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General study and evaluation of potential impacts of climate change in Belgium

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# Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXECUTIVE SUMMARY</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>iv</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>ii</td>
</tr>
<tr>
<td>DOCUMENT INFORMATION</td>
<td>i</td>
</tr>
</tbody>
</table>

## 1 CLIMATE CHANGE

1.1 INTRODUCTION ................................................................. 1
1.2 CLIMATE CHANGE IN AN INTERNATIONAL CONTEXT .......... 2
1.3 REGIONAL CLIMATE UNCERTAINTIES .............................. 3
1.4 EVIDENCE OF CLIMATE CHANGE IN BELGIUM ................. 3

## 2 PRIMARY IMPACTS OF CLIMATE CHANGE

2.1 CLIMATE PROJECTIONS FOR BELGIUM ............................ 4
2.1.1 Temperature ................................................................. 4
2.1.2 Precipitation ................................................................. 7
2.1.3 Climate variability and extreme weather phenomena .... 8
  A. Rainfall and storms ...................................................... 8
  B. Heat waves and drought ............................................. 10
2.2 DIRECTLY LINKED EFFECTS ............................................. 10
  2.2.1 Sea level rise ......................................................... 10
  2.2.2 Flooding ................................................................. 11

## 3 SECONDARY IMPACTS OF CLIMATE CHANGE

3.1 INTRODUCTION ............................................................... 17
3.2 GENERAL DESCRIPTION OF SECONDARY IMPACTS ... .... 17
  3.2.1 Definition of secondary impacts ............................. 17
  3.2.2 Interconnections between secondary effects ............ 19
  3.2.3 Adaptive capacity and prevention ....................... 19
3.3 ECONOMIC ASPECTS ...................................................... 21
  3.3.1 The economy and linkages to climate change policy 21
  3.3.2 Human settlements ................................................ 23
  3.3.3 Industry ................................................................. 24
  3.3.4 Agriculture sector .................................................. 25
  3.3.5 Forestry sector ....................................................... 26
  3.3.6 Fisheries ............................................................... 26
  3.3.7 Energy sector ........................................................ 27
    A. Production ............................................................ 27
    B. Consumption ....................................................... 28
  3.3.8 Transport sector ..................................................... 29
  3.3.9 Tourism sector ...................................................... 30
  3.3.10 Financial sector .................................................... 31
    A. The banking sector ................................................. 31
    B. The insurance sector .......................................... 33
  3.3.11 Conclusions towards work package II .................... 34
### Table of contents

**3.4 ECOLOGICAL ASPECTS**

3.4.1 *Impact of climate change on natural ecosystems and associated services* 36

3.4.2 *Wetlands* 37

A. Impact on functionality of wetlands 37
B. Impact on wetlands biodiversity 37
C. Greenhouse gasses 38

3.4.3 *Lakes, streams and rivers* 39

A. Impact on functionality of lakes, streams and rivers 39
B. Impact on biodiversity of lakes, streams and rivers 39

3.4.4 *Estuaries* 39

A. Impact on the functionality of estuaries 39
B. Impact on biodiversity of estuaries 42

3.4.5 *Conclusions towards work package II* 43

**3.5 SOCIAL ASPECTS** 44

3.5.1 *Society and linkages to climate change* 44

3.5.2 *Unequal distribution of the effects: winners and losers* 46

3.5.3 *Less welfare, more poverty* 47

3.5.4 *More health risks* 48

A. Heat-related health effects 48
B. Allergies 49
C. Food-borne and water-borne diseases 49
D. Vector-borne diseases: TBE, Lyme disease and malaria 50
E. Extreme weather events 50
F. Climate change and the ozone layer 51

