# The Cost of Extreme Events in 2030

## A Report for United Nations Framework Convention on Climate Change

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# Contents

# 1. Introduction

## 1.1. Objectives

This paper has several aims. It attempts to provide:

- a projection of extreme event costs in 2030 in as much geographic and sectoral detail as possible.
- an overview of current levels of extreme event costs
- an overview of current sources of financing extreme events
- parallel estimates of "attritional" losses from smaller events
- an assessment of how current financing arrangements need to change to meet the requirements of adaptation

Data limitations and, to a lesser extent, time constraints, prevented some of these ambitions.

## 1.2 Risk and adaptation

Extreme or unprecedented levels of climatic and marine conditions create costs by damaging or destroying natural and economic assets, preventing activity, and even killing or injuring humans and other living species. The cost is compounded by knock-on effects such as changes in commodity prices, delays or cessation of unrelated activity ("crowding out"), and in some cases relocation.

The relationship between damage and event severity is non-linear. Frequent events cause little damage, while infrequent events can be very costly. For that reason it is impossible to avoid climate damage completely, because for any level of protection, there is still a probability that an event can occur that will exceed the design threshold. Indeed, since the cost of protection rises as the threshold of protection rises, there comes a point at which for economic efficiency, it would not be sound to continue to improve the defences or adaptive measures. **Adaptation cannot eliminate damage.**

## 1.3 Limitations.

In this paper we do not adopt a fixed definition of an extreme event, because the historical data does not permit it. Often the exact climatic conditions were not recorded, and the event is categorised on the basis of its impact in terms of costs incurred. Given the enormous socio-economic changes that have taken place since 1950, such a flexible approach is necessary. This means that extreme events are defined in a dynamic way, relative to the society in which they occur.

The emphasis is on direct economic cost. This means ignoring the very considerable impacts and risks connected with damage to subsistence economies, natural systems, cultural assets and also human injury and death. It also omits most of the knock-on costs which can follow an extreme event. Because much damage occurs in smaller events, and because the definition of "extreme" varies, this study also considers the total cost of climatic losses, including minor or attritional events.

## 1.4 Methodology

The data is provided by four organisations, to whom the author is indebted: Assocation of British insurers (ABI), Munich Re (MR), Risk Management Solutions (RMS), Swiss RE (SR), as well as in publications of the Centre for Research on the Epidemiology of Disasters (CRED).

The method of calculating future costs is described fully in later sections of this report so that other researchers can validate and compare the projections.

No attempt was made to attribute current costs to climate change versus natural variability or other effects. The approach was to assess the current level, then consider that might change in future, due to climate change and economic development.

As there is considerable natural variability in the occurrence of extreme events, the projections are not to be seen as literally the cost in 2030. Rather they are the average level centred around that point in time. Some indication of the uncertainty is provided.

The cost projections are relatively unaffected by any mitigation policies between now and 2030, because of the lag in the climate system response to greenhouse gas emissions. impacts. However, adaptation policies can have an immediate effect, and so a range of adaptation scenarios is considered.

## 2. An overview of current levels of extreme event costs

2.1 Literature

The best-known reports in this field come from Munich Re, Swiss Re and the Centre for Research on the Epidemiology of Disasters (CRED), and are often cited by other key institutions like Intergovernmental Panel on Climate Change ( IPCC), International Strategy for Disaster Reduction (ISDR), Organisation for Economic Co-operation and Development (OECD) and the World Bank. However, there are differences between the data, and reconciling these is a prime task of this study.

2.2 Data sources

Five sources of data were used in this study: Munich Re (MR), Swiss Re (SR), RMS (Risk Management Solutions), CRED (Centre for Research on the Epidemiology of Disasters) and ABI (Association of British Insurers).

*Munich Re (MR)* This source is a global listing from 1950 of individual "great natural catastrophes" as defined in Table 2.1 below. The data for each comprises, deaths, insured cost, total economic cost, and is often split between countries when the event crosses frontiers. The compilation uses a variety of sources.

Table B2.1 Munich Re categorisation of events

| | | | | | |
|---|---|---|---|---|---|
| 0 | Natural event | No property damage (e.g. forest fire with no damage to buildings) | | | |
| 1 | Small-scale loss event | 1-9 fatalities and/or hardly any damage | | | |
| 2 | Moderare loss event | 10-19 deaths and/or damage to buildings and other property | | | |
| | | | **2000-2005** | **1990s** | **1980s** |
| 3 | Severe catastrophe | 20+ fatalities and/or overall losses | US$ > 50m | >40m | >25m |
| 4 | Major catastrophe | 100+ fatalities and/or overall losses | US$ > 200m | >160m | >85m |
| 5 | Devastating catastrophe | 500+ fatalities and/or overall losses | US$ > 500m | >400m | >275m |
| 6 | Great natural catastrophe „*GREAT disaster*" | Thousands of fatalities, economy severely affected, extreme insured losses (UN definition) | | | |

*Swiss Re (SR)* Again this is a global listing of events, but from 1970, using a variety of sources. The data here is more generally defined, with reporting thresholds that are raised each year in economic terms. The geographical separation of costs between countries is not so readily available as for Munich Re data. In 2006 the thresholds were that the impact had to be greater than one of the following: insured losses 40 million USD, total economic losses 80 million USD, 20 dead or missing, 50 injured, or 2,000 homeless.

*Risk Management Solutions (RMS)* This is a custom-built database, covering key types of climatic events in countries that are significant for the insurance industry. As such, it is not a global database, but can be useful for cross-checking. The data is focussed ion economic loss, and the start date of the series varies country by country, reflecting the different dates at which satisfactory data became available. The series generally end in 2005 or before, because the data was used for a specific project ( see Miller, Muir-Wood and Boissonade, 2008). Because the quality of data is higher than the worldwide average, and the coverage in economic terms is high, it is also useful for trend analysis.

*CRED* This is a global listing of individual events which satisfy one or more of the following criteria: 10 or more people killed, 100 people or more affected, a declaration of a state of emergency, or a call for international assistance. The data gives the numbers of people affected, and the total economic losses.

*ABI* This is a summation of the cost of individual insurance claims in UK ,compiled quarterly by the ABI from its member companies. It distinguishes climate-related cases, and commenced in 1988. To the extent that it is based on factual costs, it is more accurate than other series, and also it includes the very smallest "events", since every single claim is inclded. It does not distinguish specific extreme events, and it is not comprehensive, since it excludes non-Property types of claim e.g. Motor, non-ABI insurers and non-submitting ABI members. Nevertheless, the data is consistently high quality, and the author is personally familiar with it, having worked in the UK insurance industry in statistical functions, and also having used the data for recent papers, during which some imperfections were remedied. This series does not contain the number of people affected, nor any information on uninsured losses.

All the above data series are affected by the timing issue to some extent. The initial estimates may be too high ( often in order to attract external attention), or too low ( because the scale of losses is not appreciated for some time). The latter was the case in the European heatwave of 2003. A death toll of 35,000 is usually quoted, but Kosatsky,2005 indicates 50,000 and Sapir, 2007 states 71,000. Generally information is not revised once it is posted in the data bases, so this timing issue is a major source of inaccuracy.

Reporting inconsistencies are also a major problem. As the reach and capabilities of the media have greatly strengthened since 1950, the coverage and quality of data capture has not been constant. For that reason, care must be taken in considering the fitness of the data for temporal trend analysis. (See Guha-Sapir; CRED workshop 2007).

The question of what is an economic cost is likely to change with time, and possibly with the nature of the event (see Figure B2.2). As economies move from subsistence, then primary sector losses are increasingly monetised. In particular, agricultural losses in developing countries are unlikely to be recorded.

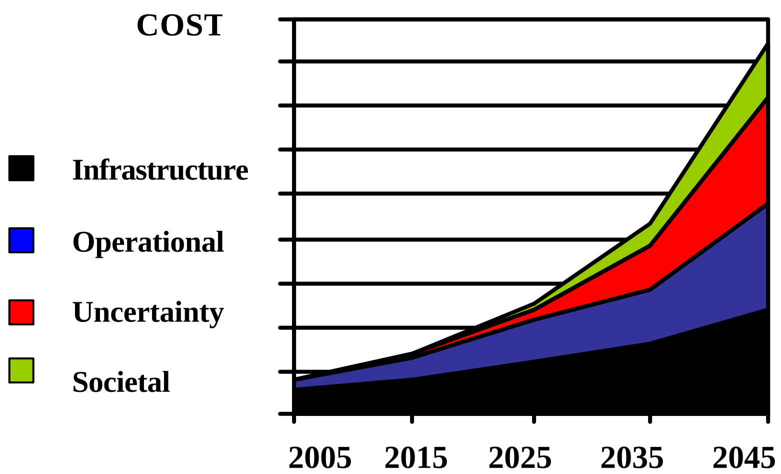



**Figure B2.2 Progressive onset of climate change costs**

*Source: Andlug Consulting, loosely based on Kemfert (2005)*

**A typology of impact costs**

As climate change spreads it generates costs in a number of ways ( Figure B2.2 is a schematic illustration). Changing weather patterns and rising sealevel increase the operating costs of consumers and businesses. Also considerable damage is occurring to public and private infrastructure and assets.

In future, it is expected that damage and operating costs will rise faster due to climate change, to the extent that a third burden, "opportunity cost", will emerge, the deferment of decisions due to uncertainty - as the realisation grows that climate change is a key decision factor.

There is also a fourth category of societal costs, where those who are economically active have to support others who are inactive, or have to contribute to the remedial costs of environmental damage. These act as a drag on economic growth generally, and so impede sustainable development (Kemfert, 2005).

Other problems with the basic data are :

- it lacks a breakdown into types of loss e.g. by economic sector,
- the location is often only vaguely specified
- slow onset events like drought or sealevel rise are often ignored, as they do trigger major losses at a definite point in time.
- Causes are not consistently defined e.g between storm and flood
- It usually ignores contingent losses e.g. due to loss of the use of production facilities, or loss of customers, or changes in the price of commodities, as happened after Hurricanes Katrina, and Rita in 2005. It can be argued that a loss for one person is a gain for another, but that ignores the redistributional aspects, and also the likely frictional losses that occur when altering demand and supply patterns.

The potential effects of these omissions can be very large. For example, the unrecorded costs of Hurricanes Katrina and Rita (particularly on energy markets) may have pushed the total economic loss up to $450 billion, compared to the MR database cost of $150 billion (Kemfert, personal communication, Munich, May 25 2006).

2.3 Comparison of cost data

The MR data appeared to be the most useful, in that it is subject to a reasonably rigorous check on the raw data, and has been the longest running. Because it relates only to great disasters, the likelihood of reporting inconsistencies is much reduced. In general the comparisons here are on the total recorded losses, i.e. including uninsured loses. The exception is when using the ABI data, which excludes uninsured losses.

However, comparing the MR data with SR and CRED indicates that it is likely to give a misleading impression, since the balance by region and peril type is significantly different, even when looking at the current decade (2000-2006), when reporting is at its best. Particular issues are the under-representation of flood and heat-related events, and of events in developing countries in the MR data. In part this may be to do with the definition of great disasters, since one of the thresholds is fixed in economic terms , regardless of the country or region concerned. It may also reflect the immaturity of the insurance market in developing countries. A final factor is that flood and heat-related events are often not insured, or even are seen as uninsurable.

**Table B3.1 MR data as proportion of SR data by cause: 2000-2006: all losses**

| Big Storm | Flood | Heat/drought | Convective | Cold | All Types |
|---|---|---|---|---|---|
| 66.8% | 31.7 | 42.6 | 76.3 | 0 | 57.5 |

**Table B3.2 MR data as proportion of SR data by region: 2000-2006: all losses**

| N Am | S Am | Europe | China | Rest Asia | Carib | Oth SIS | Africa | ANZ | World |
|---|---|---|---|---|---|---|---|---|---|
| 76.8% | 55.2 | 42.2 | 0 | 26.6 | 37.3 | 0 | 47.0 | 0 | 57.5 |

**Table B3.3 MR data as proportion of CRED data by cause: 2000-2006: all losses**

| All Storms | Flood | Other | All Types |
|---|---|---|---|
| 85.2% | 26.3 | 42.0 | 67.1 |

**Table B3.4 MR data versus CRED data by region: 2000-2006: all losses**

| Americas | Europe | Asia | Oceania | Africa | World |
|---|---|---|---|---|---|
| 95.7% | 57.7 | 15.6 | 0 | 30.4 | 67.1 |

There are interesting differences between SR and CRED. SR reports much more data for European and American losses than CRED, but the reverse is true for Africa. The two sources are similar for Asia in total.

