to 0.67°C) [WGI AR5 SPM, 2.4], which is used here as an approximation of the change in global mean surface temperature since preindustrial times, referred to as the period before 1750. [WGI and WGII AR5 glossaries]

Figure 2: Damage graph by the IPCC, possible temperature development and the probability of severe damage in five different damage areas (IPCC 2014, p. 13)

Additionally, Working Group II demonstrates in its report how big individual risks develop in relation to a temperature increase until the end of the century. From the example given in figure 3, it can be clearly inferred that these risks will reach considerable dimensions at a temperature increase of markedly more than 2 °C; and that they cannot be alleviated by adaptive measures.



Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Reduction in terrestrial carbon sink: Carbon stored in terrestrial ecosystems is vulnerable to loss back into the atmosphere, resulting from increased fire frequency due to climate change and the sensitivity of ecosystem respiration to rising temperatures (*medium confidence*) [4.2, 4.3]	• Adaptation options include managing land use (including deforestation), fire and other disturbances, and non-climatic stressors.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	
Boreal tipping point: Arctic ecosystems are vulnerable to abrupt change related to the thawing of permafrost, spread of shrubs in tundra, and increase in pests and fires in boreal forests (*medium confidence*) [4.3, Box 4-4]	• There are few adaptation options in the Arctic.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	
Amazon tipping point: Moist Amazon forests could change abruptly to less-carbon-dense, drought- and fire-adapted ecosystems (*low confidence*) [4.3, Box 4-3]	• Policy and market measures can reduce deforestation and fire.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	
Increased risk of species extinction: A large fraction of the species assessed is vulnerable to extinction due to climate change, often in interaction with other threats. Species with an intrinsically low dispersal rate, especially when occupying flat landscapes where the projected climate velocity is high, and species in isolated habitats such as mountaintops, islands, or small protected areas are especially at risk. Cascading effects through organism interactions, especially those vulnerable to phenological changes, amplify risk (*high confidence*) [4.3, 4.4]	• Adaptation options include reduction of habitat modification and fragmentation, pollution, over-exploitation, and invasive species; protected area expansion; assisted dispersal; and *ex situ* conservation.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	
Reduced growth and survival of commercially valuable shellfish and other calcifiers (e.g., reef-building corals, calcareous red algae) due to ocean acidification (*high confidence*) [5.3, 6.1, 6.3, 6.4, 30.3, Box CC-OA]	• Evidence for differential resistance and evolutionary adaptation of some species exists, but they are *likely* to be limited at higher CO_2 concentrations and temperatures. • Adaptation options include exploiting more resilient species or protecting habitats with low natural CO_2 levels, as well as reducing other stresses, mainly pollution, and limiting pressures from tourism and fishing.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	
Marine biodiversity loss with high rate of climate change (*medium confidence*) [6.3, 6.4, Table 30-4, Box CC-MB]	• Adaptation options are limited to reducing other stresses, mainly pollution, and limiting pressures from coastal human activities such as tourism and fishing.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	

Table TS.4 | Key sectoral risks from climate change and the potential for reducing risks through adaptation and mitigation. Key risks have been identified based on assessment of the relevant scientific, technical, and socioeconomic literature detailed in supporting chapter sections. Identification of key risks was based on expert judgment using the following specific criteria: large magnitude, high probability, or irreversibility of impacts; timing of impacts; persistent vulnerability or exposure contributing to risks; or limited potential to reduce risks through adaptation or mitigation. Each key risk is characterized as very low to very high for three timeframes: the present, near term (here, assessed over 2030–2040), and longer term (here, assessed over 2080–2100). The risk levels integrate probability and consequence over the widest possible range of potential outcomes, based on available literature. These potential outcomes result from the interaction of climate-related hazards, vulnerability, and exposure. Each risk level reflects total risk from climatic and non-climatic factors. For the near-term era of committed climate change, projected levels of global mean temperature increase do not diverge substantially for different emission scenarios. For the longer-term era of climate options, risk levels are presented for two scenarios of global mean temperature increase (2°C and 4°C above preindustrial levels). These scenarios illustrate the potential for mitigation and adaptation to reduce the risks related to climate change. For the present, risk levels were estimated for current adaptation and a hypothetical highly adapted state, identifying where current adaptation deficits exist. For the two future timeframes, risk levels were estimated for a continuation of current adaptation and for a highly adapted state, representing the potential for and limits to adaptation. Climate-related drivers of impacts are indicated by icons. Risk levels are not necessarily comparable because the assessment considers potential impacts and adaptation in different physical, biological, and human systems across diverse contexts. This assessment of risks acknowledges the importance of differences in values and objectives in interpretation of the assessed risk levels.

Figure 3: Development of key risks of climate change until the end of the 21st century in relation with the temperature changes that are caused (excerpt from IPCC 2014, p. 64, table TS.4)

2.2 The Cost of Reducing Greenhouse Gas Emissions

The IPCC predominantly quantifies the costs of climate protection in the report by Working Group III. The Working Group explicitly points out that the estimated costs do not include the benefits of climate protection gained from mitigation: *“Further, these costs do not capture the benefits of reducing climate change impacts through mitigation”* (IPCC 2014a, p. 59).

Since the results of different models for measuring climate protection costs often vary significantly, the IPCC specifies ranges for these costs. In each instance, it is measured by how much higher the costs are in contrast to a baseline development without climate protection measures. Here, the costs for pervasive climate protection measures under scenario RCP2.6, pertaining to a greenhouse gas concentration of 430–480 ppm CO_{2eq} in the years 2030, 2050 and 2100, is much higher than the costs for very moderate climate protection strategies, which merely ensure a greenhouse gas concentration of 650–720 ppm CO_{2eq} (RCP4.5 upper bracket, cf. table 1), or the costs of a strategy without mitigation (e.g. as in RCP8.5).

The cost for climate protection is measured in different models on different scales (metrics). Hence, the IPCC calculates the costs in three different metrics (reduction of the Gross Domestic Product (GDP), reduction of possible consumption and mitigation costs). These are each expressed as a percentage of the GDP of the reference year. Figure 4 shows the reduction of consumption, in contrast to the base scenario without climate protection, in five different climate protection scenarios.

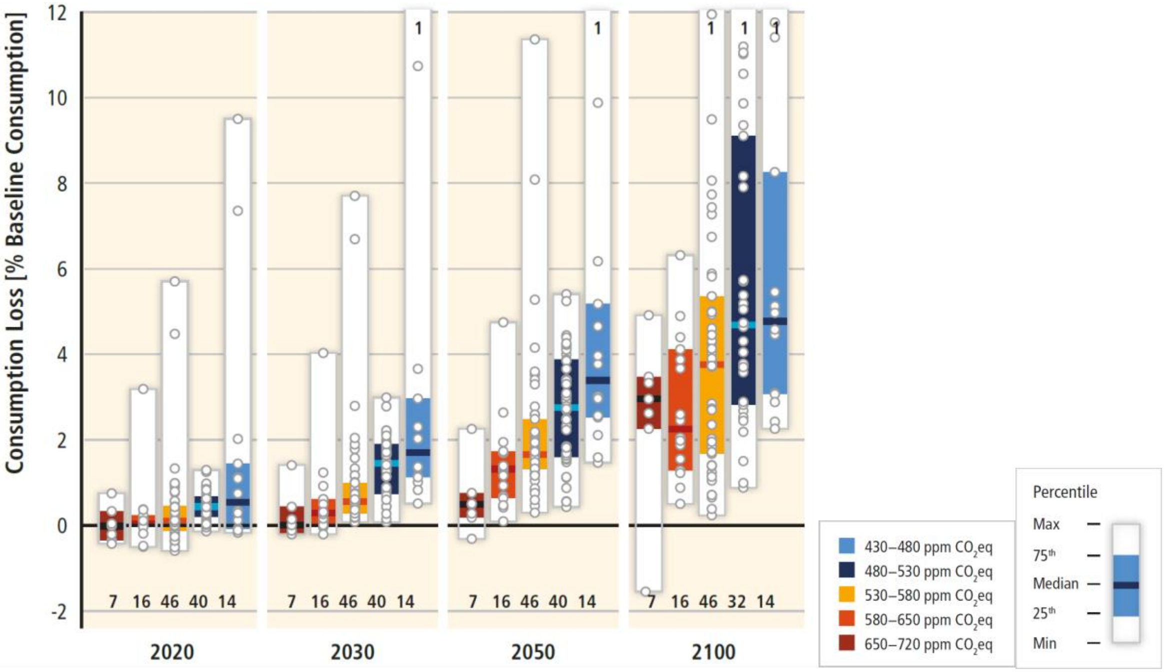


Figure 4: Cost for climate protection for different settings measured as a percentile of reduced consumption without climate protection (IPCC 2014a, p. 450). The figures below the bars give the numbers of the scenarios included in each case. The figures at the top of the bars show the number of scenarios outside of the specified range.

Scenarios which lead to a limitation of the greenhouse gas concentration within a range of 430–480 ppm CO_{2eq}, and thus offer a very good chance (66–100 %) to limit the temperature increase until 2100 to less than 2 °C, lead to a reduction of possible consumption of around 1–4 % until the year 2030, until 2050 around 2–6% and until 2100 around 3–11 % (IPCC 2014a, p.449). The mean values for these years are, respectively, ca. 1,8 %, 3,35 % and 4,8 % of the respective consumption.

The decrease of the Gross Domestic Product is on a very similar scale to this, which figure 5 shows. The numbers are not wholly comparable, since this is not an exact match of statistical populations of models and scenarios.

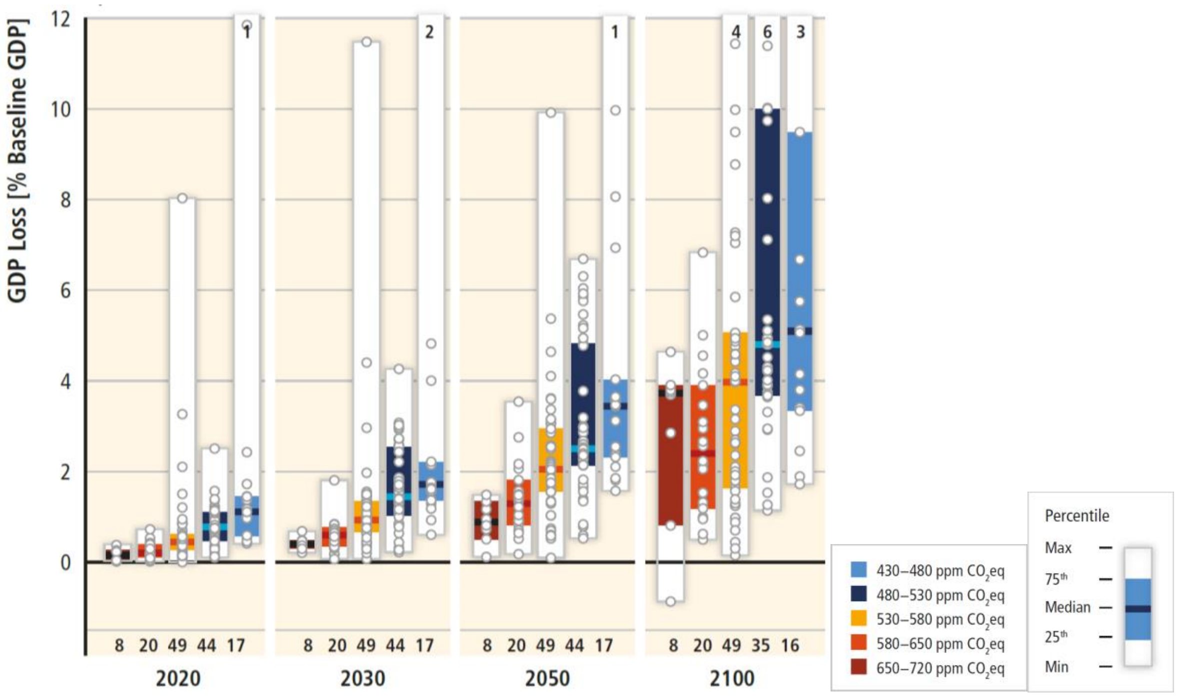


Figure 5: Cost for climate protection for different settings measured as a percentile of a reduced Gross Domestic Product without climate protection (IPCC 2014a, p. 450). The figures below the bars give the numbers of the scenarios included in each case. The figures at the top of the bars show the number of scenarios outside of the specified range.

