METHODOLOGY NOTE

METHODOLOGICAL DOCUMENTATION FOR THE CLIMATE VULNERABILITY MONITOR

2nd Edition

This documentation will be subject to flagged updates in particular if it is deemed useful following comments received and as proves feasible within the scope of the document.

This documentation is available online at: www.daraint.org/cvm2/method

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CONTENTS

TABLE OF CONTENTS

1 INTRODUCTION

THE METHODOLOGY NOTE

This methodological documentation provides an explanation of how the quantitative architecture of the *Climate Vulnerability Monitor* has been developed with detailed descriptions of each indicator relied upon and the aggregation and integration steps taken to create a common framework of analysis.

THE NEW MONITOR

GENERAL STRUCTURE OF NEW MONITOR

The *Climate Vulnerability Monitor* (or "the Monitor") in its 2nd edition is based on a quantitative framework comprised of two key parts as follows:

1. *Part I:* A "Climate"*, meaning Climate Change, impact/vulnerability assessment including 22 indicators across four Impact Areas (Environmental Disasters, Habitat Change, Health Impact, Industry Stress) measuring the positive and negative effects of climate change as they are experienced by 184 countries worldwide in socio-economic terms, in particular for the timeframes of 2010 and 2030. Part I/Climate relates to adaptation to climate change in that effective adaptation strategies and policies could target the minimization of the impacts/vulnerabilities assessed here.

2. *Part II:* A "Carbon"*, meaning carbon economy-related, impact/vulnerability assessment including 12 indicators across the same four Impact Areas measuring the positive and negative effects of carbon-intensive energy reliance as experienced by countries worldwide in particular for 2010 and 2030. Part II/Carbon relates to mitigation of climate change in that the impacts/vulnerabilities assessed here potentially represent co-benefits of different mitigation policies.

The Monitor has also been informed by two country studies, undertaken in Ghana and Vietnam, supported by hundreds of interviews in groups or individual settings, and national level workshops of key policy-makers. The Monitor additionally includes a review of international climate change financing, as well as analysis of allocations versus potential mitigation and adaptation co-benefits.

*See also the "Key Concepts and Definitions" and "Methodology" sections of the 2nd Monitor report itself.

BASIC APPROACH

The Monitor aggregates together an internationally comparable and global picture of the current impact of climate change and the carbon economy as can be implied by current science and research. The chosen methodology that is the basis of the analysis of the Monitor's second edition is described in detail here. Different methodologies would generate different results and reach different conclusions, just as the 2010 Monitor, with another methodology, differs from the latest version of the report in some of these respects.

In effect, the Monitor seeks less to impose its own methodology, then to create and serve as a type of linguistic framework for the latest leading scientific work and research on the impact of climate change/carbon-intensive practices to speak the same language. This methodology note is in many ways a log of what has not been done to the underlying research and data, exclusively drawn from recognized/authoritative external sources, very predominantly from peer-reviewed scientific literature. Where transformations have taken place efforts have been made to use simple adjustments, mainly in order to extrapolate effects from one or a limited number of localities to other areas with similar hazard exposures and varying vulnerabilities – where research is more advanced, less interventions are made, and vice versa. Adjustments are also made in places to combine separate bodies of research within one indicator.

All of the key papers/research documents relied upon for each indicator are referenced in this methodology note. It is worth mention that a significant proportion of the research relied upon has only been made available since development of the first Monitor began in 2010, which underscores the pace at which this field of study is now evolving.

COUNTERFACTUAL ANALYSIS

When combing the full array of information the Monitor is each time attempting to measure the difference between a scenario with/without climate change (or the carbon economy), meaning, for instance, how many less (or more) lives would be lost in a given year, and how much wealthier (or poorer) would economies be, if there had not been climate change (or the carbon economy), which is "the counterfactual". Independent research is piece-by-piece measuring some aspect of this difference - research the Monitor brings onto the same plane of interpretation. This analysis is notwithstanding cost-benefit/net benefit analysis of carbon-intensive versus low-carbon economic systems (i.e. the costs of mitigation), which is covered in the actual second edition Monitor report itself.

MONITOR OUTPUTS: IMPACTS AND VULNERABILITY LEVELS

The Monitor's data outputs are given both as levels of vulnerability and as estimates of the levels of absolute (i.e. dollar gain) and/or relative (i.e. percentage loss of GDP) loss or gain – termed "impact" – implied by today's (2010) or tomorrow's (2030) situation, which is a scenario *with* climate change (N.B. information has also been compiled for the year 2000, however this data does not figure in the final report). With respect to vulnerability, the level of impact is deemed indicative of the level of vulnerability. Meaning, where impacts are more significant in relative terms (i.e. in relation to the size of the economy or population), vulnerability is taken to be higher. The approach has been termed "outcome vulnerability", since it is the outcome of the vulnerability – the degree/absence of harm incurred – that is the indicator of the level of vulnerability present in the first place. Higher levels of impact are estimated, for instance, to have resulted from higher levels of vulnerability, and vice versa, low levels of impact and vulnerability go hand in hand. The Monitor expresses these vulnerability levels in five categories, which are statistically determined using a (mean absolute) standard deviation approach, as follows:

- Acute (most vulnerable category)
- Severe
- High
- Moderate
- Low (least vulnerable category)

Countries with a level of vulnerability of "Low" are most likely experiencing nil impact or benefits to some degree due to climate change. However, the purpose of the Monitor is not to pinpoint the level of benefits since the policy response is generally less relevant. Although, the Monitor does provide indications of the level of benefits in the outputted impact estimate data together with net results taking into account global gains and losses.

For the purpose of the Monitor and the indexes that the Monitor relies on, all impact estimates of gain or loss are measured only in mortality or share of GDP, so as to capture a comparable social or economic impact across wide-ranging countries. Equating all outputs to similar units means that diverse environmental phenomenon must be quantified in human terms or in economic terms, inside or outside the market, including for example, biodiversity, water resources and desertification – methodologies for translating these effects into economic data are drawn from relevant research or compiled and proposed where specific studies have not yet addressed the matter. GDP losses are 2010 USD PPP, although for 2030 losses these are additionally determined in relation to future expected economic development (but are not inflation adjusted for true 2030 dollars). Likewise, for mortality, the 2030 figures take into account projected population growth. All modeled data outputs in the Monitor in economic or other terms are rounded using a basic graded rounding protocol, which may be adapted for key sections.

THEMATIC AND INDEX-BASED FRAMEWORK

Each Part of the Monitor is constructed as a compilation of many different indicators that are each grouped under four themes per Part, termed Impact Areas, above all for ease of comprehension. The different impact areas are as follows:

Part I/"Climate" -

- Habitat Change – which measure the effects of climate change on aspects of human and ecological habitats and the economic gains and losses of these
- Health Impact – which measures the effects of climate change on human health and the social (i.e. mortality) and economic gains and losses of this
- Industry Stress – which measures the effects of climate change on specific industry sectors of the economy, and the economic gains and losses of these
- Environmental Disasters – which measures the effects of climate change on one-off, punctual or geographically restricted extreme weather events, and the direct economic and social gains and losses of these

Part II/"Carbon" -

- Environmental Disasters – which measures the effects of location or type specific environmental damage incidents and the economic gains/losses of these
- Habitat Change – which measures the effects of the carbon economy for aspects of human and ecological habitats and the economic gains/losses of these
- Health Impact – which measures the effects of the carbon economy on human health and the social and economic gains/losses of this
- Industry Stress – which measures the effects of the carbon economy on specific industry sectors of the economy, and the economic gains/losses of these

A series of indexes form the mathematical backbone of the statistical language that the Monitor uses in order to translate the implications of varied research in social or economic terms and aggregate or enumerate that information together. The indexes are presented in the Monitor is different ways: an overall index aggregating Part I and Part II; an aggregate index for Part I, and likewise for Part II; aggregate sub-indexes for the different impact areas (Habitat Change, etc.) which combine the indicators for each; and at the indicator level, single indexes for each group of effects form the foundation of the statistical architecture upon which the rest is built. Every category and indicator represents distinct climate impacts without overlap (or only statistically insignificant/marginal overlap).

SPECIFIC APPROACH TO CLIMATE CHANGE

The Monitor takes a moderate precautionary approach to climate change and the effects of the carbon economy. As described in the relevant section below, mid to high range emission scenarios are chosen by default where possible. Likewise, means of estimates for impact/effects are taken where ranges are provided through research. This means a degree of under-counting as well as over-counting is possible versus what could be the reality of the situation. Despite its comprehensiveness, by no means are all of the effects of climate change/the carbon economy taken into account, mainly due to the limitations of current research that any indicator in the Monitor must reflect.

The Monitor relies where feasible on empirical studies that observe as directly as possible the consequences of primary changes in the climate (such as temperature or rainfall change) on secondary phenomenon. Examples include the World Health Organization's research into the implications of temperature and other climate-related variables as they react at the pathogen level of diseases, which has also been counter-verified in cases like diarrhea against information of disease prevalence versus climate parameters – i.e. hospital admittance rates during high temperatures episodes (McMicheal et al., 2004). However, in many cases, direct empirical evidence of effects on a global level is not possible. In these cases, the Monitor instead relies on a clear physical process and relationship for which there is both observational evidence and independent modeled agreement rather than on inconclusive and deficient instrumental records directly measuring the precise phenomenon of interest.

INDEX ARCHITECTURE

The aggregate index each for Part I (Climate) and Part II (Carbon) of the Monitor comprises four sub-indices, each made up by a number of indicators.

A country's sub-index scores are summarized in to an aggregate index score, which indicates the overall impact of climate change.

The structure of the Indexes for Part I and Part II are described in the tables below.

PART I: "CLIMATE" INDEX

Aggregation of indicators to overall index

OVERALL INDEX	SUB-INDEX	INDICATORS
AGGREGATION OF SUB-INDEXES	Habitat Change	• Biodiversity • Desertification • Heating and Cooling • Labour Productivity • Permafrost • Sea-level Rise • Water

	Health Impact	• Diarrheal Infections • Heat & Cold Illnesses • Hunger • Malaria & Vector-borne • Meningitis
	Industry Stress	• Agriculture • Fisheries • Forestry • Hydro Energy • Tourism • Transport
	Environmental Disasters	• Floods and landslides • Storms • Wildfires • Drought

PART II: "CARBON" INDEX

Aggregation of indicators to overall index

OVERALL INDEX	SUB-INDEX	INDICATORS
AGGREGATION OF SUB-INDEXES	Environmental Disasters	• Oil Sands • Oil Spills
	Habitat Change	• Biodiversity • Corrosion • Water
	Health Impact	• Agriculture • Air Pollution • Indoor Smoke • Occupational Hazards
	Industry Stress	• Agriculture • Fisheries • Forestry

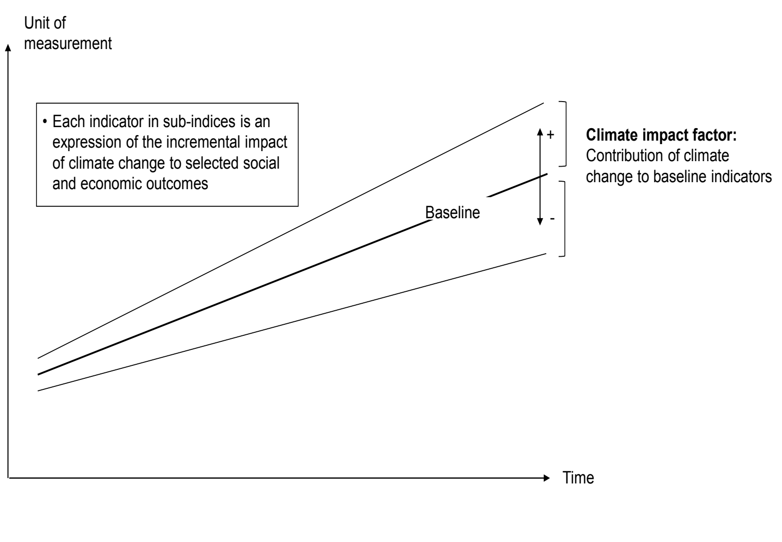
"CLIMATE/CARBON EFFECT", "CLIMATE/CARBON IMPACT FACTOR"/"ATTRIBUTABLE FRACTION", AND CLIMATE SCENARIO

The Monitor measures the impact of climate change or the carbon economy through socio-economic indicators based on a climate/carbon effect (CE).

The Monitor assesses the CE in two ways as determined by the nature of the source information:

1) By attributing, for Part I/Climate, a "climate impact factor" (CIF) or, for Part II/Carbon, an "attributable fraction" (AF)/"carbon impact factor" (also CIF) to baseline data derived from third-party research/scientific literature (see Figure 3 Below);
2) By using existing complex models that calculate the CE.

Figure 3: Contribution of climate impact factors to social/economic indicators



Source: DARA analysis

Indicators measure the effects of climate change/carbon economy on social and economic variables at the country level. This CE is calculated based on observed values of social and economic variables and the effects of climate change/carbon economy.

The extent to which climate change/the carbon economy contributes to the development of a given variable is expressed as a climate impact factor (CIF) or attributable fraction (AF). An indicator's CE is calculated as follows:

$$CE = CIF \times variable$$

$$CE = AF \times variable$$

Variables are expressed in proportional terms to compare scores between countries: per GDP or per capita.

The other approach to indexing the CE is using existing models such as the model used in the index for Sea Level Rise:

Dynamic Interactive Vulnerability Assessment (DIVA), which estimates economic losses due to sea-level rise, directing generating the equivalent of CE as estimative outputs. Given the authority enjoyed by this particular complex model in its field, its outputs are preserved as they are generated and are directly integrated into the index scoring system.

In general, the various climate change models the Monitor uses have a starting point (base period) with single point or mean around the year 1990 (+/- 10 years). Where applicable/possible, medium-range climate scenarios have been chosen for each indicator to calculate projections, except for in the sea-level rise indicator, where a high-emission scenario. This is because recent research-based observations suggest that the high scenario is likely the most appropriate for sea-level rise projections.

INDEX SCORING

Key purposes of an index in this context are deemed to include:

- Drawing attention to departures from average behaviour
- Enabling comparison between countries
- Monitoring of variable evolution over time

Constructing an index score based on a cross-section of univariate measures requires the choice of a transformation. In the context of monitoring climate-related impact, the transformation is expected to balance the following goals:

- Preservation of the shape of the original distribution
- Unit-free measure
- Similarity of scale across indices
- Robustness, in the sense that a few extreme observations must not hide changes in remaining observations

The dispersion measure used was chosen based on the following criteria:

- An affine transformation that preserves the shape of the original distribution
- Given a measure of dispersion expressed in units of the original distribution, if the measure is used as a normalizing factor, the resulting score is both unit-free and similar with respect to scale across indices
- Robust dispersion measures such as mean absolute deviation or median absolute deviation are preferable, since they are somewhat insensitive to extreme observations. Mean absolute deviation (MAD) is the specific choice for dispersion measure, since it weighs in extreme observations to some degree, while median absolute deviation does not

The index scores are constructed so that a CE of 100 indicates a neutral climate/carbon effect (CIF=0; AF=0), while values above 100 indicate a negative climate/carbon effect, and values below 100 indicate a net gain from the impact of climate change/carbon economy.

On the sub-index level, the countries have received an index score between 50 and c.500. Data is standardized using the following formula:

Index score = ((SUM ($CE_{t,i}$))/(10xMAD (SUM(CE_{2010}))+1)x100

Where variable is an indicator representing each country (i) at t=2000, 2010, 2030.

In sub-indices, variations in data are collapsed by dividing with 10*MAD. By adding 1 and finally multiplying by 100, a neutral or zero climate effect is expressed by 100 while values above 100 express a negative effect of climate change. The MAD is kept at a constant 2010 level to allow for variations over time.

The countries are categorized in bands made in steps of ½*MAD from 100. The construction of the scoring means that one MAD of the 2010 score equals 10, resulting in the category bands listed below:

- Below 100 = Low (reflecting positive impact of climate change)
- 100-104.99 (1/2*MAD from 100) = Moderate
- 105-109.99 = High -
- 110-114.99 = High +
- 115-119.99 = Severe -
- 120-124.99 = Severe +
- 125-129.99 = Acute -
- 130 and above = Acute +

While comparatively Low is almost indefinite, ranging from an index score of 100 to 50. Moderate as a category has a narrower range than the other vulnerability levels given, equivalent to one half level of that for High, Severe and Acute. This is because statistically for most indicators for 2010 a majority of countries is located within the Moderate band or just below it (in Low), whereas in other half bands, there are generally far less countries. So in order not to have too many category names, the bandwidth is doubled with +or– given on occasion to indicate in which half category a country scored.

This construction method also enables an intuitive comparison between index scores Past (2000), Now (2010) and in the Near Term (2030).

AGGREGATE/MULTI-DIMENSIONAL INDEX SCORING

The purpose of the aggregate index scoring – referred to a "Multi-Dimensional Vulnerability" - is to:

- Reflect countries highly impacted in one or more of the of the sub-indices
- Ensure that outliers in one of the sub-indices are not reflected disproportionally in the overall index

To achieve this scoring each category band on each sub-index is given a number:

- Below 100 = 1
- 100-104.99 = 2
- 105-109.99 = 3
- 110-114.99 = 4
- 115-119.99 = 5
- 120-124.99 = 6
- 125-129.99 = 7
- 130-134.99 = 8
- 135 and above = 9

The countries' average score on the sub-indices is calculated either for economic or mortality values only, but not combined, as follows e.g.:

Part I/II Aggregate Index = Sub-Indices Mean (Health Impact + Environmental Disasters + Habitat Change + Industry Stress)

The countries are categorized by final score using the legend below (corresponding to half sub-index category scores):

CATEGORIZATION

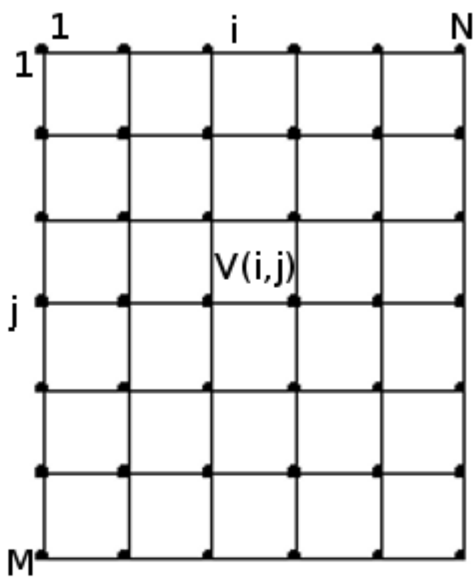
By category scores

CATEGORY	LOW	HIGH
ACUTE	>5	
SEVERE	>4	<=5
HIGH	>3	<=4
MODERATE	>2	<=3
LOW		<=2

Other aggregates are provided for total deaths (mortality) and total costs (economic) for both Part I/Climate and Part II/Carbon as well as overall/combined (climate+carbon).

GEOGRAPHIC CALCULATIONS

For many of the indexes, the data format, "ASCII grid", has been used to read and manipulate the data.



The figure above shows a schematic representation of the data structure.
V(i,j) represents the value of the variable in the cell (i,j); $1 \le i \le N$ is the longitude and $1 \le j \le M$ is the latitude.
In general, the great majority of the data used has a resolution ranging from 0.5 to 5.0 degrees.
It is therefore possible to say that for a typical resolution of 0.5° X 0.5° the matrix has a size of (720,360).

In some cases, several matrices were combined in order to obtain the value of a particular variable in a specific field.

When the resolution of the data sources was different, a simple standardization process was applied, which downscaled all the grids to the one with the highest resolution keeping constant the value of the variable in the previous domain. A similar process was used if the grid files had different mapping origins.

To obtain the values of a variable in a specific country, a grid map with a resolution of 0.5° was used, and every cell has a particular value associated with the country included.
Therefore:

$$\text{Value}(\text{country\_k}) = A(V(i,j)) \text{ where } \text{Map}(i,j)=k$$

where A is a generic operator and Map the countries data matrix.

It is clear that this technique has different advantages that avoid projection problems and simplify the entire algorithm.
However, the overall resolution changes in function of the latitude in the following way:

$$S=(\pi/180) \times R^2 \times |\sin(lat1)-\sin(lat2)| \times |lon1-lon2|$$

where S is the surface between two defined latitudes and longitudes (lat1,lat2 and lon1,lon2) on a sphere.

The major challenge associated with this approach is to model realistically countries with a size smaller than the grid cell that at the equator measure approximately 3000 Km^2. To avoid possible overestimations, a regional mean has been calculated and applied to the country's actual surface.

COUNTRIES INCLUDED AND SPATIAL SCALE

The index is calculated for 184 countries given the global focus and due to the upper limits of data availability for small numbers of countries, particularly Small Island Developing States (SIDSs) that have not met the minimum requirements for data. Since its main objective is to enable comparisons between nations and sub-regions, it measures vulnerability at the national level. Assessment of vulnerability at the sub-national and local level is beyond the scope of this report aside from conclusions of the field research and national workshops undertaken as a part of the Country Studies for the Monitor.

Countries are divided into 21 regions for presentation purposes. These sub-regions provide the basis for extrapolations of data when countries – habitually small island developing states with populations below 250,000 people – do not have adequate information to generate endogenous results. For instance, if no results are able to be obtained for Marshall Islands, Marshall Islands is attributed a GDP or Population scaled regional mean from all Pacific countries.

REGIONS & COUNTRIES

List of countries by Monitor sub-region

REGION	COUNTRY
AUSTRALASIA	Australia, New Zealand
CARIBBEAN	Antigua and Barbuda, Bahamas, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, Saint Lucia, Saint Vincent, Trinidad and

REGION	COUNTRY
	Tobago
CENTRAL AFRICA	Angola, Cameroon, Central African Republic, Chad, Congo, DR Congo, Equatorial Guinea, Gabon, Sao Tome and Principe
CENTRAL AMERICA	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama
CENTRAL ASIA	Afghanistan, Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
EAST AFRICA	Burundi, Comoros, Djibouti, Ethiopia, Eritrea, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Seychelles, Somalia, Sudan/South Sudan, Tanzania, Uganda, Zambia, Zimbabwe
EAST ASIA	China, Japan, North Korea, South Korea
EASTERN EUROPE	Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, Slovakia, Ukraine
MIDDLE EAST	Bahrain, Cyprus, Iraq, Iran, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, Yemen
NORTH AFRICA	Algeria, Egypt, Libya, Morocco, Tunisia
NORTH AMERICA	Canada, United States
NORTHERN EUROPE	Denmark, Finland, Iceland, Ireland, Norway, Sweden, United Kingdom
PACIFIC	Fiji, Kiribati, Marshall Islands, Micronesia, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu
RUSSIA/NORTH ASIA	Mongolia, Russia
SOUTH AMERICA	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela
SOUTH ASIA	Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka
SOUTHEAST ASIA	Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, Vietnam
SOUTHERN AFRICA	Botswana, Lesotho, Namibia, South Africa, Swaziland
SOUTHERN EUROPE	Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Macedonia, Malta, Portugal, Slovenia, Spain
WEST AFRICA	Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo
CENTRAL EUROPE	Austria, Belgium, France, Germany, Luxembourg, Netherlands, Switzerland

Some 20 countries are regularly attributed sub-regional means for either climate or socio-economic indicator, in order to ensure a wider indication of effects for countries that would otherwise not be able to manifest results. These countries are as follows:

Cuba	Palau
Dominica	Papua New Guinea
Dominican Republic	Saint Lucia
Fiji	Saint Vincent
Grenada	Samoa
Haiti	Solomon Islands
Jamaica	Tonga
Kiribati	Trinidad and Tobago
Marshall Islands	Tuvalu
Micronesia	Vanuatu

The information in the report is presented throughout for four key country groups, called emission groups, based on the United Nations Framework Convention on Climate Change (UNFCCC) and on the emission levels of countries. These four groups are as follows in the table below. “Developed” countries are the Annex II state parties to the UNFCCC. “Other Industrialized” countries are the remainder of the Annex I state parties to the UNFCCC. “Developing countries”, all non-Annex I/II countries, are divided into two categories based on their mean per capita emissions in 2005 for all Kyoto Protocol greenhouse gas emissions including for land use change and forestry (LULUCF). The threshold is set at 4 tons per capita of CO2 equivalent, which broadly implies that countries below this threshold may not need to take (any/extensive) mitigation measures in order to achieve an equitable average of per capita emissions level by 2020 congruent with achieving the international temperature rise goal of 2.0 degrees Celsius.