**Table B3.5 MR data coverage in relation to SR data : all losses**

| Period | 1970’s | 1980’s | 1990’s | 2000-06 |
|---|---|---|---|---|
| MR data: SR data | 202% | 158% | 88% | 58% |

**Table B3.6 SR data versus CRED data: 2000-06 by region and cause: all losses**

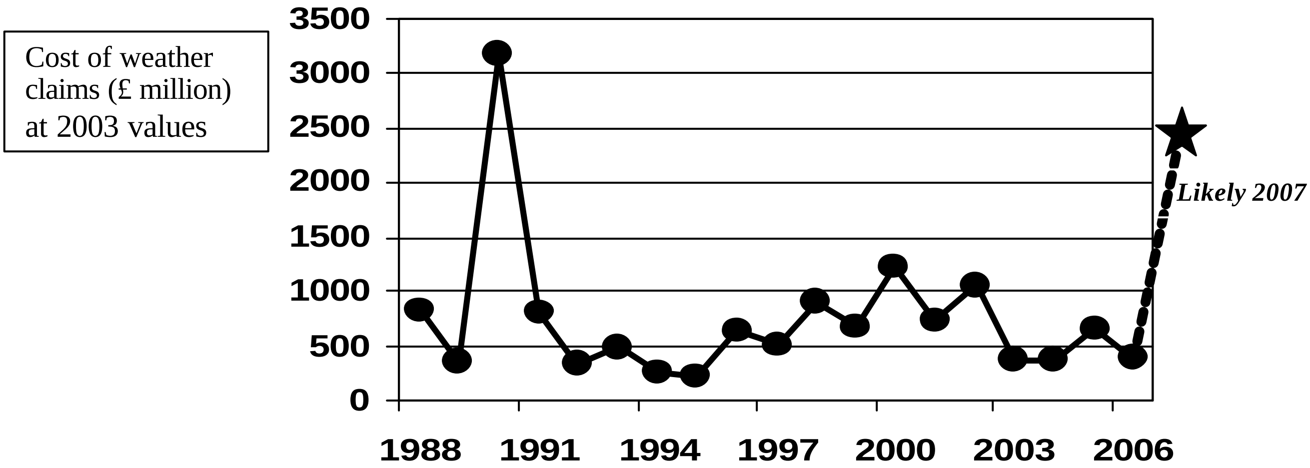
| | Americas | Europe | Asia | Oceania | Africa | World |
|---|---|---|---|---|---|---|
| All causes | 121.6% | 136.9 | 99.7 | 93.1 | 63.5 | 116.6 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Flood | 84.5 | 108.2 | 65.1 | 123.6 | 99.7 | 83.0 |
| Storm | 123.1 | 463.0 | 130.2 | 85.4 | 2.6 | 127.1 |
| Other | 122.5 | 152.1 | 121.9 | 90.6 | 0 | 127.7 |

The RMS data has not been used at this point. Preliminary review shows that it requires comparison against relatively small subtotals of the MR and SR data, which are often not subdivided into that degree of detail e.g. typhoon costs for North Korea, and that events may have been assigned to different causes e.g. storm versus flood. This could be a worthwhile area for further more detailed research, and could be useful to place in context the RMS findings on climate change and trends in extreme event costs (see Section 5).

Finally , there is the ABI data for UK, displayed in Figures B3.7 and B3.8. The former relates to sudden-onset events, while the latter deals only with claims caused by subsidence of the ground. The usefulness of this source is that, because the UK is well-insured against climatic hazards, ( >80% of households have a property insurance policy with such cover), the data illustrates the scale of small losses relative to "events". Table B3.7 shows how important disasters are, since there is a large "spike" in 1990 due to storms, and another is anticipated in 2007, due to a storm in January, and floods in June. (There was another disaster in 1987 due to a storm, but data was not collected systematically before 1988).

**Figure B3.7 ABI member companies' weather claims, 1988-2006 (excluding subsidence)**




Interestingly, Figure B3.8 suggests that there has been adaptation, since the subsidence losses in 1996 did not reach the level of 1990/91, despite drier conditions. This is also backed up by the gradual downward trend. There is substantial anecdotal evidence of this in terms of repair techniques, tree management, and also the building regulations have changed to reduce subsidence damage.

**Figure B3.8 UK household buildings subsidence damage and drought 1988-2006**

*Subsidence damage measured in 2003 constant £million. Data supplied by Association of British Insurers. Drought intensity measured in 18 month accumulated precipitation to September of year (in mm)*

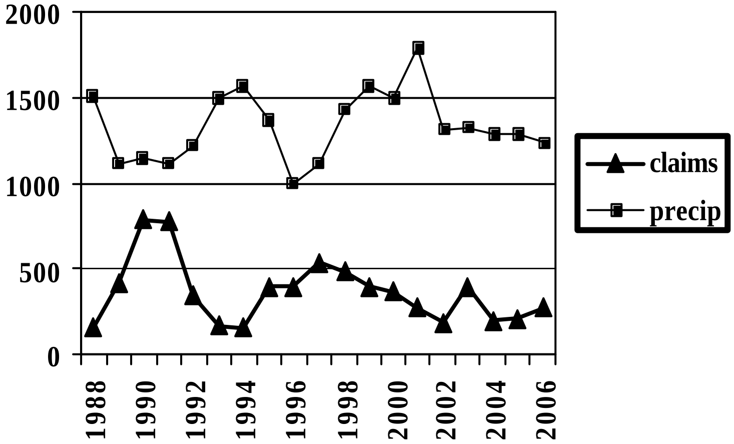



**Table B3.9 Comparison of UK insured weather losses by source 1988-2006**

| Source | MR | SR | ABI weather (ex subsidence) | ABI subsidence |
|---|---|---|---|---|
| Losses relative to MR | 100 | 180 | 490 | 240 |

This suggests that the losses could be five times the MR "great disaster" figure, even ignoring subsidence. Even that multiplier could be understated, since the MR data for the UK in this period relates entirely to storms in 1990, but that MR figure looks very high compared to the SR and ABI figures for 1990 alone. This may reflect premature estimation, or even double-counting, since that was the era of the notorious London Market Spiral, where risks were reinsured several times over.

Neither MR nor SR include subsidence losses. These are real costs, and are not a peculiarly UK phenomenon; they were enormous in France in during the 2003 heatwave for example. What is true, is that in many countries they are uninsured losses. The data here suggest that slow onset damage could be 50% of the recorded rapid-onset losses.

2.4 A proposed base level of climatic losses

Here we attempt to derive current-day costs for a matrix of loss type/region. This will draw on the previous tables to manipulate the data. It is worth considering two definitions- catastrophic losses or disasters, and climate-related damage, including slow onset events like droughts, and attritional or micro-level losses

The question of a suitable base period is key. Given that the reporting outside the MR database has been rising (see Table B3.5) , it is appropriate to use the most recent data, say 2000-2006. It is most accessible, and also likely to be of the highest quality, given the attention now paid to such information.

A second issue is whether the period has had a typical number of losses. If anything, the MR data suggests that 2000-06 may be on the low side, with a slight overweight of storm claims, but a large deficit of flood claims (see Table B4.2)

Given the enormous socio-economic changes that have occurred in the world, we do not consider data prior to 1980 in this context. Losses for future years 2007-09 are allowed for by grossing up the current decade by a factor of 1.53, to allow for 3 missing years, and an assumed growth in real exposure at 5% per year during those years).

**Table B4.1 MR losses by cause 1980-2009 ($billion at 2006 values)**

| | 1980's | 1990's | 2000-06 | 2000's (proj) |
|---|---|---|---|---|
| Flood | 31.7 | 262.1 | 29.6 | 45.3 |
| Storm | 59.7 | 217.0 | 267.2 | 408.8 |
| Other | 53.8 | 18.9 | 18.5 | 28.3 |
| Total | 145.2 | 498.0 | 315.3 | 482.4 |

Next we standardise these figures very roughly, assuming a growth in real exposure of 5% per year, to check for any glaring anomalies. This implies inflating past losses at a rate of 1.63 per decade to adjust for real exposure.

**Table B4.2 MR losses by cause 1980-2009 ($billion at 2006 values) , corrected for assumed secular increases in real exposure.**

| | 1980's | | 1990's | | 2000's (proj) | |
|---|---|---|---|---|---|---|
| Flood | 84.2 | *22* | 427.2 | *53* | 45.3 | *9* |
| Storm | 158.6 | *41* | 353.7 | *43* | 408.8 | *85* |
| Other | 142.9 | *37* | 30.8 | *4* | 28.3 | *6* |
| Total | 385.7 | *100* | 811.7 | *100* | 482.4 | *100* |
| Factor relative to 2000's | 0.8 | | 1.66 | | 1.0 | |

This suggests that the 1980's were slightly more benign, and the 1990's much more damaging, than the base period of 2000-06. Again, the 2000's appear to be high on storms ( due to USA, not shown here), and low on flood (particularly in Asia, not shown here) compared to 1990's. The high proportion of "other " losses in the 1980's seems anomalous, as it was not found in earlier decades or later ones. We therefore propose three alternative bases for projecting the base figure of disaster losses forward:

**Low** 2000-06 scaled to 1980's level by a factor 0.8 and converted to an annual loss.

**Medium** 2000-06, converted to an annual loss.

**High** 2000-06 scaled to 1990's level by a factor 1.66 and converted to an annual loss.

**Flood basis**
An alternative basis by cause may also be considered, transferring 40% of total losses from Americas-storm to Asia-flood. This represents the mix found in the 1990's.

Table B4.3 presents a proposed ***composite basis*** base-line for disaster losses, based largely on the SR data, which is more comprehensive than the MR data, and less volatile for that reason. In general the SR data is more extensive than the CRED data also. However, in a few cases there is more data in the CRED database cell, particularly for developing countries. In such cases, the CRED data has been taken , in order to yield a more balanced picture regionally. This can be justified on the basis that often SR data presents no economic loss for an event, but records human impacts like deaths. The overall effect of the adjustment is relatively small on the global total; an increase of $24 billion, or 4.5%, from 548.2 billion to 572.7 billion.

**Table B4.3 Climate – related disasters 2000-06 Base period: Composite basis $ billion at 2006 prices, and compared with MR, SR and CRED**

***Composite method uses SR data, except where bold face indicates data taken from CRED.***

| | Americas | Europe | Asia | Oceania | Africa | World |
|---|---|---|---|---|---|---|
| Flood | **10.2** | 42.4 | **60.3** | 1.2 | 1.9 | 116.0 |
| Storm | 306.8 | 12.7 | 77.2 | **2.0** | **0.4** | 399.1 |
| Other | 16.1 | 22.7 | 15.0 | **3.1** | **0.7** | 57.6 |
| All causes | 333.1 | 77.8 | 152.5 | 6.3 | 3.0 | 572.7 |
| MR all causes | 260.9 | 32.8 | 20.7 | 0 | 0.9 | 315.3 |
| SR all causes | 331.6 | 77.8 | 131.5 | 5.6 | 1.9 | 548.2 |
| CRED all causes | 272.6 | 56.8 | 131.9 | 6.0 | 3.0 | 470.2 |

To arrive at figures for attritional or micro-level losses and slow onset events, the ABI data is used. It relates only to insured losses, but is high quality, and can be compared with MR and SR data on insured losses.

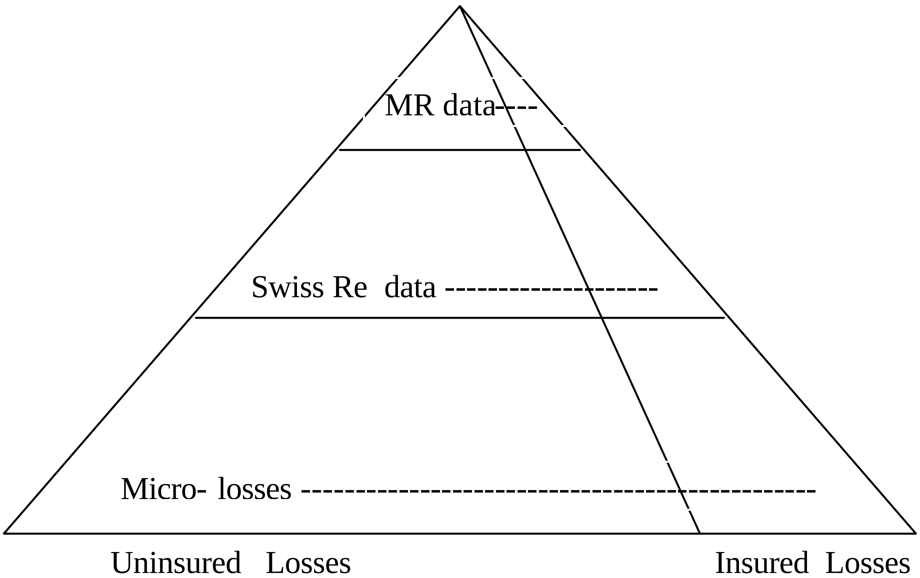



**Figure B4.4 UK weather losses, showing coverage of MR,SR and ABI databases.**

To estimate the total weather losses starting from the SR disaster losses, we can see what relationships exist in the UK between total insured losses including insured micro-losses, as reported by the ABI, and the parallel SR data.