For an aggregation of the climate protection costs over the complete timeframe from 2015–2100, and a discount of 5% to a standardized cash value by the authors of the IPCC-report, it becomes evident that the percentage reductions in the domain of consumption are very similar to the reductions in the domain of the Gross Domestic Product, whereas the pure (rather technically estimated) avoidance costs for emissions are situated at less than a half of those costs which also include the economic costs of climate protection measures induced by higher production costs and displaced consumption (compare figure 6 below). The authors of the IPCC report indicate that the models used for the calculation of the decrease of consumption assume that the overall consumption for the base case will grow at a coefficient of 2 to 4,5 until the year 2050 and at a coefficient of 4 to 10 until the year 2100. The decreased consumption until the year 2050 of 2 to 6 % is thus subsumed under a consumption which has grown by a total 200 to 450 %, which incisive climate protection measures that ensure the two-degree limit reduce to ca. (200% - 2% =) 198 % to (450% - 6% =) 444 % (own calculations on the basis of the data by the IPCC 2014a, p. 449).

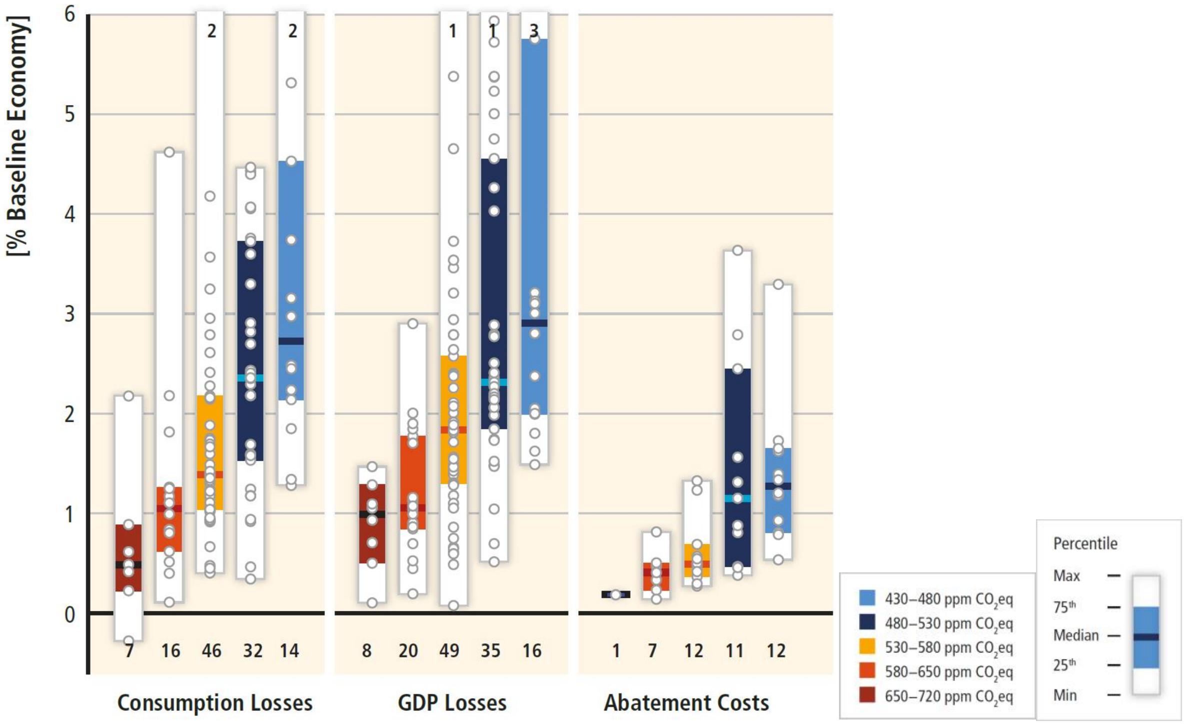


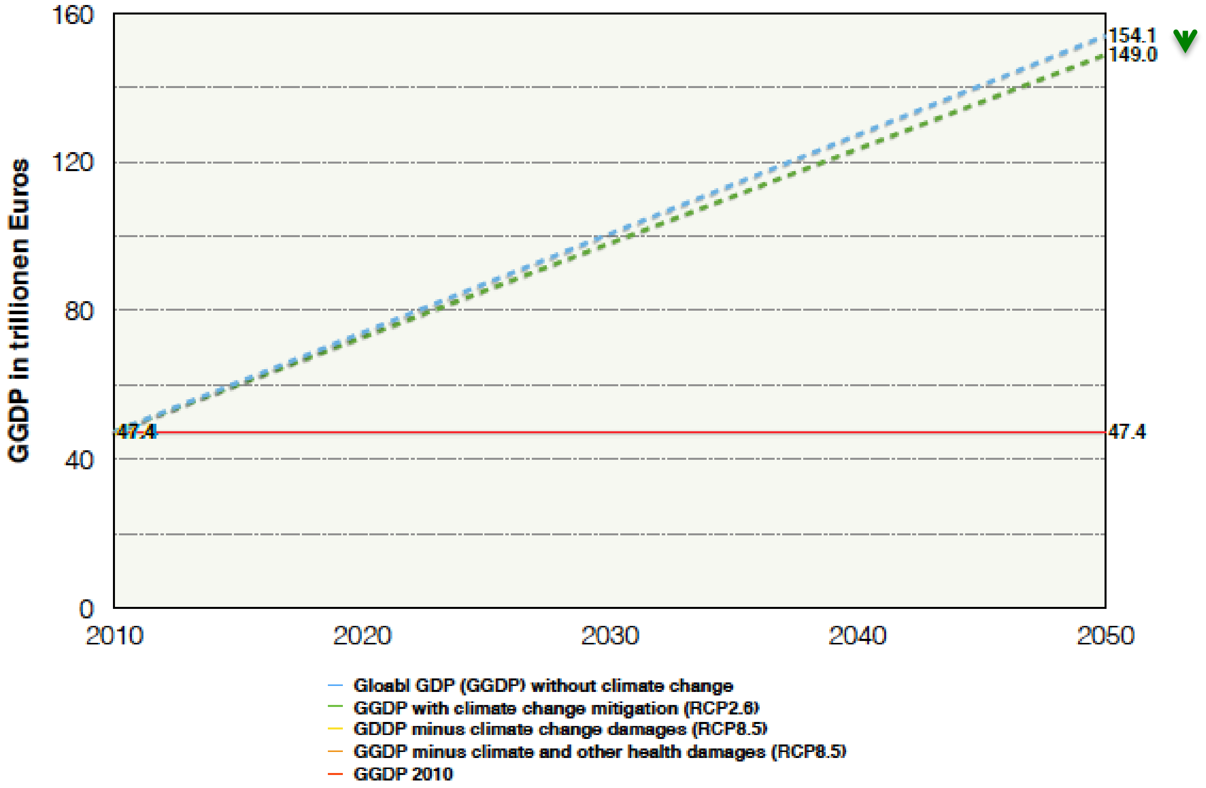
Figure 6: Comparision of cumulative climate protection costs (cash value with a discount interest rate of 5 %) measured as consumption reduction, reduction of the GDP and as emissions reduction costs (IPCC 2014a, p. 450)

As figure 7 illustrates, the report by Working Group III gives the impression that decisive climate protection (with a stabilization concentration of 430–480 ppm CO_{2eq}) causes high economic costs and a moderate climate protection (650–720 ppm CO_{2eq}) leads to much lower costs, since only the additional costs for climate protection and how they diminish the Global Gross National Product are calculated. If the medium assumptions for the calculations are used, the Global Gross National Product without climate protection measures (RCP8.5) grows from 47.7 Trillion $Euro_{2010}$ in 2010 to some 154 Trillion $Euro_{2010}$ in 2050. This value is suggested by the result graphics which are reported by the IPCC in figure 6 for a development without climate protection according to the scenario RCP8.5. Even the written remark in the text that this value does exclude the climate damage costs which possibly develop, does not alter the visually induced impression.

The calculated development of the Global Gross National Product without climate protection is contrasted with the costs of a decisive climate protection which limits the greenhouse gas concentration to 430–480 ppm CO_{2eq}. If, once again, the medium assumptions of the IPCC are used to indicate these climate protection costs for 2050, the Gross National Product is diminished by 5.1 Trillion $Euro_{2010}$ to 149 Trillion $Euro_{2010}$ in 2050. Figure 7 illustrates this development.

In order to deliver a complete picture of the costs and benefits of climate protection, the climate damage costs resulting from an omission of climate protection need to be indicated. As ordered, Working Group III of the IPCC does not provide this comparison, since the international community in the IPCC plenary allocated the assessment of climate change impacts to Working Group II.

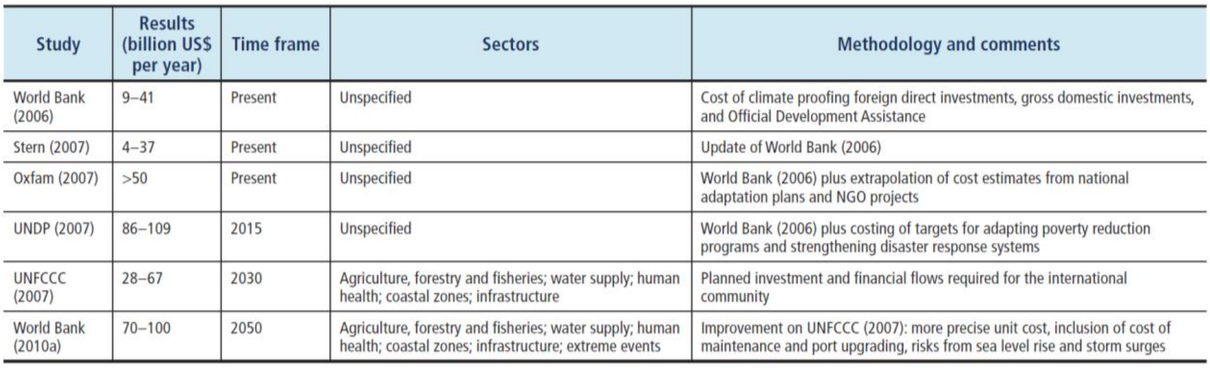
Figure 7: Development of the Global Gross National Product until 2050 with (RCP2.6) and without climate protection measures (RCP8.5) according to IPCC 2014a (own calculations on the basis of IPCC Working Group III 2014)



2.3 The Cost of Adapting to Climate Change

The chapter of the report by Working Group II of the IPCC on the question of assessing the economic aspect of the measures to adapt to climate change (IPCC 2014, p. 944–966), collates the findings of diverse studies, which usually consider a timescale until 2050. As table 2 demonstrates, the given, yearly adaptive costs in 2050 range between magnitudes of 28 to 109 Billion US Dollars per year.

Table 2: Overview of the results of different studies on climate change adaptation costs with a timescale until 2050 (IPCC 2014, p. 959)



Study	Results (billion US$ per year)	Time frame	Sectors	Methodology and comments
World Bank (2006)	9–41	Present	Unspecified	Cost of climate proofing foreign direct investments, gross domestic investments, and Official Development Assistance
Stern (2007)	4–37	Present	Unspecified	Update of World Bank (2006)
Oxfam (2007)	>50	Present	Unspecified	World Bank (2006) plus extrapolation of cost estimates from national adaptation plans and NGO projects
UNDP (2007)	86–109	2015	Unspecified	World Bank (2006) plus costing of targets for adapting poverty reduction programs and strengthening disaster response systems
UNFCCC (2007)	28–67	2030	Agriculture, forestry and fisheries; water supply; human health; coastal zones; infrastructure	Planned investment and financial flows required for the international community
World Bank (2010a)	70–100	2050	Agriculture, forestry and fisheries; water supply; human health; coastal zones; infrastructure; extreme events	Improvement on UNFCCC (2007): more precise unit cost, inclusion of cost of maintenance and port upgrading, risks from sea level rise and storm surges

Source: Modified from Agrawala and Fankhauser (2008) and Parry et al. (2009) to include estimates from World Bank (2010a).

Even if the studies by the UNFCCC and the World Bank arrive at similar overall results, the estimated costs for the reviewed subsectors differ dramatically, as figure 8 shows.

On the one hand, the authors of Working Group II of the IPCC note that the estimations for adaptive costs so far are still rather preliminary, but they also point out that, until 2050, a very high demand for financial transfers into developing countries will exist. This demand, at ca. 70–100 Billion Dollars per year, exceeds current international endowment funds in the climate protection sector by orders of magnitude. In contrast to the climate protection costs of ca. 5 Billion Euro$_{2010}$ in 2050, which are given by Working Group III, these numbers still appear to be rather modest in nature.