EMISSION GROUPS

List of countries by main Monitor emission groups

GROUP	COUNTRY
DEVELOPED (ANNEX II)	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States
OTHER INDUSTRIALIZED (ANNEX I OUTSIDE OF ANNEX II)	Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Russia, Slovakia, Slovenia, Turkey, Ukraine
DEVELOPING COUNTRY HIGH EMITTERS (NON-ANNEX I ABOVE 4 TONS CO2E 2005)	Algeria, Antigua and Barbuda, Argentina, Azerbaijan, Bahamas, Bahrain, Belize, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei, Bulgaria, Cambodia, Central African Republic, Chile, China, Congo, Cote d’Ivoire, Cyprus, DR Congo, Equatorial Guinea, Gabon, Grenada, Guatemala, Guinea, Guyana, Indonesia, Iran, Iraq, Israel, Kazakhstan, Kuwait, Laos, Libya, Macedonia, Malaysia, Mexico, Mongolia, Myanmar, Namibia, North Korea, Oman, Papua New Guinea, Paraguay, Qatar, Saudi Arabia, Seychelles, Singapore, Solomon Islands, South Africa, South Korea, Suriname, Thailand, Trinidad and Tobago, Turkmenistan, United Arab Emirates, Uruguay, Uzbekistan, Venezuela, Zambia

GROUP	COUNTRY
DEVELOPING COUNTRY LOW-EMITTERS (NON-ANNEX I BELOW 4 TONS CO2E 2005)	Afghanistan, Albania, Angola, Armenia, Bangladesh, Barbados, Benin, Bhutan, Burkina Faso, Burundi, Cape Verde, Chad, Colombia, Comoros, Costa Rica, Cuba, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Eritrea, Ethiopia, Fiji, Gambia, Georgia, Ghana, Guinea-Bissau, Haiti, Honduras, India, Jamaica, Jordan, Kenya, Kiribati, Kyrgyzstan, Lebanon, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Marshall Islands, Mauritania, Mauritius, Micronesia, Moldova, Morocco, Mozambique, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Palau, Panama, Peru, Philippines, Rwanda, Saint Lucia, Saint Vincent, Samoa, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, Sri Lanka, Sudan/South Sudan, Swaziland, Syria, Tajikistan, Tanzania, Timor-Leste, Togo, Tonga, Tunisia, Tuvalu, Uganda, Vanuatu, Vietnam, Yemen, Zimbabwe

The report also makes use of a variety of socio-economic groupings as in the below table.

SOCIOECONOMIC GROUPS

List of countries by main Monitor socio-economic groups

GROUP	COUNTRY
LANDLOCKED LEAST DEVELOPED COUNTRIES (LLDC)	Afghanistan, Armenia, Azerbaijan, Bhutan, Bolivia, Botswana, Burkina Faso, Burundi, Central African Republic, Chad, Ethiopia, Kazakhstan, Kyrgyzstan, Laos, Lesotho, Macedonia, Malawi, Mali, Moldova, Mongolia, Nepal, Niger, Paraguay, Rwanda, Swaziland, Tajikistan, Turkmenistan, Uganda, Uzbekistan, Zambia, Zimbabwe,
SMALL ISLAND DEVELOPING STATES (SIDS)	Antigua and Barbuda, Bahamas, Bahrein, Barbados, Belize, Cape Verde, Comoros, Cuba, Dominica, Dominican Republic, Fiji, Grenada, Guinea-Bissau, Guyana, Haiti, Jamaica, Kiribati, Maldives, Marshall Islands, Mauritius, Micronesia, Palau, Papua New Guinea, Saint Lucia, Saint Vincent, Samoa, Sao Tome and Principe, Seychelles, Singapore, Solomon Islands, Suriname, Timor-Leste, Tonga, Trinidad and Tobago, Tuvalu, Vanuatu
INDUSTRIALIZED COUNTRIES (ANNEX I)	Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Russia, Slovakia, Slovenia, Turkey, Ukraine,
DEVELOPED COUNTRIES	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, South Korea, Spain, Sweden, Switzerland, United Kingdom, United States
HIGH-GROWTH EMERGING COUNTRIES	Bangladesh, Brazil, China, Egypt, India, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Russia, South Korea, Turkey, Vietnam
DEVELOPING	Afghanistan, Albania, Algeria, Angola, Antigua and Barbuda, Argentina,

GROUP	COUNTRY
COUNTRIES	Armenia, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Cape Verde, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo, Costa Rica, Cote d'Ivoire, Cuba, Cyprus, Djibouti, Dominica, Dominican Republic, DR Congo, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Ethiopia, Fiji, Gabon, Gambia, Georgia, Ghana, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, India, Indonesia, Iran, Iraq, Israel, Jamaica, Jordan, Kazakhstan, Kenya, Kiribati, Kuwait, Kyrgyzstan, Laos, Lebanon, Lesotho, Liberia, Libyan Arab Jamahiriya, Madagascar, Malawi, Malaysia, Maldives, Mali, Marshall Islands, Mauritania, Mauritius, Mexico, Micronesia, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Nicaragua, Niger, Nigeria, North Korea, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Qatar, Rwanda, Saint Lucia, Saint Vincent, Samoa, Sao Tome and Principe, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Singapore, Solomon Islands, Somalia, South Africa, Sri Lanka, Sudan/South Sudan, Suriname, Swaziland, Syria, Tajikistan, Tanzania, Thailand, Timor-Leste, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkmenistan, Tuvalu, Uganda, United Arab Emirates, Uruguay, Uzbekistan, Vanuatu, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe

MULTI-DIMENSIONAL CAPACITY

Countries may experience different levels of impact/vulnerability that are independent of the level of capacity to respond to these impacts/vulnerabilities. Therefore, the Monitor provides additional information with respect to national capacity and/or capabilities to address climate change issues. This information is formulated as a four tier/category "Multi-Dimensional Capacity" assessment.

The calculation of capacity categories follows a three-step procedure as follows:

Step 1: Calculating the simple (arithmetic) average of three complementary capacity indices

- Government Effectiveness (World Bank)*
- Infrastructure (Pillar in Global Innovation Index)
- Human Capital (Pillar in Global Innovation Index)

*Government Effectiveness (World Bank) is comprised of the following sub-indicators:

- Voice and Accountability
- Political Stability and Absence of Violence
- Government Effectiveness
- Regulatory Quality
- Rule of Law
- Control of Corruption

The three indices all range from 0-100, with capacity increasing in the index score; i.e. the higher the score the higher the capacity.

Step 2: Weighing the average by

- Population (UN population)
- National income (GNI per capita, UN DESA)

The weights run through 0.50, 0.75, 1.00 and 1.25, where 0.50 represents the lowest quartile and 1.25 represents the highest quartile.

The rationale is that countries with larger populations and national income have a greater capacity to mobilize a response to climatic challenges.

Step 3: Categorizing by quartiles

The numerical capacity index is sorted and capacity categories are assigned according to quartiles.

- Extensive capacity (3rd to 4th)
- Intermediary capacity (2nd to 3rd)
- Restricted capacity (1st to 2nd)
- Highly restricted capacity (- 1st)

CONFIDENCE/AGREEMENT/UNCERTAINTY

The Monitor presents a range of information relating to the confidence of different indicators, the agreement of different research/models or not as relates to these indicators, and levels of uncertainty associated with each.

For Part I of the Monitor, two different indication sets are provided. First is a confidence indicator, which has three overall scores, from highest confidence to lowest confidence, termed as follows: 1) “Robust”; 2) “Indicative”; and, 3) “Speculative”. One of three overall scores is attributed on the basis of the research teams’ assessment of four different criteria, which itself is a three point scale from low (1) through to high (3) confidence – each assessed in relative terms in the context of the overall field of climate change research and in relation to the various indicators of the Monitor. These are: first, “Science”, which refers in particular to recent IPCC confidence in that primary and secondary effects analyzed are clear manifestations of climate change or not; second, “Architecture”, which refers to the sophistication and robustness of the indicator as grounded in underlying studies – as an example, sophisticated multiple country study global models from peer reviewed literature score high; third, “Climate”, refers to the degree of agreement or not between different interpretations of effects, particularly magnitude – climate science may agree an effect is related to climate change but models may predict scales of increases or decrease for different regions with a high degree of discord, which is captured here; fourth, “Data”, refers to the relative quality of baseline socio-economic data relied upon, in particular, its international span and comparability, as well as the level of precision it is understood to carry. The below table provides an example of how the Confidence indicator scoring system operates.

CONFIDENCE INDICATOR EXAMPLE

Hypothetical illustration of the indicator scoring system

		SPECULATIVE (1) 4-6 PTS	INDICATIVE (2) 7-9 PTS	ROBUST (3) 10-12 PTS
OVERALL CONFIDENCE LEVEL			X	
NO.	SUB-INDICATOR	*Low (1 points)*	*Medium (2 points)*	*High (3 points)*
1.	SCIENCE		X	
2.	ARCHITECTURE	X		
3.	CLIMATE			X
4.	DATA		X	

The second uncertainty system relied upon for Part I of the Monitor is to present the levels of agreement between different models, typically an ensemble of more than 10-20 IPCC models as relates to the underlying climate trigger for each effect/indicator. Three grades of uncertainty are presented for each of the 21 world sub-regions of the Monitor, as follows: 1) "Limited", which means less than 10% of models disagree on the direction of change (i.e. that rainfall will increase or decrease overall in a sub-region as a result of climate change), often considerably less; 2) "Partial", which means less than 33% of models disagree on the direction of change; and, 3) "Considerable", which means that more than 33% of models disagree on the direction of change.

In this way, policy-makers have access to a range of useful information about the scale of estimated effects and different elements of uncertainty, disagreement and confidence in each indicator presented. The indicators estimate a mean level of magnitude in line with the approach of the Monitor and as assessed by the research team.

For Part II of the Monitor a similar system is used, however the confidence indicator does not have the climate variable and has only 3 sub-variables, with scoring system adjusted evenly. Likewise, since sub-regional uncertainty of climate variables does not apply, this information is not presented.

AFFECTED PEOPLE QUANTIFICATION

In some cases absolute data outputs in the Monitor is also presented for Affected Persons, meaning people suffering illness because of a specific disease/disability, or people in need of emergency assistance during environmental disaster crises. For health-linked affected people, ratios between mortality and WHO figures on affected people are established at a regional/country group level then used to estimate the number of affected people per single mortality. For emergency assistance situations, similar ratios are derived from disaster databases i.e. EM-DAT CRED.

1 PART I: HABITAT CHANGE

The Monitor's Part I/Climate Impact Area of Habitat Change (similar to the 2010 Monitor section, called: "Habitat Loss") measures negative effects in economic terms for human and/or ecological habitat as a result of climate change. Indicators included under Habitat Change are:

- Biodiversity
- Desertification
- Heating and Cooling
- Labour Productivity
- Permafrost
- Sea-level Rise
- Water

1.1.1.1 TABLE OF INDICATORS

Habitat Change - Impact Area

SUB-INDEX	INDICATOR	CLIMATE EFFECT (CE) SUB-INDICATOR
HABITAT CHANGE	Biodiversity	Biodiversity losses relative to GDP (USD) (%)
	Desertification	Costs of lost land crop productivity due to desertification relative to GDP (USD) (%)
	Heating and Cooling	Marginal costs for Heating and cooling relative to GDP (USD) (%)
	Labour Productivity	Marginal costs of productivity change relative to GDP (USD) (%)
	Permafrost	Accelerated depreciation costs as a result of permafrost dissipation relative to GDP (USD) (%)
	Sea-Level Rise	Sea-Level rise costs relative to GDP (USD) (%)
	Water	Marginal water costs relative to GDP (USD) (%)

*Sea-level rise costs comprise the following costs relative to GDP (USD):

- Tidal basin nourishment costs
- Beach nourishment cost
- Land loss costs
- Migration costs
- River dike costs
- River flood costs
- Salinity intrusion costs
- Sea dike costs
- Sea flood costs
- Wetland nourishment costs

N.B. the DIVA model estimates protection costs, such as Sea dike costs, when these costs are lower than the value of land that would otherwise be lost if not protected.

The total excess damage costs due to climate change for a country is the sum of the CE for the indicators comprising the sub-index Habitat degradation:

- $SUM (CE_{2010,gdp}) = CE\_SLR_{2010,} + CE\_Desertification_{2010} + CE\_Water_{2010} + CE\_Permafrost_{2010} + CE\_Biodiversity_{2010}$

The sub-index score is calculated by using the index calculation formula below:

- $Index\ score_{2010} = ((SUM (CE_{2010,gdp})/(10xMAD(SUM(CE_{2010,gdp}))+1)x100$

IMPACT AREA BASELINE DATA AND PROJECTIONS

SOCIOECONOMIC BASELINE

Habitat Change

DEFINITION	RESOLUTION	SOURCE
GDP 2010 in 2010 USD (by country)	Country level, 184 countries	IMF, World Economic Outlook Database, September 2011

SOCIOECONOMIC PROJECTION

Habitat Change

DEFINITION	RESOLUTION	SCENARIOS	SOURCE
Relative change in real GDP 2010 to 2030	Country level, 184 countries	SRES A1B	CIESIN

BIODIVERSITY

RESEARCH/DATA SOURCES: BIODIVERSITY

CLIMATE IMPACT FACTOR

Biodiversity

DEFINITION	Additional losses in 2050 compared to 2000
SOURCE(S)	The value of the world's ecosystem services and natural capital, Costanza et al., 1997. Extinction risk from climate change, CD Thomas et al., 2004.

	Ecosystems and Human Well-being: Current State and Trends, Mace et al. in Hassan et al. (eds), 2005. Income Distribution and Willingness to Pay for Ecosystem Services, Baumgartner et al., 2011.
RESOLUTION	163 countries
MODEL YEARS	2000-2050
MODEL DISTRIBUTION	Linear
EMISSIONS SCENARIO	A1B

BASELINE IMPACT

Biodiversity

DEFINITION	RESOLUTION	SOURCE
Global distribution of biomes Species concentrations per biome	Global, by biome	Potential vegetation distribution (average for 1961-1990) simulated using the MC1 model with CRU (TS 2.0) historical climate at a half degree of spatial grain over the globe. US Forest Service, 2010 Mace et al. in Hassan et al. (eds), 2005.

CALCULATION OF CLIMATE EFFECT: BIODIVERSITY

Zones of biodiversity are examined through the many world biomes. Estimates to assess the value of a particular biome were retrieved by Costanza et al.(1997), and the biodiversity losses for different biomes due to climate change from Hassan et al. Using the grid data from the US Forest Service (2010) provides the baseline distribution of global biomes. This data was used to perform a country-by-country integration to model the CIF country values. Finally the value was surface-normalized on the US biodiversity value.

1990 was assumed to be the base year with zero climate effect and assumed that the given losses from above are the additional losses in 50 years.

Additional losses are weighed in 50 years with the GDP PPP per capita:

$$\text{weight\_costs}_{50\text{years}} = addcosts_{50years} * \frac{GDP\ PPP\ per\ capita(N)}{GDP\ PPP\ per\ capita(USA)}$$

According to Baumgartner et al. (2011) the cost were corrected using a WTP (willingness to pay) function of the mean income per inhabitant per country.

With a linear approach the losses are computed for the years 2000, 2010 and 2030:

$$\text{costs}_{2000} = \frac{1}{5} * \text{weight\_costs}_{50\ \text{years}}$$

$$\text{costs}_{2010} = \frac{2}{5} * \text{weight\_costs}_{50\ \text{years}}$$

$$costs_{2030} = \frac{4}{5} * weight\_costs_{50\ years}$$

Then these costs are compared to the GDP of 2010 as follows:

$$CE_{2000} = costs_{2000}/GDP_{2010}$$
$$CE_{2010} = costs_{2010}/GDP_{2010}$$
$$CE_{2030} = costs_{2030}/GDP_{2010}$$

DESERTIFICATION

RESEARCH/DATA SOURCES: DESERTIFICATION

CLIMATE IMPACT FACTOR

Desertification

DEFINITION	Future vegetation distribution due to climate change.
SOURCE(S)	Dangerous human-made interference with climate: A GISS model study, J Hansen et al, 2007 Database: Global Geospatial Potential EvapoTranspiration & Aridity Index Methodology and Dataset Description, Trabucco and Zomer, 2009 Global data set of Monthly Irrigated and Rainfed Crop Areas around the year 2000 (MIRCA2000), version 1.1, Portmann et al. 2010. Average Percent Forest Cleared Per Year, 2000-2005, by Terrestrial Ecoregion, Hoekstra et al., 2010 Predicting the deforestation-trend under different carbon-prices, Kindermann et al., 2006 Global Map V.1, Vegetation (Percent tree cover), F Modis Data 2003. (Geospatial Information Authority of Japan, Chiba University and collaborating organizations.)
Resolution	Hansen: 4° x 5° MIRCA2000: 0.5° x 0.5° Modis: 0.5°x0.5°
MODEL YEARS	Base: 1961-1990; Projection: 2070-2099
MODEL DISTRIBUTION	Linear
EMISSION SCENARIO	IPCC SRES A1B

BASELINE IMPACT

Desertification

DEFINITION	RESOLUTION	SOURCE

Surface potentially used for crops.	55 countries (EPA/FAOSTAT: global)	EPA (2010): land area used for CROPS in the USA (to improve) FAOSTAT: gross production value for all crops FAOSTAT:land investment

CALCULATION OF CLIMATE EFFECT: DESERTIFICATION

Desertification was measured in terms of aridity. Aridity is defined as the mean amount of precipitation divided by the mean annual potential of evapotranspiration. Change in aridity was assessed by taking the data of precipitation and evapotranspiration from the Hansen model. Using climate class categories provided by UNEP 1997, the change in climate type distribution was assessed by observing how changes in aridity interacted with changes in agricultural cropland area from Portmann et al. (2010) and deforested surface from Hoekstra et al. (2010). By assessing the changes in each category using the basedata, economic losses and gains can also be derived. The difference between the years 1961-1990 and 2000-2030 were observed.

Information concerning the projected deforestation trend in the period under consideration and tree cover density were retrieved respectively from Kindermann and the "Global vegetation map".

A linear growth is assumed for the area affected by desertification per year.

From EPA the land area used for crops in USA of 1298636.226 km2 was obtained.

From FAOSTAT the Gross production value for all crops = 158133 million USD was obtained.

From FAOSTAT the land investment values for every country was retrieved and the mean investment value per km2 calculated.

Then the VALUE per km2 CROP (in MIO USD) was calculated, being the crop_value = 0.121768511.

The costs are scaled to the GDP PPP of countries and were computed per year:

$$Costs_{2000} = (crop\_value+Invest\_value) \times km^2\_loss_{2000} \times \frac{GDP\ PPP\ per\ capita(N)}{GDP\ PPP\ per\ capita(USA)}$$

$$Costs_{2010} = (crop\_value+Invest\_value) \times km^2\_loss_{2010} \times \frac{GDP\ PPP\ per\ capita(N)}{GDP\ PPP\ per\ capita(USA)}$$

$$Costs_{2030} = (crop\_value+Invest\_value) \times km^2\_loss_{2030} \times \frac{GDP\ PPP\ per\ capita(N)}{GDP\ PPP\ per\ capita(USA)}$$

These costs are then compared to the GDP of 2010:

$$CE_{2000} = costs_{2000}/GDP_{2010}$$

$$CE_{2010} = costs_{2010}/GDP_{2010}$$

$$CE_{2030} = costs_{2030}/GDP_{2010}$$

HEATING & COOLING

RESEARCH/DATA SOURCES: HEATING & COOLING

CLIMATE IMPACT FACTOR

Heating and Cooling

DEFINITION	Future change Heating Degree Days (HDDs) and Cooling Degree Days (CDD) due to global warming
SOURCE(S)	Heating and Cooling Degree Days; World Resources Institute, Baumert and Selman, 2003. Estimation of Heating Energy use if Existing Houses in a Future Climate Change: 2050 vs. 2007, Zmeureanu and Renaud, 2008. Modeling global residential sector energy demand for heating and air conditioning in the context of climate change, Isaac and van Vuuren, 2008. A review on buildings energy consumption information, L Perez-Lombard et al., 2008.
RESOLUTION	183 countries
MODEL YEARS	Base: 1970-1990; Projected: 2000-2050 and 2050-2100
CLIMATE EFFECT	Polynomial degree 2
EMISSION SCENARIO	TIMER/IMAGE reference scenario for the ADAM project

BASELINE IMPACT

Heating and Cooling

DEFINITION	RESOLUTION	SOURCE
The total private households and private households with all basic facilities (basic_facility_hh) by country	166 countries	United Nations Compendium of Housing Statistics and UNECE Statistical Division Database, 2012 Electricity Prices for Households, Energy Information Administration (US EIA) , 2011 Future of air conditioning energy. McNeil and Letschert, 2008

* To obtain values for countries not contained in the database, countries were ordered by GDP PPP per capita and classified into 5 groups. For each group a mean was calculated (total_households/Population) and Mean (basic_facility_hh/total_households). These means were used to provide any missing values for basic_facility_hh.

CALCULATION OF CLIMATE EFFECT: HEATING & COOLING

A linear relationship is assumed between average temperature and energy; i.e. that positive or negative deviations from the optimal temperature (18 °C) have equal and linear effects on energy expenditures. Projected data concerning heating and cooling degree days was then retrieved from the Baumert and Selman, 2003 paper. It is assumed that the universal marginal temperature effect on energy use per household is 3 kWh (the cost associated with one heating or cooling degree day), which represents the rounded mean in Zmeureanu and Renaud (2008) with global energy prices retrieved from US Energy Information Administration (2011).

Isaac and van Vuuren (2008) give the heating-CIFs for the period 2000-2050 and 2000-2100 and cooling-CIFs for the period 2000-2100.

The cooling-CIF for 2050 is calculated using the heating-CIF fraction:

$$frac_{heat}=(1 - heat\_CIF_{2050})/(1 - heat\_CIF_{2100})$$

$$cool\_CIF_{2050} = 1 - CE_{heat} \times (1 - cool\_CIF_{2100})$$

CIF_{2000} = 1 is assumed. A polynomial of degree 2 is used to calculate $heat\_helpCIF_i$, $cool\_helpCIF_i$ i={1990, 2000, 2010, 2030} describing the change compared to the year 2000 for heating and cooling.

Then the CIFs are compared to the base year of 1990 as follows:

$$heat\_CIF_i = heat\_help\_CIF_i/heat\_help\_CIF_{1990}$$

$$cool\_CIF_i = cool\_help\_CIF_i/cool\_help\_CIF_{1990}$$

HDD and CDD are calculated for the years i= {2000, 2010, 2030}:

$$HDD_i = heat\_CIF_i \times HDD_{1990}$$

$$CDD_i = cool\_CIF_i \times CDD_{1990}$$

HDD and CDD change for i = {2000, 2010, 2030}:

$$HDD\_change_i = HDD_i - HDD_{1990}$$

$$CDD\_change_i = CDD_i - CDD_{1990}$$

The cost of Heating Cooling is calculated in each country using the formula below:

$$costs_i = 3 \times [(Air\_con_i * CDD\_change_i) + HDD\_change_i] x basic\_facility\_hh x Price_i$$

The basic facility data was obtained from the UNECE Statistical Division Database.

THEN the CE is calculated for the years in question as follows:

$$CE_{2000} = costs_{2000}/GDP_{2010}$$

$$CE_{2010} = costs_{2010}/GDP_{2010}$$

$$CE_{2030} = costs_{2030}/GDP_{2010}$$

Using Van Vuuren et al, the global air conditioner density growth from 2000-2050 was retrieved and combined with the above results. Perez-Lombard et al. (2008) also provides data to include the costs generated by the private sector. It is assumed that private and commercial surfaces have the same percentage of buildings using air conditioners.