3.5.5 *More social distress* 51

3.5.6 *Changing risk perception and difficult policymaking* 51

3.5.7 *More international instability* 52

3.5.8 *Conclusions towards work package II* 53

**4 CONCLUSIONS** 55

**5 LITERATURE** 56
List of abbreviations

ACEA: European Automobile Manufacturers Association
CCI-HYDR: Climate change impact on hydrological extremes along rivers and urban drainage systems
CEEE: Centre for Economic and Social Studies on the Environment
COP: Conference of the Parties
CRT: Controlled Reduced Area
DEFRA: Department for Environment Food and Rural Affairs (UK)
ECOBE: Ecosystem Management Research Group
EEA: European Environment Agency
EM-DAT: Emergency Disasters Data Base
FCA: Flood Controlled Area
FOD: Federal Public Service (FPS)
GCMS: Global Circulation Models
GFDL: Geophysical Fluid Dynamics Laboratory (USA)
GHG: greenhouse gas
HACCH: Applied Hydrodynamics and Hydraulic Constructions
HIVA: Higher Institute for Labour Studies
IPCC: Intergovernmental Panel on Climate Change
IRGT-KINT: Royal Institute for the Sustainable Management of Natural Resources and the Promotion of Clean technology
JAMA: Japan Automobile Manufacturers Association
KAMA: Korean Automobile Manufacturers Association
KMNI: Koninklijk Nederlands Meteorologisch Instituut
MA: Millennium Ecosystem Assessment
MIRA: Milieuraapport Vlaanderen
MNP: Netherlands Environmental Assessment Agency
NCAR: National Center for Atmospheric Research (USA)
OECD: Organisation for Economic Co-operation and Development
RMI: Royal Meteorological Institute of Belgium
SRES: Special Report on Emissions Scenarios
TBE: Tick-Borne Encephalitis
UA: University of Antwerp
UCL: Université catholique de Louvain
ULB: Université Libre de Bruxelles
Ulg: University of Liège

WP1: General study and evaluation of potential impacts of climate change in Belgium
UN: United Nations
UNFCCC: United Nations Framework Convention on Climate Change
UNEP: United Nations Environment Programme
UV: ultraviolet
WHO: World Health Organization
List of figures

Figure 1: Evolution of the mean annual temperature in Uccle over the period 1833-2005 (source: RMI, 2006) ............................................................................................................ 5

Figure 2: Evolution of the average world temperature between 1000 and 2100 (source: IPCC, 2001).................................................................................................................. 6

Figure 3: Mean climate change over an area approximately equivalent to Belgium, for the period 1961-1990 to 2071-2100. Results are shown for two emissions scenarios (“○” : “short term politics” and “×” : “politics more oriented towards a sustainable development”), from five general circulation models (coloured symbols), and for a set of regional climate models (the error bars relate to uncertainty in regional change) (Commission Nationale Climat, 2006). .................................................................................................................. 8

Figure 4: Changes expected in 2070 compared to 2000, regarding annual averaged discharge of rivers in Europe for two different climate models (EEA, 2005) (source: Lehner et al., 2001). ............................................................................................................................ 12

Figure 5: Relative change in monthly values of surface flow, for eight Belgian catchments, under climatic change conditions: scenario “GFDL mixed (stationary)” (Gellens and Roulin, 1998). .................................................................................................................. 14

Figure 6: Relative change in monthly values of surface flow under climatic change conditions (Gellens and Roulin, 1998). ....................................................................................... 15

Figure 7: Number of flood days under baseline climate and under climatic change conditions. ................................................................................................................................. 16

Figure 8: The place of secondary impacts in the climate issue ........................................... 18

Figure 9: Numbers of natural disasters 1900-2005 (source: EM-DAT, 2006)............... 45
List of tables

**TABLE 1: SUMMARY OF THREATS AND OPPORTUNITIES FOR THE FINANCE INDUSTRY (INNOVEST STRATEGIC VALUE ADVISORS AND UNEP FINANCE INITIATIVE CLIMATE CHANGE WORKING GROUP, 2002)** .................................................................................................................... 32

**TABLE 2: SUMMARY OF THREATS AND OPPORTUNITIES FOR THE INSURANCE INDUSTRY (INNOVEST STRATEGIC VALUE ADVISORS AND UNEP FINANCE INITIATIVE CLIMATE CHANGE WORKING GROUP 2002)** ..................................................................................................................... 34
Executive summary

In order to get a proper understanding of the issue, we first describe what climate change is about and place it in an international context. As the impacts of climate change in Belgium are the focal point of this working paper, we try to shed some light on the key uncertainties and the evidence of climate change in Belgium. In a second part, we discuss the primary impacts of climate change in Belgium paying particular attention to the links with the impacts on human and natural systems. These are referred to in this paper as secondary impacts and will be discussed in chapter three. Before discussing the economical, ecological and social effects of climate change on Belgium, we first want to stress the particular strong interconnections between these impacts and the role of adaptation therein. In a last chapter, the appropriate spatial and temporal dimensions of the case study about floods will be discussed and determined.
1 CLIMATE CHANGE

1.1 INTRODUCTION

Weather and climate have a large influence on both natural and human systems. When we are confronted with weather conditions which differ much from what we expect, we wonder how exceptional these might be and whether we need to consider these in future. As climate has always been changing, humanity and nature constantly need to adapt to these changes.