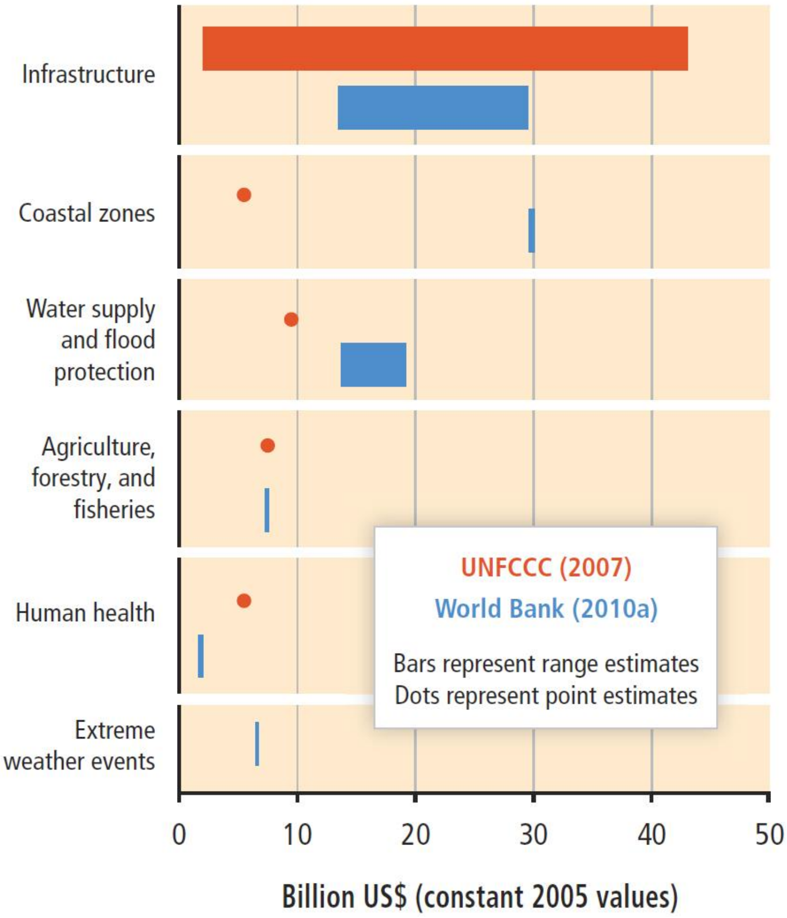


Figure 8: Comparison of the sectoral findings of the World Bank and the UNFCCC about the climate adaptation costs in developing countries in 2050 (IPCC 2014, p. 960)

2.4 Monetized Benefits of Climate Protection

In the report of Working Group II of the IPCC, the authors retreat to the position that honouring the damage through climate change needs to exceed an economic valuation. They develop strategies for decision support which aim to aid complex decisions under uncertainty (cf. IPCC 2014, p. 195–217). In respect to possible damage costs, the report only sporadically states figures. In the summary for political decision makers, a section surfaces which is specifically marked as an incomplete estimation. This section enumerates the possible damage for an increase of global temperature by 2 °C to 0.2–2 % of the (presumably global) income (IPCC 2014, p. 19). It is specifically highlighted that these numbers are not reliable, omit a multitude of important damage types and that they are based on contested assumptions. The report by Working Group II declines to deliver figures which are comparable to the costs of climate protection given by Working Group III (cf. IPCC 2014a, p. 450). On the other hand, the report by Working Group II does indeed offer particulars about the costs of possible adaptive strategies (IPCC 2014, p. 959f).

Even if the basic assumption and approach of the authors of Working Group II in principle has to be endorsed because of the difficult data situation and the necessary value judgements, the approach still leads to the situation that, on the one hand, the individual IPCC reports present high costs for climate protection, whereas, on the other hand, they assume extremely low damage costs, which are situated far below the costs which decisive climate protection can mitigate. In spite of all good intentions to capture and describe the consequences of climate change in its various qualitative dimensions, for the general public this results in the impression that climate protection above all costs a lot of money and growth. Particularly from the presentation in the report by Working Group III (cf. IPCC 2014a, p. 450), without even considering the economic consequences of climate change, politicians gain the impression that a "light" version of climate protection potentially avoids severe drawbacks in growth. Observers need to laboriously extract damage costs from the figures which are scattered throughout the report by Working Group II, since climate damage costs are neither systematically reported for all individual, examined sectors, nor presented in relation to the relevant emission scenarios in the summary overview. Even by detective piecemeal work, only a rather random and small range of the costs can be compiled.

Mostly, scattered statements for monetarily assessed, individual incidences of damage can be found. These statements are often based on single studies, and, on the whole, the impression arises that the Working Group avoids to suggest a unified procedure for estimating the monetized damage costs. It is notable that one of the coordinating lead authors of chapter 10 ("Key Economic Sectors and Services"), which handles the question of monetized damage, is Richard Tol. For years, Tol has been known to attempt to minimize the calculated damage costs of climate change. It has been proven that his own work contains grave scientific errors which lead to a severe underestimation of climate damage costs (cf. Nestle 2010, p. 61ff). It is striking that the study, in which these systematic misjudgments have been proven, is neither quoted by the IPCC report nor contained in the database for the studies about climate damage costs, which the report relies upon (cf. 2014, p. 690). Similarly, one of the groundbreaking studies in this field does neither emerge in the report nor database. The paper, published by the UBA, offers a systematic way to estimate climate damage costs on the basis of a process that meets broad scientific consensus (UBA 2007 and 2012).

The only halfway usable document for a systematic quantification of climate damage costs in the whole report by Working Group II is a table (IPCC 2014, p. 691; cf. table 3), which summarises the results of a relatively large number of different studies and which states the variance of the average damage cost estimations in relation to the assumed time preference rates (0,1 and 3 %). However, it is not transparent which changes of the greenhouse gas concentration and which timescales have been examined in each case. Still, the table provides initial footholds for the dimension of possible climate damage costs, which, as an average of all studies combined, arrives at 428 US-Dollars per tonne of carbon. The impact of the alleged "discounting" of future damage costs becomes very distinct here. The values reach 585 US$/t C for a time preference rate of 0 %, while they decrease to 40 US$/t C for a time preference rate of 3 %. The Working Group itself comments that different studies show that the results can vary by a factor of 2 according to the assumed population growth, by the factor of 3 when uncertainties are included, and could vary by at least the factor of 4 with the assumed time preference rate (IPCC 2014, p. 691). In the worst case scenario the calculated costs for the same physical damage would drift apart by a factor of 24.

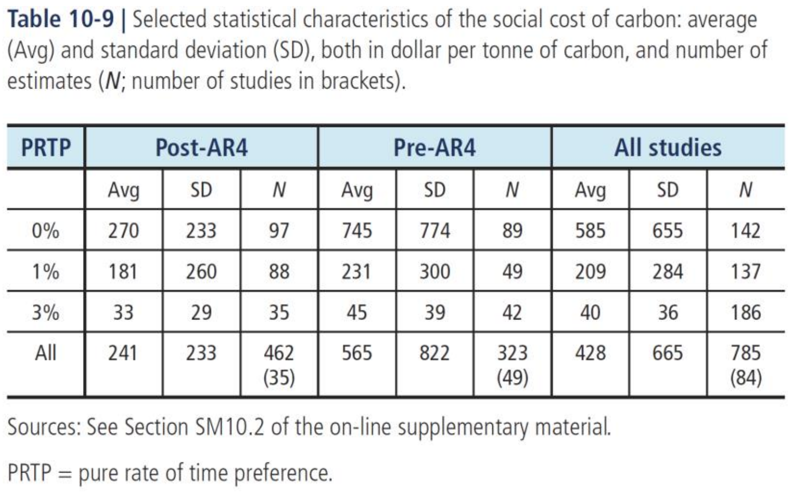


Table 10-9 | Selected statistical characteristics of the social cost of carbon: average (Avg) and standard deviation (SD), both in dollar per tonne of carbon, and number of estimates (*N*; number of studies in brackets).

PRTP	Post-AR4			Pre-AR4			All studies		
	Avg	SD	*N*	Avg	SD	*N*	Avg	SD	*N*
0%	270	233	97	745	774	89	585	655	142
1%	181	260	88	231	300	49	209	284	137
3%	33	29	35	45	39	42	40	36	186
All	241	233	462 (35)	565	822	323 (49)	428	665	785 (84)

Sources: See Section SM10.2 of the on-line supplementary material.

PRTP = pure rate of time preference.

Figure 3: Mean social costs and standard deviation for CO_2-Emissions in US$/t C for the time preference rates 0, 1 und 3 % (IPCC 2014, p. 691, table 10-9)

Hohmeyer (2005) exposes even severer discrepancies, and arrives at a difference of six orders of magnitude in a study about the impact of three parameters on climate damage costs in the area of effects of a diminished agricultural production on feeding the world and hunger in the world. Here, however, he varies the possible “discounting” of future climate damages between 0 and 10 %.

Since the climate damage costs stated in chapter 10 of the report of Working Group II of the IPCC cannot be related to the emissions in the different climate protection scenarios, they also do not permit it to put the costs of climate protection, which, in spite of all uncertainties, can be determined based on uniform assumptions (value judgments), into a relation with the costs which can be avoided by means of this climate protection. Hence, the readers are confronted by the findings of Working Group III without being able to integrate these into a meaningful economic framework.

3 How can the Benefit of Climate Protection be monetized?

As has been indicated in chapter 2, it is difficult to monetize the benefit of climate protection, since this presupposes a valuation of the mitigated climate damage costs, which is not possible without consensus about key value judgements. The monetary value of environmental and health-related damage is usually dominated by the avoided consequences for human health and human life. Therefore, it is indicative for the valuation of avoided climate damage, how high the value of an avoided case of illness or death is set. There is a multitude of different studies on this issue, which have been systematically collected under the framework of the ExternE-projects by the EU Commission (1991–2005) and its successors, such as the NEEDS-project (2004–2008) or the CASES-project (2006–2008). For European industrial countries, these values, which usually reflect the societal willingness to pay for the avoidance of an additional casualty through the “Value of statistical life” (VSL), are in the region of 2,5–4,4 Million Euro per avoided casualty (European Commission 1995, p. 49).

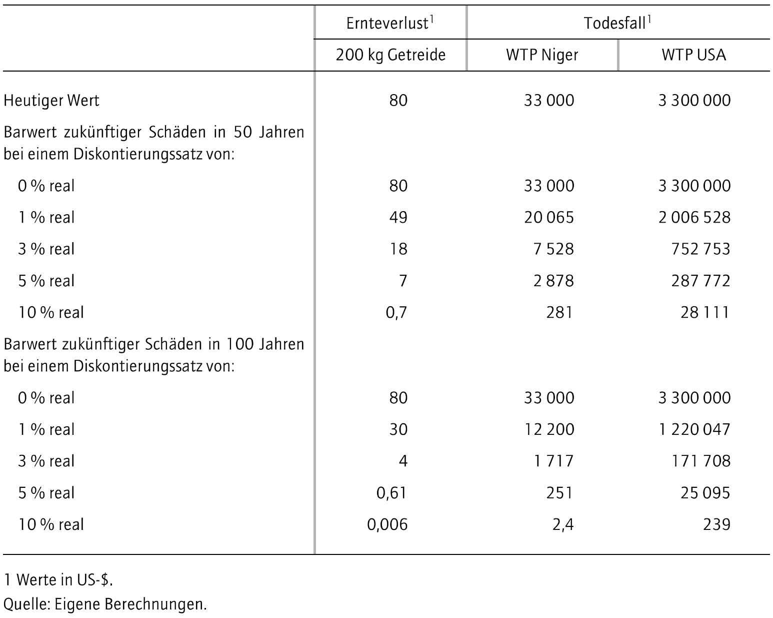
Since the climate damage of greenhouse gases that are emitted today, because of the long retention period of greenhouse gases in the atmosphere and continually rising global warming, will occur predominantly in the distant future, the question arises how the loss of human lives in the future should be valued. Should the assigned value be discounted just as a material damage because of the increased per-capita income, or does this value rise proportionally to income and should thus, in contrast to material goods, not be discounted, as Rabl (1999) very convincingly argues? Opinions vary greatly in the economic literature on this subject.