LABOUR PRODUCTIVITY

RESEARCH/DATA SOURCES: LABOUR PRODUCTIVITY

CLIMATE IMPACT FACTOR

Labour Productivity

DEFINITION	

SOURCE(S)	The direct impact of climate change on regional labour productivity, Kjellstrom et al., 2009 Importance of Recent Shifts in Soil Thermal Dynamics on Growing Season Length, Productivity, and Carbon Sequestration in Terrestrial High-Latitude Ecosystems, ES Euskirchen, 2006. Modeling global residential sector energy demand for heating and air conditioning in the context of climate change, Isaac and van Vuuren, 2009. Productivity of production labor, non-production labor, and capital: An international study Wacker et al 2006. Estimation Of Labor Demand Elasticity for the RMSM-LP: Revised Minimum Standard Model For Labor And Poverty Module, Min, 2007.
RESOLUTION	Sub-continental
MODEL YEARS	Base: 1961-1990 Projection: 2050
MODEL DISTRIBUTION	Linear
EMISSION SCENARIO	IPSS SRES Scenario A2

BASELINE IMPACT

Labour Productivity

DEFINITION	RESOLUTION	SOURCE
Labour productivity due to climate change	192 countries	See Kjellstrom et al. above

CALCULATION OF CLIMATE EFFECT: LABOUR PRODUCTIVITY

From Kjellstrom et al. (2009) productivity changes have been obtained for the 21 sub-regions of the world based on different localized studies.

The two scenarios compared follow the boundary conditions described by Kjellstrom et al. (2009) that models a labour distribution evolution under the A2scenario with and without climate change.

Therefore the final productivity change can be written as:

Pi=Pi(Changing labour constant climate)+Pi(Changing labour and climate)

In order to obtain the relative losses in terms of GDP_{year} several corrections have been implemented to take into account the people working in air conditioned places using the data from (Isaac and van Vuuren, 2009) and a positive correction for hi-latitude countries not taken into account in Kjellstrom and provided by (Euskirchen, 2006).

This last correction reflects the effect of the reduced length of the frost period. The number of people affected has been assessed from the previous analysis carried out in the"Permafrost" index.

Afterward the corrected productivity values were translated in a GDP percentage using the labour demand elasticity, differentiated by sector for every country, using the data provided by (Wacker et al., 2006 and Min, 2007) derived using the Cobb-Douglas model and a climate factor value reflecting the percentage of GDP exposed to temperature changes (outdoor workers and indoor without air conditioned).

Therefore:

$Gdp\_Perc\_Cost_{year\_i}=(P_i+C_i)x\ LE_{\_i}\ x\ CF_i$

Where P_i is the incremental working day loss in the year (2000,2010,2030) for the country I, C is the hi-latitude productivity gain (if present), LE is the labour elasticity and CF the climate factor showing the GDP percentage affected by climate change.

Therefore the final costs are easily derivable in the following way:

$Costs_{year\_i}= Gdp\_Perc\_Cost_{year\_i}\ x\ GDP\_PPP_{year\_i}$

To avoid a double counting issue with the index "Cooling" the costs were corrected reducing the losses in productivity for work places where air conditioning systems are or will be installed. While the Heating and Cooling indicator includes both commercial and residential energy costs, the correction might be considered exaggerated, but it was not possible to distinguish adequately between people working from home or not internationally.

New_Costsyear_i=Costsyear_i– (Cooling_costsyear_ix Fi)

WhereFi is the fraction of indexes overlap.

PERMAFROST

RESEARCH/DATA SOURCES: PERMAFROST

CLIMATE IMPACT FACTOR

Permafrost

DEFINITION	Change in frozen ground under projected climate forcing and resulting accelerate depreciation of infrastructure
SOURCE(S)	How Much Might Climate Change Add to Future Costs for Public Infrastructure?, Larsen and Goldsmith, 2007.

	The 'Frost Index' Permafrost Model: Variations in Circumpolar Frozen Ground Conditions and Modeled Future Conditions; Nelson et al, 2001 Population Density grid data (2000), The Atlas of Global Conservation, Hoekstra et al., 2010.
MODEL	UKTR GCM
RESOLUTION	2 x 1 degrees
MODEL YEARS	Base: 1994; Projection: 2050
MODEL DISTRIBUTION	Polynomial degree 2 for additional costs per year
EMISSION SCENARIO	UKTR GCM-based scenario

BASELINE IMPACT

Permafrost

DEFINITION	RESOLUTION	SOURCE
Population affected. Accumulated extra costs for infrastructure.	17 countries	How Much Might Climate Change Add to Future Costs for Public Infrastructure?, Larsen and Goldsmith, 2007. Census of Housing, United States Census Bureau Website, 2012. The 'Frost Index' Permafrost Model: Variations in Circumpolar Frozen Ground Conditions and Modeled Future Conditions, Nelson et al. 2001 Households size, United Nations Statistics Division (UNSD), 2010

CALCULATION OF CLIMATE EFFECT: PERMAFROST

Larsen and Goldsmith estimate additional infrastructure costs through an accelerated depreciation rate in Alaska for two time periods: 2006-2030 and 2006-2080. With this, 3 constraints are obtained for a polynomial, which describes the cumulated costs per year (additional costs in 2006, in 2030 and in 2080). The assumption that the slope of the polynomial in 1990 is zero is the 4th constraint and means that zero costs are assumed in the year 1990 due to climate change. So a polynomial of degree three can be fitted to describe how the cumulated costs per year evolve. To obtain the additional costs ($costs_{2000}$(USA) , $costs_{2010}$(USA) and $costs_{2030}$(USA)) for Alaska the derivate of the polynomial was calculated and evaluated the slope in these years.

With respect to the populations affected (16 countries), the model output from F.E. Nelson et al provides the number of affected people by permafrost in 2050 for country N (affected(N)). This is taken as constant in order that impacts from climate change would not be inadvertently derived from population growth.

From the UNSD household sizes for the country N was retrieved.

Costs due to the private sector were also calculated, taking into account the population affected, the mean household size and the mean property value obtained from the US Census Bureau for Alaska. The costs from both the private and public sector were then added to give total costs, which were extrapolated to affected countries on a GDP PPP and population basis for affected areas.

To calculate the costs for the different countries N we used the given costs, the affected people and the GDP PPP per capita 2010 of Alaska (USA) and the number of affected people and their GDP PPP per capita 2010 of country N:

K(N)=(household_size_USA/household_size_country_N)

$$costs_{2000}(N) = costs_{2000}(USA) * \frac{[affected(N)*GDP\_PPP2010(N)]}{[affected(USA)*GDP\_PPP2010(USA)]} \text{ x } K(N)$$

$$costs_{2010}(N) = costs_{2010}(USA) * \frac{[affected(N)*GDP\_PPP2010(N)]}{[affected(USA)*GDP\_PPP2010(USA)]} \text{ x } K(N)$$

$$costs_{2030}(N) = costs_{2030}(USA) * \frac{[affected(N)*GDP\_PPP2010(N)]}{[affected(USA)*GDP\_PPP2010(USA)]} \text{ x } K(N)$$

Then we compare these costs to the GDP of 2010:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

SEA-LEVEL RISE

RESEARCH/DATA SOURCES: SEA-LEVEL RISE

CLIMATE IMPACT FACTOR

Sea-Level Rise

DEFINITION	Costs due to climate change-induced sea-level rise for coastal zones (Change in tidal basin nourishment costs, beach nourishment costs, land loss costs, migration costs, river flood costs, salinity intrusion costs, sea dike costs, sea flood costs and wetland nourishment costs due to climate change).
SOURCE(S)	Dynamic Interactive Vulnerability Assessment, DIVA 2003, DINAS-COAST 2003
RESOLUTION	147 Countries
MODEL YEARS	Base: 1990; Projection: 2050
CLIMATE EFFECT	SLR_Tidal_basin_nourishment_costs_2010=SLR_

	Tidal_basin_nourishment_costs_2010/GDP_2010_Country SLR2010_index = ((SLR_Adaptcost_PERGDP_2010/(SLR_MEAN_DEV_MEAN*10))+1)*100
EMISSION SCENARIO	A1FI

BASELINE IMPACT

Sea-Level Rise

DEFINITION	RESOLUTION	SOURCE
Cost of sea level rise	147 Countries	DIVA, 2003

CALCULATION OF CLIMATE EFFECT: SEA-LEVEL RISE

The comprehensive DIVA model provides cost outputs for different factors and timeframes autonomously generating a Climate Effect for sea-level rise. Cost data for the ten different variables provided by the DIVA program are used as follows:

Total_costs = Tidal_basin_nourishment_costs + Beach_nourishment_costs + Land_loss_costs + Migration_costs + River_dike_costs+ River_flood_costs+ Salinity_intrusion_costs + Sea_dike_costs+ Sea_flood_costs+ Wetland_nourishment_costs

These costs were then compared to the GDP of 2010:

$$CE_{2000} = costs_{2000}/GDP_{2010}$$
$$CE_{2010} = costs_{2010}/GDP_{2010}$$
$$CE_{2030} = costs_{2030}/GDP_{2010}$$

WATER

RESEARCH/DATA SOURCES: WATER

CLIMATE IMPACT FACTOR

Water

DEFINITION	Marginal (adaptation) costs for replacing water losses due to climate change adjusted for local market conditions/scarcity.
SOURCE(S)	Impact of Climate Change on River Discharge Projected by Multimodel Ensemble, Nohara et al., 2006.

	Global data set of Monthly Irrigated and Rainfed Crop Areas around the year 2000 (MIRCA2000), version 1.1, Portmann et al., 2010. Charting Our Water Future: Economic frameworks to inform decision-making, McKinsey & Company, 2009. Population Density grid data (2000), The Atlas of Global Conservation, Hoekstra et al., 2010. World water and Food to 2025 dealing with scarcity, International Food Policy Research Institute, Rosengrant et al., 2002
RESOLUTION	184 Countries, 2.5°X2.5° (Nohara et al.) 0.5°X 0.5° (MIRCA 2000), 0.5° X 0.5° (Hoekstra et al.)
MODEL YEARS	Base: 1980-2000; Projection: 2080-2100
MODEL DISTRIBUTION	Linear
EMISSION SCENARIO	IPCC SRES A1B

BASELINE IMPACT

Water

DEFINITION	RESOLUTION	SOURCE
Water cycle supply conditions per country	Global	Nohara 2006

CALCULATION OF CLIMATE EFFECT: WATER

The indicator calculates a change in the price situation of a given country depending on the increase/decrease in the supply of water due to climate change and its influence on water availability, which is gauged through a change in runoff (ratio of rainfall to evaporation). Runoff data was obtained from Nohara et al.(2006) This runoff data was overlapped with information regarding population and agriculture. Population and agriculture were then used, taking into account the projected municipality demands from Rosengrant et al. (2002). Using the paper from McKinsey & Co. (2009) curves are derived that depict the marginal costs of supplying/procuring water as determined by local water scarcity conditions, and extrapolated to different countries on the basis of closest associations with those cases reported in the paper. Areas that are without croplands and reporting low population densities were not taken into account. The total amount of monetary loss or gain (water) is then assessed using the determined amount of runoff coming from the runoff integration under the previous boundary conditions.

The annual average losses were weighed with the GDP PPP per capita for each year:

$$\text{adjusted\_costs}_t = costs_i * \frac{GDP\ PPP\ per\ capita(N)}{GDP\ PPP\ per\ capita(USA)}$$

Then these costs were compared to the GDP of 2010:

CE_{2000} = adjusted_costs$_{2000}$/GDP$_{2010}$

CE_{2010} = adjusted_costs$_{2010}$/GDP$_{2010}$

CE_{2030} = adjusted_costs$_{2030}$/GDP$_{2010}$

2 PART I: HEALTH IMPACT

The Monitor's Impact Area of Health Impact (Part I: Climate) measures negative effects for human health in terms of different climate sensitive diseases as a result of climate change in terms of mortality. Indicators included under Health Impact are:

- Diarrheal Infections
- Heat & Cold Illnesses (Cardiovascular Disease, Influenza/Respiratory, Skin Cancer)
- Hunger (Malnutrition and Malnutrition risk diseases/illnesses)
- Malaria & Vector-Borne (Malaria, Dengue, Yellow Fever)
- Meningitis

2.1.1.1 TABLE OF INDICATORS

Health Impact - Impact Area

SUB-INDEX	INDICATOR	CLIMATE EFFECT (CE) SUB-INDICATOR
HEALTH IMPACT	Diarrheal Infections	Excess deaths per capita due to climate change for diarrhea (%)
	Malaria & Vector-Borne	Excess deaths per capita due to climate change for malaria & other vector borne – yellow fever and dengue fever (%)
	Hunger	Excess deaths per capita due to climate change for hunger, including malnutrition and associated risk factor diseases/illnesses (%)
	Meningitis	Excess deaths per capita due to climate change for Meningitis (%)
	Heat & Cold Illnesses	Excess deaths per capita due to climate change for respiratory diseases, including cardiovascular diseases and skin cancer (%)

The total excess deaths due to climate change for a country is the sum of the CE for diseases comprising the sub-index health impact:

- SUM ($CE_{2010,deaths}$) = CE_Diarrheal $Infections_{2010}$ + $CE\_Malaria_{2010}$ + CE_Hunger_{2010} + $CE\_Meningitis_{2010}$ + CE_Heat & Cold $Illnesses_{2010}$

The sub-index score is calculated by using the index calculation formula below:

- Index score $_{2010}$ = ((SUM ($CE_{2010,deaths}$)/(10xMAD (SUM($CE_{2010,deaths}$))+1)x100

The calculation of 2030 estimates use McMicheal et al. (2004) CIF for 2030 and the disease burden projected for 2030, using population projections from the UN for all diseases except of meningitis, for which we do not have CIF from WHO so its calculation is explained separately.

To calculate the 2000 estimates we used a linear approach to evaluate the CIF for 2000 with the CIFs we have for the years 2010 and 2030.

IMPACT AREA BASELINE DATA AND PROJECTIONS

SOCIOECONOMIC BASELINE

Health Impact

DEFINITION	RESOLUTION	SOURCE
Population (per country) divided by 1000	By country	UN Population Division - Medium-fertility variant, 2010-2100

SOCIOECONOMIC PROJECTION

Health Impact

DEFINITION	RESOLUTION	SCENARIO	SOURCE
Population (per country) divided by 1000	By country	UN Stat	Population (per country) divided by 1000

RESEARCH/DATA SOURCES: HEALTH IMPACT

CLIMATE IMPACT FACTOR

Health Impact (All Indicators except meningitis, heat & cold illnesses)

DEFINITION	Marginal mortality due to climate change for a range of climate sensitive diseases
SOURCE(S)	WHO
MODEL	Comparative Quantification of Health Risks, Global and Regional Burden of Disease Attributable to Selected Major Risk Factors McMichael et al in Ezzati et al (eds.),WHO, 2004
EMISSION SCENARIO	IPCC S750
RESOLUTION	By WHO sub-region
MODEL YEARS	Base: 2004; Projection: 2000, 2010, 2030
MODEL DISTRIBUTION	-

BASELINE IMPACT

Health Impact (All Indicators)

DEFINITION	RESOLUTION	SOURCE
Total deaths divided by 1000 for the year 2008	Global, by country (193 countries)	Global Burden of Disease Study April 2011, WHO* (WHO BDD)

*2004 database for Yellow Fever: Yellow fever is the only disease with no updated data for the year 2008, so the similar but year 2004 database from WHO is drawn upon instead.

ECONOMIC GROWTH ADJUSTEMENTS FOR 2030

For 2030 disease projections, a deviation factor is applied for certain diseases/illnesses in order to take account their evolution in accordance with expected future economic growth, in particular that emerging markets will gain in capacity to deal with diseases that more advanced economies have largely eradicated.

Given the uncertainty associated with these projections, deviation factors were only applied to a limited basket of diseases/illnesses, including nutritional deficiencies, malaria and diarrhea, but not respiratory illnesses (inc. influenza/pneumonia) and diseases, cardiovascular diseases, dengue fever, yellow fever, skin cancer, for which less clear evidence exists that economic growth results in significant modifications in disease burdens.

To predict the associated evolution of diseases (nutrition-related, malaria, diarrhea) due to economic development a deviation factor was generated for the WHO regions of Africa, South-East-Asia and other lower-income countries. The midpoint of two different approaches was drawn upon to derive the deviation factors:

1. The predictions from Mathers and Loncar (2006) Projections of global mortality and burden of disease from 2002 to 2030)
2. A comparison of the GDP growth in the period 2000-2010 with the disease growth based on the 2002 to 2008 years WHO Global Burden of Disease databases (WHO BDD, 2000), a correlation then applied to the GDP growth from 2010 to 2030 to obtain the change in burdens.

For all lower-income countries not in these WHO regions, the average of these results was applied as a deviation factor. The table below details the final factors used. Note that all deviation factors result in a reduction in the burden of disease due to economic growth except for diarrhea in SE Asia and lower-income countries.

ECONOMIC GROWTH DISEASE BURDEN

Deviation Factors for 2030 by Group

	Nutritional	Diarrhea	Malaria
Africa	0.799	0.935	0.557
SE Asia	0.921	1.169	0.496
Other Low income	0.86	1.052	0.5265

HEALTH COSTS QUANTIFICATION

Health costs were estimated using a modified version of the WHO Disability Adjusted Life Years (DALYs) burden on GDP per capita income, which is a common indicator of health costs in economic terms (World Economic Forum, 2011). DALYs are derived in relation to the scale of mortality estimated to be caused by climate change in the Monitor. The adjustment made was to multiply DALYs due to climate change first by factor shares of the production value of labour to national income, which were obtained from Wacker et al. (2006) and Min (2007). These health costs represent lost income due to the effect of climate change and do not account for costs relating to the health sector, not all of which would in any case generate loss of economic output/income. The same system was used for Part II of the Monitor based on the attributable fraction of mortality due to greenhouse gas related activities.

CALCULATION OF CLIMATE EFFECT: VECTOR-BORNE DISEASES, HUNGER AND DIARRHEAL INFECTIONS

The World Health Organization's (WHO) 2004 "Comparative Quantification of Health Risk, Global and Regional Burden of Disease Attributable to Risk Factors" report, has estimated climate impact factors (CIF) for climate-sensitive diseases at the level of WHO regions (14 sub-regions globally) derived from complex models that account for a number of different climatic influences on climate-sensitive health disorders/diseases.

There is no CIF available for Yellow Fever or Dengue Fever in the WHO's publication. Instead, CIFs for these well-recognized climate-sensitive diseases are derived from the closest proxies of CIFs for other diseases. For both Yellow Fever and Dengue Fever that is Malaria, which, as a vector-borne disease, reacts to climate parameters in a comparable enough fashion to Yellow Fever and Dengue Fever to be considered an interim workable proxy.

For Hunger, the disease burden attributable to hunger-related risks calculated spans more than just mortality from nutritional deficiencies. It also includes an impact on diarrhea, malaria and pneumonia/respiratory infections, and measles, since hunger/malnutrition is a risk factor for these. WHO 2004 specifies the impact that of climate change on health effects these diseases in two distinct ways, first through meteorological effects directly on the pathogens and vectors themselves, and second through an increased incidence of undernutrition which also increases risk of mortality to these diseases. The direct effects on pathogens and vectors themselves are captured in the relevant disease specific indicators of the Monitor. The hunger/undernourished-related effects are captured in the hunger indicator of the Monitor.

The climate effect (CE) is calculated by multiplying the variable (disease burden) with the CIF, as shown in the formula below:

$CE\_Hunger_{2010} = (CIF\_Hunger_{2010,country} \times \text{Disease burden}_{2008,country})/\text{Population}_{2010,contry}$

The WHO has three emission scenarios and three uncertainty scenarios resulting in a total of nine climate impact factors (CIF) per region. For the purpose of the Health Impact sub-index, the two mid-range scenarios have been applied to measure the medium expected climate change impact:

- Mid-range: "Emission reduction resulting in stabilization at 750 ppm CO2 equivalent by 2210 (s750)"
- Mid-range uncertainty scenario is used "Making an adjustment for biological adaptation"

This selection results in only one impact factor being chosen per region.

The WHO CIF estimates include 2010, 2020, and 2030 estimates. It uses the HadCM2 global climate model previously used by IPCC.

CLIMATE IMPACT FACTORS

RANGE OF CIFs

Health Impact (All Indicators)

INDICATOR	2010	2030
Heat & Cold Illnesses (non-	-0.1 – 1.1%	-0.2 – 1.2%

influenza)		
Dengue Fever	0 – 15.97%	0 – 24.81%
Diarrheal Infections	0 – 3.85%	0 – 6.54%
Malaria & Vector-Borne	0 – 15.97%	0 – 24.81%
Hunger	0 – 9.09%	0 – 14.5%
Meningitis	0 – 11.13%	0 – 12.39%
Heat & Cold (Influenza)	-3.5% – 0	-7% – 0

MENINGITIS

RESEARCH/DATA SOURCES: MENINGITIS

CLIMATE IMPACT FACTOR

Meningitis

DEFINITION	Marginal meningitis mortality due to climate change
SOURCE(S)	Integration of Demographic, Climate and Epidemiological Factors in the Modeling of Meningococcal Meningitis Epidemic Occurrence in Niger, S Adamo et al. 2011 Projected changes in drought occurrence under future global warming from multi-model, multi-scenario, IPCC AR4 simulations, Sheffield and Wood, 2008. Population Density grid data (2000), The Atlas of Global Conservation, Hoekstra et al., 2010.
MODEL	Several (IPCC AR4)
EMISSION SCENARIO	A1B
RESOLUTION	Sub-continental 10 regions
MODEL YEARS	Base: 2008; Projection: 2010, 2030
MODEL DISTRIBUTION	Linear

CALCULATION OF CLIMATE EFFECT: MENINGITIS

According to several publications that show a strong link between drought periods/wind intensity and meningitis outbreaks (principally in the "Meningitis belt") an index based on the drought return time has been drawn upon (Sheffield and Wood, 2008). From this basis, the return time change for 2050 has been obtained and combined with the model provided by S Adamo et al.(2011)

$$N_{m(2010)} = N_{m(2000)} + 2 \text{ x } \frac{X(2050)}{6} \text{x } Y$$

$$N_{m(2030)} = N_{m(2000)} + 4 \text{ x } \frac{X(2050)}{6} \text{x } Y$$

Y represents the percentage of burdens due to climate factors and *X* represents the drought return time change. In this case, droughts are periods between four and six months with substantial lack of precipitation.

To extrapolate the real atmospheric variable incidence on the global number of affected people a logarithmic approach used by (S Adamo et al., 2011) coupled with a grid density chart were combined.

HEAT & COLD ILLNESSES (NON-INFLUENZA)

The Heat & Cold illnesses indicator measures three different groups of health impact that are understood to be affected in particular by extremes in heat and cold:

- Non-influenza (chronic cardiovascular and respiratory disease)
- Skin cancer
- Influenza Type Illnesses

RESEARCH/DATA SOURCES: HEAT & COLD ILLNESSES (NON-INFLUENZA)

CLIMATE IMPACT FACTOR

Heat & Cold Illnesses (Non-Influenza)

DEFINITION	Marginal heat & cold triggered mortality for chronic cardiovascular and respiratory diseases due to climate change.
SOURCE(S)	Temperature and Mortality in 11 cities of Eastern United States, Curriero et al., 2002 A Review of Uncertainties in Global Temperature Projections over the Twenty-First Century R. Knutti et al. 2008 The World Factbook, CIA 2012 (for poverty levels) World Bank Database, 2012 (for percentage of people with more than 65 years of age) Future of air conditioning energy.

	McNeil and Letschert, 2008 The mortality impact of the August 2003 Heat Wave in France Toulemon and Barbieri 2006
MODEL	Several (IPCC AR4)
EMISSION SCENARIO	A1B
RESOLUTION	2 Climate zones. 169 countries.
MODEL YEARS	Base: 1980-1990; Projection: 2000,2010,2030
MODEL DISTRIBUTION	Linear

CALCULATION OF CLIMATE EFFECT: HEAT & COLD ILLNESSES (NON-INFLUENZA)

In order to predict the associated change of Heat & Cold mortality due to climate change the paper published by Curriero at al. (2002) has been used to assess the relative mortality risk curves in function of the mean external temperature for chronic cardiovascular and respiratory disease sufferers (the WHO database relied on for disease burden estimates as for other health indicators).

The mechanism for the increase in mortality increases or decreases stress placed on the respiratory and circulatory system (Temperature and Mortality in 9 U.S. cities California Energy Commission).