The ABI data represents about 90% of insured losses in UK, since it excludes policies issued by Lloyd's and certain other specialist organisations, such as corporate "captives" or self-insurance arrangements, as well as some minor non-reporting ABI members. The SR data in principle includes all insurers with UK losses. Thus the factor to arrive at the total losses, given the SR data, is, from Table B3.9 :
(490 x 0.9)/ 180 = **2.45**

Naturally, the question arises whether it is appropriate to apply this factor to insured and uninsured losses of all types in all regions to estimate the total cost of rapid-onset climate-related losses. Without parallel information from a variety of sources we cannot know how inaccurate the method is. However, Figure B4.4 illustrates a classical pattern in accident analysis. There is a small number of critical incidents (the MR disasters), a larger number of serious ones (the SR events), and a host of "near-misses" (here represented by micro-losses). The relationship of SR to MR and ABI to SR gives some reassurance:

SR/MR = **1.74** ( from Table B4.3 ) and ABI/SR = **2.45** (as above)

There is also the fact that insurance coverage in UK is widespread , with high market penetration except in the poorest social segments.

It is not really possible to assess the cost of slow-onset events at global level. As stated previously, they can be very high e.g. subsidence of buildings during droughts has costs insurers in UK and France many billions of dollars in recent decades. However, it is not possible to relate the "average" cost of such losses to the SR or MR data , because they do not really include such damages as disasters in bad years. In a similar way, agricultural losses are difficult to estimate, and are not well reported: the focus is usually on property damage and human injury.

Table B4.4 Annual disaster losses *($bn 2006 value)*: base period 2000-06: medium basis

| | Americas | Europe | Asia | Oceania | Africa | World |
|---|---|---|---|---|---|---|
| Flood | 1.46 | 6.06 | 8.61 | 0.17 | 0.27 | 16.57 |
| Storm | 43.83 | 1.81 | 11.03 | 0.29 | 0.06 | 57.01 |
| Other | 2.30 | 3.24 | 2.14 | 0.44 | 0.1 | 8.23 |
| All causes | 47.59 | 11.11 | 21.78 | 0.90 | 0.43 | **81.81** |

The alternative bases for projecting the base figure of disaster losses give:

**Low**: 2000-06 scaled to 1980's level by a factor of 0.8, then converted to an annual loss…………………………………………… **65.4 billion USD**

**Medium** 2000-06, converted to an annual loss, as in Table B4.4 ..........…………………………………………**81.8 billion USD.**

**High** 2000-06 scaled to 1990's level by a factor of 1.66, then converted to an annual loss………………………… ………..**135.8 billion USD**

NB – The above estimates are all for a typical year. The loss in an extreme year would be above even the "high" estimate.

**Micro-loss basis**
Additionally, the above methods can be scaled up by a factor of 2.45, as described earlier, in order to include micro-losses from weather damage. It can be debated whether micro-losses would fluctuate decadally in the same way as disaster losses vary. No information is available to determine this point. If it is assumed that the micro-losses are fixed in proportion to the medium projection, at a figure of 118.6 billion USD, that reduces the range or smooths the volatility somewhat:

**Low : 160.2 billion USD or smoothed 184 billion USD**

**Medium: 200.4 billion USD ( no difference in smoothing version)**

**High: 332.7 billion USD or smoothed 254.4 billion USD**

**Regional bias**
All the above bases are likely to understate the impacts in developing nations, because
1. reporting is less systematic there
2. many losses are non-financial ie subsistence crops, self-made implements, personal injuries.

No attempt is made here to correct for such deficiencies. At the least, it suggests that using the micro-loss basis would be closer to the real burden of climatic losses, although the regional split would still be wrong.

**General caveats**
Finally, earlier caveats should be borne in mind- the estimates omit gradual onset events, and also exclude contingent costs, which can be enormous.

2.5 Other aspects

In the absence of an explicit sectoral split of the data, can anything be done to subdivide it? Table B5.1 makes a tentative advance, drawn from personal experience and the literature. Note that infrastructure and internal assets can reside in the public, corporate, or consumer sectors. However, this cannot be used in the current report, as the underlying values at risk are unknown.

**Table B5.1 Event Type and Sectoral Impact**

| Event type | Infrastructure | Internal assets | Production | Agriculture |
|---|---|---|---|---|
| Storm (ex surge) | H | L | L | M |
| Flood & surge | H | H | H | V |
| Drought/heat | M | L | M | H |
| Convective | M | L | L | M |
| Cold | M | M | M | V |

H = high M = medium L= low V = variable, depends on activity mix or timing

An attempt was made in the UK insurer-funded TSUNAMI initiative, to investigate uninsured losses and sectoral impacts in four flood events (Linnerooth-Bayer et al.,2001). Unfortunately, the quality of data was poor, and no systematic patterns could be reported.

Additionally, there are many studies by actors in the insurance industry, of individual major disasters, in which attempts are made to assign losses to sectors, and these might be useful to explore at a future date. For example, Hallegatte 2005, citing Munich Re on German floods of 2002:10 billion euros total cost; infrastructures (4 billions euros), trade & industry (2 billions euros), household (2 billions euros) and other sectors e.g. agriculture (2 billions euros). Tower Perrins (2005) found that only 60% of insured damage from Hurricane Katrina stemmed from damage to insured buildings and contents. The rest came from business interruption, private sector energy infrastructure, transportation equipment, and pollution liability. Munich Re (2004) noted that while the European drought of 2003 cost 13 billion USD, there were large but unquantified losses from disruption of inland river transportation and industrial production.

For working purposes, it is necessary to make some assumption about the proportion of losses that is infrastructure. In the absence of satisfactory data, it is assumed that infrastructure comprises half of the losses in a business-as-usual scenario i.e. with no explicit adaptation. Clearly, in reality the event type and the economic structure of the affected area are key features, and that can vary enormously. It is likely that each event will affect a number of sectors.

**3. An overview of current sources of financing extreme events.**

3.1 Introduction

The damage caused by climate-related events can be financed in various ways: from within the country affected or internationally. Funds can be provided through public finances, or the private sector, and within those through contractual arrangements like insurance, or informally through charitable relief. In the last resort, the damage may simply be taken as a loss in assets or income potential by the victims.

The author is unaware of any comprehensive international study on the funding of climate-related losses. There have been case-studies, as with the TSUNAMI project study of four major flood events. The most systematic data is that held by SR and MR, where the losses are simply assigned to insurance or "other" financial arrangements.

3.2 Patterns of insured-finance losses

In this section we examine the current role of insurance in financing climate-related events– by economy, region, and cause.

**Table C 2.1 Funding for great disasters - Munich Re database**
**($ billion at 2005 values)**

| Period | 1950's | 1960's | 1970's | 1980's | 1990's | 2000-06 |
|---|---|---|---|---|---|---|
| Insured | 1.5 | 6.7 | 13.7 | 26.2 | 110.7 | 139.9 |
| Total | 46.7 | 62.9 | 88.7 | 141.8 | 477.0 | 301.1 |
| % insured | 3.2 | 10.7 | 15.4 | 18.5 | 23.2 | 46.5 |

There is clearly a trend towards more insurance, but the current decade is misleadingly high, because the events were dominated by American storms (84% of the total cost between 2000 and 2006), of which 52.6% was insured.

To look more closely at patterns by region and cause, we use the Swiss Re data for 2000-06 (see Table C 2.2).

**Table C 2.2 Insured proportion of disaster costs: SR data 2000-06**
***Costs in $ billion at 2006 values***

| | | Africa | Americas | Asia | Europe | Oceania | World |
|---|---|---|---|---|---|---|---|
| Storm | Cost | <0.1 | 306.8 | 77.2 | 12.7 | 1.8 | 398.6 |
| | **% insured** | **n.a.** | **55.6** | **14.9** | **50.9** | **29.6** | **47.4** |
| Flood | Cost | 1.9 | 8.6 | 39.3 | 42.4 | 1.2 | 93.3 |
| | **% insured** | **9.0** | **26.5** | **4.8** | **23.4** | **23.6** | **15.6** |
| Other | Cost | 0 | 16.1 | 15.0 | 22.7 | 2.6 | 56.4 |
| | **% insured** | **n.a.** | **46.8** | **0.6** | **2.7** | **11.8** | **15.2** |
| All Types | Cost | 1.9 | 331.6 | 131.5 | 77.8 | 5.6 | 548.2 |
| | **% insured** | **8.9** | **54.4** | **10.3** | **21.8** | **20.1** | **38.7** |

Storms are quite well-insured at disaster scale, in developed countries, with about 50% of the cost transferred to the insurance market. In developing markets, the proportion is much less, around 10%. ( Japan and Australia/New Zealand raise the averages for Asia and Oceania).

Flood. In developed markets, around 25% of flood costs are insured, with again only about 10% insured in developing countries.

Other weather losses. Here the position varies greatly, depending on the nature of the event, not just the type of market. For example, the costs for Europe are dominated by the 2003 drought, while the losses in the Americas are largely attributable to cold waves and forest fires.

One important reason why the insured proportion of costs is not higher, is that public sector assets are not generally insured, but they are vulnerable to damage, as they often comprise infrastructure in exposed locations. In developed countries this may not be a serious issue, at least for central government, but the increasing tendency to devolve or privatise assets does open this practice to question. In developing countries, where often natural hazards are more severe and public finances are less robust, the absence of no-questions post-loss finance can be a major constraint on economic recovery.

3.3 Developing countries

Hoeppe and Gurenko, 2006 considered the financing of disaster losses (including earthquakes) in developing countries. In some cases e.g. the Caribbean , the funding has been by means of donor aid and concessional funding from multilateral banks. However, the increasing indebtedness of developing countries is making further borrowing impossible. Donor aid has not kept pace with the rising cost of disasters, is mostly used for developmental projects, and is very uncertain. The proportion of the economic cost of disasters in developing nations that was covered by donor aid between 1987 and 2003 never exceeded 10% globally, and was generally used for emergency relief, not reconstruction.

3.4 Trends - likely changes between now and 2030.

A number of features are appearing with increasing frequency when considering financial management of climatic risks. Often these new features are combined to produce novel solutions.

a. **Off-shore centres** These provide tax advantages and reduced regulation or greater flexibility. In particular Bermuda has become a centre for reinsurers specialising in catastrophe reinsurance (Benfield Group Limited, 2007).

b. **Innovation with ART** (alternative risk transfer). Instruments like catastrophe bonds are being trialled as an alternative to reinsurance to deal with key catastrophic risks (Fitch Ratings,2006a;2006b; Benfield Group Limited, 2007). Perhaps 5% of the cover available for catastrophic events like US hurricanes is provided via ART. There are significant differences from reinsurance- the cover is triggered by the occurrence of pre-defined meteorological circumstances, rather than a financial loss ( in fact such products are often referred to as *parametric* for that reason). This means there can be a significant *basis risk*, in that the buyer of cover may not receive a pay-out that is correlated with his loss. Also, the cover usually lasts 3 to5 years compared to the typical 12 months for reinsurance.

The capital that supports such risk transfer can in principle come from any source, but much of it derives from reinsurers, who do not wish to be sidelined by such developments. In general, the transaction costs in designing such instruments are high compared to reinsurance, because of the need for extensive due diligence to satisfy investors that the risk analysis in every case is sufficiently detailed. Therefore, they are only suited to large transactions.

One reason why ART is attractive to non-traditional investors in insurance, is that the risks are not correlated with stock-market risks. That fact helps to smooth out volatility in an investment portfolio.

c. **Bundling dissimilar risks.** Combining climatic with geophysical, social or technological risks in the same contract has the advantage of increasing the attractiveness to buyers. From the seller's (i.e. insurer's) viewpoint it also has advantages because it reduces the opportunity for anti-selection by high-risk segments, and also reduces the potential correlation between risks that results in highly erratic costs between years (Dlugolecki and Hoekstra, 2006).

d. **Public sector.** Interest is rising among governments and multilateral financial institutions in using ART instruments, particularly catastrophe bonds and weather derivatives to deal with the macro-economic financial impact of disasters (Linnerooth-Bayer and Mechler, 2006). This is because it has become clear that ex-post financing is inefficient for several reasons ( e.g. tardiness, impact on other projects, uncertainty), while insurance also has some deficiencies, principally lack of continuity in terms. A particular example is the Caribbean Climate Risk Insurance Facility (see box).