According to the IPCC (IPCC 2014, p. 6), climate damage will hit the poorest countries and the poorest population groups in all countries of the world the hardest, because these groups of victims have the least opportunity to adapt to climate change. For example, affluent citizens in an industrial country can react to food prices which rise because of climate change by spending a larger part of their income on the now pricier groceries. Subsistence farmers in the Sahel zone cannot compensate for the loss of their harvest because of climate change by simply purchasing the food products, which they used to grow for the sustenance of their families themselves, at the market. Crop failure will not only lead to the inability to produce food products, but also mean that they do not have an income to sustain their family with purchased groceries. Therefore, in the first case, a crop failure can mean that a farmer in the USA will produce lower amounts of grain and that this loss is only partially mitigated by raised grain prices, which the consumers in the USA have to pay for. Or, in the latter case, it means that a farmer and his family have to starve or even die of starvation because of a crop failure. At this point, the question arises whether crop failures are calculated by the diminished quantities of grain in tons, the climate damages calculated from the multiplication of these amounts with the grain price, or whether the suffering through famine and casualties from starvation are included into the climate damage costs (cf. Nestle 2010, p. 140ff).

If it is decided to include the lethal consequences of crop failures in the pricing of climate damage, the next value judgement is imminent: How and by which standards is the casualty in the Sahel zone valued? There is a school of thought in the economic sciences which conducts such a valuation according to the so-called “Willingness to Pay” (WTP). Here, the question is posed, how much would the concerned party pay to avert this case of death (IPCC 1996, p. 196f). This approach leads to a much higher pricing of the casualty in rich industrial countries, since the per-capita income is much higher, than the pricing in poor developing countries, because the people there only have a very small income at their disposal, onto which they can base their expressed willingness to pay. If this approach is followed, a casualty in the Sahel zone that occurred because of global climate change would only be priced at approximately a hundredth of the sum which would be assigned to a death in a wealthy industrial country.

There is a differently minded school of thought which demands that, especially in the area of the costs of climate change, the valuation of all casualties is to be undertaken by the monetary standard of the industrial countries, since these have caused the major portion of the problem (e.g. Hohmeyer and Gärtner 1992). This discussion has become known in conjunction with large, global climate damage under the name “Equity Weighting”. If an equal treatment of all affected humans in the world is desired, a locally assessed damage would be weighted (multiplied) by the inverse value of the relation of the local average income. For the case of a citizen of the Sahel zone, this relation is situated at about 1/0,02, so that the locally assessed damage would have to be multiplied by the factor of 50. In case of a wealthy citizen from a rich industrial country, this factor is perhaps at about 1/5. If the polluter pays principle, which is generally agreed to be the foundation for environmental policy in Germany and Europe, is applied to climate damage, Equity Weighting has to be taken one step further, and every casualty has to be assigned a value which is attributed to it in the key perpetrating country. A further school of thought proposes to use a global average for all casualties which are caused by climate change (cf. e.g. UBA 2012). It is obvious that the decision, how the vast majority of casualties from climate change in developing countries are valued, will decidedly change the overall result of the monetary assessment of climate damage. Hohmeyer (2005) has calculated the impact of the combination of the three effects which have been discussed here (diminished harvest of grain or starvation deaths, implied discount interest rate for a loss of human lives, valuation of casualties in developing countries as a consequence of climate change) in an overall calculation (cf. table 4 below), he arrives at the conclusion that just the possible variation of these value judgements can change the calculated result by six orders of magnitude.

Table 4: Influence of the variation of three key parameters on the valuation of climate damage in the area of induced casualties (Source: Hohmeyer 2005, p. 167)



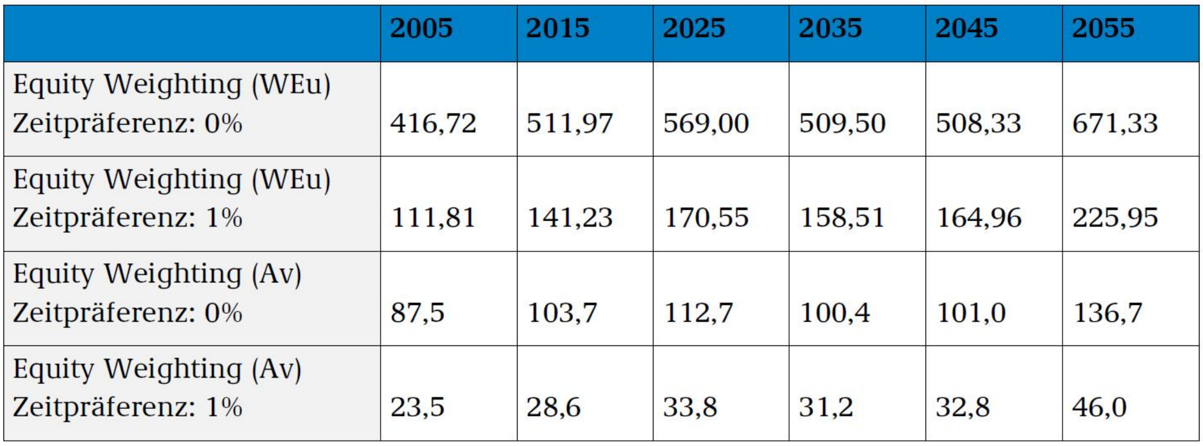
	Ernteverlust[1]	Todesfall[1]	
	200 kg Getreide	WTP Niger	WTP USA
Heutiger Wert	80	33 000	3 300 000
Barwert zukünftiger Schäden in 50 Jahren bei einem Diskontierungssatz von:			
0 % real	80	33 000	3 300 000
1 % real	49	20 065	2 006 528
3 % real	18	7 528	752 753
5 % real	7	2 878	287 772
10 % real	0,7	281	28 111
Barwert zukünftiger Schäden in 100 Jahren bei einem Diskontierungssatz von:			
0 % real	80	33 000	3 300 000
1 % real	30	12 200	1 220 047
3 % real	4	1 717	171 708
5 % real	0,61	251	25 095
10 % real	0,006	2,4	239

1 Werte in US-$.
Quelle: Eigene Berechnungen.

On the one hand, these calculations show how much the proponents of different value judgements can argue about the “correct” monetary value. On the other hand, they also show that it is certainly possible to arrive at a definite monetary result, if consensus about the three value judgements exists.

In the last twenty years, as a common basis for the valuation of climate damage in the energy and traffic sector has been developed in Europe by a comprehensive research programme of the European Commission (ExternE, NEEDS and CASES). Based on the results of this European research programme, the Umweltbundesamt has developed a unified method for several years, proposing how the environmental costs of the energy and traffic sector should be monetarily assessed (UBA 2007 and 2014). The Umweltbundesamt has, in conjunction with the most recent version of this convention on methods, published recommendations for concrete numerical values for climate damage, which are strongly oriented on the consensus which has developed in the scientific discourse in Germany. In this connection, damage values for an emissions path which was, in 2011, viewed to be attainable without substantial climate protection measures (EMP14), and which would clearly miss the two-degree limit, are given, as well as the avoidance costs for meeting the two-degree limit for specified target years. Here, the UBA specifies ranges for each different target year, in order to avoid suggesting that these values can be measured precisely, which would be the effect if a single value was listed by itself. For the monetary damage costs, the Umweltbundesamt identifies figures based on two different discount interest rates (0 % and 1 %) and two different Equity-Weighting approaches (world average and European willingness to pay) for the valuation of casualties. The results of the UBA are presented in table 5.

Table 5: Climate damage costs in $€_{2010}$/t CO_{2eq} according to the calculations of the Umweltbundesamt (UBA 2014, appendix B, p. 7)



	2005	2015	2025	2035	2045	2055
Equity Weighting (WEu) Zeitpräferenz: 0%	416,72	511,97	569,00	509,50	508,33	671,33
Equity Weighting (WEu) Zeitpräferenz: 1%	111,81	141,23	170,55	158,51	164,96	225,95
Equity Weighting (Av) Zeitpräferenz: 0%	87,5	103,7	112,7	100,4	101,0	136,7
Equity Weighting (Av) Zeitpräferenz: 1%	23,5	28,6	33,8	31,2	32,8	46,0

WEu: West European Equity Weighting; Av: Average Equity Weighting

If these numbers are converted on the basis of the emission scenario RCP8.5, which has become regarded to be more likely to be the base case without climate protection for the year 2050, the value for a European Equity Weighting and a time preference rate of 0 % is 760 $€_{2010}$/t CO_{2eq} and 216 $€_{2010}$/t CO_{2eq} for a time preference rate of 1 %. The conversion is based on a linear interpolation of the values stated by the UBA for 2045 and 2055 and a proportional conversion of these values to the higher emissions levels of the scenario RCP8.5 (20,61 Gt C_{eq} in 2050), which is contrasted to the mean value of the EMF14-scenario utilized by the UBA (16 Gt C_{eq} in a range given from 15–17 Gt C_{eq} in 2050). Since this damage progression is with great probability non-linear, and disproportionately rises with increasing emissions, this type of conversion can be considered to be conservative. Because the major part of the expected monetized damage caused by climate change will be damage such as additional cases of death and disease, it does not seem warranted to assign a time preference rate and discount to this damage (cf. Rabl 1995). Therefore, the calculated value of the damage which is based on those European value judgements is situated at 760 $€_{2010}$/t CO_{2eq} for the year 2050, rather than at the lower value of 216 $€_{2010}$/t CO_{2eq}.

The mitigation costs which enable to ensure meeting the two-degree limit, instead of this “business as usual” development, are identified by the UBA in the same report. These numbers are represented in table 6. The statements of the UBA are based on a comprehensive meta-study (Kuik et al. 2009) and an analysis by the Institute for Energy Economics and the Rational Use of Energy (IER[2]), which is based on the European research programme (Wille et al. 2012). It can be argued in favour of the usage of mitigation costs for meeting the two-degree limit because this climate protection objective has been passed by the world community during the global climate policy process in Cancún as a universally binding climate limit, and thus can be regarded as a collective

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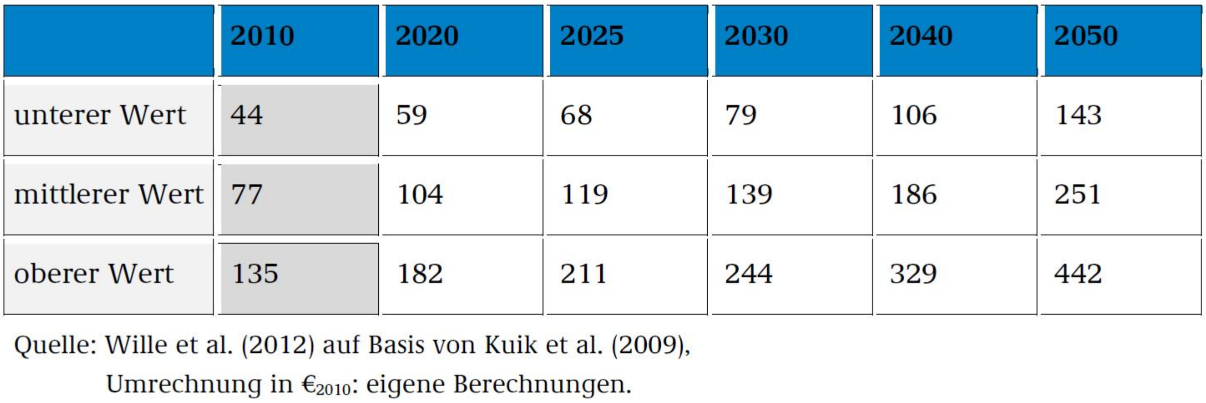
[2] “Institut für Energiewirtschaft und Rationelle Energieanwendung (IER)“

willingness of the world community to pay for the mitigation of as yet noted climate damage when this threshold is crossed.

Table 6: Recommendation of the Umweltbundesamt for greenhouse gas emission mitigation costs in €$_{2010}$/t CO_{2eq} (UBA 2014, p. 6)

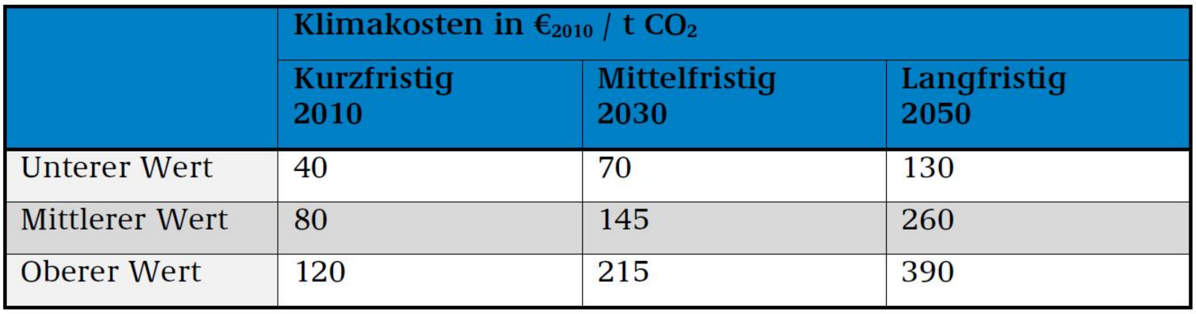


	2010	2020	2025	2030	2040	2050
unterer Wert	44	59	68	79	106	143
mittlerer Wert	77	104	119	139	186	251
oberer Wert	135	182	211	244	329	442

Quelle: Wille et al. (2012) auf Basis von Kuik et al. (2009),
Umrechnung in €$_{2010}$: eigene Berechnungen.