Two different subsets of cities have been selected to have an approximation of the mortality rates in cold/continental and tropical regions. The mean global temperature increase from 1990 to 2030 has been supposed to be around 1°C.

To generate a more realistic outcome other variables have been taken into account using the weight proposed by Curriero at al. (2002), these include: the population below poverty line (CIA World Factbook), air conditioning diffusion (McNeil et al.), and percentage of people with more than 65 years of age (World Bank 2012).

An additional correction to improve the final results comes from (Toulemon and Barbieri, 2006) that approximately estimate the harvesting effect value in the 2003 European heat event – harvesting being the short-term displacement of mortality as discussed in WHO 2004. When a harvesting effect applies, there is no true marginal effect on mortality in an annualized sense, since mortality is only displaced by a matter of days or months: meaning deaths that would have occurred in the course of the following days/months/year are merely advanced by e.g. a few months, therefore the climate change effect does not have result in a meaningful effect on the burden of disease of a given year. The harvesting effect has therefore been adjusted for and mortality deemed to be only short-term displacement are not taken account of in the outputs generated or the index results expressed through the Monitor.

The mortality change for a given country is then:

$\text{Mortality\_change}_{2030}$=($\text{Mortality\_partial\_change}_{2030(1°C)}$ +Corrections (Poverty, Age, Air_con)) x WHO_data x (1-Harvesting_effect)

The values for 2000 and 2010 have been computed in the following way:

$Mortality\_change_{2000} = Mortality\_change_{2030} \times (1/4)$,

$Mortality\_change_{2010} = Mortality\_change_{2030} \times (2/4)$,

assuming that $Mortality\_change_{1990} = 0$.

The final results have been afterward combined with the influenza values, in a single index named Heat and Cold Illnesses, since both issues relate to changes in (particularly extreme) heat and cold periods.

HEAT & COLD ILLNESSES (SKIN CANCER)

RESEARCH/DATA SOURCES: HEAT & COLD ILLNESSES (SKIN CANCER)

CLIMATE IMPACT FACTOR

Heat & Cold Illnesses (Skin Cancer)

DEFINITION	Marginal skin cancer mortality due to climate change, included in the Heat & Cold index
SOURCE(S)	Impact of climate change on skin cancer AK Bharath and Turner, 2009 A Review of Uncertainties in Global Temperature Projections over the Twenty-First Century, Knutti et al., 2008 Incidence BCC and Melanoma related to UVb radiation Prevention of Skin Cancer, Hill et al., 2004 (page 78) Impacts of climate change on stratospheric ozone recovery, Waugh et al., 2009
MODEL	Goddard Earth Observing System Chemistry-Climate Model.
EMISSION SCENARIO	A1B
RESOLUTION	Continental. 56 countries
MODEL YEARS	Base: 1980-1999; Projection: 2000, 2010, 2030
MODEL DISTRIBUTION	Linear

CALCULATION OF CLIMATE EFFECT: HEAT & COLD ILLNESSES (SKIN CANCER)

To predict the associated change of skin cancer mortality for Melanoma and Basal Cell Cancer, due to climate change two main effects were taken into account: 1) the risk impact of higher temperatures which have shown in laboratory tests to increase the rate of skin cancer (Bharath and Turner, 2009), and 2), the climate change impact on the recovery rate of the ozone depleted zone of the upper atmosphere which increases incidence of skin cancer (D.W. Waugh 2009).

Only high/medium latitudes countries of both hemispheres were taken into account in the analysis since the above effects are in large part understood to be relevant for these zones. The mean global temperature increase from 1990 to 2030 is estimated at approximately 1°C (IPCC SRES).

The relationship between UVb intensity and skin cancer incidence was retrieved from (David J. 2004) and the ozone layer thickness for a given latitude band from (D.W. Waugh 2009).

$Change\_{}_{melanoma}$=Cancer(T)+Cancer(O_3)

And $Change_{BCC}$=Cancer(T)+Cancer(O_3)

Where Cancer(T) and Cancer(O_3) are function that gives the burden incidence change in function, respectively, of the temperature, and Ozone layer thickness (and its absorbance in the UV spectrum).

A weighted mean has then been assessed to evaluate the total skin cancer variation in 2030.

$Change_{skin\_cancer\_2030}= \frac{3*Change\_Bcc(2030)+Change\_Melanoma(2030)}{4}$ x Cancer_values_Who The values for 2000 and 2010 have been computed in the following way:

$Change_{skin\_cancer\_2010=}$ $Change_{skin\_cancer\_2030}$ x (1/2),

$Change_{skin\_cancer\_2000=}$ $Change_{skin\_cancer\_2030}$ x (1/4),

assuming that $Change_{skin\_cancer\_1990}$=0.

HEAT & COLD ILLNESSES (INFLUENZA)

RESEARCH/DATA SOURCES: HEAT & COLD ILLNESSES (INFLUENZA)

CLIMATE IMPACT FACTOR

Heat & Cold Illnesses (Influenza)

DEFINITION	Influenza mortality due to climate change
SOURCE(S)	A Review of Uncertainties in Global Temperature Projections over the Twenty-First Century, Knutti et al., 2008 The role of weather on the relation between influenza and influenza-like illness, Van Noort et al., 2011 Observed and projected climate shifts 1901-2100 depicted by world maps of the Koppen-Geiger climate classification, Rubel, F., and M. Kottek, 2010 WHO Burden of Diseases Database (BDD) (2000) Population Density grid data (2000), The Atlas of Global Conservation, Hoekstra et al., 2010.

	Complications of Viral Influenza, Rothberg et al., 2008
MODEL	Several (IPCC AR4)
EMISSION SCENARIO	A1B
RESOLUTION	2 Climate zones. 169 countries.
MODEL YEARS	Base: 2003-2010; Projection: 2000,2010,2030
MODEL DISTRIBUTION	Linear

CALCULATION OF CLIMATE EFFECT: HEAT & COLD ILLNESSES (INFLUENZA)

In order to predict the associated change of Influenza mortality due to climate change the paper published by Van Noort at al.(2012) has been used to assess the occurrence curves for influenza and influenza-like illness (ILI), in particular pneumonia where it cannot be easily disassociated from influenza, which is done in function of the mean external temperature.

An assumption between the ILI and influenza variation has been made in order to transpose the ILI change to the influenza one.

To reduce the complexity of the problem tropical and desert regions have been excluded, therefore the affected population has been corrected overlapping the grid population density map (Hoekstra et al., 2010) with the Koppen climate one.

The mean global temperature increase from 1990 to 2030 is estimated at approximately 1°C (IPCC SREX).

The final results for a given country are calculated as follows:

$Mortality\_change_{2030}=Percentage\_change_{2030(1°C)} \times R \times WHO\_data \times P$

Where R is the ratio of the country's affected population to the total country's population and P is an approximate percentage of influenza related mortality to the total respiratory infection deaths (WHO BDD, 2000 and Rothberg et al. 2008).

The values for 2000 and 2010 have been computed in the following way:

$Mortality\_change_{2000}= Mortality\_change_{2030} \times (1/4)$,

$Mortality\_change_{2010}= Mortality\_change_{2030} \times (2/4)$,

assuming that $Mortality\_change_{1990}=0$.

The final results have been afterward combined with the other non-influenza and skin cancer values, in a single index named Heat & Cold Illnesses.

3 PART I: INDUSTRY STRESS

The Monitor's Part I/Climate Impact Area of Industry Stress (similar to the 2010 Monitor section, called: "Economic Stress") measures negative effects of climate change in economic terms for specific sectors of the economy known to be sensitive to changes in the climate. Indicators included under Industry Stress are:

- Agriculture
- Fisheries
- Forestry
- Hydro Energy
- Tourism
- Transport

3.1.1.1 TABLE OF INDICATORS

Economic Stress - Impact Area

SUB-INDEX	INDICATOR	CLIMATE EFFECT (CE) SUB-INDICATOR
ECONOMIC STRESS	Agriculture	Costs relative to GDP (USD) due to effect on (land-based) agriculture
	Fisheries	Change in fishery exports relative to GDP (USD) due to effect on fisheries (in-land and marine)
	Forestry	Costs relative to GDP (USD) due to effect on forestry
	Hydro Energy	Costs relative to GDP (USD) due to effect on hydro energy
	Tourism	Costs relative to GDP (USD) due to effect on tourism
	Transport	Costs relative to GDP (USD) due to effect on transport

The Economic Stress Sub-index is calculated using a set of variables indicating the projected economic losses in different sectors as a share of GDP due to climate change as follows:

- $SUM(CE_{2010,gdp}) = CE\_Agriculture_{2010,gdp} + CE\_Forestry_{2010,gdp} + CE\_Hydroenergy_{2010,gdp} + CE\_Fishery_{2010,gdp} + CE\_Tourism_{2010,gdp} + CE\_Transport_{2010,gdp}$

The sub-index score is calculated by using the index calculation formula below:

- $\text{Index score}_{2010} = ((SUM(CE_{2010,gdp})/(10 \times MAD(SUM(CE_{2010,gdp}))+1) \times 100$

In order to take into account the GDP shift between agricultural, industrial and service sectors the 2030 values from the OECD (2008) report have been used. The paper gives values for 3 country groups: OECD, BRIC and Rest of The World. This operation is necessary to assess the relevant economic sector movements in developing countries.

IMPACT AREA BASELINE DATA AND PROJECTIONS

SOCIOECONOMIC BASELINE

Economic Stress

DEFINITION	RESOLUTION	SOURCE
GDP 2010 in 2010 USD (by country)	Country level, 184 countries	World Economic Outlook Database, IMF, September 2011

SOCIOECONOMIC PROJECTION

Economic Stress

DEFINITION	RESOLUTION	SCENARIO	SOURCE
Relative change in real GDP 2010 to 2030	Country level, 184 countries	SRES A1	CIESIN (2002)

CLIMATE IMPACT FACTORS

RANGE OF CIFs

Economic Stress (All Indicators)

		2000	2010	2030
Agriculture	Min %	-0.57%	-1.34%	-3.44%
	Max %	2.92%	6.81%	17.50%
Hydroenergy	Min %	-8.00%	-16.00%	-32.00%
	Max %	8.31%	15.14%	24.32%
Forestry	Min %	-4.91%	-9.82%	-19.64%
	Max %	10.53%	21.05%	42.11%
Fisheries Inland	Min %	1.88%	5.00%	15.00%
	Max %	3.75%	10.00%	30.00%
Fisheries Marine	Min %	-9.00%	-18.00%	-36.00%
	Max %	8.00%	16.00%	32.00%
Tourism Reef	Min %	5.15%	10.31%	17.62%
	Max %	8.15%	16.31%	32.62%
Tourism Winter	Min %	0.11%	0.29%	0.86%
	Max %	0.95%	2.51%	7.49%

AGRICULTURE

RESEARCH/DATA SOURCES: AGRICULTURE

CLIMATE IMPACT FACTOR

Agriculture

DEFINITION	Percentage change of agricultural output due to climate change
SOURCE(S)	Cline, Global Warming and Agriculture; Cline, 2007 Wheeler, Quantifying Vulnerability to Climate Change: Implications for Adaptation Assistance; Wheeler, 2011
RESOLUTION	Cline gives values for 133 countries; Wheeler is used as the basis for calculating the remaining countries
MODEL YEARS	Base: 2003; Projection: 2080 (from Cline)
CLIMATE EFFECT	Polynomial degree 2
EMISSION SCENARIO	8 different models were used by Cline

BASELINE IMPACT

Agriculture

DEFINITION	RESOLUTION	SOURCE
Agricultural output in 2000 (million USD)	131 countries; Rest with sub-regional mean relative to GDP	FAOSTAT

CALCULATION OF CLIMATE EFFECT: AGRICULTURE

The climate effect is taken from the detailed country-based impact values provided by Cline, which combines a range of models estimating impacts of climate change on land-based agricultural output. The Percentage change of agricultural output in 2080 (% output_change2080) compared to 2003 is employed from Cline "Global warming and agriculture" (2007).

For countries without a percentage of Output change were used the regional mean with the classification given by Wheeler. Wheelers' assumption that half of the effect materializes in 2050 has been adopted. Zero output change is assumed in 2000. Within these restrictions is computed, with a polynomial of degree two, the percentage of output change in the years (represented by i) 1990, 2010, 2030

The agricultural output share of GDP for the year 2000 is computed – for missing countries the sub regional mean was again used as Wheeler estimated. There are some exceptions to this – see below.

The calculation for the agricultural output for 2000 is undertaken as follows:

$$output_{2000} = Agri\_share_{2000} \times GDP_{2000} \times inflation\_rate_{2000-2010}$$

With the percentage change are computed the Agricultural outputs for the years i ={1990, 2010, 2030}

$$output_i = output2000 \times (1+\%output\_change_i)$$

The CE is then computed for the years in question:

$$CE_{2000} = (output_{2000} - output_{1990}) / GDP_{2010}$$
$$CE_{2010} = (output_{2010} - output_{1990}) / GDP_{2010}$$
$$CE_{2030} = (output_{2030} - output_{1990}) / GDP_{2010}$$

There are 71 countries without estimates in Cline. So an average of the sub regions from Wheeler is applied. There are still 18 countries without values. So the following is assumed:

- For the 4 Indian Ocean countries (Comoros, Maldives, Mauritius, Seychelles): the average of Madagascar and Sri Lanka
- For Sao Tome & Principe and Cape Verde: the mean of sub regional Coastal West Africa
- For Iceland: the mean of the other Scandinavian countries
- For the Pacific Islands: the sub regional mean of South East Asia

FISHERIES

RESEARCH/DATA SOURCES: FISHERIES

CLIMATE IMPACT FACTOR

Fisheries

DEFINITION	Decrease in fish catch yield due to climate change
SOURCE(S)	Marine: Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change, Cheung et al., 2010. Inland: "Climate change decreases aquatic ecosystem productivity of Lake Tanganyike, A. O´Reilly et al., 2003.
RESOLUTION	18 countries and 9 subcontinental regions
MODEL YEARS	Base Marine: 1980-2000 Marine projected: 2005-2055; Inland projected: Sub-regional CIFs derived from values for Africa
CLIMATE EFFECT	Linear
EMISSION SCENARIO	IPCC SRES A1B

BASELINE IMPACT

Fisheries

DEFINITION	RESOLUTION	SOURCE

Fishery capture 2009 (Inland and Marine) in current USD	Inland: 153; Marine: 133	FAOSTAT

CALCULATION OF CLIMATE EFFECT: FISHERIES

MARINE

The CIFs from Cheung are for the period 2005-2055.

It is assumed that $CIF_{1990}=1$ as base year with zero CC impact.

It is assumed that the CIFs from Cheung represent the change in 50 years ($CIF_{50years}$).

Using this, the required CIFs are calculated with a linear approach:

$CIF_{2000}=1/5x\ CIF_{50years}$ $CIF_{2010}=2/5x\ CIF_{50years}$ $CIF_{2030}=4/5x\ CIF_{50years}$

Losses are computed for the years in question (i = 2000, 2010, 2030):

$costs_i=(1-CIF_i)xproduction_{1990}$

The CE is calculated at as follows for the years in question:

$CE_{2000}(marine) = costs_{2000}/GDP_{2010}$ $CE_{2010}(marine) = costs_{2010}/GDP_{2010}$

$CE_{2030}(marine) = costs_{2030}/GDP_{2010}$

INLAND

O'Reilly et al. (2003) estimates a 30% decrease in fish yields over the last 80 years (1920-2000) due to climate change in Lake Tanganyika. Given the highly restricted ability of in-land fish populations to migrate, the study from Lake Tanganyika is deemed to be representative of in-land fish responses to climate change globally, although variations in losses would no doubt exist. For want of a broader set of studies, the implications of O'Reilly are extrapolated.

A decrease of the same magnitude is assumed for 2000 to 2030 due to the accelerating temperature changes.

CIFs for inland fisheries are assumed as: $CIF_{2010} = 0.9$ and $CIF_{2030} = 0.7$ in Africa.

These values serve as a benchmark to determine the CIFs of the other regions. The computation of the fraction of GDP_{2010} is then the same as for marine fishery.

To obtain the combined CE for fishery, the results are added as follows:

$CE_i = CE_i(marine) + CE_i(inland)\ _i = \{2000, 2010, 2030\}$

FORESTRY

RESEARCH/DATA SOURCES: FORESTRY

CLIMATE IMPACT FACTOR

Forestry

DEFINITION	Change in forestry under projected climate change.
SOURCE(S)	Potential vegetation distribution (2070-2099 vs. average for 1961-1990) simulated using the MC1

	model with CRU (TS 2.0) historical climate at a half-degree spatial grain over the globe, US Forest Service, 2010.
RESOLUTION	0.5°x 0.5°
MODEL YEARS	Base: 1961-1990 Projection: 2070-2099
CLIMATE EFFECT	Linear
EMISSION SCENARIO	IPCC SRES A1B

BASELINE IMPACT

Forestry

DEFINITION	RESOLUTION	SOURCE
The Area (in ha) of forest in 1990	Global/184 countries	FAOSTAT (2012)

CALCULATION OF CLIMATE EFFECT: FORESTRY

From US Forest Service (2010) data concerning the potential area covered by forest in the period 1961-1990 (sqm1975) and the simulated estimations for 2071-2099 (sqKm2085) under the climate change effects has been retrieved. This information is necessary to assess the change in the vegetation potential trend during the period under consideration under a A1B scenario. Then the hypothetical projected forest surface in 2030 has been obtained by multiplying the potential forest-trend, found with the previous operation, for the forest surface in the year 1990 (FAOSTAT, 2012), an operation made for each country.

A linear approach is used to calculate the CIFs describing the change compared to the year 1975

$$helpCIF_{2085} = m^2\ 2085 / m^2\ 1975$$

$$helpCIF_{1990} = 1 - 14/109 \times (1 - Help\_CIF_{2085})$$

$$helpCIF_{2000} = 1 - 24/109 \times (1 - Help\_CIF_{2085})$$

$$helpCIF_{2010} = 1 - 34/109 \times (1 - Help\_CIF_{2085})$$

$$helpCIF_{2030} = 1 - 54/109 \times (1 - Help\_CIF_{2085})$$

For missing countries a sub-regional mean is applied to calculate the helpCIF. CIFs are then compared the 1990 base year as follows:

$$CIF_{2000} = helpCIF_{2000}/helpCIF_{1990}$$

$$CIF_{2010} = helpCIF_{2010}/helpCIF_{1990}$$

$$CIF_{2030} = helpCIF_{2030}/helpCIF_{1990}$$

For the value per ha, the article “The value of the world’s ecosystem services and natural capital” by Costanza et al.(1997) provides the average global value for boreal 25USD (1994 US$ ha^{-1} yr^{-1}) and tropical 315USD (1994 US$ ha^{-1} yr^{-1}) forest. An inflation rate of 1.471 is used to translate this into 2010 USD. To convert this into a country specific value, the global value was weighted with the GDP PPP per capita of the different countries N:

$$value_N = global\_value \times \frac{GDP\ PPP\ per\ capita(N)}{GDP\ PPP\ per\ capita(USA)}$$

Tropical is assumed as the following sub-regions/countries:

India, Caribbean, Central America, South America, West Africa, Central Africa, East Africa, South East Asia.

Forest area is calculated for in the years 2000, 2010 and 2030 (in ha) as follows:

$forest_{2000}= CIF_{2000} \times forest_{1990}$

$forest_{2010}= CIF_{2010} \times forest_{1990}$

$forest_{2030}= CIF_{2030} \times forest_{1990}$

And the costs of forest-change due to climate change compared to 1990:

$costs_{2000}= (forest_{2000} - forest_{1990}) \times value_N$

$costs_{2010}= (forest_{2010} - forest_{1990}) \times value_N$

$costs_{2030}=(forest_{2030} - forest_{1990}) \times value_N$

The following then yields the CE for the years in question:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

HYDRO ENERGY

RESEARCH/DATA SOURCES: HYDRO ENERGY

CLIMATE IMPACT FACTOR

Hydro Energy

DEFINITION	Change in developed hydropower potential due to impact of climate change on river discharge
SOURCE(S)	Impact of Climate Change on River Discharge Projected by Multimodel Ensemble, Nohara et al., 2006. Europe's Hydropower Potential Today and in the Future, Lehner et al., 2001
RESOLUTION	141 countries: 78 drawn from Nohara et al., 36 from Lehner et al.
MODEL YEARS	Nohara et al.: Base – 1990 (1981-2000), Projection – 2090; Lehner et al.: Base – 1975 (1961-1990), Projection – 2020 & 2070
CLIMATE EFFECT	Nohara et al.: linear; Lehner et al.: polynomial degree 2
EMISSION SCENARIO	A1B

BASELINE IMPACT

Hydro Energy

DEFINITION	RESOLUTION	SOURCE
Electricity production from hydroelectric sources in kWh	115 countries	Lehner et al., 2001

for the year 2000		International Energy Agency (year)

CALCULATION OF CLIMATE EFFECT: HYDRO ENERGY

EUROPE (36 countries)

Lehner et al. (2001) provides the change in developed hydropower potential (%) for the HADCM3 scenario in the years 2020 and 2070 (CIF_{2020}, CIF_{2070}). These values are changes compared to the base year 1975 (1961-1990). For 1975, a $CIF_{1975} = 1$ is assumed.

A polynomial of degree 2 is used to calculate $helpCIF_{1990}$, $helpCIF_{2000}$, $helpCIF_{2010}$, $helpCIF_{2030}$, describing the change compared to the year 1975.

Then the CIFs are compared to the base year 1990:

$CIF_{2000} = helpCIF_{2000}/helpCIF_{1990}$ $CIF_{2010} = helpCIF_{2010}/helpCIF_{1990}$

$CIF_{2030} = helpCIF_{2030}/helpCIF_{1990}$

Hydroelectric electricity production for the required years is calculated as follows:

$kWh_{1990} = help\_CIF_{1990} * kWh_{1975} = help\_CIF_{1990} * kWh_{2000} / help\_CIF_{2000}$

kWh_{2000} given by webpage

$kWh_{2010} = CIF_{2010} * kWh_{1990}$

$kWh_{2030} = CIF_{2030} * kWh_{1990}$

Then the production changes for the years 2000, 2010 and 2030 are calculated and compared to the base year 1990 in kWh:

$change_{2000} = kWh_{2000} - kWh_{1990}$ $change_{2010} = kWh_{2010} - kWh_{1990}$

$change_{2030} = kWh_{2030} - kWh_{1990}$

OUTSIDE EUROPE (78 countries)

Nohara et al. (2006) provides river discharge data that proxies for hydro energy production potential change. Nohara provides a CIF for the year 2090 compared to the year 1990 (1981-2000).

A linear approach is used to evaluate the CIFs for the years of interest (2000, 2010 and 2030) since only one projection year is available. The electricity production for the required years is calculated as follows:

$kWh_{1990} = kWh_{2000}/CIF_{2000}$

kWh_{2000} given from the International Energy Agency

$kWh_{2010} = CIF_{2010} x kWh_{1990}$

$kWh_{2030} = CIF_{2030} x kWh_{1990}$

Production changes for the years 2000, 2010 and 2030 are then calculated and compared to the base year of 1990 in kWh as follows:

$change_{2000} = kWh_{2000} - kWh_{1990}$ $change_{2010} = kWh_{2010} - kWh_{1990}$

$change_{2030} = kWh_{2030} - kWh_{1990}$

ECONOMIC CALCULATION

0.04 USD as price per kWh of hydropower is assumed (Europe´s Energy Portal) as a global constant. That price is multiplied by the production changes in 2000, 2010 and 2030 to obtain the losses per country as follows:

$Loss_{2000} = 0.04 \text{ x } change_{2000}$

$$Loss_{2010} = 0.04 \times change_{2010}$$
$$Loss_{2030} = 0.04 \times change_{2030}$$

The CE is then calculated for the years in question as follows:

$$CE_{2000} = Loss_{2000}/GDP_{2010}$$
$$CE_{2010} = Loss_{2010}/GDP_{2010}$$
$$CE_{2030} = Loss_{2030}/GDP_{2010}$$

TOURISM

RESEARCH/DATA SOURCES: TOURISM

The Tourism indicator measures losses to the tourism sector globally based on modeled losses incurred through two separate effects: 1) the loss of revenues due to shorter/less advantageous winter sports seasons; and 2) the loss of revenues associated with reef-based tourism where these are under stress. An overarching assumption has been made that Tourism will have no net positive or negative outcome due to climate change, and will only redistribute any gains and losses. Net loss redistributions methods are detailed below.