**Caribbean Catastrophe Risk Insurance Facility (CCRIF)**

The CCRIF is being established under the coordination of the World Bank to provide Member States with index-based insurance (cat bonds) against government losses caused by natural disasters. It represents an important shift from disaster response to ex-ante disaster management and mitigation. Governments will purchase catastrophe coverage to provide them with a cash payment within one month after a major hurricane or earthquake. These funds are intended to meet a portion of the immediate liquidity problems that face governments in the aftermath of a disaster.

Pooling risk among 15 countries has enabled the premiums to be reduced by about 50% from the aggregate value of the individual premiums, due to the benefit of non-correlated risks , even within a fairly focused area like the Caribbean. The Facility will be created with the premiums from participating countries and substantial assistance from donors (47 million USD). For poorer countries, the fees will be subsidized or contributed by donors also. For tax efficiency, CCRIF will be domiciled in the Cayman Islands.

e. **Micro-insurance.** In developing countries, poor farmers are the main victims of climatic hazards. They are not easily accessed by formal financial instruments like insurance, nor do they benefit greatly from top-down financing. The success of microfinance ( The Economist, 2005) has opened new possibilities for risk management of climatic perils like drought and flood. Already successful pilots have been carried out in Malawi ( Linnerooth-Bayer and Mechler, 2006) and India (UNEPFI,2006;Kelkar, James and Kumar,2006) using weather derivative insurance targeted at individual farmers , distributed through microfinance institutions and NGO's, and insured by the private sector.

f. **Catastrophe reserves.** One retrograde step has been the phasing out of tax-allowable catastrophe reserves in the process of harmonising insurance regulations, and consolidating accountancy principles across industries and regions. This means that insurers find it more difficult to balance good years with bad, and so catastrophe insurance is less attractive, because of the volatility of results. Reinsurance can only be a partial solution, because the reinsurance market fluctuates unpredictably.

## 4. Projections of extreme event costs in 2030 in geographic and sectoral detail.

### 4.1 Assumptions about adaptation that affect extreme event costs.

Three bases are considered, **business-as-usual**, **partial** (i.e. non-infrastructure only) and **active** adaptation.

*Business-as-usual* Here we assume that there is no recognition of climate change beyond what is already occurring in the base period. This reflects political and social inertia, the reluctance to commit resources to work which may not be required given the inherent uncertainty in impacts.

*Partial* The projection horizon is in 2030, a mere 23 years away. Section 2.5 suggested that half of the losses from extreme events emanate from impacts on infrastructure, which has a long lifespan, and is costly to retrofit. Further, adaptation has only recently begun to attract attention, and new infrastructure takes some years to design and instal. For these reasons, it is assumed that nothing substantive can be done by way of new adaptation strategies that would substantially alter impacts in 2030.

That is not to say that there is no adaptation of infrastructure, simply that it will continue in the same way as hitherto, and so does not require to be explicitly factored in. On the other hand, non-infrastructure is renewed much faster, sometimes within weeks, and can therefore be adapted at shorter notice. In broad terms it is assumed that this is a new effect, and that such assets and exposures are adapted to a level that reduces losses by 50% in 2030 in all regions.

The net effect of this is to **reduce losses by 25% from business-as-usual**.

*Active*
It is assumed that no existing infrastructure is retrofitted to reduce impacts, but that from 2010, new infrastructure is improved, to reduce impacts by 50%. In rough terms, infrastructure is renewed about every 20 years, but it would be wrong to assume that all infrastructure would be better adapted within 20 years (i.e. between 2010 and 2030), because in some sectors like energy, transport and formal domestic housing the lifespan is much longer. In fact, about half of current infrastructure might still be

operational. This inertial effect will be more pronounced in regions where growth is slower. Table 3 in Appendix 1 shows that Asia and Africa are expected to develop much more rapidly, with the Americas, Europe and Oceania being slower, roughly doubling in real terms between the base period and 2030.

It is assumed that in slow-growth regions infrastructure losses can be reduced by 30%, reflecting the mix of old and new infrastructure. In fast growth regions, the "drag" of existing infrastructure is assumed to be nil, with full adaptation. As before, we assume non-infrastructure is fully adapted to reduce losses by half. This gives:

**For Africa and Asia, losses are reduced by 50% from business-as-usual. For Americas, Europe and Oceania, losses are reduced by 40%. At global level, this approximates to a 45% reduction in b.a.u. losses.**

*Comment. Larsen et al.,2007, agree that strategic design adaptations have much more potential to reduce extra costs in the long run. For public infrastructure in Alaska, they estimate it might reduce costs related to climate change by anywhere from zero to as much as 13%, depending on the extent of climate warming. But between now and 2080, adaptations could save anywhere from 10% to 45% of costs resulting from climate change. However, their methodology assumes no real growth in the infrastructure asset portfolio, and so is an underestimate of the savings that adaptation would generate in a dynamic (expanding) portfolio.*

4.2 Projections at global and regional level

We use three projection methods to asses the future level of losses, staring from the base period 2000-06:

Implicit- based on MR data, with no explicit GDP assumptions
Composite- using RMS findings about climatic losses, plus GDP growth assumptions
Explicit- using detailed assumption about climatic changes, and GDP growth

Two of the projection methods below make an explicit assumption about GDP, as an independent exogenous factor that represents exposure. However, the first method incorporates exposure implicitly in the projection method.

The explicit methods all use an adjustment for real exposure between the base period 2000-06 and 2030. For comparability, these are based on the SRES scenarios ( see Appendix 1). Adaptation is assumed to occur in three possible intensities, as described in section 4.1.

**Table D2.3 Multiplicative adjustment factors for future increases in real exposure: between base period 2000-06 and 2030**

| Region | Africa | Americas | Asia | Europe | Oceania | World |
|---|---|---|---|---|---|---|
| SRES A1 | 5.59 | 2.65 | 4.55 | 2.10 | 1.78 | 3.00 |
| SRES B1 | 7.18 | 2.27 | 3.24 | 1.95 | 1.63 | 2.54 |

Briefly, scenario A1 relates to a world with high economic growth, but static population, and an emphasis on technology and globalisation. Scenario B1 is a similar world, but with less emphasis on growth, and more on sustainability.

## 4.2.1 Implicit approach

This is a "ball-park" projection, without giving full consideration to regional or causal factors. It also makes no attempt to project losses in relation to shifting climatic patterns, but simply assumes that the past trend will continue into the future. However, it can provide a probabilistic aspect to the projection.

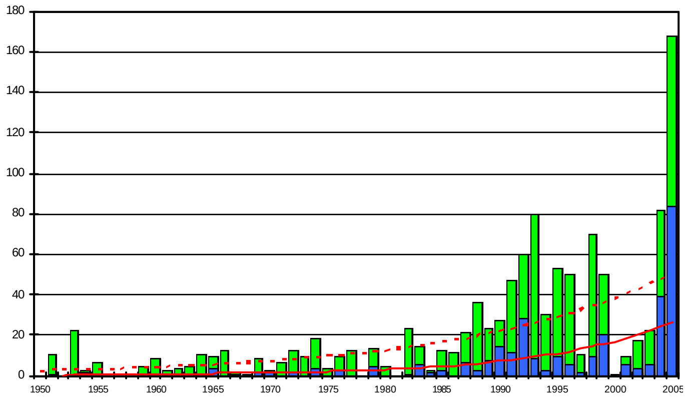



**Figure D2.1 Cost of great weather disasters 1950-200**

*( Source: Munich Re) Costs in USD billion,2005 values .*

Insured Uninsured

The MR data only covers "infrastructure" and part of "operational" costs, and does not include "small" incidents, or micro-losses, which together might add another 350% to the MR damages ( see section 2.4). The simple MR cost reported in 2005 came to 165 billion USD, of which half was insured ( Figure D2.1). **MR records the underlying trend in the costs as 6 percent per year, shown by the curves on Figure D2.1** (Munich Re, 2006). Analysis of similar costs by RMS suggests there is an underlying "climate change" trend of 2 percent per year. The remainder is due to the fact that modern economies are vulnerable to climatic variability.

However, great disasters often appear in clusters: Figure D2.1 shows that one year in three, the costs are 50% higher than the trend-line. In fact since 1990 they were more than double the trend value in 1992, 1993 and 2005, a frequency of one-fifth. Even if this only applies to the largest events, those reported by Munich Re, it still constitutes a significant variation, and needs to be allowed for in planning.

*Disaster cost projection*

The trend value for economic losses in 2005 is 50 billion USD in 2005 values from Figure D2.1. Table B4.3 show that this is about 55% of all weather disaster costs, which therefore are 90 billion USD. The long-term trend of 6% annual growth means costs double every 12 years, taking them to 380 billion USD by 2030 in 2005 values, or

<u>390</u> billion USD in 2030 (2006 values).

Allowing random fluctuations in timing of the largest events (55% of the estimate), gives:

<u>500</u> billion USD or more (+28%), with a one-third probability

<u>600</u> billion USD or more (+54%), with a one-fifth probability.

*Total including micro-losses*

Applying the grossing-up factor for micro-losses would take this estimate up to

<u>955</u> billion USD in 2030 (2006 values) [390 x2.45]

Allowing for random timing of the largest "MR" disasters gives, but a constant volume of medium and micro-losses:

<u>1,060</u> billion USD or more (+11%), with a one-third probability

<u>1,170</u> billion USD or more (+22.5%), with a one-fifth probability

4.2.2 Composite method

**Apply the RMS hypothesis, that losses rise at 2% per year due to climate** (see Miller, Muir-Wood, Boissonade,2008). This gives an adjustment factor of 1.707 from the base period to 2030. Then compound this with changes in real exposure by 2030, derived from Table D2.3.

**Table D2.4 Adjustment factors for future increases in real exposure: Composite basis according to SRES scenario**

| Region | Africa | Americas | Asia | Europe | Oceania |
|---|---|---|---|---|---|
| Uplift Factor A1 | 9.54 | 4.52 | 7.77 | 3.58 | 3.04 |
| Uplift Factor B1 | 12.26 | 3.87 | 5.53 | 3.33 | 2.78 |

Applying these uplift factors to Table B4.4 gives:

**Table D2.5 Composite-basis: 2030 weather costs ($ billion at 2006 values) Scenario A1**

| Basis | Americas | Europe | Asia | Oceania | Africa | World |
|---|---|---|---|---|---|---|
| Medium- disasters | 215.1 | 39.8 | 169.2 | 2.7 | 4.1 | 430.9 |
| Low- disasters | 172.1 | 31.8 | 135.4 | 2.2 | 3.3 | 344.8 |
| High - disasters | 357.1 | 66.1 | 280.9 | 4.5 | 6.8 | 715.4 |
| Flood basis | 67.2 | 39.8 | 423.5 | 2.7 | 4.1 | 537.3 |

To convert these to a figure including microlosses, multiply by a factor of 2.45 e.g. Medium basis,including microlosses of 624.8, world total = 1,055.7 billion USD

**Table D2.6 Composite-basis: 2030 weather costs ($ billion at 2006 values) Scenario B1**

| Basis | Americas | Europe | Asia | Oceania | Africa | World |
|---|---|---|---|---|---|---|
| Medium- disasters | 184.1 | 37.0 | 120.4 | 2.5 | 5.3 | 349.3 |
| Low- disasters | 147.3 | 29.6 | 96.3 | 2.0 | 4.2 | 279.4 |
| High - disasters | 305.6 | 61.4 | 199.9 | 4.1 | 8.8 | 579.8 |
| Flood basis | 57.5 | 37.0 | 301.4 | 2.5 | 5.3 | 403.7 |

To convert these to a figure including microlosses for the medium basis, multiply by a factor of 2.45 i.e. Medium basis, world = 855.8 billion USD (incl microlosses)

For the alternative bases, it is suggested that the microlosses would remain unaltered. For B1 they are 506.5 billion, giving totals of:
Low = 506.5 + 279.4 = 785.9 billion USD ( an 11% reduction on medium)
High = 506.5 + 579.8 = 1,086.3 billion USD (a 27% increase over medium)
Flood = 506.5 + 403.7 = 910.2 billion USD (a 6% increase)

4.2.3 Explicit basis projections

Apply "scientific" projections of climate to each loss type/region cell to generate a 2030 loss figure, which can then be scaled for GDP change by that date.

This method is likely to underestimate the future costs, for several reasons. GCM projections of extreme events are sparse; they are averaged across large regions often, which conceals significant sub-regional effects; they find it difficult to discriminate a climate signal from underlying natural variability, which is high; they are not designed to explore the effects of extremes, yet damage varies strongly in a nonlinear way as the intensity of a climate variable rises. .

*Storm*

- Africa - no information, so assume no change.

- Americas- this is dominated by hurricane losses. ABI 2005 provided a projection of a 75% increase in losses over 85 years. This is a relatively small shift over such a period, so that a linear interpolation suffices, using a simple approximation of 75/(85x100) = 0.88% per year. The increase is 27x 0.88% = 24% , a factor of 1.24.