Based on both approaches, the Umweltbundesamt recommends a mixed, founded approach, which includes damage costs on the one hand, but also adjusts these to the mitigation costs for the two-degree limit. Table 7 indicates the values recommended by the UBA for the assessment of the external costs of climate change for the years from 2010 until 2050. Moreover, average values on the basis of a time preference rate of 1 %/year are given as a recommendation, while, simultaneously, value ranges are specified in order to classify them. Based on this, the Umweltbundesamt recommends the usage of a value of 260 €$_{2010}$/t CO_{2eq} for the year 2050 (cf. table 7). However, it also explicitly notes that significantly higher values are justifiable, if another time preference rate is used, as the damage cost in table 5 (above) clearly prove.

Table 7: Recommendations for the quantification of the expected costs of human-made climate change by the Umweltbundesamt (in €$_{2010}$/t CO_{2eq}) (UBA 2014, p. 7)



	Klimakosten in €$_{2010}$ / t CO_2		
	Kurzfristig 2010	Mittelfristig 2030	Langfristig 2050
Unterer Wert	40	70	130
Mittlerer Wert	80	145	260
Oberer Wert	120	215	390

Since the values proposed by the Umweltbundesamt for the assessment of the costs of climate change are based on a wide-ranging evaluation of the literature and the results of a long-term European research programme, as well as on an elaborate discussion process in conjunction with the development of a convention on methods and the recommended numerical values (the project by the Umweltbundesamt was closely accompanied by a specially created scientific advisory board), these figures can currently be regarded as the best and most undisputable estimation of the costs of climate change from a German and European perspective. The average value of 260 $€_{2010}$/t CO_{2eq} recommended by the UBA for 2050 thus forms the basis of the comparison of the costs and benefits of climate protection in the following analysis. As has been mentioned in conjunction with the estimation of climate damage costs by the UBA above, because of the employed the emission scenarios (EMF 14), these values are rather conservative. The greenhouse gas emission values which are assumed in EMF 14 for 2050 are lower by ca. 20 % than in the case of the RCP8.5 scenario.

The value judgements which are included into the recommendations of the Umweltbundesamt can be regarded as the attempt to make the principle of the equality of all people, in accordance with article 1 of the UN-Convention on Human Rights (UN 2015), the guiding principle of all value judgements which enter monetization.

4 Comparison of the Costs and Benefits of Climate protection

4.1 Comparison of Climate Protection Costs with the Direct Benefits of Climate Protection

In the following, the year 2050 shall be made the basis for the considerations about comparing the costs and direct benefits of climate protection which are attained from mitigating the damage from climate change, since, until 2050, significant climate protection costs will result for meeting the two-degree limit, but, also, substantial damage will result from unchecked climate change. Considerably higher damage costs can be expected to be incurred in the second half of the century, if the greenhouse gas emissions are not reduced drastically. For 2050, damage costs per t CO_{2eq} are available from the estimations of the Umweltbundesamt, which involve a high amount of societal consensus and allow for a calculation of the costs which can be avoided through decisive climate protection, based on the IPCC scenarios (RCP2.6 and RCP8.5).

The report by Working Group III of the IPCC specifies the costs with 1–4 % of possible consumption until the year 2050 (cf. chapter 2.2 accordingly), which meeting the two-degree limit ensures to a large extent by staying, in accordance with RCP2.6, within a concentration corridor from 430 to 480 ppm CO_{2eq}. This decrease has to be regarded in context with an overall level of consumption which is increased by a factor of 2–4,5 (IPCC 2014a, Chapter 6, p. 449). In order to calculate the absolute costs of necessary climate protection and the costs per tonne CO_{2eq}, the reductions of the Global Gross National Product in 2050 which are indicated in the report by Working Group III are also included in the following, since these can be calculated on the basis of the contemporary GNP (2010), whereas it is uncertain how the consumption which is specified in the report was delimited. Globally, Gross National Product and Gross Domestic Product are identical. The model calculations, which the IPCC has evaluated, usually calculate the sum of the changes of the Gross National Products, which is why the report of Working Group III employs the label “Gross Domestic Product” (GDP). When observing the aggregated, global effects, however, the notion of the Global Gross National Product is much more convincing than the Global Gross Domestic Product. Because both terms describe the same technical fact when a global perspective is applied, the term Global Gross National Product will be used in the following.

According to the World Bank, the Global Gross National Product for the year 2010 amounted to 63,048 Trillion Dollar_{2010}/a (World Bank 2014). If this is converted into Euro by using the average exchange rate of 2010 (cf. Wirtschaftskammer Österreich/ Austrian Federal Economic Chamber, 2014) of 1,33 US$/€, the global GNP for the year 2010 amounts to 47,4 Trillion Euro_{2010}/a.

Proceeding from a real growth of 2- to 4,5 times of this value until 2050, a Global Gross National Product of 94,8–213,3 Trillion Euro_{2010} /awill be reached. If it is attempted to connect these values to the central estimate of climate protection costs for the year 2050 (reduction of the global GNP by about 3,3 % as depicted in figure 6.21 in the report by Working Group III of the IPCC) (IPCC 2014a, p. 450), the average value of the Global Gross National Product for the year 2050 of 154,05 Trillion Euro_{2010}/a has to be used. The climate protection costs in 2050, which are necessary to meet the two-degree limit, thus amount to ca. 5,1 Trillion Euro_{2010}/a.

This value, in turn, needs to be compared with the follow-on costs of a drastic climate change without climate protection measures that are mitigated by this climate protection. For this purpose, the reductions of greenhouse gases which are reached by 2050 are calculated in a comparison of the scenarios RCP8.5 (uninhibited development of emissions) and RCP2.6. (climate protection for meeting the two-degree limit). According to Working Group I (IPCC 2013, Annex II, table AII.2.1.c, p. 1410), 20,61 Gt C/a is specified in RCP8.5 for the year 2050. This corresponds to 75,57 Gt CO_{2eq}/a of Carbon dioxide emissions, if the conversion is undertaken with the molecular weights of Carbon (12 g/mol) and CO_2 (44 g/mol). Since the emissions in the scenario RCP2.6, amounting to 3,5 Gt C/a and 12,83 Gt CO_{2eq}/a respectively, cannot be avoided by these climate protection measures, as they are compatible with meeting the two-degree limit, these have to be deducted from the emissions in the scenario RCP8.5. As it is, the greenhouse gas emissions which are avoided by 2050 through complying with the scenario RCP2.6 amount to 62,64 Gt CO_{2eq}/a.

If the mitigated greenhouse gas emissions are then rated in accordance with the baseline by the Umweltbundesamt of 260 $€_{2010}$/t CO_{2eq}, mitigated climate damage costs of 16,31 Trillion $€_{2010}$/a result.

With a value of a solid 16 Trillion Euro_{2010}/a, the mitigated climate damage in 2050 amount to more than the triplicate of the climate protection costs of ca. 5 Trillion Euro_{2010}/a, which would result for mitigating this damage in the same year. In contrast to the impression raised by Working Group III of the IPCC, which implies that the Global Gross National Product for 2050 would be lower than without climate protection measures, the Global Gross National Product without climate protection is, because of the resulting climate damage, more than 10 Trillion Euro_{2010} lower than with decisive climate protection measures, as figure 9 illustrates clearly.

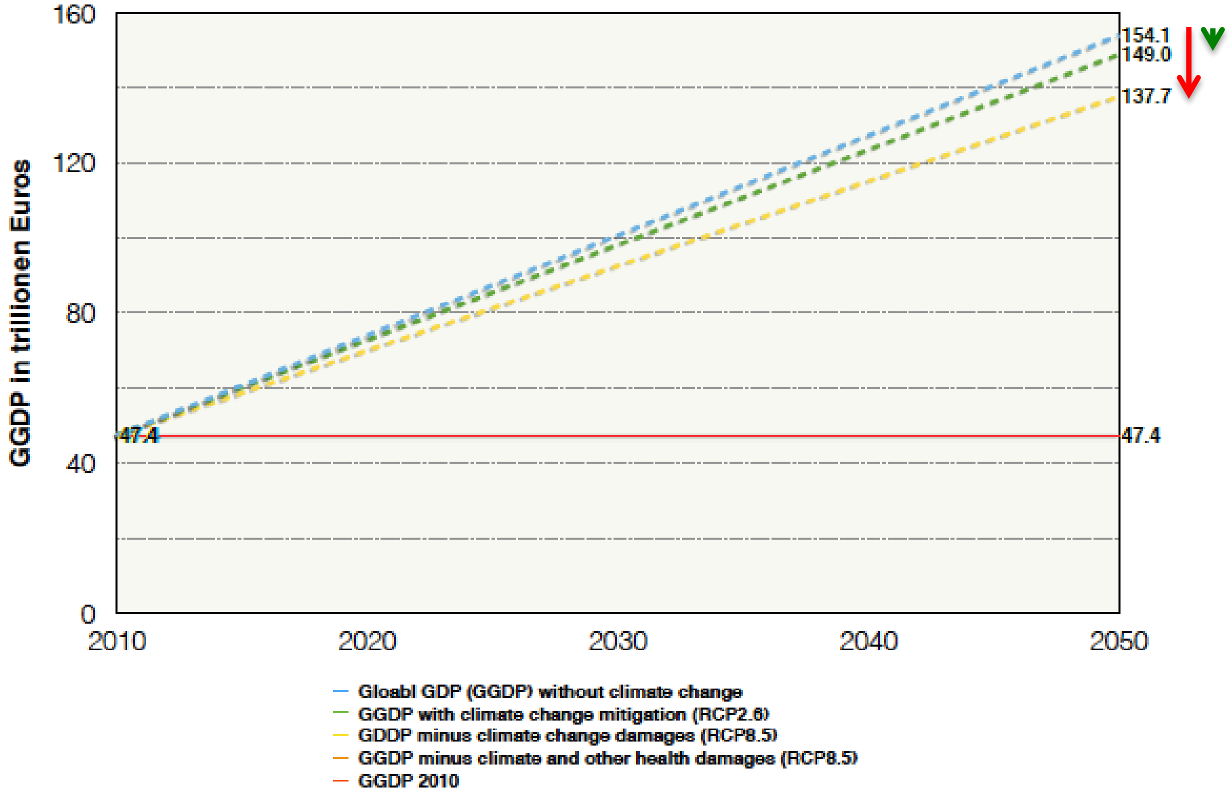


Figure 9: Global Gross National Product without climate change, with climate protection measures (RCP2.6) and without climate protection measures (RCP8.5) (own calculations based on IPCC 2014a and UBA 2014).

A possible increase of the Gross National Product arising from repairing climate damage is included here. On the one hand, in the system of an economic total account, repairs lead to a positive contribution to the Gross National Product. On the other hand, the resources which are employed for these repairs are not available for the demand that would be adopted in the normal case, which would normally have led to an increase of the Gross National Product. Since repaired damage does not represent profit to the affected parties, but only restores the previous state, repaired damage does significantly reduce wealth, if contrasted with a development without damage. Furthermore, it has to be considered that the most important climate damage types, such as irremediable environmental damage or casualties, cannot be “repaired”.

From the perspective of European value judgements and based on the values of equality and justice drawn from the UN Convention on Human Rights, drastic climate protection is urgently recommended from an economic perspective as well, since its benefit exceeds the costs by 2050 by more than their triplicate.

4.2 Co-benefits of Climate Protection

The co-benefits of climate protection have been analysed in the recently published “New Climate Economy Report” by the Global Commission on the Economy and Climate (2014), as they have been in the third progress report by the IPCC (IPCC 2001, p. 523ff). The analysis is centred on the decrease of air pollutants and the health damage effects associated with them, which is a side-effected of the reduced use of fossil fuels in order to reduce of greenhouse gas emissions.