CLIMATE IMPACT FACTOR

Tourism - Winter

DEFINITION	Decrease in winter tourism revenue due to climate change
SOURCE(S)	The impact of snow scarcity on ski tourism, Steiger, 2011.
RESOLUTION	33 countries
MODEL YEARS	Base: 2006-2007; Projection: 2060
MODEL DISTRIBUTION	2000 with a polynomial degree 2
EMISSION SCENARIO	IPCC SRES A1B

Tourism – Reef-based

DEFINITION	Decrease in reef tourism revenue due to climate change
SOURCE(S)	ECLAC 2011 Barbados; WRI GIS “Reefs at Risk”, 2012
RESOLUTION	44 countries
MODEL YEARS	Base: 2005; Projection: 2010-2050
MODEL DISTRIBUTION	Linear
EMISSION SCENARIO	IPCC SRES A1B

BASELINE IMPACT

Tourism - Winter

DEFINITION	RESOLUTION	SOURCE
Value of skier visits	32 countries	2011 international paper on mountain tourism, Vanat, 2011.

Socioeconomic losses across affected countries, all else equal, are assumed to be directly proportional to GDP per capita. To obtain a country specific estimate of daily expenses GDP per capita of Country i is divided by GDP per capita in Austria and that ratio is then multiplied by 137 euro = 181.8 USD- which is the average per day expenses for a skier visitor, Steiger (2011).

The average daily expenses is multiplied by the number of skier visits (SV) in each country and converted into USD to obtain an overall estimate of revenue generated by winter tourists.

Tourism – Reef-based

DEFINITION	RESOLUTION	SOURCE
Revenue of the tourism sector per country (2010 and forecasts until 2021)*	44 countries	World Travel and Tourism Council (WTTC), 2012

*Reef tourism is estimated at 25% of the tourism sector for small islands (based on ECLAC report (2011); 10% for medium-sized tropical countries and 5% for larger countries. For countries not included in the database (e.g. small islands) the mean ((tourism revenue)/(GDP 2010)) per sub-region is multiplied by the GDP of the missing country.

CALCULATION OF CLIMATE EFFECT: TOURISM

WINTER

The impact estimate for Tyrol in Steiger (2011) is used as a benchmark to calculate CIFs for all 33 countries with functioning ski resorts.

Steiger (2011) estimates an economic loss in the year 2060 equal to 3% of revenues generated by winter tourists; not including investment costs (snowmaking machines, higher altitude lifts etc.). Therefore the following CIFs are assumed for Austria: $CIF_{1990} = 1$; $CIF_{2010}=0.9933$; $CIF_{2030}=0.98$. A polynomial of degree 2 is used to calculate the $CIF_{2000}=0.997475$

Estimations of the CIFs for the remaining countries are derived from elevation and latitude data that enable calculation of a factor that can then be applied to the Austrian estimates, as follows:

- Countries located above latitude 60 are assigned Austrian CIFs that are reduced by a factor 0.5.
- Calculate the ratio between the highest point in Austria and $Country_i$ and apply that factor to the Austrian loss factor which is (1-CIF). Thus, if the highest point in $Country_i$ is double of that in Austria, the loss_factor will be multiplied by a factor 2.

A redistribution factor based on a temperature factor has been used to redistribute the global losses using a weighted mean that include GDP 2010_i and temperature of the $country_i$. The new value of losses is equivalent to the old value added to the global losses multiplied by the redistribution factor. Same for reef-based (see fuller explanation of assumptions for redistribution further below). The winter tourism revenue and the losses are calculated in 2000, 2010 and 2030 as follows:

$$winter\_revenue_{2010} = \frac{GDP\ PPP\ per\ capita\_2010(N)}{GDP\ PPP\ per\ capita\_2010(Austria)} \times skier\_visits \times 181.8$$

$$winter\_revenue_{1990} = winter\_revenue_{2010} / winter\_CIF_{2010}$$

$winter\_costs_{2000} = winter\_revenue_{1990} - winter\_CIF_{2000} \times winter\_revenue_{1990}$

$winter\_costs_{2010} = winter\_revenue_{1990} - winter\_revenue_{2010}$

$winter\_costs_{2030} = winter\_revenue_{1990} - winter\_CIF_{2030} \times winter\_revenue_{1990}$

The CE for the years in question for winter tourism is then as follows:

$winter\_CE_{2000} = winter\_costs_{2000}/GDP_{2010}$

$winter\_CE_{2010} = winter\_costs_{2010}/GDP_{2010}$

$winter\_CE_{2030} = winter\_costs_{2030}/GDP_{2010}$

REEF BASED

The WRI GIS "Reefs at Risk" data sets are used to identify countries, where coral reefs are prevalent. It is assumed that all coral reefs have the same socioeconomic significance and a simple country specific average of the WRI-specified risk categories is calculated for: Low, Medium, High and Very High.

The present value loss figure is used for the A2 scenario in ECLAC Barbados (2011) that reflects the economic loss in the tourism industry due to coral reef degradation.

Furthermore, it is assumed that the cumulative loss of 1.333 billion USD by 2050 is distributed linearly across the period from 2010 to 2050, which results in a 2050 loss of approximately 66.65 million measured in present value USD. The period under review is transposed from 2010-2050 to 1990-2030 assuming the same results, i.e. a loss in 2030 of approximately 66.65 million USD, since the effect is understood to be linear.

The GDP growth factor is used to calculate the tourism revenue for 2030 with the WTTC data per country. Then the Barbados CIF is calculated as follows:

$CIF_{2030}(Barbados) = 1 - 66.65/(0.25 \times tourism\_revenue_{2030}) = 0.67$

$CIF_{2010} = 1 - 2/4 \times (1-CIF_{2030})=0.84$

$CIF_{2000} = 1- ¼ \times (1-CIF_{2030})=0.92$

Barbados is used as a benchmark CIF to which is added 0.01, 0.02 or 0.05 depending on the WRI category and year, see "Reef Risk" table below. By way of example, if Barbados is in the *Very High* category and Australia is in the *LOW*, Australia will have a CIF equal to 0.82.

REEF RISK

RISK CATEGORY	2000	2010	2030
LOW	0.948454	0.896907	0.823815
MEDIUM	0.938454	0.876907	0.773815
HIGH	0.928454	0.856907	0.723815
VERY HIGH	0.918454	0.836907	0.673815

The coral reef tourism revenue and the losses in 2000, 2010 and 2030 for all countries are calculated as follows:

$reef\_revenue_{2010} = tourism\_revenue_{2010} \times market\_share$

$reef\_revenue_{1990} = Reef\_revenue_{2010} / reef\_CIF_{2010}$

$reef\_costs_{2000} = Reef\_revenue_{1990} - reef\_CIF_{2000} \times Reef\_revenue_{1990}$

$reef\_costs_{2010} = Reef\_revenue_{1990} - reef\_revenue_{2010}$

$$reef\_costs_{2030} = Reef\_revenue_{1990} - winter\_CIF_{2030} \times reef\_revenue_{1990}$$

The CE for the years in question for reef tourism is as follows:

$$reef\_CE_{2000} = reef\_costs_{2000}/GDP_{2010}$$
$$reef\_CE_{2010} = reef\_costs_{2010}/GDP_{2010}$$
$$reef\_CE_{2030} = reef\_costs_{2030}/GDP_{2010}$$

To obtain the combined costs both tourism results are added together as follows:

$$CE_i = reef\_CE_i + winter\_CE_i \quad i = \{2000, 2010, 2030\}$$

REDISTRIBUTION OF TOURISM LOSSES

All losses are redistributed back as gains to "Cool countries" in an equilibrium approach. It is assumed that just because some countries are less attractive does not mean globally people will stop taking holidays with tourism revenues being accrued. The assumption follows that if reef and mountain tourism decline, any slack will be picked up by currently lower-temperature countries, which are undergoing a perceived improvement in their climate as the planet warms. Redistribution is on the basis of the size of their comparative total GDP and according to the relative "improvement in climate. It is assumed that "Cool countries" are all countries in the following regions: North America, Northern Europe, Western Europe, Eastern Europe, Russia/North Asia, East Asia, Australasia; plus the following countries: Argentina, Chile, South Africa, and Uruguay.

TRANSPORT

RESEARCH/DATA SOURCES: TRANSPORT

CLIMATE IMPACT FACTOR

Transport

DEFINITION	Marginal costs of riverine discharge decline linked to climate chagne for river-borne transportation in the transport sector
SOURCE(S)	Impact of Climate Change on River Discharge Projected by Multimodel Ensemble, Journal of Hydrometeorology vol. 7, Nohara et al., 2006 Climate Change and Inland Waterway Transport: Welfare Effects of Low Water Levels on the River Rhine, Jonkeren et al., 2011
RESOLUTION	For 24 rivers; CIF only for Netherlands
MODEL YEARS	Base: 1981-2000; Projectios: 2081-2100 Nohara et al., (2006)
CLIMATE EFFECT	Calculated loss in 2000 with polynomial of degree 2
EMISSION SCENARIO	IPCC SRES A1B

BASELINE IMPACT

Transport

DEFINITION	RESOLUTION	SOURCE
Inland waterway carriage of goods by millions of tonnes-km	28 countries (where river flow is declining)	UNECE Transport Division Database, 2012

CALCULATION OF CLIMATE EFFECT: TRANSPORT

Nohara et al. (2006) identifies river basins (and countries), where mean annual discharge is projected to decrease due to climate change.

It is assumed that river discharge is a proxy for the river-based water levels for an entire country. The Amu Darya (Tajikistan; Afghanistan; Turkmenistan; Uzbekistan) is disregarded, as the effect is deemed statistically insignificant. Based on Jonkeren et al. (2011), the Rhine is used as a benchmark to calculate the ratio between the change in River i and the Rhine. These ratios serve as *weight*, see table below, with the implicit assumption that the ratios are constant through time (below table is "Countries with no data on inland waterways").

The set of countries described in same below table with no data on inland waterway carriage of goods, are equated to similar countries and multiplied with a factor that reflects the ratio of inland waterways (km) in the two countries. The ratio between GDP per capita in Countryi and the Netherlands is used to transpose effects for other countries.

Assuming that the welfare loss of 91 million euro, estimated for 2003 in Jonkeren et al. (2011), represents the economic loss due to climate change in the Netherlands in 2030, the CE; Assuming also that the 20 year average welfare loss of 28 million euro represents the loss due to climate change in the Netherlands in 2010; assuming a zero impact in the Netherlands in 1990; the impact in the Netherlands in 2000 is: → 9.625 million euro.

The economic losses for the years t = 2000, 2010, 2030 in these countries (i) are calculated using the Dutch estimates as benchmark and by applying the relevant weight as well as tonne-km and GDP PPP 2010 per capita ratio, as follows:

$$Loss_{country\ i,\ t} = (GDP\ per\ capita_{country\ i} / GDP\ per\ capita_{Netherlands}) \times (tonne\text{-}km_{country\ i} / tonne\text{-}km_{Netherlands})\ weight\ Loss_t$$

The CE for the years in question is then as follows:

$$CE_{2000} = Loss_{2000}/GDP_{2010}$$

$$CE_{2010} = Loss_{2010}/GDP_{2010}$$

$$CE_{2030} = Loss_{2030}/GDP_{2010}$$

COUNTRIES WITH NO DATA ON INLAND WATERWAYS

Carriage of goods by millions of tonne-km

COUNTRY	WATERWAYS (KM)*		SET EQUAL TO	WATERWAYS (KM)*
IRAQ	5,279 km (the Euphrates River (2,815 km), Tigris River (1,899 km), and		KAZAKHSTAN	4,000 km (on the Ertis (Irtysh) River (80%) and Syr Darya (Syrdariya)

	Third River (565 km) are the principal waterways) (2010)			River) (2010)
SYRIA	900 km (2010)		IGNORE (navigable but not economically significant)	N/A
TURKEY	1,200 km (2008)		KAZAKHSTAN (multiply with a factor 0.25)	4,000 km (on the Ertis (Irtysh) River (80%) and Syr Darya (Syrdariya) River) (2010)
AUSTRALIA	2,000 km (2006)		IGNORE (mainly used for recreation inc. Murray-Darling river systems)	N/A
LIECHTENSTEIN	28 km (2010)		AUSTRIA (multiply with a factor 0.1)	358 km (2011)
SWITZERLAND	1,299 km (there are 1,227 km of waterways on lakes and rivers for public transport and another 65 km on the Rhine River between Basel-Rheinfelden and Schaffhausen-Bodensee used for the transport of commercial goods) (2010)		AUSTRIA (multiply with a factor 4.0)	358 km (2011)
MEXICO	2,900 km (navigable rivers and coastal canals mostly connected with ports on the country's east coast) (2010)		UNITED STATES (multiply with a factor 0.15)	19,312 km used for commerce; Saint Lawrence Seaway of 3,769 km, including the Saint Lawrence River of 3,058 km, is shared with Canada) (2008)
UZBEKISTAN	1,100 km (2009)		KAZAKHSTAN (multiply with a factor 0.25)	4,000 km (on the Ertis (Irtysh) River (80%) and Syr Darya (Syrdariya) River) (2010)
TAJIKISTAN	200 km (along Vakhsh River) (2010)		KAZAKHSTAN (multiply with a factor 0.25)	4,000 km (on the Ertis (Irtysh) River (80%) and Syr Darya (Syrdariya) River) (2010)

*CIA World Factbook (2012)

4 PART I: ENVIRONMENTAL DISASTERS

The Monitor's Part I/Climate Impact Area of Environmental Disasters measures negative ramifications for populations and infrastructure as a result of the effect of (very largely) human-induced climate change on forms of extreme weather effects. Indicators included under Climate Environmental Disasters are:

- Floods and Landslides
- Storms
- Wildfires
- Drought

TABLE OF INDICATORS

Environmental Disasters - Impact Area

SUB-INDEX	INDICATOR	CLIMATE EFFECT (CE) SUB-INDICATOR
ENVIRONMENTAL DISASTERS	Floods and Landslides	Excess deaths per capita and excess damage costs relative to GDP (GDP USD %) due to climate change for floods and landslides (%)
	Storms	Excess deaths per capita and excess damage costs relative to GDP (GDP USD %) due to climate change for storms (%)
	Wildfires	Excess deaths per capita and excess damage costs relative to GDP due to wildfires (GDP USD %) due to climate change for wildfires (%)
	Drought	Excess damage costs relative to GDP (GDP USD %) due to climate change for drought and soil subsidence (%)

The total excess deaths due to climate change for a country is the sum of the CE for disasters comprising the sub-index Environmental Disasters:

. SUM ($CE_{2010,deaths}$)=CE_Storm$_{2010,deaths}$ + CE_Floods&Landslides$_{2010,deaths}$ + CE_Wildfires$_{2010,deaths}$ The total excess damage costs due to climate change for a country is the sum of the CE for disasters comprising the sub-index Environmental Disasters:SUM ($CE_{2010,gdp}$)=CE_Storm$_{2010,gdp}$ + CE_Floods&Landslides$_{2010,gdp}$ + CE_Wildfires$_{2010,gdp}$ + CE_Drought$_{2010,gdp}$

- Calculation of the index score is completed using the method described in the introductory section:
- Index score $_{2010}$ = ((SUM ($CE_{2010,deaths}$)/(10xMAD(SUM($CE_{2010,deaths}$))+1)x100
- Index score $_{2010}$ = ((SUM ($CE_{2010,gdp}$)/(10xMAD(SUM($CE_{2010,gdp}$))+1)x100

To reflect both deaths and damage costs in the weather disaster sub-index, the overall index score is constructed by adding the two indices with a weight of 100% of damage cost and 100% weighting of deaths. This is because while on the one hand it is recognized that mortality is a more robust indicator globally than economic effects (which vary more in accuracy due to uneven reporting and insurance coverage/services), ignoring economic effects presents an under appreciation of countries that suffer extreme economic losses but have managed to mitigate loss of life during disaster. Economic effects were counted at 100% as for deaths, since a number of small countries with populations beneath one million would otherwise be penalized in terms of their vulnerability assessment given that estimated climate-related deaths per ten million people number only in single or double digits globally. Countries with both high mortality and high economic losses score higher for a given value than those with high results for one but not the other. The equation is:

- Weather Disaster Sub-Index/Aggregate Indicator Score = 100% (index score deaths - 100) + 100% x (index score damage cost – 100)

Which translates to:

- Weather Disaster Sub-Index/Aggregate Indicator Score = index score deaths + index score damage cost

IMPACT AREA BASELINE DATA AND PROJECTIONS

SOCIOECONOMIC DATA

Environmental Disasters

DEFINITION	RESOLUTION	SOURCE
Population 2010 (per country)	Country level, 184 countries	United Nations, Department of Economic and Social Affairs, Population Division, World Population Prospects, 2011
GDP 2010 in 2010 USD (by country)	Country level, 184 countries	IMF, World Economic Outlook Database, September 2011

SOCIOECONOMIC PROJECTION

Environmental Disasters

DEFINITION	RESOLUTION	SCENARIO	SOURCE
Relative change in population mean from 2010 to 2030*	Country level, 184 countries	SRES A1	CIESIN, 2012
Relative change in real GDP 2010 to 2030**			

*The projection is only applied to the absolute figures as mortality and population are assumed to grow proportionally

**The projection is only applied to the absolute figures as GDP and damage costs are assumed to grow proportionally.

RESEARCH/DATA SOURCES: ENVIRONMENTAL DISASTERS

BASELINE IMPACT

Environmental Disasters (All Indicators)

DEFINITION	RESOLUTION	SOURCE

Mean number of deaths per year	Average from the years 1990-2010 to get the data for the base year 2000	EM-DAT CRED* and Munich RE NATCAT** (both inflation adjusted); UNEP Grid 2012***
Mean damage costs in current USD		

*The EM-DAT CRED Database is the most comprehensive global disaster database available publically today. CRED is known not to be entirely accurate, and reporting quality does vary across countries, although mortality demonstrates higher robustness than other categories accounted for, such as people "affected". That said, UNISDR highlighted in the 2009 Global Assessment Report on Disaster Risk Reduction the case of the Vargas flood disaster in Venezuela, which CRED registers as 30,000 when detailed post disaster studies have shown the death toll was under 1,000. Detailed analysis of CRED database outliers was undertaken for each variable source used and subjected to desk research for validation. However, the Vargas disaster is the only outlier to not be validated, therefore the value for this particular incident was modified to that published in the report cited by the UN ISDR. No other values taken from CRED have been modified.

** Munich Reinsurance Company, Geo Risks Research, NatCatSERVICE – Since both CRED and Munich Re NATCAT share similar sources of information, but also have distinct information sources between them, it was assumed that neither necessarily had perfect nor false information, but that one or the other could have more complete information. Therefore, for those indicators where a hybrid database of CRED and NATCAT was able to be used, the highest value for a given country from either database was chosen.

***The UNEP Grid database was only used to substitute mortality data for floods and landslides and storms (no data from UNEP Grid for mortality risk for Wildfires was available).

CLIMATE IMPACT FACTORS

RANGE OF CIFs

Environmental Disasters (All Indicators)

INDICATOR	TYPE	2010	2030
Floods	Mortality & Damage	12.8%-29%	26.9- 65.9%
Landslides	Mortality & Damage	14.7% – 34%	29.5% – 80.1%
Tropical Storms	Mortality & Damage	0 – 2.85%	0 – 6.56%
Wildfires	Mortality & Damage	-5.95% - 5.05 %	-9.48% – 12.73%
Drought	Damage	14%-156%	34%-203%

FLOODS & LANDSLIDES

Floods and landslides are a combined indicator since the main socio-economic base data source (EM-DAT/CRED) has only collected landslide data in very few countries, while some serious landslide incidents (such as the Vargas disaster) are reported in that database as floods. It was therefore deemed misleading to provide two separate indicators.

The combination indicator for deaths* and damages are yielded from:

Total Deaths = Deaths floods + Deaths landslides

Total Damages = Damages floods + Damages landslides

RESEARCH SOURCES: FLOODS & LANDSLIDES

CLIMATE DATA

Floods

DEFINITION	Effect of change in magnitude and frequency of extreme precipitation with return time of 20 years accumulated in 24 hours due to climate change on flood mortality and economic damages
SOURCE(S)	Changes in Temperature and Precipitation Extremes in the IPCC Ensemble of Global Coupled Model Simulations, Kharin et al., 2007. The Death Toll From Natural Disasters: The Role of Income, Geography, and Institutions, Kahn, 2005 Impact Of Climate Change On Snowmelt Runoff: A Case Study Of Tamakoshi Basin In Nepal, Shilpakar et al., 2011.
RESOLUTION	Sub continental scale, 9 sub regions
EMISSION SCENARIO	IPCC SRES A1B
MODEL YEARS	Base: 1981-2000; Projection: 2046-2065, 2081-2100
MODEL DISTRIBUTION	Exponential
UNIT OF MEASUREMENT	Increase factor for number of deaths and damages associated with floods due to climate change.
DYNAMIC ADJUSTMENT	Base year: CIF=1; R was used to find the best fit exponential function for these three points. With this polynomial the CIFs were calculated for 2010 and 2030. Two different CIFs were obtained, one for deaths and the other for damages, as the effect of floods on each indicator is different.
CLIMATE EFFECT	CE_deaths_per_capita(year)=CIF(year)*UNEPGrid_mortality/population(2010) CE_costs_per_GDP(year)=CIF(year)*Max{MunichRe_costs;CRED_costs1990-2010}/GDP(2010) Year = 2000, 2010, 2030
OUTPUT	Excess deaths due to climate change for floods in total and as a share of population. Damage costs due to climate change for floods in total and as a share of population.

Landslides

DEFINITION	Effect of change in magnitude and frequency of extreme precipitation with return time of 20 years accumulated in 24 hours due to climate change on landslide mortality and economic damages
SOURCE(S)	Changes in Temperature and Precipitation Extremes in the IPCC Ensemble of Global Coupled Model Simulations, Kharin et al.,

	2007.
RESOLUTION	Sub continental scale, 9 sub regions
EMISSION SCENARIO	A1B
MODEL YEARS	Base: 1981-2000; Projection: 2046–2065, 2081-2100
MODEL DISTRIBUTION	Exponential
UNIT OF MEASUREMENT	Increase factor for number of deaths and damages associated with landslides.
DYNAMIC ADJUSTMENT	Base year: CIF=1; R was used to find the best fit exponential function for these three points. With this polynomial the CIFs were calculated for the years of interest 2010 and 2030. Two different CIFs are obtained, one for deaths and the other for damages, as we can consider that the effect of floods on them is different, so we are able to approximate the different effect of each one of them.
CLIMATE EFFECT	CE_deaths_per_capita(year)=CIF(year)xUNEPGrid_mortality/population(2010) CE_costs_per_GDP(year)=CIF(year)xMax{MunichRe_costs;CRED_costs1990-2010}/GDP(2010) Year = 2000, 2010, 2030
OUTPUT	Excess deaths due to climate change for landslides in total and as a share of population. Damage costs due to climate change for landslides in total and as a share of population.

CALCULATION OF CLIMATE EFFECT: FLOODS & LANDSLIDES

FLOODS

Latitude and longitude information for countries and cities was obtained from Geoworldmap. This geographical information was used to generate subregions according to those defined by Kharin et al. (2007) in *Changes in Temperature and Precipitation Extremes in the IPCC Ensemble of Global Coupled Model Simulations*. Rain data with a return time of twenty years and intensity change was used from Kharin et al. (2007) as the precipitation variable in the models for both mortality and damages. The climate impact factors (CIF) were calculated by multiplying the change in magnitude and frequency of extreme precipitation with return time of twenty years cumulated over 24 hours. As for landslides, the information was directly coupled with UNEP Grid modeled mortality risk data and the hybrid economic database from Munich Re and EM-DAT CRED.

To include the influence of climate change on snowmelt runnoff in snow-dominated regions data coming from Shilpakar were retrieved and the CIFs have been updated in the following way:

CIF_snowmelt_included=CIFxsnowmelt_correction_factor

where snowmelt_correction_factor>1.

An additional correction to take into account the economic growth was applied following the statistical analysis performed by Kahn.