- Asia- ABI 2005 suggested an increase of 66% over 85 years for Japanese typhoons.. Using the same methodology as for the Americas the increment is
  27x 66/(85x100)= 21% approximately, a factor of 1.21.

- Europe- ABI 2005 yielded a very low increase of 5%. Literature on European storms appears to be moving towards higher estimates. For example, Swiss Re 2006 suggests a 44% increase over 110 years. With the same methodology, as for the Americas and Asia, the increment is 27x 44/(110x 100) = 11% , a factor of 1.11.

- Oceania - no information, but it is certain that sealevel rise (SLR) will compound the storm risk for islands, so assume a 10% rise to represent this, ie a factor 1.10.

*Flood*

Predicting floods is complex, because precipitation is inconsistent between climate models, and there are several factors which can have a big effect; evaporation in a warmer climate, take-up by vegetation in a richer atmosphere, glacier melt, sea-level at the estuary mouth etc.

- Africa – no clear overall trend, so assume no change

- Americas- in Latin America, peak river flows are increasing due to glacier melt. In North America, the projections are inconsistent, but peak precipitation will increase. Use a factor of 1.10.

- Asia- no clear overall trend in populated areas before 2030, assume no change.

- Europe- currently dominated by events in central and northern Europe, where flooding is expected to worsen. Adopt a factor of 1.10 .

- Oceania- no clear trend, possibly even a decrease- assume no change.

*Other*
This is dominated by wild-fire, drought and heat- and cold-wave events at present. Hadley centre projects a doubling of global increase in land area under drought by 2100, or 25% by 2030. Global wildfires are tending up at 10% every 20years. Insect infestations and famine also fall into this category.

- Africa – great problems of water availability, and also crop failure. Based on Ashton, cited in IPCC , assume an uplift factor of 1.38.

- Americas- drought and water stress, due to glaciers shrinking, will be major problems in Latin America. In North America, thawing in the Arctic and wildfires will be serious. This will be offset somewhat by fewer cold waves in North America. A detailed analysis is not available: use a factor of 1.2.

- Asia – food production and water availability are expected to reduce, and insect infestations are likely to rise, but no clear statements are given. Assume an increase of 10% by 2030, a factor of 1.10.

- Europe- additional losses in heatwaves will be compensated by fewer losses in cold waves. However, water stress will increase from 19 to 35% of land area in 70 years, giving an increase for 2030 of (25/70)x(35/19). Applying this to half the losses, gives a factor = 1.33.

- Oceania –based on projections for drought in Australia, and problems in small islands with coral bleach and saline intrusion, assume an increase of 20%, or a factor 1.20.

**Table D2.5 Summary of explicit adjustment factors for event types**

| | Americas | Europe | Asia | Oceania | Africa |
|---|---|---|---|---|---|
| Flood | 1.10 | 1.10 | 1.0 | 1.0 | 1.0 |
| Storm | 1.24 | 1.11 | 1.21 | 1.1 | 1.0 |
| Other | 1.20 | 1.33 | 1.10 | 1.2 | 1.38 |

**Table D2.6 Projected annual disaster losses in 2030 ($bn 2006 values): Explicit approach- medium basis- current GDP**

| | Americas | Europe | Asia | Oceania | Africa | World |
|---|---|---|---|---|---|---|
| Flood | 1.61 | 6.66 | 8.61 | 0.17 | 0.27 | 17.32 |
| Storm | 54.35 | 2.01 | 13.35 | 0.32 | 0.06 | 70.09 |
| Other | 2.76 | 4.31 | 2.35 | 0.53 | 1.38 | 11.33 |
| All causes | 58.72 | 12.98 | 24.31 | 1.02 | 1.71 | 98.74 |

This yields a constant-exposure damage figure of $98.74 billion in 2030, an increase of 20.6% over the average annual loss in the base period 2000-06.

Applying a real-growth adjustment, as per Table D 2.3, and then a micro-loss adjustment give the following projections for "all causes":

**Table D2.7 Annual weather costs in 2030: explicit approach - medium basis**
***($ bn 2006 values)***

| Basis | | Americas | Europe | Asia | Oceania | Africa | World |
|---|---|---|---|---|---|---|---|
| Scenario A1 | Disasters | 155.6 | 27.3 | 110.6 | 1.8 | 9.6 | 304.9 |
| | Incl microlosses | 381.2 | 66.8 | 271.0 | 4.4 | 23.4 | 746.8 |
| Scenario B1 | Disasters | 133.3 | 25.3 | 78.8 | 1.7 | 12.3 | 251.4 |
| | Incl microlosses | 326.6 | 62.0 | 193.0 | 4.1 | 30.1 | 615.8 |

Projections can be generated for low, high, and flood bases as before, and also broken down into storm, flood, and other causes.

4.3 Summary of projections
Table 2.8 assembles the various projections on the medium basis ( i.e. using 2000-06 as the base period with no alteration) . For disasters only, as reported by CRED and SR, the range is 251 to 431 billion USD. Including microlosses takes the range to between 616 and 1,056 billion USD.The range is wider than presented there, because there are alternative variations.

**Table D3.1 Comparison of damages in 2030: medium basis (billion 2006 USD)**

| Projection | Scenario | Disasters only | Incl microlosses | GDP |
|---|---|---|---|---|
| Implicit | (similar to A1) | 390 | 955 | 90,721 (A1) |
| Composite | A1 | 431 | 1,056 | 90,721 |
| | B1 | 349 | 856 | 76,440 |
| Explicit | A1 | 305 | 747 | 90,721 |
| | B1 | 251 | 616 | 76,440 |

*Variations*
Partial adaptation might reduce these damages by -25%.
Active adaptation could reduce the losses by -45%.

Using the 1990's as the base (high basis), increases disaster losses by + 66%.
Using the 1980's as the base ( low basis), reduces disaster losses by -20%

The effect on total losses varies somewhat depending on the basis e.g.
for 1990's (high), composite method, scenario B1, increase losses by +27%
for 1980's (low) , composite methid, scenario B1, decrease losses by -11%

4.4 Other estimates

Work by others has focussed on longer term damage from climate change impacts, and so is not directly comparable with the projections in this study. For example, Stern, 2006, reports many of the previous studies, but with a deliberate focus on post-2050, and also including non-impact adaptation costs such as increased spending on air-conditioning.

Most recently, work by Kemfert and Schumacher (2005) , and Hallegatte has emphasised the costly nature of secondary effects and non-linearity, both of which have been ignored by previous work. Hallegatte 2005 reports that:

(i) Dynamic processes multiply the extreme event direct costs by a factor 20; half of this increase comes from short-term processes;
(ii) Modification of the extreme event distribution due to climate change can be responsible for significant GDP losses;
(iii) The production losses caused by extreme events depend, with strong non-linearity, both on the changes in the extreme event distribution and on the ability to fund the rehabilitation after each disaster.

This is particularly important for small states, whether sovereign or sub-national. As soon as extreme event costs exceed the economic funding capacity, the damages are multiplied very rapidly. It is vital to have an economic organization able to cope efficiently with extreme events. This shows clearly the necessity of establishing pre-event risk transfer or risk funding mechanisms. Hallegatte provides the example of Guatemala and the Honduras. There is numerous other literature, including World Bank and Munich Climate Insurance Initiative (MCII).

Hallegatte believes earlier literature did not recognize the importance of extreme events in the shorter term: " After the first enumerative studies of climate change impacts (e.g. Nordhaus (1991), Cline (1992), Mendelsohn and Neumann (1999)), it has been argued that it was necessary to account for longterm economic dynamics (by Tol (1996) or Fankhauser and Tol (2002)). .. it is also absolutely necessary to account for short-term dynamics and for the consequences of shocks like extreme events."

Kemfert and Schumacher, 2005 give a strong critique of earlier work, particularly by Tol. They observe that previous analysis was too simplistic, based on linear damage functions, with no feedback mechanisms for damage in one region to influence future actions, or other regions. Like Hallegatte, they stress the importance of "crowding out" i.e. that recovery from damage prevents intended or expected investment. They do not present a damage figure for 2030, but project a global loss without adaptation, of 21% of world GDP in 2050. This is not comparable to the estimates in the present report, because it includes imputed values for ecosystem loss and human deaths. Also, Kemfert and Schumacher do not present a scenario with adaptation, as they are primarily interested in exploring the trade-off with mitigation.

The importance of "bottlenecks" in the economic system is stressed by practical experience from the hurricane seasons of 2004 and 2005. Munich Re 2005 notes that repair costs rose by double or treble their pre-hurricane levels due to shortage of supplies and workers. Munich Re 2006 noted that 89 drilling platforms were totally destroyed by Hurricanes Ivan , Katrina and Rita, with many other installations damaged or destroyed also, at a cumulative insured cost of nearly 15 billion USD, resulting in major problems for oil and gas supply for a considerable time.

Finally, Larsen et al., 2007 provides an interesting perspective on gradual onset costs in the Arctic (Alaska to be precise). The changing climate could make it roughly 10% to 20% more expensive to build and maintain public infrastructure ( roads, hospitals, etc) in Alaska between now and 2030 , or from 3.6 to 6.1 billion USD. This is a cumulative figure- the annual cost would be from 0.15 to 0.3 billion USD in 2030 alone. Data on the value of current public infrastructure assets was very difficult to obtain, but an estimate of around 39 billion USD was considered reasonable. This means the additional cost is about 0.5% of the asset value.

## 5. Impacts under mitigation scenario

There is almost nil difference to extreme events in 2030 as a result of mitigatory actions between now and then, because of the lag between the release of emissions and their effects on the climate. In a few situations, it is possible that a mitigatory action might reduce impacts e.g. forests planted to absorb carbon dioxide might reduce the flood hazard. This is not anticipated to be a major benefit, but could be important locally. A prime example is the use of mangrove plantations in coastal sites.

On the other hand, some mitigation projects themselves will be exposed to extreme events, and so might increase the total cost of an extreme event by contributing additional damage costs as a second-order effect. It is even possible that the existence of a mitigation project could exacerbate an extreme event, through the escape of pollutants, or the presence of combustible materials e.g. hydrogen, or wood. For example, large forests could become fire hazards themselves. Again, this is unlikely to be a major aspect before 2030.

On balance, therefore, impacts, in terms of extreme events in the year 2030, are seen as invariant in respect of mitigation scenarios.

## 6. An estimation of total investment needed for extreme events adaptation under the mitigation scenario

In principle this is a fairly simple exercise

– calculate the incremental costs by assuming that mitigation actions need to be climate-proofed as per World Bank research, at a cost of around 1% of total project value (see Box 1 below).

- there are some savings in the 2030 timeframe, though no material difference in extreme events can happen by 2030, whatever the mitigation actions before then. However, by adapting the mitigation projects and outputs, damage from extreme events will be reduced. What is lacking currently is a measure of the damage potential to infrastructure alone. In broad terms, climate damage will be about 1% of global GDP in 2030, from Table D2.8. However, this is not the same as the damage to infrastructure, since losses occur from damage to other assets, consumables, and interruption of income also.

If we assume that "at risk" means a 50% chance of 50% damage in the useful lifetime of the infrastructure, say 25 years, then the annual losses on infrastructure would be
0.4 (fraction at risk)x 0.5 (chance of loss)x 0.5 (damage suffered)/25 (lifetime)
= 0.4 % of the total project value.
From the perspective of the total portfolio of projects, that would mean that the saving was less than the adaptation cost, but from the point of individual projects, it is within the range of viability for risk management in order to avoid the local disruption from a loss. However, this is mere speculation, and would need further investigation.

***Box 1 Financing for climate change adaptation (van Aalst, 2006)***
*A rough estimate suggests that project preparation costs could increase by 5 to 15 percent for the Bank projects that may be at risk from climate change, which are estimated at about 40 percent of the total portfolio.*
*The impacts on investments, through increased costs or significant redirection, are estimated at 1 to 2 percent of the investment portfolio, or about $200 million to $400 million per year within the World Bank Group and at least $1 billion for all official development assistance and concessional lending. The total costs of adaptation for all activities, including government and private investments, in developing countries will be at least an order of magnitude larger.*

## 7. Assessment of needed changes in financial arrangements to meet the requirement of anticipated additional costs of extreme events

7.1 The scale of the adaptation deficit

The sums required for comprehensive adaptation to extreme events are very large. The entire capital of the global insurance industry is around 700 billion USD. Perhaps 200 billion is earmarked for catastrophe, including earthquake. This provides security for only 20% of today's economic losses from extreme events, so to fully fund disaster risk needs around 1 trillion USD. Allowing for economies of scale might reduce this by one-third, but still the gap is enormous: around **450 billion USD capital for extreme events** (= 650 required-200 current). Initially, the private sector's contribution would be principally through skills, but private capital would enter as local capacity builds and commercial viability is demonstrated.