Contrary to the IPCC, the Global Commission on the Economy and Climate cites usable figures. Hence, based on a study (Hamilton et al., 2014) conducted for the report, it identifies global health-care costs of between 50 to 200 US$/t CO_2 (Global Commission on the Economy and Climate 2014a, S. 11) which could be avoided through climate protection. Assuming that these figures are given in values pertaining to the prices in 2010, this range can be converted to 37,6–150,4 $€_{2010}$ /tCO_{2eq}.

When combining these additional benefits of climate protection, valued in monetary units, with the greenhouse gas emissions that can be avoided by 2050, and which result from a development without decisive climate protection that would see a massive employment of fossil fuels, additional cost savings, which derive from climate protection measures, of 2,4–9,4 Trillion $€_{2010}$/a result. At an average value of 5,9 Trillion $€_{2010}$/a, the additional benefit of relevant climate protection in order to decrease emissions in 2050 surpasses the costs for the necessary climate protection measures in the same year. The Global Gross National Product without climate protection, considering the costs of climate change and the simultaneously resulting damage costs from air pollutants which could be avoided by climate protection measures, reaches only 131,8 Trillion $Euro_{2010}$/a and not, as implicitly suggested by Working Group III of the IPCC, 154,1 Trillion $Euro_{2010}$/a.

Figure 10 illustrates clearly how the Global Gross National Product develops from 2010 to 2050 with and without climate protection, and how the consideration of the costs of climate change and of the damage costs that are caused by air pollutants, and which can be avoided through climate protection, affect the Global Gross National Product until 2050, if it is assumed that the costs develop proportionally to the growth of the Gross National Product (an assumption which only serves illustrational purposes here). The Global Gross National Product of 154,1 Trillion $Euro_{2010}$, which is suggested by Working Group III of the IPCC, is not the Gross National Product that is possible without climate protection, but the potential Gross National Product, if the greenhouse gases emitted by humankind had no effect on climate change. A completely hypothetical number, which nonetheless is related to scenarios without climate protection measures.

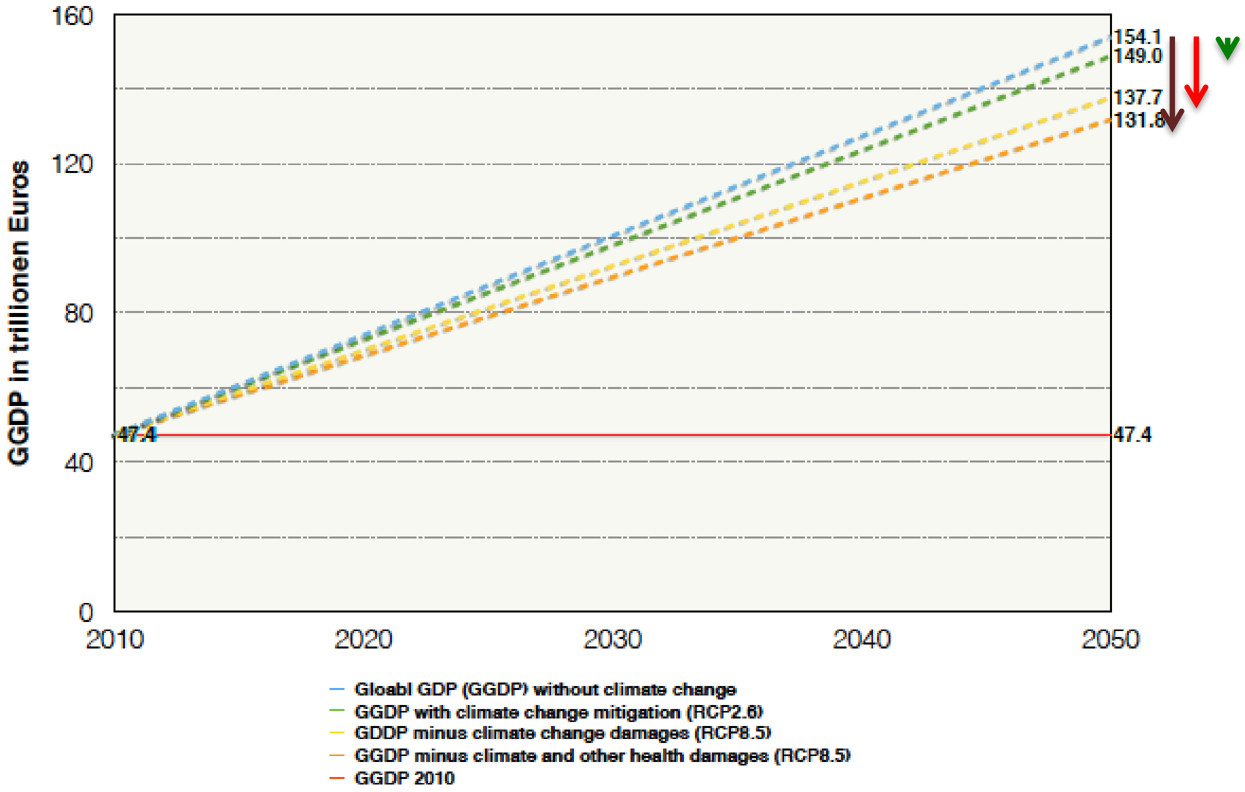


Figure 10: Development of the Global Gross National Product with and without climate protection (own calculations based on IPCC 2014a and UBA 2012)

5 The Necessary Transformation to Decisive Climate Protection

The fifth progress report of the IPCC demonstrates that a rapid and severe change of direction concerning anthropogenic greenhouse gas emissions is urgently necessary (IPCC 2014, p. 13). The comparison of avoidable damage costs with the costs of a necessary climate protection highlights that climate protection is indeed profitable from an economic perspective. In order to reach the necessary decrease in greenhouse gas emissions, a drastic transformation of the world economy, particularly in the areas of energy supply, urban development and land use is indispensable. Recent studies have shown that this transformation can create additional, positive economic effects on a massive scale. Thus, the following will briefly outline the basic elements of this transformation and present their economic benefit.

5.1 Key Elements of the Transformation

As the Global Commission on the Economy and Climate highlights, the world economy will undergo a fundamentally transformative process in the next 15 years. In the course of this process, approx. 90 Trillion Dollar will have to be invested into urban infrastructure, land use and the energy system (2014, p.8). The way in which these investments are deployed will essentially decide the future of the world's climate. Similar elaborations can also be found in the expertise by the German Advisory

Council on Global Environmental Change[3] (WBGU) "Welt im Wandel – Gesellschaftsvertrag für eine Große Transformation" (WBGU 2011), i.e. "World in Transition – A Social Contract for a Major Transformation".

The subsequent development of the fast growing cities of the world will have a considerable influence on their energy needs. If the cities are compactly developed around a well-planned and upgraded public transportation system, the required investment into urban infrastructure over the next 15 years can be lowered by more than 3 Trillion Dollars (Global Commission on the Economy and Climate 2014, p. 8).

According to the Global Commission on the Economy and Climate, the productivity development of land use over the next 15 years will determine whether it is possible to successfully support the world population, which will grow to 8 Trillion. Reinstating just 12 % of the degraded agricultural areas of the world could potentially support an additional 200 Million human beings and simultaneously contribute dramatically to a decrease of greenhouse gas emissions (Global Commission on the Economy and Climate 2014, p. 8).

The energy system will have to support this growth with the required energy in all countries. Landmark decisions are imminent within the next 15 years: Either the share of fossil energy sources in the energy supply mix will be increased, thus provoking the danger that the facilities which are built, such as power plants, later have to be decommissioned prematurely for reasons of climate protection. Or, the transition to an energy system which is mainly supported by regenerative energy supply sources and further advances in energy efficiency (Global Commission on the Economy and Climate 2014, p. 8) will be attained.

In order to support the essential transitory developments toward a sustainable and climate-friendly growth of cities, the Global Commission on the Economy and Climate argues that three major drivers of change need to be deployed accordingly. These are a substantial increase of resource productivity, investments into the infrastructures fit for the future, which are geared towards sustainability and climate protection, as well as the stimulation of climate-friendly innovations (cf. Global Commission on the Economy and Climate 2014, p. 9).

The elaborations by the Global Commission on the Economy and Climate differ from the suggestions by the WBGU particularly in that the commission also considers nuclear energy as a potential energy source for climate-friendly development, whereas the WBGU dismisses it as an unsustainable energy source, on the grounds of the hazardous risk potential which nuclear energy bears. The position of the Global Commission on the Economy and Climate is not surprising, since three of the seven countries which financed the report – Great Britain, Sweden and South Korea – belong to the most important advocates of a continuing use of nuclear energy. Also, Indonesia, as a fourth country which funded the report, is pursuing plans to build its own nuclear power plants.

In its most recent special report "Klimaschutz als Weltbürgerbewegung" ("Climate protection as a world citizen's movement"), the WBGU supplements their statements on the necessity of a fundamental transformation towards a climate-friendly society from 2011. In this, the WBGU

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[3] The German federal government set up the WBGU ("Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen") as an independent, scientific advisory body in 1992.

underlines the part of decentralised institutions and civil society as drivers of the required transformation process (WBGU 2014).

5.2 Economic Opportunities of the Transformation

The Global Commission on the Economy and Climate underlines that the majority of the funds for the required transformation need to be assigned to the upcoming modernisation in any case, e.g. for the required capacity expansion of the capital stock in the energy supply sector and for urban infrastructure (Global Commission on the Economy and Climate 2014, p. 8). Therefore, the primary concern is that these funds are not invested into the wrong technologies, which would cement the continuing dependence on fossil fuels and motorized individual transport for decades. Investments into power plants and urban infrastructure define development paths for many decades. After investments into the wrong technology, these can only be remedied at great economic losses.

The Global Commission on the Economy and Climate (p. 8f) especially views investments into new technologies for the utilization of renewable energy sources and for increasing energy and resource efficiency as drivers for a new and sustainable growth.

With the emergence of a new industry with almost 400.000 employees (cf. O'Sullivan et al. 2014, p. 8), the example of German development in the area of renewable energy sources is proof that the transformation of the energy sector can lead to significant new economic activities and employment effects. In 1990, before the introduction of the "Stromeinspeisegesetz" (electricity feed-in law) for the advancement of renewable energy production, this industry did not exist beyond the building and operation of large hydropower plants. By 2004, the number of employees had already risen to ca. 160.000, only to reach its provisional peak of just under 400.000 employees in 2012 (cf. figure 11). In 2013, employment in the solar energy sector plummeted, because grants from the German Renewable Energies Act (EEG) were drastically reduced. It is contentious how much of a role other factors that have aggravated the crisis of the German solar industry have played. Almost 50.000 jobs were lost in 2013 alone (cf. O'Sullivan et al. 2014, p. 12 and figure 12 below).

The job loss in the area of solar energy usage highlights that the development of new industries in the field of climate protection depends heavily on the provision of a governmental framework. A discontinuity of government aid can rapidly lead to quite critical courses of development. For instance, the overly generous funding policy for photovoltaic energy production in Germany initially led to an explosive growth of turnover and employment from approx. 25.000 jobs in 2004 to a good 110.00 jobs in 2012. Because the extreme growth in the photovoltaic electricity generation sector led to high cost burdens for the consumers, this development had to be curbed by drastic counter measures in funding politics. These counter measures were the main cause for the extreme decline of the German photovoltaics industry.