The importance of study performed by the last author shows the positive impact of the socio-economic growth on the global death toll through the improvement of basic infrastructures and risk culture in general.

LANDSLIDES

Latitude and longitude information for countries and cities was obtained from Geoworldmap. This geographical information was used to generate subregions according to those defined by Kharin et al. (2007) in *Changes in Temperature and Precipitation Extremes in the IPCC Ensemble of Global Coupled Model Simulations*. Rain data with a return time of twenty years and intensity change was used from Kharin et al. (2007) as the precipitation variable in the models for both mortality and damages. The climate impact factors (CIF) were calculated by multiplying the change in magnitude and frequency of extreme precipitation with return time of twenty years accumulated over 24 hours.

STORMS

RESEARCH SOURCES: EXTRA-TROPICAL STORMS

CLIMATE DATA

Extra-Tropical Storms

DEFINITION	Average simulated loss ratios of seven different GCMs for 2021-2050 and 2071-2100 (losses due to climate change) with 1960-2000 as base years
SOURCE(S)	*Future change in European winter storm losses and extreme wind speeds inferred from GCM and RCM multi-model simulations*; Natural Hazards and Earth System Sciences Paper, Donat et al., 2011.
RESOLUTION	CIFs available for three European countries (Germany, France, Poland) and three areas (Iberia, UK, Benelux) There are 13 countries for which no CIF is available but EMDAT data is available (other European countries, Russia, USA), in which case there is an application of average mean of CIFs.
MODEL YEARS	Base: 1980; Projection: 2021-2050 and 2071-2100
MODEL DISTRIBUTION	Polynomial time fit (degree: 2) using the following data points: 1980 (zero impact), 2035 (as estimate for 2021-2050), 2085 (as estimate for 2071-2100); Polynomial interpolation with 1980, 2035 and 2085 data and extrapolation of CIFs for 1990, 2000, 2010 and 2030
UNIT OF MEASUREMENT	Per capita deaths and per GDP cost
BASELINE DATA	UNEP GRID (Cyclones and Surge) for mortality (modeled); EM-DATA CRED and Munich Re for economic
DYNAMIC ADJUSTMENT	Base year: CIF=1; R was used to find the best fit exponential function for these three points. With this polynomial the CIFs were calculated for 2000, 2010 and 2030
OUTPUT	Excess deaths due to climate change for extra tropical storms in total and as a share of population. Damage costs due to climate change for extra tropical storms in total and as a share of GDP.

CALCULATION OF CLIMATE EFFECT: EXTRA-TROPICAL STORMS

Climate effect/CIF is derived from Donat et al, (2011) with baseline data from CRED for mortality and the hybrid CRED/Munich RE database for economic. Application of average CIF for remaining countries with available CRED data (other European countries, Russia, United States).

Polynomial interpolation with 1980, 2035 and 2085 data and extrapolation of CIFs for 1990, 2000, 2010 and 2030, as follows:

- CIF_{2000} = CIF (1980-2000)/ CIF (1980-1990)
- CIF_{2010} = CIF (1980-2010)/ CIF (1980-1990)
- CIF_{2030} = CIF (1980-2030)/ CIF (1980-1990)

Application of CIFs to obtain CC_COSTS_2000, CC_COSTS_2010, CC_COSTS_2030, CC_DEATHS_2000, CC_DEATHS_2010 and CC_DEATHS_2030

RESEARCH SOURCES: TROPICAL STORMS

CLIMATE DATA

Tropical Storms

DEFINITION	Yearly cost of tropical storm activity in affected countries due to climate change
SOURCE(S)	*The Impact of Climate Change on Global Tropical Storms Damages*; World Bank Working Paper, Mendelsohn et al., 2011. *Global trends in tropical cyclone risk*, Peduzzi et al., 2012
RESOLUTION	84 countries, assumption of zero climate impact on remaining 100 countries (mainly not exposed to tropical storms because of their distance from oceans)
EMISSION SCENARIO	IPCC SRES A1B
MODEL YEARS	Base: 2000; Projection: 2100
MODEL DISTRIBUTION	Assumption of linearity and extrapolation of climate impact for 2000, 2010 and 2030 (zero impact in base year 1990 assumed)
UNIT OF MEASUREMENT	Per capita deaths and per GDP cost
BASELINE DATA	UNEP GRID (Cyclones and Surge) for mortality (modeled); EM-DATA CRED and Munich RE for economic
MODEL DISTRIBUTION	Linear
OUTPUT	Excess deaths due to climate change for tropical storms in total and as a share of population. Damage costs due to climate change for tropical storms in total and as a share of GDP.

CALCULATION OF CLIMATE EFFECT: TROPICAL STORMS

DAMAGES

A linear approach was used to assess the damages in the years 2000, 2010 and 2030.

$COSTS_{2000}$=0.1x$EXTRACOSTS_{2100}$

$COSTS_{2010}$=0.2x$EXTRACOSTS_{2100}$

$COSTS_{2030}$=0.4x$EXTRACOSTS_{2100}$

From Mendelsohn et al. (2011) the MIROC model is chosen to estimate the climate effect, and which utilizes A1B boundary conditions. Mendelsohn et al. (2011) analyses multiple models, most of which generate conflicting results making a mean of the models uninformative. MIROC was chosen since it appeared more closely aligned with observational and analytical evidence of changes as documented by the IPCC (IPCC, 2007a). In addition, MIROC is a more conservative model that downplayed interference the most extreme storms versus other models analyzed in Mendelsohn et al. (2011).

The percent change of costs from 2000-2010 and from the years 2000-2030 were calculated and applied to the fatalities retrieved from the UNEP Grid database (Cyclone and Surge) to provide the values for DEATHS_2010 and DEATHS_2030.

DEATHS

Using the relative risk classes coming from Peduzzi et al, (2012) the number of deaths in 2010 per country is calculated. This number is divided by the yearly average costs for 1990-2010 from CRED to obtain a death per damage factor. Deaths in 2000, 2010, 2030 were then evaluated as follows:

$Deaths_{2000}$ = death_per_damage x $Costs_{2000}$

$Deaths_{2010}$ = death_per_damage x$Costs_{2010}$

$Deaths_{2030}$ = death_per_damage x $Costs_{2030}$

CONSTRUCTION OF DAMAGE AND DEATHS STORMS INDEX (FOR TROPICAL STORMS AND EXTRA TROPICAL STORMS):

The sum of per capita deaths / per GDP costs from tropical and extra-tropical storms were combined.

Calculation of MAD was based on 2010 data, only taking into account affected countries (i.e. with extra tropical storms between 1990-2010 registered in the CRED database: (COSTS_2000>0 or DEATHS_2000>0)).

WILDFIRES

RESEARCH SOURCES: WILDFIRES

CLIMATE DATA

Wildfires

DEFINITION	Marginal gains/losses due to the effect of climate change on wildfire occurance globally
BASE YEAR	Mean from 1990-2010 to give base year 2000
SOURCE(S)	Global Pyrogeography: the Current and Future Distribution of Wildfire, Krawchuk et al., 2009.
MODEL	Geophysical Fluid Dynamics Laboratory Climate Model 2.1; dynamic global vegetation models (DGVMs)
RESOLUTION	Global 100 km on 100 km
EMISSION SCENARIO	IPCC SRES A2

MODEL YEARS	Base: 2000 (1990-2010); Projections: 2010-2039, 2040-2069, 2070-2099
MODEL DISTRIBUTION	Polynomial degree 3
UNIT OF MEASUREMENT	Increase factor for number of deaths and damages associated with climate-induced wildfires.
DYNAMIC ADJUSTMENT	Base year: CIF=1; With R we calculated a polynomial of degree 3 which includes these four points. With this polynomial we calculated the CIFs for the years of interest 2010 and 2030.
CLIMATE EFFECT	CE_deaths_per_capita(year)=CIF(year)x CRED_mortality1990-2010/population(2010) CE_costs_per_GDP(year)=CIF(year)xMax{MunichRe_costs; CRED_costs1990-2010}/GDP(2010) year = 2010, 2030
OUTPUT	Excess deaths due to climate change for wildfires in total and as a share of population. Damage costs due to climate change for wildfires in total and as a share of population.

CALCULATION OF CLIMATE EFFECT: WILDFIRES

Global data for "changes in the global distribution of fire-prone pixels under the A2 (mid-high) emissions scenario," showing the differences in current and future fire distributions was collected from Krawchuk et al. (2009) authors of "Global Pyrogeography". The current and the future distribution of wildfire data was obtained in a grid format and then stored in a matrix. Latitude and longitude information for cities, states and countries were retrieved from the Geoworldmap. A density map was also coupled with information provided by Geoworldmap database to weight the variable change. The information taken from Geoworldmap grid and the density map was then matched with the data values of the modeled values received from Krawchuk et al. (2009) in order to provide values for the variables around cities. Values for the variables around cities were then combined to provide values state by state with a mesh dimension of 100 kilometers. The modeled CIFs were the3n matched with EM-DAT CRED aggregated data from 1990-2010 for wildfire mortality and the hybrid database for economic losses from Munich Re/EM-DATA CRED to produce the climate effect for the relatively limited set of countries that have experienced noticeably damaging wildfires in the last 20 years.

DROUGHT

The Drought indicator is comprised of 1) drought or anomalous hydrological events and agricultural damages incurred, and 2) drought-induced soil subsidence and the damage to infrastructure this can cause.

RESEARCH/DATA SOURCES: DROUGHT

CLIMATE IMPACT FACTOR

Soil Subsidence

DEFINITION	Accumulated drought extra costs due to Climate change.
SOURCE(S)	Projected changes in drought occurrence under future global warming from multi-model, multi scenario, IPCC AR4 simulations, Sheffield and Wood, 2008.
RESOLUTION	Subregional
MODEL YEARS	Base: 1980-2000; Projection: 2030
MODEL DISTRIBUTION	Linear
EMISSION SCENARIO	IPCC SRES A1B

BASELINE IMPACT

Soil Subsidence

DEFINITION	RESOLUTION	SOURCE
Accumulated extra costs due to drought	192 countries	EM-DATA CRED

In order to assess the drought damages due to climate change, the return time change of long drought period (4-6 months) in the period 1990-2030 were retrieved from Sheffield and Wood (2008).

To calculate the costs for the different countries N the given costs data from CRED were used:

$costs_{2000}(N) = costs_{2000}(N) \times Cif_{2000}$
$costs_{2010}(N) = costs_{2000}(N) \times Cif_{2010}$
$costs_{2030}(N) = costs_{2000}(N) \times Cif_{2030}$

Where Cif_{year} is the drought frequency change in the period 1990-year.

Then we compare these costs to the GDP of 2010:
$CE_{2000} = costs_{2000}/GDP_{2010}$
$CE_{2010} = costs_{2010}/GDP_{2010}$
$CE_{2030} = costs_{2030}/GDP_{2010}$

DROUGHT (SOIL SUBSIDENCE)

RESEARCH/DATA SOURCES: SOIL SUBSIDENCE

CLIMATE IMPACT FACTOR

Drought (Soil Subsidence)

DEFINITION	Accelerated infrastructure depreciation due to a lowering of terrain/ground levels due to climate change.
SOURCE(S)	Simulating past droughts and associated building damages in France, Corti et al. 2009 Projected changes in drought occurrence under future global warming from multi-model, multi scenario, IPCC AR4 simulations, Sheffield and Wood, 2008. Population Density grid data (2000), The Atlas of Global Conservation Hoekstra et al., 2010. Observed and projected climate shifts 1901-2100 depicted by world maps of the Koppen-Geiger climate classification, Rubel and Kottek, 2010
RESOLUTION	184 0.5°X 0.5° (Corti et al. 2009), 0.5° X 0.5° (Hoekstra et al. 2010)
MODEL YEARS	Base: 1980-2000; Projection: 2030
MODEL DISTRIBUTION	Linear
EMISSION SCENARIO	IPCC SRES A1B

BASELINE IMPACT

Drought (Soil Subsidence)

DEFINITION	RESOLUTION	SOURCE
Accumulated extra costs for infrastructure in extreme heat conditions (not exclusively climate change).	192 countries	Simulating past droughts and associated building damages in France, Corti et al. 2009

CALCULATION OF CLIMATE EFFECT: DROUGHT (SOIL SUBSIDENCE)

To assess the soil subsidence drought-induced damages two main publications has been used: Corti (2009), to assess the mean damage per inhabitant in France; and Sheffield and Wood (2008) to analyse the return time change of long drought period (4-6 months) in the period 1990-2030 globally.

To assess the population living in affected regions inside and outside of France (globally) the population density map has been overlapped with the climate Koppen map. Populations in desert and permafrost regions have not been taken into account for reasons of non-applicability and overlap with respect to the permafrost indicator of the Monitor. A different approach has been used for small islands and archipelago countries, to improve the accuracy of the data due to their limited size and their particular geologic and infrastructural conditions. For these reasons they have the same GDP fraction as the most similar larger sub-regional country or a regional basket-country mean.

To calculate the costs for the different countries N the given costs, the affected people and the GDP PPP per capita 2010 of France were used and the number of affected people and their GDP PPP per capita 2010 of country N:

$$costs_{2000}(N) = costs_{2000}(FRA) * \frac{[affected(N)*GDP\_PPP2010(N)]}{[affected(FRA)*GDP\_PPP2010(FRA)]} \, x Cif_{2000}$$

$$costs_{2010}(N) = costs_{2000}(FRA) * \frac{[affected(N)*GDP\_PPP2010(N)]}{[affected(FRA)*GDP\_PPP2010(FRA)]} \, x Cif_{2010}$$

$$costs_{2030}(N) = costs_{2000}(FRA) * \frac{[affected(N)*GDP\_PPP2010(N)]}{[affected(FRA)*GDP\_PPP2010(FRA)]} \, x Cif_{2030}$$

Where Cif_{year} is the drought frequency change in the period 1990-year.

Then we compare these costs to the GDP of 2010:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

5 PART II: BASE INDICATORS – CARBON

The Monitor's Part II ("Carbon") relies on a range of population, economic and emission/projection scenarios across different indicators and impact areas.

POPULATION INDICATORS

KEY DATA
Overview

	DEFINITION	RESOLUTION	SOURCE
SOCIOECONOMIC BASELINE	Population (per country) divided by 1000	By country	UNSD, 2010
SOCIOECONOMIC PROJECTION	Population (per country)	By Country	UN Population Division - Medium-fertility variant, 2010-2100, 2012

ECONOMIC INDICATORS

KEY DATA
Overview

	DEFINITION	RESOLUTION	SOURCE
SOCIOECONOMIC BASELINE	GDP 2010 in 2010 USD (by country)	Country level, 184 countries	IMF, World Economic Outlook Database, September 2011
SOCIOECONOMIC PROJECTION	Relative change in real GDP 2010 to 2030	Country level, 184 countries	CIESIN (SRES A1)
SOCIOECONOMIC ABSOLUTE VALUE	GDP PPP 2000, 2010, 2030 current USD	Country level, 184 countries	IMF, Economic Outlook database; Columbia growth rates for 2030

EMISSION/PROJECTION SCENARIOS

EMISSION/PROJECTION SCENARIOS BY INDICATOR
Overview

IMPACT AREA	INDICATOR (SUB-INDICATOR)	SCENARIO
ENVIRONMENTAL DISASTERS	OIL SANDS	CAPP market forecast
	OIL SPILLS	EIA Douglas-Westwood analysis

HABITAT CHANGE	BIODIVERSITY (OZONE) BIODIVERSITY (ACID)	"GHGs capped-no ozone" and "Climate and GHGs only" scenario OECD (450 ppm) scenario
	CORROSION	OECD (450 ppm) scenario
	WATER	OECD (450 ppm) scenario
HEALTH IMPACT	AIR POLLUTION (URBAN) AIR POLLUTION (ASTHMA)	OECD (450 ppm) scenario A2
	INDOOR SMOKE (RESPIRATORY, COPD) INDOOR SMOKE (CARDIOVASCULAR) INDOOR SMOKE (TUBERCULOSIS) INDOOR SMOKE (VISUAL IMPAIRMENT)	OECD (450 ppm) scenario UN Population Division - Medium-fertility variant scenario UN Population Division - Medium-fertility variant scenario UN Population Division - Medium-fertility variant scenario
	OCCUPATIONAL HAZARDS (ASTHMA & COPD) OCCUPATIONAL HAZARDS (CWP) OCCUPATIONAL HAZARDS (STOMACH CANCER)	WHO scenario IEA "450 Scenario" IEA "450 Scenario"
INDUSTRY STRESS	AGRICULTURE (OZONE) AGRICULTURE (ACID)	A2 OECD (450 ppm) scenario
	FISHERIES (MARINE) FISHERIES (INLAND)	A1B A1B
	FORESTRY (ACID) FORESTRY (OZONE)	OECD (450 ppm) scenario "GHGs capped-no ozone" and "Climate and GHGs only" scenario

6 PART II: ENVIRONMENTAL DISASTERS

The Part II/Carbon Environmental Disasters Impact Area covers two indicators of highly geographically restricted environmental damage phenomena linked to the carbon economy and greenhouse gas activities. These are: 1) Oil Sands (otherwise known as "Tar Sands"); and, 2) Oil Spills – each are detailed below.

OIL SANDS

RESEARCH/DATA SOURCES: OIL SANDS

KEY DATA

Oil Sands

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	Resources and production of Natural Bitumen - tar sands – 2008 (million barrels)	10 countries (4 with an existing production)	2010 *Survey of Energy Resources* , World Energy Council, 2010
IMPACT ESTIMATE	Bioremediation cost from fine tailings (FT - waste from extracting the oil) Pollution associated with fine tailings represents the primary environmental impact from tar sands extraction One barrel of oil results in 2.83 barrels of FT that has an estimated bioremediation cost of CAD $50/ton The pollution/cost ratio associated with barrel of oil (from tar sands mining) is assumed constant across time and countries	Estimates based on Canada only	Canada's Oil Sands Shrinking Window of Opportunity, CERES RiskMetrics Group, 2010

IMPACT PROJECTIONS	Only Canada is assumed to have tar sands production in 2000 Canada, USA, Indonesia, and Russia have tar sand production in 2008, which is assumed to represent 2010. The 3 latter countries are assumed to have the same tar sand oil production growth as Canada. 7 other countries are assumed to have a production in 2030, based on the World Energy Council Publication, where it is assumed they have the same production/total resources ratio*	N/A	CAPP Canadian Crude Oil Production Forecast 2011 – 2025, Canadian Association of Petroleum Production, 2011

*The yearly projected production estimates to 2025 is extrapolated to 2030 by assuming constant growth and applying a linear projection

CALCULATIONS: OIL SANDS

PRODUCTION

The World Energy Council provided resource/production figures for tar sands for 2008. Only Canada (represents 98% of global production), USA, Indonesia, and Russia have tar sands production. While the Canadian Association of Petroleum Production provided year-by-year projections of future production level to 2025, other countries are projected to have the same growth rates as Canada. Based on qualitative assessments, drawing on the World Energy Council Publication, a further 7 countries are assumed to have a significant production in 2030, where we assume they have the same production/total resources ratio.

COSTS

To translate the production into USD we used the assumption from CERES "One barrel of oil results in 2.83 barrels of FT that has an estimated bioremediation cost of CAD $50/ton" was converted into USD by multiplying with 1.0021.

Then these costs are compared to the GDP of 2010 as follows:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

OIL Spills

RESEARCH/DATA SOURCES: OIL SPILLS

KEY DATA

Oil Spills

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	67 incidents in 33 affected countries since 1980 (barrels) Tankers Rigs Other disasters Decadal aggregation removes stochastic and irregular years, so 2010 data does not e.g. represent the reality for 2010 The effect is assumed to be isolated to the country in which the reported coast line is*	Country level/international	CEDRE, Centre of Documentation, Research and Experimentation on Accidental Water Pollution, Spill Database Center for Tankship Excellence, CTX version 4.6 Oil Spill Database, Tryse,2010
IMPACT ESTIMATE	The spills are translated into costs by applying the cost tables in Etkin (2004) that provide unit costs (USD) for spill type and volume within three mutually exclusive areas Spill response costs Socioeconomic costs Environmental costs These costs are assumed to be similar across years and countries Deepwater drilling is understood to carry 3 times the risks of accident as other forms of drilling taken together	Estimates based on the United States	Modelling Oil Spill Response and Damage Costs, Environmental Research Consulting, EPA, Etkin, 2004 Muehlenbachs et al., 2011
IMPACT PROJECTIONS	Deepwater production is projected to increase through to 2015	Global	"Global Deepwater Prospects", Westwood , 2010

CALCULATIONS: OIL SPILLS

The Douglas Westwood report "Global Deepwater Prospects" provided baseline information of the current and future intensity of deepwater drilling. A highlight is that deepwater production increases from 2% of liquid fuels in 2002, 8% in 2009 to 12% in 2015, after which it is expected to stabilize. The US based RFF Center for Energy Economics provided analysis of how incident risks changes when drilling deeper. Based on this analysis, the assumption is adopted that the risk of an incident (spill, fire, injury) is three times as high for deepwater than for traditional drilling (shallow waters, land etc.). A hybrid baseline database was drawn upon to increase coverage consisting of CEDRE, Centre for Tankship Excellence and Tryse.

Using these assumptions the costs were calculated as follows:

$costs_{2000}$ = 20_year_average (yearly average, without deepwater effect)

$costs_{2010}$ = 20_year_avrage * (1 + 0.08 x 3) (yearly average + 2010 deepwater effect)

$costs_{2030}$ = 20_year_avrage * (1 + 0.12 x 3) (yearly average + 2030 deepwater effect)

The annual average losses were weighed with the GDP PPP per capita for each year:

$$adjusted\_costs_i(N) = costs_i * \frac{GDP\ PPP\ per\ capita(N)}{GDP\ PPP\ per\ capita(USA)} \quad ; i \in (2000, 2010, 2030)$$

Then these costs are compared to the GDP of 2010 as follows:

CE_{2000} = $adjusted\_costs_{2000}/GDP_{2010}$

CE_{2010} = $adjusted\_costs_{2010}/GDP_{2010}$

CE_{2030} = $adjusted\_costs_{2030}/GDP_{2010}$

7 PART II: HABITAT CHANGE

The Impact Area for Habitat Change under Part II/Carbon of the Monitor is divided into three indicators – Biodiversity, Corrosion and Water. The Biodiversity indicator comprises two separate effect components: 1) the effect of ozone toxicity on biodiversity; and, 2) the effect of acid rain on biodiversity.

BIODIVERSITY (OZONE)

RESEARCH/DATA SOURCES: BIODIVERSITY (OZONE)

KEY DATA

Biodiversity (Ozone)

DATA	DEFINITION (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
IMPACT ESTIMATE	Ozone impact on pastures and boreal and tropical forests.	Continental and Sub-Continental	Global economic effects of changes in crops, pasture, and forests due to changing climate, carbon dioxide, and ozone, Reilly et.al., 2007
	Carbon stock per grid cell.	Rescaled to 0.5 ° x 0.5°	Global Vegetation biomass carbon stocks - 1 km resolution, Ruesch and Gibbs, 2008. New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000.
	Net primary productivity in gram carbon/cell.	0.5 ° x 0.5 °	Spatial Distribution of Net Primary Productivity (NPP), Imhoff et al., 2004.
	Relationship between net primary production and ecosystem services value per hectare per year.		Biodiversity and ecosystem services: A multi-scale empirical study of the relationship between species richness and net primary production, Costanza et al., 2007.

IMPACT PROJECTIONS	Linear in relation to 2100 scenario against a 1990-2005 baseline	Continental and Sub-Continental	Reilly et al., 2007

CALCULATIONS: BIODIVERSITY (OZONE)

Information on NPP (net primary productivity) change in forests and pastures due to ozone was retrieved from Reilly, including projection. Then, combining the information coming from the global NPP distribution and the biomass concentration, the location and coordinates of different biomes were estimated. The relative losses were computed using the following relationship between NPP and biodiversity loss provided by Costanza et al, (2007)

$$\ln(V) = -12.057 + 2.599 \ln(NPP)$$

where V is the annual value of ecosystem services in US\$ $ha^{-1}year^{-1}$ and NPP is expressed in gram $ha^{-1}year^{-1}$. The NPP has been adjusted to the losses coming from Reilly et al (2007) to obtain the values for the desired years 2000, 2010, and 2030. Costs per country were then cumulated.