Turning to slow-onset problems, to capitalise microfinance for the world's poorest billion would also require massive funds. Taking an average family of five, and an advance of 50 USD per family for agricultural purposes, would imply aggregate credit of 10 trillion USD. Setting aside the issue of providing the capital ( an amount of 200 billion USD at a reserve ratio of 2%), what about insuring the loans against such risks as drought? If we assume a premium rate of 4.0% of the sums insured, and a solvency margin requirement of 25% of premiums written, that implies **a capital requirement of at least 100 billion USD for insuring slow onset events in the rural sector**.

There are UNFCCC adaptation funds but currently the committed funds remain at around 200 million USD annually. Other sources include disaster relief, which could be switched to hazard reduction. The net effect on donors would be an increase at the beginning, then a fall as capacity grows, vulnerability reduces and resilience improves. Also, a portion of revenue raised under mitigation actions like emissions trading and CDM could be earmarked for adaptation, possibly via the adaptation funds. Another interesting possibility is granting adaptation credits for reducing impact risk, similar to mitigation credits for abating emissions, but little work has been done on that issue.

### 7.2 Reasons for insurance market failure

The barriers to the ability of insurers to provide pure private catastrophe insurance solutions can be classified as supply-side and demand-side (Dlugolecki and Hoekstra, 2006).

#### 7.2.1 Supply-side barriers

On the supply side, the main barriers to the participation of the private market in catastrophe insurance lie in the area of risk financing. The main problems are:

*Volatility* Capital is the fundamental element for any insurance operation as it ensures its ability to accept risks and pay claims. Capital mainly comes from private investors, who expect to receive a 10-20% risk adjusted return. As insurance companies' financial performance may be adversely affected by large claims from catastrophic events (which would prevent them from meeting their return targets), they make heavy use of reinsurance to stabilise their earnings. In the absence of affordable reinsurance capacity, insurers would be unwilling to provide catastrophe insurance coverage. Even major public insurance schemes have faced technical insolvency, in France from subsidence claims, and in the US from flood claims following Hurricane Katrina.

Alternatives like equalisation reserves[1] are in principle equivalent, but may require special accounting and taxation treatment, because the modern accounting practice is to avoid financial transfers between years. Participation of the public sector in providing additional reinsurance capacity to the market is likely to reduce the price fluctuations of the reinsurance market and hence would create a more stable and longer-term price stability on the reinsurance side.

*Freedom to manage the underwriting process* A balance is needed between regulatory control of the market (to protect consumers), and flexibility in managing insurance operations in response to a changing risk landscape. To compete, companies need scope to underwrite more skilfully, design innovative products, and distribute more efficiently. Geographical information systems (GIS ) are increasingly used for locational underwriting of natural hazards. Overly rigid insurance regulations in local markets will deter private operators or result in less optimal insurance solutions. To stay in business, in addition to adequate product design and pricing, insurers must be able to control their aggregate risk accumulations arising from the sale of individual insurance policies.

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[1] Money is put into and out of an equalisation reserve when the actual claims are below or above expected levels, to give a better measure of the long-term performance of a portfolio that is subject to erratic losses.

*Data availability- on hazards and exposures* Poor data means that uncertainty is much greater and the private market will be less able to participate in risk-bearing. Geographical , economic and climate data tend to be poorer for developing countries and access to such information is often prohibitively costly. A particular issue with climate change is that the risks are dynamic i.e. rapidly changing, so that projections are essential. The case of the UK is instructive, because the data there is high quality.

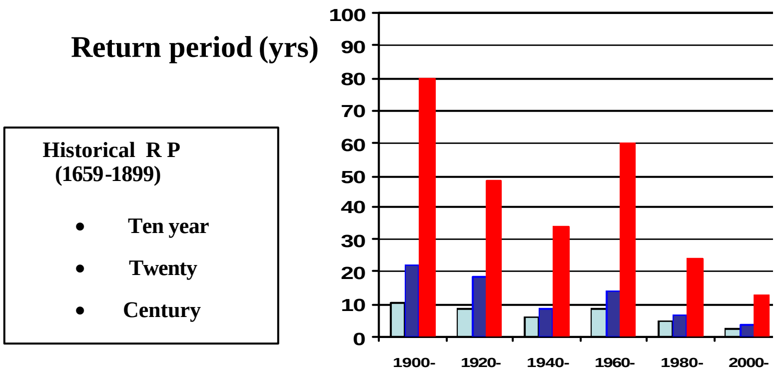



**Figure G1**
**Shrinking return periods: Hot UK months**

Figure G1 shows that this is already fact. Extreme monthly temperatures that used to occur once every hundred years in the UK now happen eight times more often. Twenty-year events have become four-year ones, and ten-year events recur every three years. By extension, the return period for the 1,000 year event is now 83 years!

Figure G1 relates to temperature, which is not a crucial impact parameter for insurers. Data on rainfall is not so good, nor are climate models so precise as for temperature. In general, the intensity of precipitation is expected to be more severe (IPCC, 2007). It is notable that UK has been impacted four times in 10 years by severe inland flooding (1998, 2000, 2002, 2007). The position for storms is even obscure- data is less good, and GCM projections generally lacking or inconsistent (IPCC, 2007).

*Risk prevention.* In highly regulated markets, where insurers are limited in their ability to introduce appropriate risk-related discrimination among different risk classes of insured in terms of premium rates, deductibles and the scope of coverage, catastrophe insurance coverage may reduce consumers' risk awareness. It is therefore vital that public control of the risk management framework (land development, building design, construction standards etc) is maintained and that regulators set a reasonable standard of care for policyholders to avoid such "moral hazard". The private sector can be a partner in this. In the UK, for instance, the insurance industry actively engages with policymakers on flood defence funding, land zoning and construction standards; while in USA insurers help to fund the technical training of publicly paid building inspectors and Australian insurers helped Fiji to set standards for cyclone-resistant buildings. One way to overcome anti-selection is to make catastrophe cover compulsory or bundle it with other finance products e.g. mortgages or fire insurance.

*Scale of operation* Since capital and management time in the private sector are limited, the market potential versus other opportunities is key. Currently 80% of worldwide economic losses caused by natural catastrophes is not insured. If methods can be found to make these risks insurable, then the market potential is high. In some developing markets there are limitations to the proportion of equity capital that foreign shareholders can hold, which may limit the scale of coverage due to the small capital base of the domestic partners.

*Financial exclusion.* Even in developed countries, this is a major problem. For example in UK, though 80% of households have property insurance, this falls to under half for the poorest decile. The situation may be worsening with the decline of old distribution channels, ( local branch network, home service agents) and the spread of direct debit and the internet . On the supply side, the problems in insuring this sector are administrative expense ( a high minimum premium is necessary to reflect fixed costs per case, and also to avoid underinsurance) and anti-selection, e.g., often there is a high crime risk in poorer areas. On the demand side, consumers distrust the complex product, and are deterred by occasional unsatisfactory claims-handling experiences. One solution is to offer insurance collection with rent, using the (often public sector) landlord as distribution channel, or via a microfinance institution where a loan is to be insured.

*Synergy with other operations* Private market operators can gain significant economies of administration if they have a parallel operation that provides other products eg fire or auto insurance, or can provide economies of scale from existing skillsets in other countries eg modelling capability, policy administration systems. This is particularly important for claim-handling, as capacity can be redirected from non-catastrophe work to assist in emergencies.

*Availability and scale of publicly-funded disaster relief* Often there is public disaster relief system to cater for victims eg emergency subsistence, soft loans. Unless it is carefully designed, it can undermine the viability of a private insurance market.

*Profit distribution* In some developing countries there are major restrictions on the repatriation of dividends, which naturally deters the foreign private market.

7.2.2 Demand side barriers

There are various demand-side barriers as well. While some of them can be overcome by the private sector over time, others may need public sector intervention.

*Perception of risk* Often consumers have low risk awareness of their risk exposures, particularly in the case of low frequency-high impact events. The private market can play a useful role in awareness-raising, since it has a profit motive to increase market penetration. As consumers are usually not willing to purchase disaster insurance, introduction of compulsory disaster insurance by governments may be an important element in overcoming this problem.

*Price* When premiums are high, consumers will not insure. This may be a signal from the private market that the risk is very high (unsustainable), or that there is great uncertainty, or that the scale of operations is too small, or that more risk management by at-risk parties is needed.

*Efficiency* The insurance process must be expedient - payment of claims must be achieved within acceptable timeframes or else consumers will not purchase the product. Here private operators will seek to attract customers by being more efficient than competitors.

*Fairness* If consumers believe that they are paying more than their "fair share" to the insurance fund, they will not insure willingly. The private market will seek to segment customers, thus eliminating cross-subsidies. However, this may be contrary to public policy in terms of solidarity.

## 7.3 Public-private partnership

From section 7.2, a public-private partnership (PPP) seems to be the appropriate model for insuring climate risk, because in developing countries public resources are limited. This would have to overcome significant barriers to private capital, many of which can be resolved by the public sector.

The most important attractions for the private sector are the prospect for a positive profit margin, and size. Image and corporate social responsibility alone do not justify sizeable commitments of resources. Assessing the profit margin requires good knowledge of the basic costs. For climatic risks there is a high degree of volatility, so the probable maximum loss (PML) is uncertain. If it is possible to create synergy by marketing adaptation products with other ones, that improves the margins. Also, if the regulatory regime permits flexibility in product design, that allows the provider to incorporate experience quickly and improve profitability. Corporates will look at the long-term viability of the market before entering- is the public sector able to perform its role? How big is the likely market? What restrictions are there on foreign entrants?

Using the private sector has advantages. It applies cost/benefit to its actions to avoid inefficiency. In the context of climate risk, this means that high hazards are priced out as an option. Competition gives it an incentive to innovate. Global corporates can rapidly spread best practice. Numerous specialisms have evolved so that a variety of solutions can be tried out. In particular, insurers can provide efficient administration for climate risks, even when they do not carry the risk. Table G2 outlines the potential respective roles of the public and the private sectors.

| Issue | Role of government | Role of private sector |
|---|---|---|
| Hazard reduction | Basic data and research<br>Awareness-raising | Risk modelling |
| Resilience-enhancing measures | Regulation and enforcement | Incentives in product design |
| Product design | Public policy | Efficiency, marketability |
| Vulnerable sectors/communities | Infrastructure<br>Pilot adaptation scheme funding<br>Diminishing livelihood support | Micro-finance and –insurance backed by reinsurance<br>Pooled development funds |
| Risk transfer | Guarantee fund<br>Volatility smoothing | Insurance if conditions of insurability are met, otherwise services for public schemes |
| Disaster relief | Restricted, using hazard reduction and pre-funding | Relaxed terms of business during emergency<br>Services for public schemes<br>Claims under climatic impact insurance |
| Administration, including loss-handling | Minor | Major, using back-up from non-climatic business and overseas at peak-load times |
| Capacity building | Funding | Technical assistance |
| Technology for adaptation | Basic research<br>Incubator stage funding | Finance and insurance for consumers and operators<br>Venture capital |
| Public goods - ecosystems, heritage | Conservation policy and funding | Technical advice, flagship funding |
| Economic stability | Security. Sound financial policy | Availability and accessability |
| Financial markets | Policy and governance | Distribution and marketing<br>“After- sale” service e.g. claims administration |

**Table G2 Public-private partnership roles in financing adaptation to extreme events**
*Source - UNEPFI, 2006*

7.4 Current financial sector experience with adaptation to extremes

Because of the catastrophic nature of climatic risks, insurers have developed strategies for managing them (see Table G3). Often they are defensive, seeking to avoid loss or preserve profit, but they can also provide a basis for growth. They are continually refined in the light of experience and new knowledge. Effort has been focussed on regulatory, business and market risks, but also with good attention to counterparty, operational and reputational risks. Until recently, concern was driven by natural variability, but the techniques are equally valid for climate change, and are applicable to the wide variety of insurance systems that exist at national and even subnational levels. As yet, few insurers have taken climate change on board. In the US, only 7 of 104 insurers listed in New York identify climate change as a relevant risk for their shareholders (UNEPFI, 2006). Insurers are not generally willing to underwrite flood risk, or slow-onset hazards in agriculture. CERES, a US-based NGO, has identified a growing move by insurers to reduce coverage in the coastal zone.