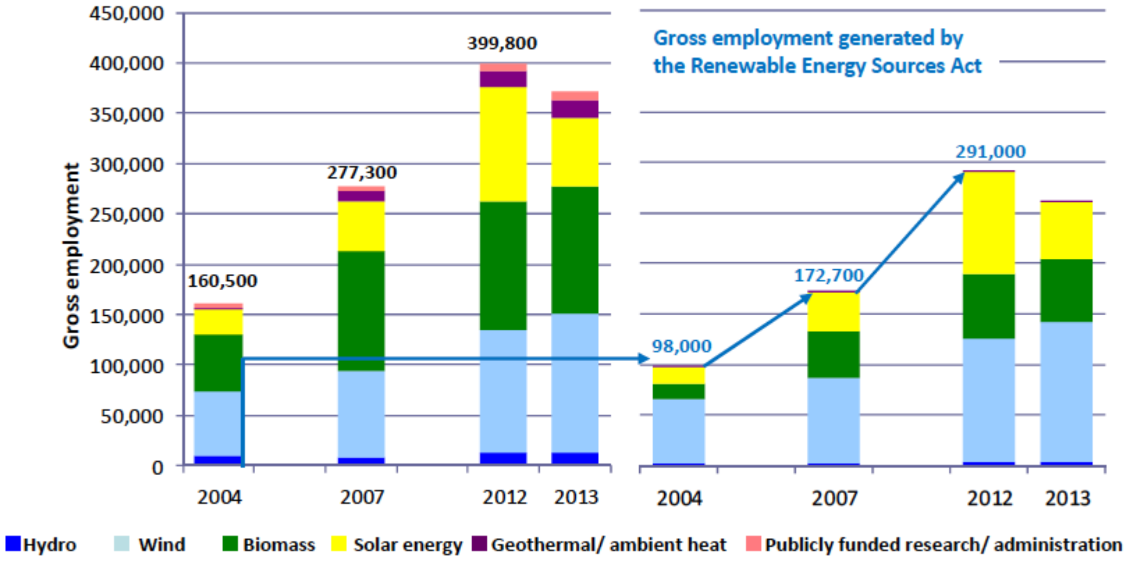


Figure 11: Development of employment in the renewable energy sector as well as employment induced by the EEG from 2004 until 2013 (Source: O'Sullivan et al. 2014, p. 8)

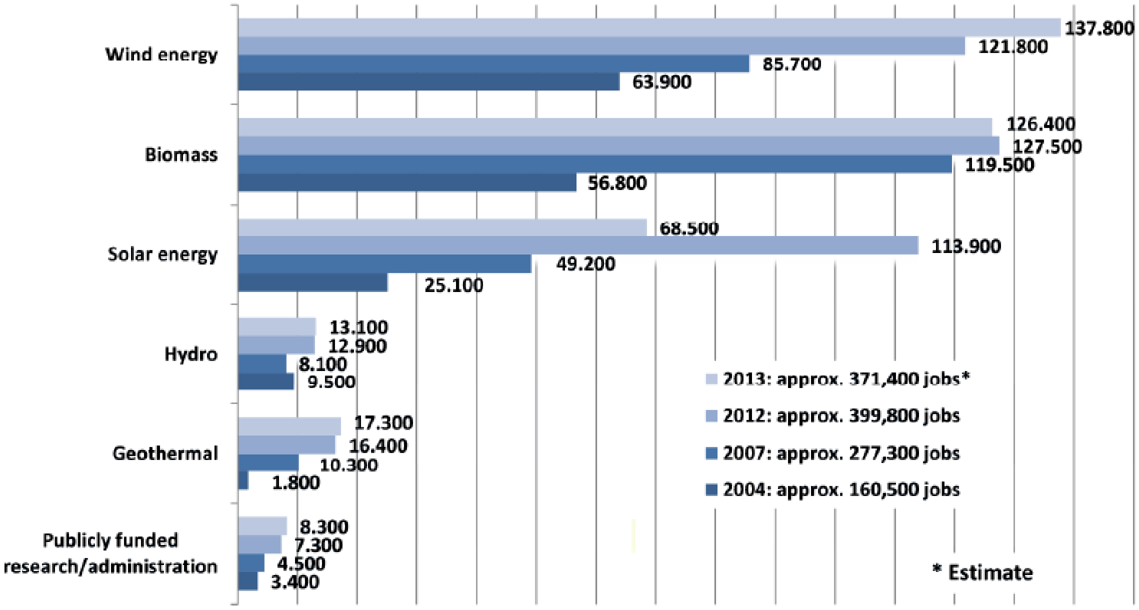
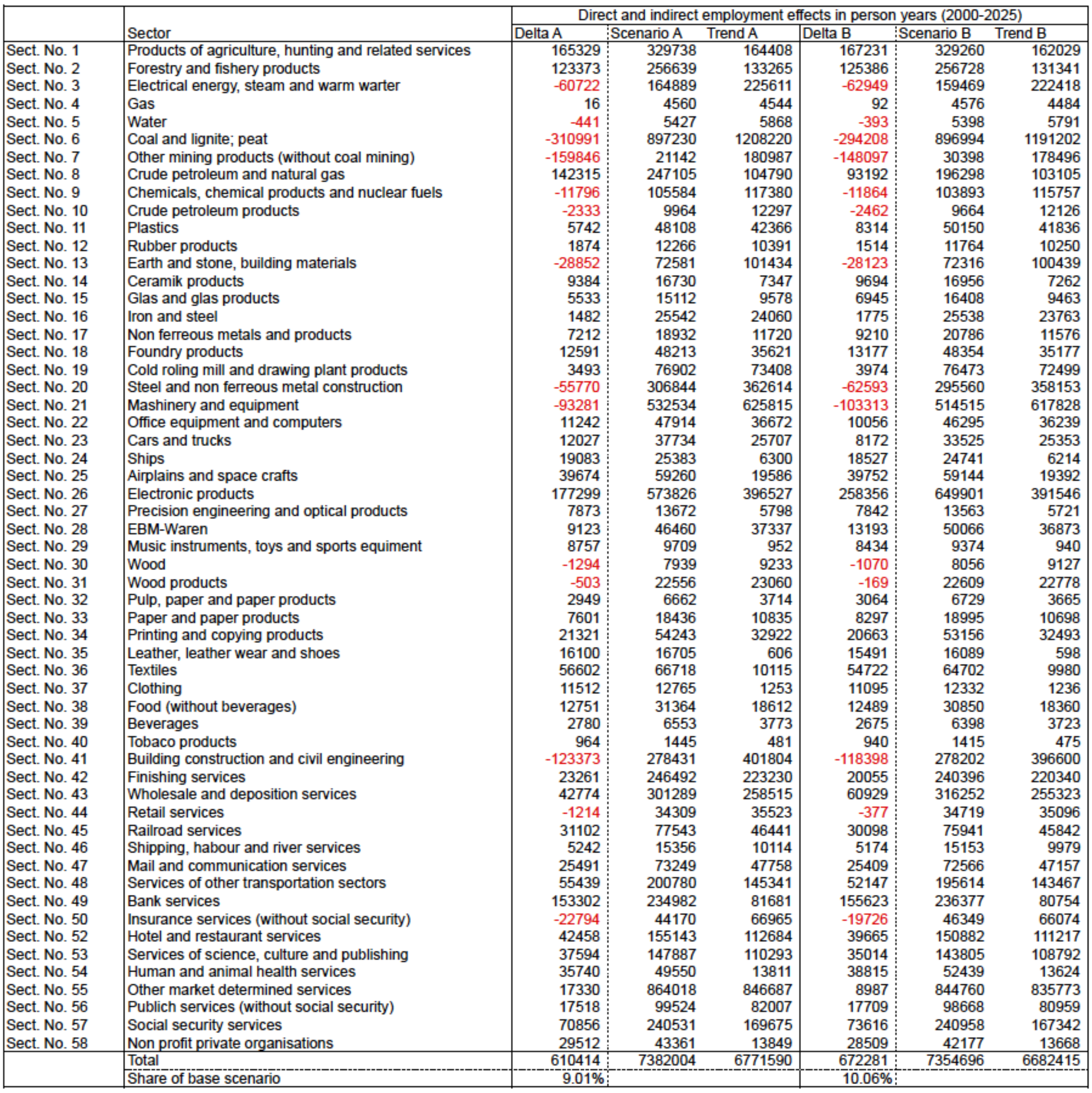


Figure 12: Development of gross employment through renewable energy in Germany from 2004 to 2013, ordered by technology sectors (Source: O'Sullivan et al. 2014, p. 12)

Therefore, in order to ensure the necessary transformation without any critical developments, rather dependable political conditions are required, which ascertain the needed pace of development without simultaneously causing a critical overheating and the subsequent collapse of the new markets.

However, the transformation that is needed will not just create new industries with increasing production and employment. It will also lead to a loss of turnover and employment in other industries, such as the coal and mineral oil industries. In a corresponding analysis of the net cumulative effects of an early withdrawal from nuclear energy and a concurrent securing of the German climate protection limits in Germany, Hohmeyer et al. (2000) have examined how many jobs would be lost in the sector of conventional energy production, while new jobs would be created in the sectors of renewable energy sources and energy conservation. Table 8 not only illustrates the direct, but also the indirect employment gains and losses in the different sectors of the German economy for two exit scenarios pertaining to a termination of the use of nuclear energy until 2010 (Scenario A and B) and a further trend scenario for an unlimited, continued operation of the nuclear stations existing in Germany in 2000. The “Delta” columns each show the cumulative employment gains and losses for the timeframe from 2000 until 2025 per sector in person years (in labour productivity of the year 1995). Overall, employment for the complete economy is 10 % higher for a fast withdrawal from nuclear energy than for a continued operation of the nuclear stations; however, 14 of 58 sectors also show employment losses.

Table 8: Direct and indirect employment effects of different energy scenarios with and without a withdrawal from nuclear energy until 2010 for the sectors of the German economy and a timeframe from 2000–2025 in person years (productivity of 1995, the base year of the utilized input-output table (Source: Hohmeyer et al. 2000, p. 58)



		Direct and indirect employment effects in person years (2000-2025)					
	Sector	Delta A	Scenario A	Trend A	Delta B	Scenario B	Trend B
Sect. No. 1	Products of agriculture, hunting and related services	165329	329738	164408	167231	329260	162029
Sect. No. 2	Forestry and fishery products	123373	256639	133265	125386	256728	131341
Sect. No. 3	Electrical energy, steam and warm warter	-60722	164889	225611	-62949	159469	222418
Sect. No. 4	Gas	16	4560	4544	92	4576	4484
Sect. No. 5	Water	-441	5427	5868	-393	5398	5791
Sect. No. 6	Coal and lignite; peat	-310991	897230	1208220	-294208	896994	1191202
Sect. No. 7	Other mining products (without coal mining)	-159846	21142	180987	-148097	30398	178496
Sect. No. 8	Crude petroleum and natural gas	142315	247105	104790	93192	196298	103105
Sect. No. 9	Chemicals, chemical products and nuclear fuels	-11796	105584	117380	-11864	103893	115757
Sect. No. 10	Crude petroleum products	-2333	9964	12297	-2462	9664	12126
Sect. No. 11	Plastics	5742	48108	42366	8314	50150	41836
Sect. No. 12	Rubber products	1874	12266	10391	1514	11764	10250
Sect. No. 13	Earth and stone, building materials	-28852	72581	101434	-28123	72316	100439
Sect. No. 14	Ceramik products	9384	16730	7347	9694	16956	7262
Sect. No. 15	Glas and glas products	5533	15112	9578	6945	16408	9463
Sect. No. 16	Iron and steel	1482	25542	24060	1775	25538	23763
Sect. No. 17	Non ferreous metals and products	7212	18932	11720	9210	20786	11576
Sect. No. 18	Foundry products	12591	48213	35621	13177	48354	35177
Sect. No. 19	Cold roling mill and drawing plant products	3493	76902	73408	3974	76473	72499
Sect. No. 20	Steel and non ferreous metal construction	-55770	306844	362614	-62593	295560	358153
Sect. No. 21	Mashinery and equipment	-93281	532534	625815	-103313	514515	617828
Sect. No. 22	Office equipment and computers	11242	47914	36672	10056	46295	36239
Sect. No. 23	Cars and trucks	12027	37734	25707	8172	33525	25353
Sect. No. 24	Ships	19083	25383	6300	18527	24741	6214
Sect. No. 25	Airplains and space crafts	39674	59260	19586	39752	59144	19392
Sect. No. 26	Electronic products	177299	573826	396527	258356	649901	391546
Sect. No. 27	Precision engineering and optical products	7873	13672	5798	7842	13563	5721
Sect. No. 28	EBM-Waren	9123	46460	37337	13193	50066	36873
Sect. No. 29	Music instruments, toys and sports equiment	8757	9709	952	8434	9374	940
Sect. No. 30	Wood	-1294	7939	9233	-1070	8056	9127
Sect. No. 31	Wood products	-503	22556	23060	-169	22609	22778
Sect. No. 32	Pulp, paper and paper products	2949	6662	3714	3064	6729	3665
Sect. No. 33	Paper and paper products	7601	18436	10835	8297	18995	10698
Sect. No. 34	Printing and copying products	21321	54243	32922	20663	53156	32493
Sect. No. 35	Leather, leather wear and shoes	16100	16705	606	15491	16089	598
Sect. No. 36	Textiles	56602	66718	10115	54722	64702	9980
Sect. No. 37	Clothing	11512	12765	1253	11095	12332	1236
Sect. No. 38	Food (without beverages)	12751	31364	18612	12489	30850	18360
Sect. No. 39	Beverages	2780	6553	3773	2675	6398	3723
Sect. No. 40	Tobaco products	964	1445	481	940	1415	475
Sect. No. 41	Building construction and civil engineering	-123373	278431	401804	-118398	278202	396600
Sect. No. 42	Finishing services	23261	246492	223230	20055	240396	220340
Sect. No. 43	Wholesale and deposition services	42774	301289	258515	60929	316252	255323
Sect. No. 44	Retail services	-1214	34309	35523	-377	34719	35096
Sect. No. 45	Railroad services	31102	77543	46441	30098	75941	45842
Sect. No. 46	Shipping, habour and river services	5242	15356	10114	5174	15153	9979
Sect. No. 47	Mail and communication services	25491	73249	47758	25409	72566	47157
Sect. No. 48	Services of other transportation sectors	55439	200780	145341	52147	195614	143467
Sect. No. 49	Bank services	153302	234982	81681	155623	236377	80754
Sect. No. 50	Insurance services (without social security)	-22794	44170	66965	-19726	46349	66074
Sect. No. 52	Hotel and restaurant services	42458	155143	112684	39665	150882	111217
Sect. No. 53	Services of science, culture and publishing	37594	147887	110293	35014	143805	108792
Sect. No. 54	Human and animal health services	35740	49550	13811	38815	52439	13624
Sect. No. 55	Other market determined services	17330	864018	846687	8987	844760	835773
Sect. No. 56	Publich services (without social security)	17518	99524	82007	17709	98668	80959
Sect. No. 57	Social security services	70856	240531	169675	73616	240958	167342
Sect. No. 58	Non profit private organisations	29512	43361	13849	28509	42177	13668
	Total	610414	7382004	6771590	672281	7354696	6682415
	Share of base scenario	9.01%			10.06%		