Then these costs are compared to the GDP of 2010 as follows:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

BIODIVERSITY (ACID RAIN)

RESEARCH/DATA SOURCES: BIODIVERSITY (ACID RAIN)

KEY DATA

Biodiversity (Acid Rain)

DATA	DEFINITION (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
IMPACT ESTIMATE	Biodiversity loss due to acid rainfall (wet and dry deposits). Carbon stock per grid cell. Net primary productivity in gram carbon/cell. Relationship between net primary production and ecosystem services value per hectare per year.	Rescaled to 0.5 ° x 0.5 ° 0.5 ° x 0.5 °	Global Vegetation biomass carbon stocks - 1 km resolution, Ruesch and Gibbs, 2008. New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000. Spatial Distribution of Net Primary Productivity (NPP) Imhoff et al., 2004. Biodiversity and ecosystem services: A multi-scale empirical study of the relationship between species richness and net primary production, Costanza et al., 2007 A global synthesis reveals

	Net primary productivity logarithmic response ratio acidification.		biodiversity loss as a major driver of ecosystem change, Hooper et al., 2012.
IMPACT PROJECTIONS	Projected SO2 emissions, based on OECD (2012), have been used for a linear projection of impacts (base: 2000; projection: 2030)	OECD, BRICs and Rest of World	*OECD Environmental Outlook to 2050,* OECD, 2012

CALCULATIONS: BIODIVERSITY (ACID RAIN)

Information on NPP (net primary productivity) change due to acid rain was retrieved from Hooper, 2012. Then, combining the information coming from the global NPP distribution, the biomass concentration and the OECD SO2 projections, the impact on different biomes has been estimated. The relative biodiversity losses from NPP change were calculated using the following relationship provided by Costanza et al, (2007)

$$\ln (V)=-12.057 + 2.599 \ln (NPP)$$

where V is the annual value of ecosystem services in US\$ $ha^{-1}year^{-1}$ and NPP is expressed in gram $ha^{-1}year^{-1}$. The NPP has been adjusted to the losses coming from the Hooper, 2012 paper to obtain the values for the desired years 2000, 2010, and 2030. Costs per country were then cumulated.

Then these costs are compared to the GDP of 2010 as follows:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

CORROSION

RESEARCH/DATA SOURCES: CORROSION

KEY DATA

Corrosion

DATA	DEFINITION (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
IMPACT ESTIMATE	Material damages (million USD) due to corrosion driven by acid rainfall (wet and dry deposits) Information concerning the SO_2 localization sources and the world population density have been combined to distribute estimates from the World Bank China study	1° x 1°	3.2 ft2000 SO_2 Emission Database, Edgar, 2012 World Bank 2005, Cost of Pollution in China Population Density grid data 2000, The Atlas of Global

	globally Two different mechanism are taken into account: dry and wet deposition of the most important acidifying gases (SO_2)	0.5°x0.5°	Conservation: Changes, Challenges, and Opportunities to Make a Difference, Hoekstra et al., 2010.
PROJECTED IMPACT	Projected SO_2 emissions, based on OECD (2012), have been used to project the impacts (base: 2000; projection: 2030)	OECD, BRICs and Rest of World	*OECD Environmental Outlook to 2050,* OECD , 2012

CALCULATIONS: CORROSION

The SO_2 emission grid generated from the Edgar database was first overlapped with country geographic information and then further overlapped with the population density grid. A worldwide robust estimation of the acid rain material damage was calculated by assuming the damage occurring on infrastructure with a particular SO_2 concentration will follow a specific trend as provided by the World Bank, 2005 paper. Costs were normalized to the losses in China for the year 2003 provided by the World Bank paper. The 2050 SO_2 emissions projections were obtained using the data from the OECD paper.

With a linear approach the losses are computed for the years 2000, 2010 and 2030:

$costs_{2000\_i} = costs_{2000\_i}$ (base value model)

$costs_{2010\_i} = Y_i \times 2/6 + costs_{2000\_i}$

$costs_{2030\_i} = Y_i \times 4/6 + costs_{2000\_i}$

Where i represents the cell i and Y_i is the mean SO_2 emission change provided by the OECD paper.

Then these costs are compared to the GDP of 2010 as follows:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

WATER

RESEARCH/DATA SOURCES: WATER

KEY DATA

Water

DATA	DEFINITION (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE

IMPACT ESTIMATE	Impact of acid rain on water resources through anticipated costs of acidity reduction, deemed to exceed costs of inaction and entailed downstream damages/losses. Potential acidification map. World water withdrawals per sector Mean pH cost per adjustment	0.5° x 0.5° 0.5°x 0.5° 0.5°x 0.5°	Global threats to human water security and river biodiversity, Vorosmarty et al,. 2010 Global data set of Monthly Irrigated and Rainfed Crop Areas around the year 2000 (MIRCA2000), version 1.1, Portmann et al., 2010 Population Density grid data (2000), The Atlas of Global Conservation, Hoekstra et al., 2010. FAO AQUASTAT,2012 Corrosion Manual for Internal Corrosion of Water Distribution Systems, EPA, 1984
PROJECTED IMPACT	Projected SO2 emissions, based on OECD (2012), have been used to project the impacts (base: 2000; projection: 2030)	OECD, BRICS and Rest of World	OECD *Environmental Outlook to 2050,* OECD, 2012

CALCULATIONS: WATER

The number of people and crop surfaces affected by water acidification was obtained overlapping the data coming from the potential acidification map (Vorosmarty 2010), using a threshold to select only the 30% most affected surfaces.

From FAO AQUASTAT the mean water consumption per inhabitants and crop surface was used and combined with the pH costs adjustment provided by EPA to derive the final impact of water acidification on the agricultural and municipal sectors in economic terms.

The global SO_2 projections estimated by OECD for 2050 were finally applied to the final costs to simulate the hypothetical wet and dry acidification trends.

$$costs\_pop_{2000\_i} = (People\_affected)_{2000\_i} \times w_i \times C_i$$

$$costs\_pop_{2010\_i} = Y_i \times (2/6) + costs_{2000\_i}$$

$$costs\_pop_{2030\_i} = Y_i \times (4/6) + costs_{2000\_i}$$

Where w_i is the mean municipal water consumption per capita of the country I and C_i the pH cost adjustment.

$$costs\_agr_{2000\_i} = (Surface\_crop\_affected)_{2000\_i} \times w_i \times C_i$$

$$costs\_agr_{2010\_i} = Y_i \times (2/6) + costs_{2000\_i}$$

$$costs\_agr_{2030\_i} = Y_i \times (4/6) + costs_{2000\_i}$$

Where w_i is the mean crop water consumption per hectar of the country i.

$$costs\_total_{year\_i} = costs\_agr_{year\_i} + costs\_pop_{year\_i}$$

Then these costs are compared to the GDP of 2010 as follows:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

8 PART II: HEALTH IMPACT

The Health Impact section of Part II/Carbon of the Monitor comprises adjustments in the predicted evolution of disease burdens as for the health section of Part I of the Monitor, where relevant. Likewise, the same system was used for calculating health costs as outlined in the Health impact section of Part I/Climate of this methodological note. The Health Impact section of Part II of the Monitor comprises the following indicators:

- Air Pollution
- Indoor Smoke
- Occupational Hazards

Each indicator aggregates relevant sub-indicators combining different health effects as detailed below.

AIR POLLUTION

The Monitor's indicator for Indoor Smoke The Indicator on the health impact of Air Pollution linked to emissions of greenhouse gases which are a principal cause of climate change is broken down from its composite form into two sub-indicators, one covering Urban Air Pollution as defined by the WHO, and a second expanding the problematic to Asthma with similar root causes (notably tropospheric ozone toxicity). These sub-indicators are detailed below.

RESEARCH/DATA SOURCES: AIR POLLUTION (URBAN)

KEY DATA

Air Pollution (Urban)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE

IMPACT ESTIMATE	Outdoor air pollution attributable deaths per 100,000 capita in 2008 due to various urban air pollutants Includes particulate matter (and black carbon), ozone, nitrogen dioxide and sulfur dioxide	192 WHO countries	WHO Burden of Diseases Database 2011 WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, Global update 2005 – Summary of risk assessment, WHO (2006),
IMPACT PROJECTIONS	Assuming a uniform distribution within each region the OECD/IMAGE estimates of premature deaths per million inhabitants due to ozone and particulate matter for 2010, 2030 and 2050 is used to calculate a polynomial fit to obtain the estimates for 2000, 2010 and 2030 (base: 2000)	regions/countries: OECD, Sub-Saharan Africa, India China, South East Asia, Indonesia, other countries	*OECD Environmental Outlook to 2050,* OECD , 2012

CALCULATIONS: AIR POLLUTION (URBAN)

The WHO Global Health Observatory provides outdoor air pollution attributable deaths per 100,000 capita in 2008. Assuming a uniform distribution within each region the OECD/IMAGE estimates of premature deaths per million inhabitants due to ozone and particulate matter for 2010, 2030 and 2050 is used to calculate a polynomial fit to obtain the estimates for 2000, 2008, 2010 and 2030 and with this the growth rates compared to the base year 2008. With this the absolute deaths in the different years are calculated as follows:

deaths2000=outdoor_deaths2008 x growth_rate2000 x Population_2000/10^5

deaths2010=outdoor_deaths2008 xgrowth_rate2010 x Population_2010/10^5

deaths2030=outdoor_deaths2008 xgrowth_rate2030x Population_2030/10^5

To calculate the index the deaths per capita are computed as follows:

$deaths\_per\_capita_{2000} = deaths_{2000}/Population_{2000}$

$deaths\_per\_capita_{2010} = deaths_{2010}/Population_{2010}$

$deaths\_per\_capita_{2000} = deaths_{2030}/Population_{2030}$

RESEARCH/DATA SOURCES: AIR POLLUTION (ASTHMA)

KEY DATA

Air Pollution (Asthma)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
IMPACT ESTIMATE	Total deaths due to asthma in 2010 from tropospheric ozone	193 WHO countries	WHO: Global Burden of disease report, 2011
IMPACT PROJECTIONS	The key findings of two papers (Bell and Sheffield) provide an average attributable fraction of air pollution related deaths in 2030 of 5% compared to 1990, and a linear progression is assumed.	Uniformity on a global scale of effects is assumed.	Climate change, ambient ozone, and health in 50 US cities; Bell et al., 2007 Modeling of Regional Climate Change Effects on Ground-Level Ozone and Childhood Asthma Sheffield et al., 2011

CALCULATIONS: AIR POLLUTION (ASTHMA)

Asthma was calculated as follows using the attributable fraction based on Bell and Sheffield:

$deaths_{2000}=AF_{2000} \times asthma\_deaths_{2010}$

$deaths_{2010}=AF_{2010} \times asthma\_deaths_{2010}$

$deaths_{2030}=AF_{2030} \times asthma\_deaths_{2010}$

To calculate the index, the deaths per capita were calculated as follows:

$deaths\_per\_capita_{2000} = deaths_{2000}/Population_{2010}$

$deaths\_per\_capita_{2010} = deaths_{2000}/Population_{2010}$

$deaths\_per\_capita_{2000} = deaths_{2030}/Population_{2010}$

INDOOR SMOKE

Indoor smoke, a form of indoor air pollution, examines the impact on human health of incomplete combustion of different fuels – coal, wood, and other forms of biomass – which generate toxic smoke, black carbon and other emissions and GHGs. The Monitor's indicator for Indoor Smoke aggregates four distinct sub-indicators, as follows: 1) Chronic respiratory diseases/illnesses complicated by indoor smoke, including Chronic Obstructive Pulmonary Disease (COPD), Lower Respiratory Illnesses (especially Pneumonia) and Lung Cancer; 2) Cardiovascular Disease; 3) Tuberculosis; and, 4) accidents related to induced/exacerbated Visual Impairment. Each sub-indicator is outlined below.

RESEARCH/DATA SOURCES: INDOOR SMOKE (COPD, RESPIRATORY, LUNG CANCER)

KEY DATA

Indoor Smoke (COPD, Lower Respiratory Illness, Lung Cancer)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
IMPACT ESTIMATE	Indoor air pollution attributable deaths per 100,000 capita – deaths primarily resulting from cooking and heating with solid fuels on open fires or traditional stoves that generate toxic indoor smoke containing a range of health-damaging pollutants, such as inhalable micro particles and carbon monoxide	192 WHO countries	WHO: Global Burden of disease report, 2011 WHO 2006, WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, Global update 2005 – Summary of risk assessment, WHO, 2006
IMPACT PROJECTIONS	Assuming a uniform distribution within each region the OECD/IMAGE estimates of premature deaths per million inhabitants due to indoor air pollution for 2010, 2030 and 2050 are used to calculate a polynomial fit to obtain the estimates for 2000, 2010 and 2030 (base: 2000)	regions/countries: OECD, BRICs, Indonesia, South Africa, Sub-Saharan Africa, Other countries	*OECD Environmental Outlook to 2050,* OECD, 2012

RESEARCH/DATA SOURCES: INDOOR SMOKE (CARDIOVASCULAR)

KEY DATA

Indoor Smoke (Cardiovascular)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	Total deaths due to cardiovascular disease	193 WHO countries	WHO: Global Burden of disease report 2011
IMPACT ESTIMATE	Indoor air pollution attributable deaths per capita in 2010 (corresponds in degree to the AF for CVD under urban air pollution)	WHO regions	Indoor air pollution from biomass fuel smoke is a major health concern in the developing world; Fullerton et al., 2008

IMPACT PROJECTIONS	Assuming that the deaths due to the diseases expand in tandem with the population growth rate – no adjustment made for declining reliance on traditional forms of heating and cooling which cause indoor smoke hazards	Global/184 countries	UN Population Division - Medium-fertility variant, 2010-2100, 2012

RESEARCH/DATA SOURCES: INDOOR SMOKE (TUBERCULOSIS)

KEY DATA

Indoor Smoke (Tuberculosis)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	Total deaths due to tuberculosis disease	193 WHO countries	WHO: Global Burden of disease report, 2011
IMPACT ESTIMATE	Indoor air pollution attributable deaths per capita in 2010: Mishra establishes that India has a considerable AF of 0.51 on indoor smoke for Tuberculosis. To calculate global AFs India is used as a benchmark.	Country specific, extrapolated with benchmark	Biomass Cooking Fuels and Prevalence of Tuberculosis in India; Mishra , 1999a
IMPACT PROJECTIONS	Assuming that the deaths due to the diseases expand in tandem with the population growth rate – no adjustment made for declining reliance on traditional forms of heating and cooling which cause indoor smoke hazards	Global/184 countries	UN Population Division - Medium-fertility variant, 2010-2100, 2012

CALCULATIONS: INDOOR SMOKE (TUBERCULOSIS)

To account for differences in exposure to indoor smoke total deaths per capita in country (i) due to indoor smoke / total deaths per capita in India due to indoor smoke is calculated.

A 1:1 relationship is assumed between overall impact (total deaths per cap due to indoor smoke) and the AF.

This ratio is multiplied by 0.51, where the maximum AF is set to 0.51. The implication is that a lower relative exposure will result in a lower AF; while a higher exposure will be set equal to India (it is not reasonable to assume higher AFs close to or above 1).

RESEARCH/DATA SOURCES: INDOOR SMOKE (VISUAL IMPAIRMENT)

KEY DATA

Indoor Smoke (Visual Impairment)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	Total deaths from unintentional injuries	193 WHO countries	WHO: Global Burden of disease report 2011
IMPACT ESTIMATE	Indoor air pollution attributable deaths per capita in 2010: Mishra finds that indoor smoke is responsible for 18% of partial and complete visual impairment/blindness in India. The same method as is employed for the Monitor's sub-indicator on Tuberculosis to obtain country-specific AFs. Lee finds that a person with some visual impairment is 1.3 times as likely to die from unintentional injury, while a person with severe visual impairment is 7.4 times as likely to die in accidents due to visual impairment. The difference between the expected (no hazard ratio) and actual deaths (with hazard ratio) are calculated using this ratio to obtain excess deaths due to visual impairment caused by indoor smoke.	Country specific	Biomass Cooking Fuels and Prevalence of Blindness in India; Mishra , 1999b Visual Impairment and Unintentional Injury Mortality: The Interview Survey 1986–1994; Lee et al., 2003
IMPACT PROJECTIONS	Assuming that the deaths due to the diseases expand in tandem with the population growth rate – no adjustment made for declining reliance on traditional forms of heating and cooling which cause indoor smoke hazards	Global/184 countries	UN Population Division - Medium-fertility variant, 2010-2100, 2012

CALCULATIONS: INDOOR SMOKE (VISUAL IMPAIRMENT)

WHO (2011) provides latest regional data on total visual impairment ("some" and "severe") as well as global data on the number of people with either some or severe visual impairment.

Key assumptions are as follows:

Visual impairment is distributed equally (according to population share) within the region

The "share of total" of some and severe visual impairment apply to all countries; i.e. 86% of the affected people have "some" while 14% have "severe" visual impairment.

Using this we calculate the expected mortality (no hazard ratio):

(Number of people with visual impairment / capita)xTotal deaths due to unintentional injuries

(Number of people with severe impairment / capita)xTotal deaths due to unintentional injuries

Actual mortality (with hazard ratio):

((Number of people with visual impairment / capita)xTotal deaths due to unintentional injuries)x1.3

((Number of people with severe impairment / capita)xTotal deaths due to unintentional injuries)x7.4

Excess deaths due to visual impairment caused by indoor smoke:

AF (0.18 for India)x((actual_some-expected_some)+((actual_severe-expected_severe))

OCCUPATIONAL HAZARDS

The Monitor's indicator for Occupation Hazards aggregates three distinct sub-indicators related to hazards stemming from workplaces closely related to high greenhouse gas emissions, as follows: 1) Asthma, from industry specific exposures; 2) COPD, for similar reasons; 3) Coal Workers Pneumoconiosis (CWP) and coal accidents that only concerns coal extraction professionals; and, 4) Stomach Cancer, which again is linked to industry specific exposures. Each sub-indicator is outlined below.

RESEARCH/DATA SOURCES: OCCUPATIONAL HAZARDS (ASTHMA & COPD)

KEY DATA

Occupational Hazards (Asthma & COPD)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	Population employed in: Electricity, Transportation, Mining Total deaths due to ASTHMA and COPD 2008	country specific country specific	ILO LABORSTAT database, 2C Total Employment by Occupation WHO burden of Disease, 2011
IMPACT ESTIMATE	Relative Risk, RRi or "Attributable Factors (AF)" for specific employment sectors	country specific	WHO: Occupational airborne Particulates, Driscoll et al., 2004
IMPACT PROJECTIONS	Deaths 2030 from COPD caused by workplace exposure using the deaths growth rates related to economic growth (minimum of Loncar-Mathers and the GDP-growth approach)	6 regions: Africa, The Americas, Eastern Mediterranean, Europe, South-East Asia, Western Pacific	Projections of global mortality and burden of disease from 2002 to 2030, Mathers and Loncar, 2006

RESEARCH/DATA SOURCES: OCCUPATIONAL HAZARDS (CWP & COAL ACCIDENTS)

KEY DATA

Occupational Hazards (CWP)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	2008 coal production (million tonnes)	71 (all coal producing) countries	2010 Survey if Energy Resources, World

			Energy Council (2010)
IMPACT ESTIMATE	We have precise CWP mortality figures (a lung disease due to coal particles) for Turkey and the US. We assume that these CWP mortality figures represent the year 2008 (the year our coal production data dates to) and calculate the deaths/million tons ratio and round. USA: 0.46 = 0.5 (represents all OECD producers) Turkey: 1.41 = 1.5 (represents all non OECD)	2 countries	Coal workers Pneumoconiosis: Mortality, CDCP , 2012b Turkey: Evaluation of the risk of coal workers pneumoconiosis (CWP): A case study for the Turkish hardcoal mining; Aydin, 2010
IMPACT PROJECTIONS	Assuming a 1:1 relationship between production volume and deaths per million tons, the BP Energy Outlook 2030 is used to calculate deaths in 2000 and 2030	6 regions: North America, S & C America, Europe & Eurasia, Middle East Africa, Asia Pacific	Energy Outlook 2030, BP , 2012

KEY DATA

Occupational Hazards (Coal accidents)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	2008 coal production (million tonnes) Total coal extraction deaths 1999-2008	59 countries 9 countries	World Energy Council (2010), 2010 Survey if Energy Resources International Mining Fatality Review database
IMPACT ESTIMATE	See below.	Continental Asia, Africa, South America, China, Eastern Europe, North America	BP (2012) Energy Outlook 2030
IMPACT PROJECTION S	Assuming a 1:1 relationship between production volume and deaths per million tons, the BP Energy Outlook 2030 is used to calculate deaths in 2000 and 2030	Regions: Asia-Africa-South America-China; Eastern Europe; North America; rest with zero increase	BP (2012) Energy Outlook 2030

RESEARCH/DATA SOURCES: OCCUPATIONAL HAZARDS (STOMACH CANCER)

KEY DATA

Occupational Hazards (Stomach Cancer)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	2008 coal production (million tonnes) Total stomach cancer deaths 2010	71 (all coal producing) countries 184 countries	World Energy Council (2010), 2010 Survey if Energy Resources WHO burden of Disease, 2011
IMPACT ESTIMATE	A comprehensive study of the coal mining industry in the Netherlands, Swaen (1995), finds that the relative difference between "observed" and "expected" deaths due to stomach cancer among coal workers are 1.47. I.e. when controlling for social and other factors coal miners have a 47 pct. higher risk of dying from stomach cancer than the general population.	Same ratio for all coal producing countries	Swaen et al., 1995
IMPACT PROJECTION S	Assuming a 1:1 relationship between production volume and deaths per million tons, the BP Energy Outlook 2030 is used to calculate deaths in 2000 and 2030	4 regions: Asia-Africa-South America-China; Eastern Europe; North America; rest with zero increase	Energy Outlook 2030, BP , 2012

CALCULATIONS: OCCUPATIONAL HAZARDS

ASTHMA AND COPD

- WHO provides "Relative Risk (RR)" that we use to calculate our risk factors or "Attributable Factors (AF)" for specific employment sectors for COPD and Asthma due to airborne particulates.
- ILO is the key source of labor statistics - COPD: Electricity, Mining, Transportation; Asthma: Mining, Transport
- WHO provides baseline deaths due to COPD and Asthma
- WHO provides regional projections for 2030

MINING SECTOR DATA

For mining sector data, only coal mining is considered. No global country specific database of employment in the coal mining industry was identified. Sound employment data from the US and China was however available (see NMA, Trends in US coal mining; International Energy Agency, Cleaner coal in China). Using the production (million tons) data from coal mining accidents was used to calculate two benchmark values of coal workers per million tons. For the US and China the approximate numbers are 80 and 1,000 miners per million tons of coal. It is assumed that there are 80 miners per million tons in all OECD countries and that all other countries need 1,000 workers to produce a million ton of coal (within a year) and calculate the corresponding employment figures for all coal producing countries.

ELECTRICITY SECTOR DATA

The workforce share employed in electricity production using fossil fuels (gas, oil and coal) was identified in order to exclude cleaner forms of energy production, such as renewables. World Bank data provides a percentage of electricity production in each country stemming from oil, gas and coal. The assumption is that this share translates directly into the employment as an equal share of the total electricity occupation (ILO data) to obtain the relevant baseline for the electricity sector.

TRANSPORT SECTOR DATA

ILO data is relied upon without any modifications, since on global and even national scales low-emission forms of transport remain overwhelmingly statistically insignificant. Due to the structure of the ILO database however, this implies including minor sub occupations mainly within “storage” and “communications” sub-sectors that are not understood to be asymmetrically affected by airborne particles and other relevant occupational hazards under analysis. However, as neither any part of the agriculture and manufacturing sectors are in the analysis, despite clear but difficult to disaggregate risks, the overall indicator results at the presentation level are still deemed conservative.

The AF is calculated from Prüss-Üstün et al., (2003) as follows:

$AF_i=(\sum P_i RR_i - 1)/\sum PiRR_i$

where:

AF_j = attributable fraction; $i \in$ {ASTMA, COPD}

P_i = proportion of the population at exposure category; $I \in$ {mining, electricity, transport}

RR_i = relative risk at exposure category i compared to the reference level.