As discussed in Section 7.3, by adopting a public-private partnership approach, it may be possible to move beyond this rather "defensive" philosophy where the private sector seeks to preserve its capital in an uncertain and risky environment, to one where its capabilities are deployed more actively so that society can develop more confidently and less constrained by the risk of financial ruin.

| Strategy | Regulatory Risk | Market risk | Business Risk |
|---|---|---|---|
| Reduce risk | Engage with government on flood defence funding and land zoning (UK), and building standards (USA, Fiji) | Withdraw from high-risk areas (USA).<br>Avoid catastrophic risk like flood (most countries) | Understand the sensitivity of new industries and locations (reinsurers) |
| Price risk correctly | Seek approval to modify prices based on risk modelling (USA) | Seasonal forecasts for hurricane risk (reinsurers)<br>Trend allowance for climate change (rare) | Use GIS to discriminate risks (UK, USA) |
| Transfer risk | Seek government back-up (France) | Reinsurance (universal) | Seek alternatives to reinsurance (brokers) |
| Check aggregate | Stress-test exposure by disaster scenarios (rating agencies, licensing authorities – common) | Internal capital-rationing (risk-based capital - common) | Consider asset-liability correlation (rare) |
| Control loss | Defend actions that seek to expand coverage (USA) | Contingency planning, pre-event deployment (USA) | Advanced techniques for subsidence repairs (UK) |
| Diversify risk Base | Open up new markets e.g. rainfall insurance and reinsurance (India) | Multiline insurance portfolio (universal) | Mine data to exploit new markets (some reinsurers) |

**Table G3: Adaptive measures in use by insurers**

*Andlug Consulting ( in UNEPFI, 2006)*

To achieve truly effective adaptation, insurers need to work closely with other stakeholders to make a difference (See Figure G4). Traditionally this only occurs in times of crisis, but with climate change this approach needs to be more systematic.

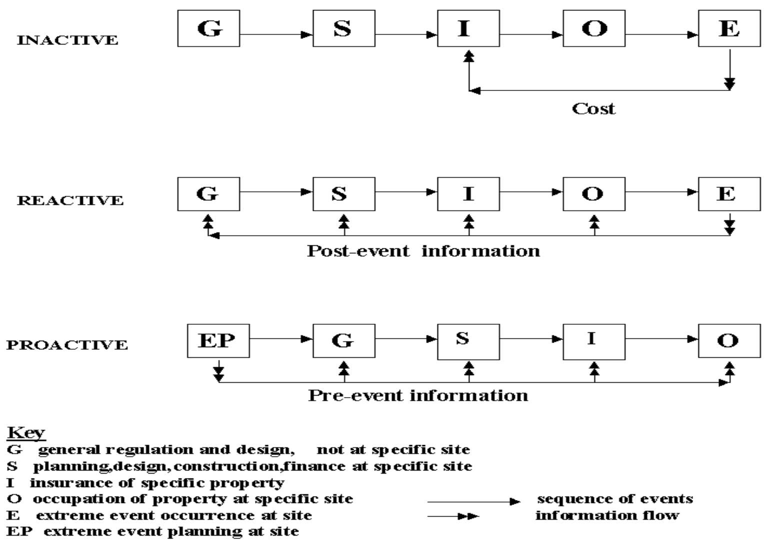



**Figure G4:**
**An integrated property damage system**

Conventionally, insurance is provided once property developments have taken place, in the *inactive mode*.

If damage becomes more frequent, insurers begin to share information about their losses to raise awareness and justify their actions e.g. exclusions (the *reactive mode*).

Climate change requires a third stage, into *proactive mode*, where insurers become partners in the process of infrastructure planning.

*Source: Chartered Insurance Institute, 2001*

Two notable initiatives on knowledge networks in this area are the Provention Consortium and the Munich Climate Insurance Initiative ( see Box).

## BOX 2 Public-private knowledge networks in the adaptation workspace.

**MCII** (Munich Climate Insurance Initiative) was founded in 2005 by Germanwatch, International Institute for Applied Systems Analysis, Munich Re, Munich Re Foundation, Potsdam Institute for Climate Impact Research (PIK), the Swiss Federal Institute of Technology, the Tyndall Centre for Climate Change Research and the Worlc Bank. Its aims are:

**1. Develop insurance-related approaches to impacts of climate change,** combining resources and expertise of public and private sectors.

**2. Support pilot projects for insurance-related solutions** in partnerships and through existing organisations an programmes.

**3. Advance insurance-related approaches with other organisations.** Identify success stories and disseminate information on success factors.

**4. Promote loss reduction measures** for climate related risks.

Currently it is engaging other stakeholders in the UNFCCC arena to identify the most fruitful starting-point.

**ProVention** was established by the World Bank in 2000 to address the increasing frequency and severity of natural disasters and their impacts on developing countries. The initiative comprises a range of stakeholders, but only three corporates, including Munich Re and Swiss Re, from the private sector. Its methodology is:

- **Forging linkages and partnerships** among key actors and sectors involved in disaster risk managemen
- **Advocating greater policy commitment** to disaster risk management by leaders and decision makers;
- **Developing and promoting innovative approaches** and applications for reducing risk;
- **Sharing knowledge and information** from ProVention partners and projects about good practices, tool and resources for disaster risk management.

All ProVention activities are intended to contribute to these four overarching and interconnected objectives and t the Hyogo Framework for Action, and reports and projects are often relevant to adaptation.

7.5 Case studies

New tools for managing the cost of weather risks have been trialled successfully by World Bank and others. Section 3.4 described the Caribbean Climate Risk Insurance Facility (CCRIF). The CCRIF will also serve as a pilot program that could be extended to other small states, such as the Pacific islands. Other cases include:

(a) The use of weather derivatives to provide disaster relief in Ethiopia

The World Food Programme (WFP) signed a contract in March 2006 with Axa Re for an indexed payout of 7 million USD in the event of a severe drought in the subsequent year, as measured by 23 weather stations in the region. Insurers were prepared to take on the risks because advances in technology meant it was easier to predict factors like rainfall. The premium for one year is 930,000 USD and has been met by a small group of donors, including the United States, together with the Ethiopian government. The scheme has several benefits:

- Fast payout for Ethiopian farmers. The WFP says the scheme will enable it to get aid to those in need at the first signs of problems without having to wait for donors to respond to appeals. Money and food at the very beginning of a crisis is critical. The same amount of money available on day one can feed 20 to 30 percent more people than that amount of money that comes in the middle of a crisis. Later food prices go up and people's physical health deteriorates, making them less able to work and more vulnerable to disease.
- Avoidance of volatile demands for finance for WFP and donors
- Minimal disruption of other WFP planned projects in other countries, through diversion of funds from development to disaster relief.

(b) Refinancing microfinance networks

In India, a microfinance institution BASIX insured some of its crop lending portfolio against a monsoon deficit during the period July-September 2004 with an Indian insurer, backed by reinsurance into the international risk transfer market with Swiss Re. It covered three business units in three districts, with a sum insured of about 0.15 million USD for a premium of around 1,600 USD. The pilot was restricted to only 3 branches in BASIX in the state of Andhra Pradesh and covered only the crop loan portfolio of these branches. Thanks to this weather hedge BASIX maintained its credit operations in those drought-prone "risky" districts, benefiting the local economy and farmers. The facility improved the quality of the BASIX portfolio, which makes it a more attractive partner for other financial institutions, and enables further expansion.

(c) Micro-level rainfall insurance in India

Traditional crop insurance is not commercially viable anywhere. Farmers understand their risks so well that only high-risk ones insure (anti-selection), and the costs of monitoring crops at field level is high. In India, this is compounded by the slow settlement of claims under the public sector scheme - often a year or more after the loss, which forces the farmer to borrow at high interest rates, default on loans or sell assets. Natural disasters affect whole districts, so that traditional social networks cannot cope. The very poor cannot diversify, and may not be able to manage debt, so weather index insurance is well-suited to their needs.

Rainfall insurance was launched in India in 2003. Since then, there have been major improvements in the product design and delivery. A key development was the partnership between BASIX, an Indian micro-finance institution based in Hyderabad, The World Bank's Commodity Risk Management Group, and private insurers.

The first pilot in 2003, was very small and the products and systems rather simple, with payouts based on the entire seasonal rainfall recorded locally. In 2004, ten rainfall insurance products were trialled, but still on a small scale. A major expansion took place in 2005. The product was no longer crop-specific, but focused on district as the risk factor. Administration was streamlined, and the product was marketed in six Indian states in several languages. Over 7,000 policies were sold, and other insurance companies and agents followed suit. The outlook for 2006 is further strong expansion, but growth may be limited by the availability of weather data. As customers gain confidence with insurance products, BASIX believes there is scope to package it with other livelihood enhancement products, thereby monsoon-proofing loans. This would provide protection for BASIX as well as its clients. Insurance for non-farming activities could also take off.

The premium rates are not low, at between 5 and 12 % of sum insured, but experience shows that insurers will not participate unless the scheme is viable, and clients are willing to pay if the claim settlement process is fast and fair. In fact the underwriter, ICICI Lombard, now sells weather insurance via BASIX, other intermediaries, and retail (direct), for crops, and also salt and brick manufacture. The insurer identified three barriers. Better weather data will reduce basis risk for clients and encourage improved reinsurance rates. Automatic reinsurance is needed to permit greater flexibility in writing new contracts and portfolios. Third, the government should revise its subsidy policy for yield-insurance products, which undermines the weather insurance market.

This initiative has succeeded due to strong collaboration between all the partners, with doorstep delivery, and quick claim settlements- even before harvesting is over, compared with customary delays of twelve months in public schemes. It featured iterative and collective product development and innovation.

All the stakeholders gain: government by reduced relief payments and social problems, and easier budgeting; the insurer by more business; the microfinance institution BASIX complements its client services; the poor farmers receive reliable protection for their income and assets; and overseas development agencies avoid disruption from emergency relief calls, and can claim speedier assistance for clients. Wider schemes would benefit intermediaries, by generating more revenue; and banks by protecting their credit risk.

7.6 The way forward

*Adopt integrated adaptation to achieve a "triple dividend"*

- Integrate climate change issues into development policy and disaster management;
- Introduce regulations to promote climate-resilience in development and infrastructure, and enforce them;
- For vulnerable sectors change the agenda from disaster relief to development by capacity building, planning (Sperling and Szekely,2005), pilot adaptation scheme funding, and the introduction of private sector resources like microfinance. Build on weather hedging to establish sustainable growth;
- Build capacity through economic diversification, infrastructure and technical training. Sponsor pilot schemes that introduce the private financial sector into the equation, using market systems whenever possible.

Effective adaptation needs to make vulnerable people resilient. This means dealing with other issues like low incomes, no title to assets, lack of education, resource depletion, governance, economic instability, disease, demographic factors, poor risk management, inadequate infrastructure and communications and access to finance. Essentially, providing these is the objective of sustainable development.

Similarly, to deal with disasters, post-event disaster relief is unpredictable, and does not tackle underlying factors that produce vulnerability. The key strategies are economic diversification, technical training like soil and water conservation, secure communications and infrastructure and, crucially, hazard reduction.

The solution is to build local capacity and resilience in a way that links sustainable development, risk management, and adaptation for a win-win-win situation. This yields a "triple dividend" in the payback for the scarce resources that are available to invest, as shown in Figure G5. Each dollar takes care of climate impacts, disaster recovery and economic growth.