The example of scenario A in table 9 enables an understanding of how these diverse employment effects in the different sectors lead to changes in the demand for the respective energy technologies. Outstanding features here are the employment losses in the operation of nuclear and coal power stations on the one hand and, on the other hand, the employment gains from the building and operation of gas powered plants, wind, solar and bioenergy plants, as well as from investments into energy conservation technologies.

Table 9: Employment effects of the exit scenario A in comparison to the trend scenario with nuclear energy, in person years for the time frame from 2000–2025 (productivities of the year 1995) (Source: Hohmeyer et al. 2000, S. 55)

	Technology	Net effect	Scenario A	Trend scenario
Investment cost	Hard coal power plant	-107.707	0	107.707
	Lignite power plant	-67.678	0	67.678
	Natural gas power plant	109.165	171.745	62.580
	Run-of-the river hydro power	-128.782	53.010	181.792
	Wind turbines	297.138	394.364	97.226
	Solar PV plants	111.466	128.737	17.271
	Bio energy power plant	76.195	91.781	15.586
	Energy saving technology	627.538	627.538	0
Operation and maintenance costs ex fuel	Hard coal power plant	-192.192	500.457	692.648
	Lignite power plant	-223.217	455.941	679.159
	Oil fired power plant	2.590	8.874	6.284
	Natural gas power plant	183.574	314.686	131.111
	Nuclear power plant	-1.195.575	68.506	1.264.080
	Run-of-the river hydro power	-4.697	168.356	173.053
	Wind turbines	208.170	355.450	147.280
	Solar PV plants	3.393	4.129	736
	Bio energy power plant	71.957	133.209	61.252
Fuel cost	Hard coal	-57.037	479.957	536.994
	Lignite	-436.745	899.421	1.336.166
	Mineral oil	5.192	17.540	12.348
	Natural gas	472.795	810.155	337.359
	Nuclear fuels and nuclear waste deposition	-524.753	30.068	554.821
	Biomass	337.943	625.607	287.664
	Funding program for energy efficiency	39.149	39.149	0
	Additional consumption	1003.323	1003.323	0
	Total employment effect	611.204	7.381.999	6.770.795

The significant job losses in the sector of building and operating conventional power plants, as demonstrated by Hohmeyer et al. 2000 for an accelerated withdrawal from nuclear energy that meets climate protection goals, highlight that a corresponding transformation, which is recommended on an even larger scale by the Global Commission on the Economy and Climate (p. 8f), necessitates accompanying strategies for securing the employment in the sectors which are negatively affected.

In their study on an accelerated withdrawal from nuclear energy in Germany, Hohmeyer et al. (2000) have also pursued this issue and developed exemplary proposals for the operating staff of the nuclear power plants Stade, Biblis A and B, as well as Isar I and II (Hohmeyer et al. 2000, p. 70ff). These propositions strongly look towards establishing new production activity by the expanding sectors on the former site of the nuclear power plants, thus directly creating qualified opportunities for employment at these disadvantaged locations. In the case of the nuclear power plant Stade, a proposal was developed to build large components such as rotor blades, towers and foundations for offshore wind energy installations there (Hohmeyer et al. 2000, p. 84ff), since the location at the Lower Elbe provides very suitable conditions for these very large and heavy components. Even though these propositions had been strongly rejected by the political representatives of the municipality, after the decommissioning of the nuclear power plant Stade, the company Areva (formerly Multibrid) has subsequently located their rotor blade manufacture there, which today employs more persons than the decommissioned nuclear plant did.

Even if the necessary big transformation of the economy and energy production is inevitable for the protection of the climate and can ultimately result in a significant plus for employment and value creation, it needs to be planned and supported as early as possible, in order to avoid severe regional job losses in the energy or automotive industry without respective compensation. Timely planning and directing of the needed restructuring process, as well as clear and dependable political signals could minimize the negative effects of adapting and maximize the benefit of the transformation for the whole society.

If a corresponding policy design, which ensures a steady development of new industries and a conversion of the now unneeded economic activities, is successful, the needed transformation offers significant economic opportunities in the area of energy use and generation, as well as in the area of urban infrastructure and can, according to the assessment of the Global Commission on the Economy and Climate (p. 10), become the motor for sustainable and climate-friendly growth.

As the comparison of the development of the Global Gross National Product with and without climate protection in chapter 4 has demonstrated, decisive climate protection which can ensure meeting the two-degree limit is the best strategy to enable a maximum of sustainable growth in the decades to come.

6 Literature

European Commission (Hrsg.) (1995):
ExternE – Externalities of Energy. Volume 1: Summary. Compiled by ETSU, UK. EUR16520 EN. Luxemburg. Im Internet verfügbar unter: http://www.externe.info/externe_d7/sites/default/files/vol1c12.pdf

Global Commission on the Economy and Climate Change (2014):
Better Growth – Better Climate. The New Climate Economy Report. The Synthesis Report. Washington D.C. Downloaded on 2.10.2014 from: http://static.newclimateeconomy.report/TheNewClimateEconomyReport.pdf

Global Commission on the Economy and Climate Change (2014a):
Better Growth – Better Climate. The New Climate Economy Report. Energy. Washington D.C. Downloaded on 2.10.2014 from: http://static.newclimateeconomy.report/TheNewClimateEconomyReport.pdf

Hamilton, K., M. Brahmbhahatt und J.I. Korsbakken (2014):
Co-Benefits and Climate Action. New Climate Economy contributing paper. Stockholm Environmental Institute. Stockholm. To be available at: http://newclimateeconomy.report (cited according to: Global Commission on the Economy and Climate).

Hohmeyer, Olav und Michael Gärtner (1992):
The Costs of Climate Change. Report to the Commission of the European Communities. Fraunhofer-Institut für Systemtechnik und Innovationsforschung. Karlsruhe

Hohmeyer, Olav, Roland Menges und Anton Schweiger (2000):
Arbeitsplatzeffekte einer integrierten Strategie für Klimaschutz und Atomausstieg in Deutschland. Untersuchung im Auftrag von Greenpeace Deutschland. Universität Flensburg, Flensburg

Hohmeyer, Olav (2005):
Die Abschätzung der Kosten des anthropogenen Treibhauseffekts – Dominieren normative Setzungen die Ergebnisse? In: *Vierteljahreshefte zur Wirtschaftsforschung*, 74(2005), 2, S. 164-168

IPCC (Intergovernmental Panel on Climate Change) (1996):
Climate Change 1995 – Economic and Social Dimensions of Climate Change. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. [J.P. Bruce, H. Lee, E.F. Haites (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (Intergovernmental Panel on Climate Change) (2001):
Climate Change 2001: Mitigation. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, R. Swart, J. Pan], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Downloaded on 10.3.2012 from: http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg3/index.htm

IPCC (Intergovernmental Panel on Climate Change) (2007):
Summary for Policymakers. In: *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds.)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Downloaded on 10.3.2012 from: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-spm.pdf

IPCC (Intergovernmental Panel on Climate Change) (2013):
Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)].

Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp. Downloaded on 15.2.2014 from: http://www.climatechange2013.org/images/report/WG1AR5_Frontmatter_FINAL.pdf

IPCC (Intergovernmental Panel on Climate Change) (2014):
Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, XXX pp. Downloaded on 30.12.2014 from: http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-PartA_FINAL.pdf

IPCC (Intergovernmental Panel on Climate Change) (2014a):
Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Downloaded on 30.12.2014 from: http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_full.pdf

Kuik, O., L. Brander und R.S.J. Tol (2009):
Marginal Abatement Costs of Greenhouse Gas Emissions. A Meta-Analysis. *Energy Policy* 37, S. 1395-1403

Nestle, Ingrid (2010):
The Cost of Climate Change in the Agricultural Sector – A Comparison of Two Calcualating Approaches. Doktorarbeit an der Universität Flensburg. Flensburg

O'Sullivan, Marlene, Dietmar Edler, Peter Bickel, Ulrike Lehr, Frank Peter und Fabian Sakowski (2014):
Gross employment from renewable energy in Germany 2013 – a first estimate. Downloaded on 30.3.2015 from:
http://www.bmwi.de/BMWi/Redaktion/PDF/B/bericht-zur-bruttobeschaeftigung-durch-erneuerbare-energien-jahr-2013,property%3Dpdf,bereich%3Dbmwi2012,sprache%3Dde,rwb%3Dtrue.pdf

Rabl, Ari (1999):
Discounting of Long Term Costs: What Would Future Generations Prefer Us to Do? In: Olav Hohmeyer und Klaus Rennings (Hrsg.): Man-Made Climate Change. Economic Aspects and Policy Options. Heidelberg

Umweltbundesamt (UBA) (2007):
Ökonomische Bewertung von Umweltschäden – Methodenkonvention zur Schätzung externer Umweltkosten. Berlin

Umweltbundesamt (UBA) (2012):
Ökonomische Bewertung von Umweltschäden – Methodenkonvention 2.0 zur Schätzung von Umweltkosten. Berlin

Umweltbundesamt (UBA) (Hrsg.) (2014):
Best-Practice Kostenansätze für Luftschadstoffe, Verkehr, Strom- und Wärmeerzeugung. Anhang B der „Methodenkonvention 2.0 zur Schätzung von Umweltkosten“. Autoren: Sylvia Schwermer, Phillip Pries und Wolf Müller. Berlin (ursprüngliche Fassung 2012), Aktualisierte Fassung vom Februar 2014

United Nations (UN) (2014):
The Universal Declaration of Human Rights. Full Text. Downloaded on 2.1.2015 from: http://www.un.org/en/documents/udhr/index.shtml

WBGU (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen) (2011):
Welt im Wandel – Gesellschaftsvertrag für eine große Transformation. Hauptgutachten. Berlin 2011

WBGU (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen) (2014):
Klimaschutz als Weltbürgerbewegung. Sondergutachten. Berlin 2014

Wille, V. und R. Friedrich (2012):
Sachstandspapier zu Treibhausgase und Klimawandel. Sachstandspapier im Rahmen des Vorhabens „Schätzung Externer Umweltkosten und Vorschläge zur Kosteninternalisierung in ausgewählten Politikfeldern“. Umweltbundesamt, Forschungsprojekte FKZ 3708 14 101, Institut für Energiewirtschaft und Rationelle Energieanwendung, Universität Stuttgart

Wirtschaftskammer Österreich (2014):
Wechselkurs: EUR (bis 1998: ATS) je Dollar. Downloaded on 15.9.2014 from: http://wko.at/statistik/widat/wechselkurs.pdf

World Bank (2014):
World Development Indicators Database. 1 July 2011. Gross domestic product 2010. Downloaded on 15.9.2014 from: siteresources.worldbank.org

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