$deaths_{2010,\,j} = AF_j \times total\_deaths_j$; $i \in$ {ASTMA, COPD}

$deaths_{2030,\,j} = deaths_{2010,\,j} \times growth\_factor_j$

$deaths_{2000,\,j} = deaths_{2010,\,j} - ½ \times (deaths_{2030,\,j} - deaths_{2010,\,j})$ (linear regression)

CWP

CWP only concerns workers in the coal mining industry, but for statistical purposes at the population level all workers in that industry are concerned. Relevant calculations for this sub-indicator are as follows:

$deaths_{2010,\,CWP} = coal\_production_{2008} \times ratio\_deaths\_per\_mio\_ton$

$deaths_{2000,\,CWP} = deaths_{2010} \times production\_growth_{2000/2010}$

$deaths_{2030,\,CWP} = deaths_{2010} \times production\_growth_{2030/2010}$

STOMACH CANCER

Stomach Cancer is another coal mining only risk factor with baseline data as for sub-indicators above.

Expected and actual deaths among coal workers due to stomach cancer are as follows:

$expected\_deaths = total\_deaths_{2010} \times (workers / Population\_2010)$

$actual\_deaths = 1.47 \times expected\_deaths$

And with this, the excess Stomach Cancer deaths due to coal mining is:

$deaths_{2010,SC} = actual\_deaths - expected\_deaths$

$deaths_{2000,SC} = deaths_{2010} \times production\_growth_{2000/2010}$

$deaths_{2030,SC} = deaths_{2010} \times production\_growth_{2030/2010}$

AGGREGATION

Relevant calculations aggregating the sub-indicators are as follows:

$deaths_{2000} = deaths_{2000,ASTHMA} + deaths_{2000,COPD} + deaths_{2000,CWP} + deaths_{2000,SC}$

$deaths_{2010} = deaths_{2010,ASTHMA} + deaths_{2010,COPD} + deaths_{2010,CWP} + deaths_{2010,SC}$

$deaths_{2000} = deaths_{2030,ASTHMA} + deaths_{2030,COPD} + deaths_{2030,CWP} + deaths_{2030,SC}$

To calculate the index we calculated the deaths per capita as follows:

$deaths\_per\_capita_{2000} = deaths2000/population2000$

$deaths\_per\_capita_{2010} = deaths2010/population2010$

$deaths\_per\_capita_{2030} = deaths2030/population2030$

SKIN CANCER

KEY DATA

Occupational Hazards (Skin Cancer)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	Total skin cancer deaths 2010	Continental. 56 countries 184 Countries	WHO burden of Disease, 2012
IMPACT ESTIMATE	A comprehensive model focused on the skin cancer evolution in Australia under different scenarios.	Australia-Focused Model	Health Impacts of Climate Change and Ozone Depletion: An Ecoepidemiologic Modeling Approach,. Martens, 1998

IMPACT PROJECTIONS	Modeling the carcinogenic risk of artificial UV sources and the use of indoor tanning facilities.	Global study	Exposure To Artificial UV Radiation And Skin Cancer 2005 WHO International Agency For Research On Cancer Martens , 1998

The work of Martens (1998) was used to assess the impact of UV exposure, caused by the ozone depletion by CFCs and halocarbons, on skin cancer incidence in the period 2000-2030.

The Australian values have been used as a proxy to describe the grown rate for all the 56 countries choosing a scenario that includes an aging population with a 50% decrease in UV exposure.

$Death_{2000\_i}=WHO_{death\_i}$ x Skin_cancer_rate_2000_modeled

$Death_{2010\_i}=WHO_{death\_i}$ x Skin_cancer_rate_2010_modeled

$Death_{2030\_i}=WHO_{death\_i}$ x Skin_cancer_rate_2030_modeled

A 5% correction to epurate the data from the additional skin cancer cases due to artificial UV exposure have been applied to the final result. (IARC).

Finally to calculate the index the death per capita are computed as follows:

$deaths\_per\_capita_{2000}$ = deaths2000/population2000

$deaths\_per\_capita_{2010}$ = deaths2010/population2010

$deaths\_per\_capita_{2030}$ = deaths2030/population2030

9 PART II: INDUSTRY STRESS

The Industry Stress section of the Monitor's Part II/Carbon covers three different sectoral effects by indicators: agriculture, fisheries and forestry. These are independently aggregate of a number of different effects comprising sub-indicators for these three areas. Agriculture is comprised of four sub-indicators: 1) acid rain, 2) ozone toxicity, 3) global dimming, and, 4) carbon fertilization. Fisheries is comprised of two sub-indicators: 1) marine fisheries (ocean acidification), and, 2) in-land fisheries (acidification/acid rain). Forestry comprises two sub-indicators, as follows: 1) ozone toxicity, and, 2) acid rain.

AGRICULTURE (ACID RAIN)

RESEARCH/DATA SOURCES: AGRICULTURE (ACID RAIN)

KEY DATA

Agriculture (Acid Rain)

DATA	DEFINITION (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
IMPACT ESTIMATE	Production losses in agriculture (million USD) due to acid rain Information concerning the SO_2 localization sources and the world population density have been combined to distribute estimates from the World Bank China study globally Two different mechanism are taken into account: dry and wet deposition of the most important acidifying gases (SO_2)	1°x 1° 0.5°x 0.5°	3.2 ft2000 SO2 Emission Database , Edgar, (2012) The World Bank (2005), Cost of pollution in China Global data set of Monthly Irrigated and Rainfed Crop Areas around the year 2000 (MIRCA2000), version 1.1, Portmann et al., 2010.
IMPACT PROJECTION	Linear (base: 2000; projection: 2030)	OECD, BRICs and Rest of World	OECD (2012), *Environmental Outlook to 2050*

CALCULATIONS: AGRICULTURE (ACID RAIN)

The SO_2 emission grid coming from the Edgar database was first overlapped with country geographic information and then further overlapped with the monthly irrigated and rainfed crop map (MIRCA2000). A worldwide robust estimation of the acid rain agricultural damage was calculated by assuming the damage occurring on crops with a particular SO_2 concentration will follow a specific trend provided by World Bank,

2005. Costs were normalized to the losses in China for the year 2003 provided by the World Bank. The 2050 SO_2 emissions projections were obtained using the data from the OECD paper.

With a linear approach the losses are calculated for the years 2000, 2010 and 2030:

$costs_{2000}$ = 1/6 x $costs_{2050}$

$costs_{2010}$ = 2/6 x $costs_{2050}$

$costs_{2030}$ = 4/6 x $costs_{2050}$

Then these costs are compared to the GDP of 2010 as follows:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

AGRICULTURE (OZONE)

RESEARCH/DATA SOURCES: AGRICULTURE (OZONE)

KEY DATA

Agriculture (Ozone)

DATA	DEFINITION (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
IMPACT ESTIMATE	Losses to agricultural production (million USD) due to tropospheric ozone	Country level	Global crop yield reductions due to surface ozone exposure: 2. Year 2030 potential crop production losses and economic damage under two scenarios of O_3 pollution, Avnery et al., 2011.
IMPACT PROJECTIONS	The 2010 and 2030 projections use a linear interpolation assuming no losses in 1990	As above	Averny et al., 2011

CALCULATIONS: AGRICULTURE (OZONE)

The costs for 2030 are provided by Avnery (2011). With a linear approach the losses are calculated for the years 2000, 2010 and 2030:

$costs_{2000}$ = ¼ x $costs_{2030}$

$costs_{2010}$ = 2/4 x $costs_{2030}$

$costs_{2030}$ = $costs_{2030}$ (provided by the paper)

Then these costs are compared to the GDP of 2010 as follows:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

AGRICULTURE (GLOBAL DIMMING)

RESEARCH DATA/SOURCES: AGRICULTURE (GLOBAL DIMMING)

KEY DATA

Agriculture (Global Dimming)

DATA	DEFINITION (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
IMPACT ESTIMATE	Losses to agricultural production (million USD) due to (polluting) atmospheric brown clouds Using the data from Hansen describing the variation in (w/m2) of incident solar radiation due to black carbon and other gases related to anthropic activities the global radiation balance was assessed With this new corrected value the approx. agricultural losses have been assessed using estimates in UNEP 2008	0.5° x 0.5° 5° x 4°	Global data set of Monthly Irrigated and Rainfed Crop Areas around the year 2000 (MIRCA2000), version 1.1, Portmann et al., 2010. Impacts of Atmospheric Brown Clouds on Agriculture Agrawal et al., UNEP 2008 Clear sky incident solar radiation (1850-2030) "Dangerous human-made interference with climate: A GISS modelE study" by Hansen et al., 2007 FAOSTAT: gross production value for all crops, 2012
IMPACT PROJECTIONS	Linear projection from 1850 (no effect) to 2030	5° x 4°	Hansen et. al., 2007

CALCULATIONS: AGRICULTURE (GLOBAL DIMMING)

Using the model provided by Hansen et al, the change in clear sky incident solar radiation was analyzed on a global scale. These changes are in general and principally attributed to greenhouse gases (black carbon, ozone, etc.). Information regarding the trends in crop growth due to change in radiation was retrieved from UNEP 2008. The map containing crop density was then overlapped with the new solar radiation field and losses were projected. The crop value was obtained from FAOSTAT.

$Loss_{i2000}$=(Percentage change in radiation)$_{i\_1850\text{-}2000}$ x Y x(Crop surface)$_i$xValue$_i$

$Loss_{i2010}$=(Percentage change in radiation)$_{i_1850\text{-}2010}$x Y x(Crop surface)$_i$xValue$_i$

$Loss_{i2030}$=(Percentage change in radiation)$_{i_1850\text{-}2030}$x Y x(Crop surface)$_i$xValue$_i$

Where i represents the cell i, Y represents the crop response to radiation change and value is the crop value. In this way, the crop loss due to global dimming is assessed. Values are then cumulated country by country.

Then these costs are compared to the GDP of 2010 as follows:

CE_{2000} = $costs_{2000}/GDP_{2010}$

CE_{2010} = $costs_{2010}/GDP_{2010}$

CE_{2030} = $costs_{2030}/GDP_{2010}$

AGRICULTURE (CARBON FERTILIZATION)

According to the IPCC agricultural yields (C3 crops) will benefit from an average of 15% increase in production (at 550 ppm CO_2) due to the effect of higher concentrations of carbon dioxide in the atmosphere predicted in line with various greenhouse gas emission scenarios - however the benefits are only to be experienced in unstressed conditions (IPCC, 2007a). Since the Monitor models a range of different climate and pollutant stress conditions at different degrees for different countries, the data framework has allowed for a graded application of the carbon fertilization effect, which was applied to all countries on the following basis (data scores as prior to application of carbon fertilization effect):

- A distribution, including all the monitor's country, of the global agricultural relative losses (or gains) was created:

  Value_i=((Losses_climate_i+Losses_carbon_i)/total_agric_production_i)

  where i is the country i.
- Impact-classes were generated splitting the distribution in slices with the same dimension (max val-min val)/11.
- The fraction of the applied fertilization effect is then linearly distributed to each category and therefore to the countries included. Assuming that the best category will have a 100% and the worse 0%.

  Fraction category_N= 1-[(N-1)x(1/10)] where N={1,2,..,11}

MARINE FISHERIES (OCEAN ACIDIFICATION)

RESEARCH/DATA SOURCES: MARINE FISHERIES (OCEAN ACIDIFICATION)

KEY DATA

Marine Fisheries (Ocean Acidification)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	Total shell fish production (tons)	Country level	FAOSTAT FISHSTAT

			database, 2012
IMPACT ESTIMATE	Net loss estimates to shell fish production in 2100 (current million USD) due to ocean acidification	35 countries/regions	Economic Costs of Ocean Acidification: A Look into the Impacts on Shellfish Production, Narita et al. , 2011
IMPACT PROJECTIONS	To calculate the effects in 2000, 2010 and 2030 we assume a zero loss in 1990 and assume a linear loss trend to 2100	35 countries/regions	Narita et al., 2011

* When Narita only presents results for a region, e.g. EU15, the net USD loss is distributed to specific countries according to the share of total shellfish production within each region

CALCULATIONS: MARINE FISHERIES (OCEAN ACIDIFICATION)

Narita provides the losses for 2100. Zero costs are assumed in 1990 due to acidification and with a linear approach the losses are computed for the years 2000, 2010 and 2030:

$costs_{2000} = 10/100 \times costs_{2100}$

$costs_{2010} = 20/100 \times costs_{2100}$

$costs_{2030} = 40/100 \times ficosts_{2100}$

Then these costs are compared to the GDP of 2010 as follows:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

INLAND FISHERIES (ACIDIFICATION)

RESEARCH/DATA SOURCES: INLAND FISHERIES (ACIDIFICATION)

KEY DATA

Inland Fisheries (Acidification)

DATA	DEFINITION/METHOD (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
BASELINE	Inland capture fishery (1000 current USD) Freshwater aquaculture (1000 current USD) Losses attribute to wet and dry deposition in an inland fresh water basin.	Country level	FAOSTAT FISHSTAT database, 2012 Integrated Assessment of Acid-Deposition Effects on Lake Acidification

			Rubin et al., 1992.
IMPACT ESTIMATE	Information concerning the SO_2 localization sources. Soil data on Ph.	1°x 1° 1°x 1°	3.2ft 2000 SO_2 Emission Database Edgar, 2012 SoilData(V.0) A program for creating global soil-property databases, IGBP-DIS, 1998
IMPACT PROJECTIONS	Linear (base: 2000; projection: 2030)	OECD, BRICs and Rest of World	OECD Environmental Outlook to 2050, 2012

CALCULATIONS: INLAND FISHERIES (ACIDIFICATION)

Costs are defined with AFs from Rubin and calculations performed with the inland FAOSTAT data only (crustaceans, trout and salmon).

The Rubin's study provide a data on Canada, to extend it globally on a continental level several operations have been made.

Coupling the information provided by the emission source position (Edgar) and the soil Ph an approximate impact level was assessed.

Assuming that the basic soils tend to neutralise the effect of the dry/wet acid deposition all the cells with these requirements were not take into account.

Therefore using the following relationship:

Continental_AF=North_AM_AF x (SO2_impact_continent/ SO2_impact_North_Am)

The 2050 SO_2 emissions projections were obtained using data from OECD paper and then applied to find the 2030 values comparing the emission with the base data.

FORESTRY (OZONE)

RESEARCH/DATA SOURCES: FORESTRY (OZONE)

KEY DATA

Forestry (Ozone)

DATA	DEFINITION (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE

IMPACT ESTIMATE	Ozone impact on yearly net primary productivity in forest (general) ecosystems.	Continental and sub-continental	Global economic effects of changes in crops, pasture, and forests due to changing climate, carbon dioxide, and ozone, Reilly et al., 2007 The value of the world's ecosystem services and natural capital, Costanza et al., 1997. The Area (in ha) of forest in 1990, FAOSTAT
IMPACT PROJECTIONS	Linear projection of impact based on the year 2100 (base period: 1995-2005)	Continental and sub-Continental	Reilly et al., 2007

10.1.1 CALCULATIONS: FORESTRY (OZONE)

Cost for country$_i$ in the years 2000-2010-2030 are derived from Reilly based yield changes, including projections, as combined with Costanza values and FAOSTAT forest area, as follows:

Cost_{i2000}= % yield change$_{2100i}$ x Forest surface area (i)/ 11 x (mean annual yield price)$_i$

Cost_{i2010}= % yield change$_{2100}$ x (2/11) x Forest surface area (i)) x (mean annual yield price)$_i$

Cost_{i2030}= % yield change$_{2100}$ x (4/11) x Forest surface area (i) x (mean annual yield price)$_i$

Then these costs are compared to the GDP of 2010 as follows:

$CE_{2000} = \text{costs}_{2000}/GDP_{2010}$

$CE_{2010} = \text{costs}_{2010}/GDP_{2010}$

$CE_{2030} = \text{costs}_{2030}/GDP_{2010}$

FORESTRY (ACID RAIN)

RESEARCH/DATA SOURCES: FORESTRY (ACID RAIN)

KEY DATA

Forestry (Acid Rain)

DATA	DEFINITION (UNIT OF MEASUREMENT)	RESOLUTION	SOURCE
IMPACT ESTIMATE	Damage (in percentage)due to acid rain on forestry Two different mechanisms are taken into account: Dry and wet deposition of the most important acidifying gas		Ursachen des Waldsterbens in Mitteleuropa. Allg. Forstzeitschr., 43: 1365-1368, Wentzel, 1982. . New IPCC Tier-1 Global

	(SO_2). Information concerning the SO_2 localization sources and the biomass concentration is combined using the value the data on German forests as reference. Used to assess the wood for tropical and boreal forests.	0.5°x0.5° 1°x1°	Biomass Carbon Map For the Year 2000, Ruesch, and Gibbs, 2008 3.2ft 2000 SO_2 Emission Database , Edgar, 2012 The value of the world's ecosystem services and natural capital, Costanza et al., (1997)
IMPACT PROJECTION	Linear (base: 2000; projection: 2030)	OECD, BRICs and Rest of World	OECD Environmental Outlook to 2050, 2012

CALCULATIONS: FORESTRY (ACID RAIN)

The SO_2 emission grid generated by the Edgar database was first overlapped with country geographic information and then further overlapped with the global biomass carbon map provided by Ruesch and Gibbs (2008) relative to the year 2000 in order to obtain the pattern of forest exposure to wet and dry acid deposition. A worldwide robust estimation of the acid rain damage on forests was calculated by assuming the damage occurring in a forest with a particular biomass index and a particular SO_2 concentration will follow a specific trend provided by Wentzel. The final costs of acid rain damage were determined by using information from the Costanza, which provides an economic value to forest ecosystems. The 2050 SO_2 emissions informed projections were obtained using data from OECD paper.

With a linear approach the losses are computed for the years 2000, 2010 and 2030:

$costs_{2000} = 1/6 \times costs_{2050}$

$costs_{2010} = 2/6 \times costs_{2050}$

$costs_{2030} = 4/6 \times costs_{2050}$

Then these costs are compared to the GDP of 2010 as follows:

$CE_{2000} = costs_{2000}/GDP_{2010}$

$CE_{2010} = costs_{2010}/GDP_{2010}$

$CE_{2030} = costs_{2030}/GDP_{2010}$

9 CLIMATE CHANGE FINANCE

The following is a brief log of data sources, methods and assumptions relied upon to create a comprehensive database of climate change financing up to 2010.

DATA SOURCES

In order to obtain a complete picture of climate change mitigation and adaptation two complementary data sources were used. The primary source was the OECD creditor reporting system. The supplementary source of information was drawn on for multi-lateral funds from individual funds' public documentation/websites. Private finance is only obtainable through wide-ranging estimates available in third party publications.

OECD CREDITOR REPORTING SYSTEM

The OECD's Creditor Reporting System (CRS) is a system for measuring Official Development Assistance (ODA) as reported by government donors and members of the OECD Development Assistance Committee (DAC). Aid in support of climate-related objectives is also tracked through detailed project-level reporting by OECD/DAC members against the so-called "Rio markers" for, amongst others, climate change adaptation and mitigation (prior to 2010 there was only a climate change marker and not a separate marker for adaptation and mitigation – so both were contained in the same marker prior to 2010). The Rio maker for climate change has been active since 1998. The latest data available for Rio markers is for 2010 (as at mid-2012), although preliminary estimates of overall ODA are available for 2011. Aid activities/flows can either be marked as "Principal objective" or "Significant objective" → If not otherwise stated, all calculations in the Monitor only include "Principal objective" aid activities.

The key assumptions for only factoring in Principal objective and not any resources for Significant objective are as follows:

- It is not customary to analyze sectoral ODA data as per the system used for Rio marker reporting given that in normal practice only one sector is ever mentioned, this means that sectoral analysis automatically excludes some activities that do relate to sectors, since only the main activity focus is logged
- Under the Rio marker system these activities would have been carried out were it not for interest in climate change – therefore in relation to Fast Start Finance commitments the resources likely stretch any definition of "new" or "additional"
- There is far lesser volume of resources labeled Significant than Principal
- There is no way to gauge what degree of focus is attributable to climate change, it could be as low as 5% or less
- Principal objective resources are neither 100% targeted towards climate change, since projects/programmes need only have climate change as a principal focus, and that the activity would not have been undertaken were it not for the interest in climate change
- Analysis has shown that reporting under Significant objective is much less rigorous than for

Principal objective, including a greater degree of so-called "over-coding" or misrepresentation of the objectives of projects

While the system is not ideal, excluding Significant objective from the analysis therefore minimizes double counting and erroneous data, providing a more measured viewpoint of resource flows on climate change.

The main database for Rio marker data are the Rio marker tables called "Full list of climate change mitigation and adaptation aid activities, 2010" and "Full list of climate change mitigation aid activities, 2007-2009" on http://www.oecd.org/document/6/0,3746,en_2649_34421_43843462_1_1_1_1,00.html that provided information on all climate change aid activities by the OECD donor countries and the European Union marked as mitigation and/or adaptation.

In addition, data from the bulk downloads was drawn upon [http://stats.oecd.org/Index.aspx?datasetcode=CRS1# → export → related files → CRS 2010.zip and CRS 2009.zip] that include all aid activities by the OECD donor countries (not only climate change) and by multilateral funds and institutions that report to the CRS system (World Bank institutions, multilateral development banks etc). Besides the donors already included in the Rio marker tables the bulk downloads include aid activities under the Rio markers for mitigation and adaptation for:

- IDA: reports on Mitigation, but only "Significant objective". Started reporting in 2010 but made it retrospective.
- GEF: reports on Mitigation "Principal Objective" but only since 2010.
- Nordic Development Fund: reports on Mitigation and Adaptation (Principal and Significant Objective)

In cases where there are aid activities marked "Principal Objective" only, these are used to determine the total amount of climate change funding (the case for the GEF and the Nordic Dev. Fund). In the case of the IDA where, there is not a single aid activity marked as "Principal Objective", in which case 40% of the amount marked as "Significant objective" is applied only.

In the case of the IDA, the resulting amount is divided by the total sum of aid activities providing the % share for climate change.

→ 1.56% in 2010 and 1.30% in 2009

This percentage is then multiplied by the donor countries' contribution (commitments) to the IDA (obtained from the CRS online system).

In case of the GEF: Based on the "Proposed Indicative Resource Envelope for GEF-5" (as reported in table 8 of "Summary of Negotiations Fifth Replenishment of the GEF", May 2010) approximately 32% of total GEF-5 fund replenishment will go towards the Climate Change focus area. Whilst cumulative funding decisions, as reported in GEF Trust Fund Trustees' Reports, fluctuate around this figure, on the advice of GEF, due to a lack of more detailed available information this data is used to approximate replenishments towards the climate change focal area.

Thus, the donor countries´ climate change funding through the GEF is calculated as 32% as their total commitment to the GEF (obtained from the CRS online system).

In case of the Nordic Dev. Fund the data from the CRS bulk download was used to determine the share for mitigation and adaptation aid activities (for 2010). These percentages are then applied to the Nordic countries´ contributions to the fund (baseline: paid-in capital during the respective calendar year).

MULTI-LATERAL FUNDS

Supplementary information on multi-lateral funds concerns the following entities:

- From individual funds' websites, annual reports and financial statement
- Adaptation Fund, Least Developed Countries Fund, Special Climate Change Fund, Climate Investment Funds, Congo Basin Forest Fund, Global Climate Change Alliance, Forest Carbon Partnership Facility, UN REDD Programme

Specific calculations are made to integrate the two data sets, using the below variables as follows:

b) Amounts from Data source 1 (GEF and IDA, see calculation method above)

c) Amounts from Data source 1 (Nordic Dev. Fund) and Data source 2 (see list of funds above)

d) Amounts from Data source 2 (CER sales of Adaptation fund)

a) Difference between amounts from Data source 1 (total contributions from donor countries and European Union) minus amounts from Data source 2 (contributions from donor countries and European Union to multilateral funds)

<u>Total: a) + b) + c) + d)</u>

→ This is done because it is assumed that the CRS reporting includes contributions to multilateral funds.

→ In the case of most funds a detailed assessment (whether the contributions to the fund are included in the CRS data) was undertaken with varying results. In most cases some countries included their contributions in their Rio marker reporting, although not all.

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