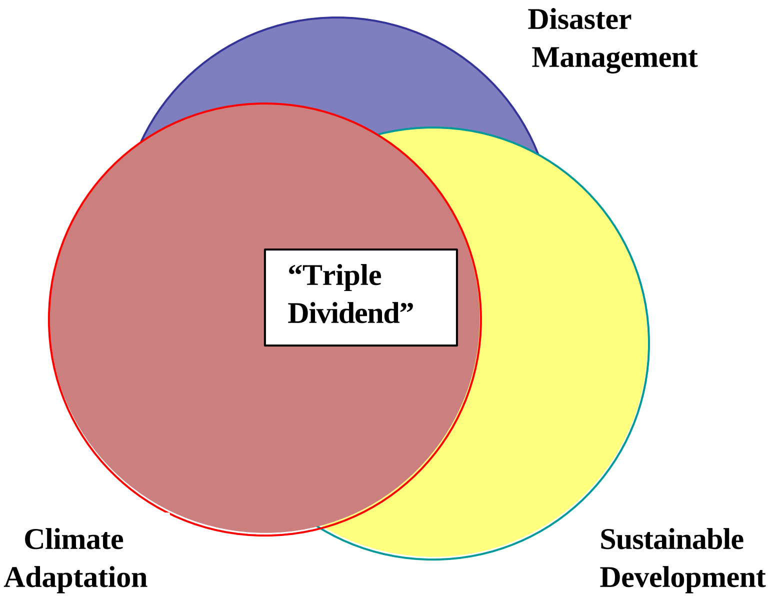



**Figure G5 The Triple Dividend**

**Effective Adaptation Means Multiple Objectives**

*Improve information about climate risk*

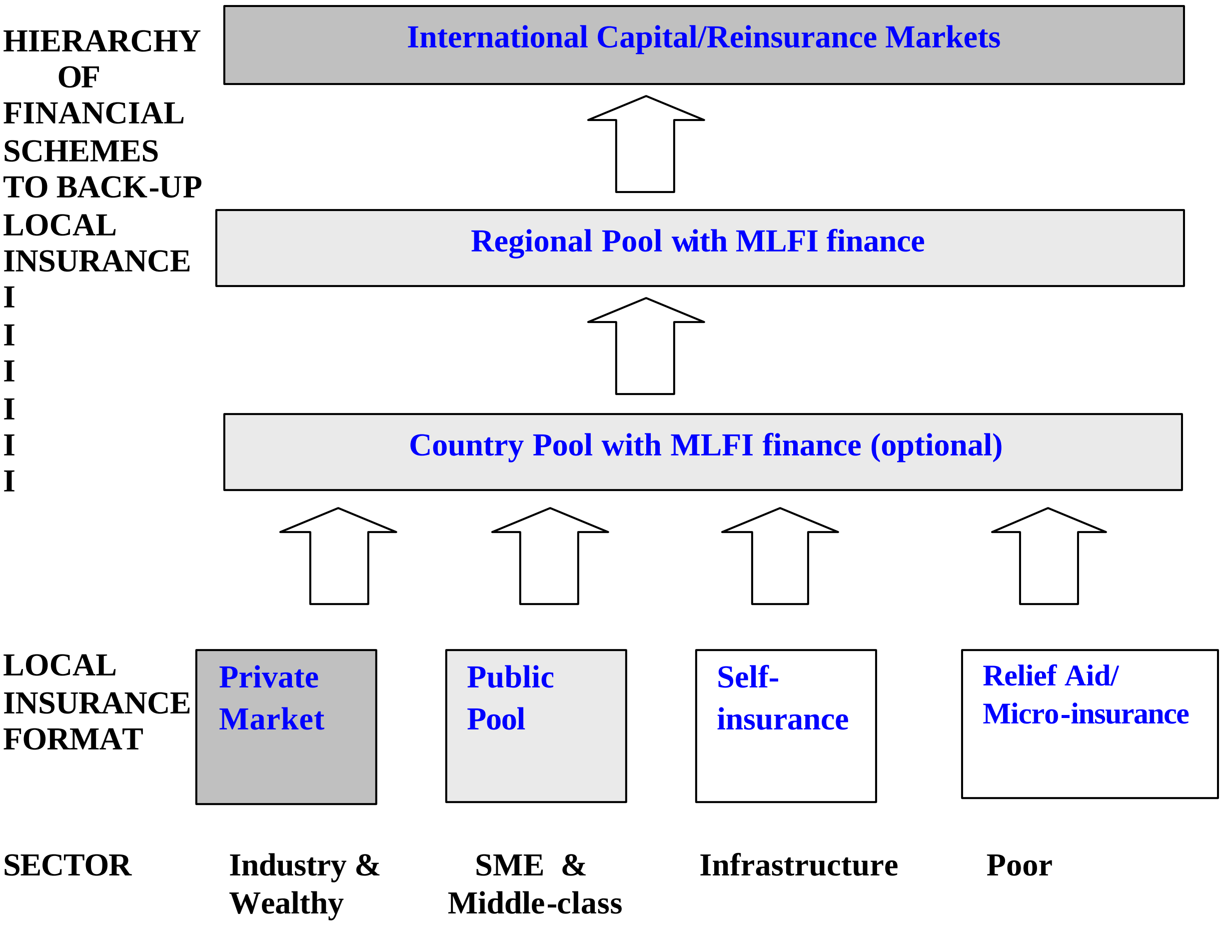
- Prioritise the identification of major climatic hazards, and make basic data and research accessible. Specifically, ensure that accurate and timely data are available at reasonable prices to support the growth in weather derivatives and other risk transfer products, especially in developing countries;
- Carry out awareness-raising and consultation programmes to engage all stakeholders in adaptation;
- Prepare for disasters on the basis that they will be greater than any seen to date in terms of local size, duration, and contingent macroeconomic impacts.

*Catastrophe insurance*

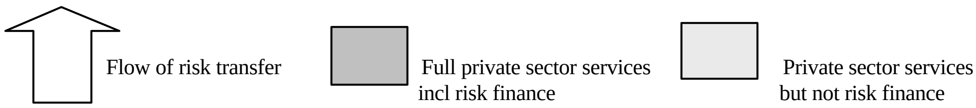
- Specifically, sponsor regulation that supports catastrophe insurance, with appropriate public sector commitments e.g. an insurance guarantee fund, subsidies for insurance premiums for poorer at-risk segments, or "soft" capital for catastrophe funds. As a general principle, premiums should be matched with the underlying risk. Allow companies to smooth the cost of extreme events. Promote a risk transfer system providing a seamless solution for victims, not disjointed recovery problems.
- Promote innovation in financial risk transfer, through ART instruments like catastrophe bonds, weather derivatives, and miocro-insurance.
- A DEFRA-funded study on insurance for small islands reported that in almost every case it is cheaper and fairer to adapt than simply accept abandonment (Silver and Dlugolecki,2007). Insurance can play a valuable role –for individuals, businesses, and the public sector. Different models may be appropriate ( see Figure G6), but can be linked together at higher levels of aggregation. As with the CCRIF, pooling the risks at regional or global level substantially lowers the variability of losses, and therefore the premiums.

**Figure G6**

**A Layered Hybrid Public/Private Scheme for Financing Natural Disasters**




Notes to diagram. SME: small and medium-size enterprises. MLFI: multilateral financial institutions e.g. World Bank



## 8. Conclusions

8.1 The cost of extreme events in 2030

Projecting the cost of weather losses is an imprecise exercise. In part this reflects the poor quality of data on historical losses, in part the lack of good information about future climate, and in part the random fluctuations in timing of extreme events. Analysis suggests that a composite approach to data is best, using information from four datasets. A fifth, partial dataset remains to be explored.

Several projection methods are proposed here, giving a range of answers. In 2006 values, for the medium basis, taking the period 2000-06 as typical, a global cost of climatic disasters in 2030 is given by:

Implicit $390 billion , with a one-third chance of over 500 billion, and a one-fifth chance of over 600 billion

Composite $350 to 430 billion (SRES scenario B1 or A1)

Explicit $250 to 300 billion (SRES scenario B1 or A1)

The total cost of weather-related damage would be about 145% higher:

Implicit $955 billion

Composite $850 to 1,050 billion, (SRES scenario B1 or A1)

Explicit $615 to 745 billion (SRES scenario B1 or A1)

For comparison, global GDP in 2030 is projected as $90,721 billion under A1, and $76,440 billion under B1.

A number of variations are feasible:

a) taking the 1990's as the base period (high) would add 66% to the disaster cost projection, and about 27% to the total loss projection

b) taking the 1980's as the base period (low) would reduce the disaster costs by 20%, and the total cost by 11%

c) adaptation might reduce the costs by between 25 and 45%.

A "best guess" would discard the explicit approach, as being too limited in its findings about underlying trends in extreme events. On the other hand, the implicit and composite methods are based on historical trends. Also, give that the 1980's have been succeeded by seventeen years of more costly experience, and that there has been a pattern for events to cluster in individual years, I would incline to taking a range based on high and medium.

Another reason for taking a higher bias, is that the data is lacking in slow-onset events, contingent effects like commodity prices, and also impacts on subsistence economies.

Finally, I think it unlikely that a determined programme of adaptation of infrastructure will commence by 2010, given the continuing debate about climate change, and the focus on mitigation rather than adaptation. However, it is likely that an acceleration of losses after 2015, say, will lead to some adaptation, particularly of non-infrastructure. Therefore, assume a partial adaptation approach that reduces damage by 25% in 2030.

Putting this together, we get, in 2006 values:
Disaster costs in 2030 $260- 540 billion, after adaptation
Climate-related costs $640- 1,000 billion, after adaptation

Because of the inherent variability of the climate, and the poor quality of the data, it is difficult to give detailed guidance on the cause or location of these losses. The principal causes of loss are likely to be storm and flood, and the worst-affected regions will probably be the Americas and Asia. However, this may reflect the facts that the data collection is weaker for the least developed countries in Africa and for slow-onset risks like drought.

8.2 The use of insurance to cope with future extreme events

There is a huge gap in the availability of capital to finance insurance of climate-related extreme events and slow-onset risks, potentially 450 billion USD for the former, and at least 100 billion USD million for the latter. Historically, the share of insurance in funding disasters in "OECD"-level countries has run at about 50% of losses for storms and 25% for floods. For developing countries it has been about 10%. It is likely that the aggregate contribution of insurance has been rising as per-capita wealth has risen globally. In developing countries, the deficit has been filled by borrowing, with less than 10% met by donor aid.

The major types of risk that are not insured have been agricultural or public sector, and also flood risks. Penetration of insurance is weaker in poorer social segments. There are many reasons for market failure. On the supply side, key ones are climatic variability, the lack of good data, regulatory restrictions or apathy, and high administrative costs. On the demand side, the main barriers are lack of awareness, price, and attitudes about cross-subsidies. To overcome them requires strong public/private collaboration. In some cases the private sector might not be willing to accept risk in the classical insurance mode, but it could still provide a rich array of other services and skills to support a publicly-funded insurance system.

Already there are many promising examples of private sector involvement in finding novel solutions to climate risk in developing countries. What is needed now, is a determined effort to address the issues in a co-ordinated way, integrating economic development, adaptation, and disaster management to gain a "triple dividend". A key enabling strategy is the generation of better quality information on risks and exposure. The needs of different sectors require different solutions, from traditional insurance, to microinsurance to catastrophe bonds and weather derivatives, but international pooling of risks is a crucial part of the answer.

## Acknowledgments

For access to data: Association of British Insurers (ABI), Munich Re (MR), Swiss Re(SR), Risk Management Solutions (RMS).
For use of unpublished report on small island developing states and climate insurance: UK Department of Environment Food and Rural Affairs (DEFRA)

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## Appendix 1 – GDP assumptions

### Table 1 Regional GDP A1 scenario 1990 billion USD

| | 1990 | 1995 | 2000 | 2005 | 2030 |
|---|---|---|---|---|---|
| Americas | 7480.8 | 8560.6 | 9757.2 | 11404.5 | 28047.5 |
| Asia | 4867.0 | 5712.4 | 6737.7 | 8486.1 | 34679.2 |
| Africa | 476.9 | 568.6 | 664.1 | 939.0 | 4478.3 |
| Europe | 8586.1 | 9324.7 | 10169.7 | 11476.9 | 22699.3 |
| Oceania | 362.0 | 398.4 | 437.5 | 480.5 | 816.2 |
| World | 21772.8 | 24564.7 | 27766.2 | 32787.0 | 90720.5 |

### Table 2 Regional GDP B1 scenario 1990 billion USD

| | 1990 | 1995 | 2000 | 2005 | 2030 |
|---|---|---|---|---|---|
| Americas | 7480.8 | 8259.8 | 9698.0 | 11310.6 | 23857.8 |
| Asia | 5021.3 | 6004.4 | 7342.0 | 9067.7 | 26559.4 |
| Africa | 476.9 | 471.0 | 635.4 | 865.9 | 5393.4 |
| Europe | 8429.8 | 8496.7 | 9541.9 | 10779.5 | 19831.0 |
| Oceania | 364.0 | 388.3 | 457.8 | 522.8 | 798.1 |
| World | 21772.8 | 23620.1 | 27675.1 | 32546.5 | 76439.7 |

### Table 3 Annual Regional GDP 2006 values billion USD

| | Scenario A1 | | | Scenario B1 | | |
|---|---|---|---|---|---|---|
| | *Base year 2000-06 (1)* | *2030 (2)* | *Growth % (3)* | *Base year 2000-06 (4)* | *2030 (5)* | *Growth % (6)* |
| Americas | 15,025 | 39,827 | 265 | 14,916 | 33,878 | 227 |
| Asia | 10,809 | 49,244 | 455 | 11,651 | 37,714 | 324 |
| Africa | 1,138 | 6,359 | 559 | 1,066 | 7,659 | 718 |
| Europe | 15,369 | 32,233 | 210 | 14,428 | 28,160 | 195 |
| Oceania | 652 | 1,159 | 178 | 696 | 1,133 | 163 |
| World | 42,993 | 128,822 | 300 | 42,757 | 108,544 | 254 |

Notes – assume base period is given by average of 2000 and 2005
Prices converted by US implicit price deflator
1990 value = 81.59
2006 value = 116.16 , so 2006 prices =1990 prices x 1.42

Obtained from United States Council of Economic Advisors. 2007. *Economic Report of the President: 2007 Spreadsheet Tables.* Table B–3. Quantity and Price Indexes for Gross Domestic Product, and Percent Changes, 1959–2006. Available at: <http://www.gpoaccess.gov/eop/2007/B3.xls>.