Climate can be referred to as the “average weather” in terms of the mean and its variability over a certain period of time and a certain area. The climate system consists of five major components: the atmosphere, hydrosphere, cryosphere, land surface and the biosphere among which many complex physical, chemical and biological interactions occur. Any change, whether natural or anthropogenic, in this extremely complex system may produce climatic variations which can have major impacts on both natural and human systems.

Radiation of the sun drives the whole climate system. The earth’s surface reflects part of the heat, received from the sun, back to the atmosphere. For a stable climate, there needs to be a balance between the incoming and the outgoing radiation. This balance is influenced by the composition of the earth’s atmosphere. The so called “greenhouse gasses” trap the heat in the earth’s climate system as they absorb the radiation emitted by the earth’s surface and the clouds. This mechanism makes the earth’s climate has an average temperature of about +15°C instead of -18°C.

Human beings have always influenced their environment. Since the beginning of the Industrial Revolution, in the middle of the 18th century, the spatial scale of human impacts on their natural environment has become much vaster. Human life style has become above all more energy-intensive. This trend has let to the combustion of ever increasing quantities of fossil fuels, inevitably causing emissions of carbon dioxide, which adds to the greenhouse effect and thus to global warming. Besides, human activities also emit other greenhouse gasses like methane, ozone, nitrous oxide, halocarbons and hexafluoride and induce major land use change. The latter impacts on nature’s capacity to absorb carbon dioxide and thus influences the concentration of carbon dioxide in the atmosphere. The warming effect of greenhouse gases might however be partly cancelled out by the increase of aerosols in the atmosphere.

Warming during the 20th century is larger than any other time during the last 1000 years, having a large impact on certain societies and ecological systems. Anthropogenic

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1 (IPCC, 2001a)
contributions are strongly implicated in this change and are expected to contribute to further changes in climate during the 21st century and beyond. Therefore it is necessary to reduce the uncertainties about climate change and its impacts and to develop a wide range of response actions; ranging from controlling emissions, adapting to impacts and encouraging scientific, technological and socio-economic research (UNEP and UNFCCC, 2002).

1.2 CLIMATE CHANGE IN AN INTERNATIONAL CONTEXT

It is impossible to consider Belgian climate without taking a look at climate on the global level. Moreover, climate has to be studied in relation to the highly complex interactions of constantly evolving natural and human systems worldwide.

As a result of their persistence, emissions of greenhouse gasses spread all over the world and by consequence are every one’s problem. A global response, supported by the majority of the world population, is needed to prevent dangerous anthropogenic interference with the climate system. This view was recognised by the international community through the signature of the UN Framework Convention on Climate Change in 1992. The Convention entered into force in 1994. During the third session of the Conference of the Parties (COP), which is the supreme body of the Convention, the Kyoto protocol was adopted. The developed countries are to reduce their emissions of six key greenhouse gasses by at least 5%.

Besides, in order to establish a sound understanding of the mechanisms driving the earth’s climate and the impacts of the predicted change and to explore response strategies, the Intergovernmental Panel on Climate Change (IPCC) was founded in 1988 by the United Nations Environmental Programme and the World Meteorological Organisation. Today, this panel is the most influential body on climate issues as it groups thousands of specialists worldwide, cooperating to get a better understanding of the climate system and the influence of human-induced climate variations. The research of the IPCC is organised in three working groups. The first establishes the scientific base of climate change, the second focuses on the impacts, adaptation measures and vulnerability and the third maps policy measures in order to limit climate change.

The IPCC establishes projections of climate change based on different scenario’s regarding socio-economic development. These scenarios serve as an input for hypotheses about the emissions of greenhouse gasses. Various climate models subsequently use these hypotheses in order to obtain estimates about different parameters of the earth’s climate like average temperature, rainfall, sea level rise etc. (Marbaix and van Ypersele, 2004).

These projections of future climate change are used by the IPCC itself as well as by a broad range of researchers, policymakers and interest groups to assess impacts and develop adaptation and mitigation measures. The modelling of the impacts of climate change on flooding is obviously also done on the basis of these different projections, although these models need local climate projections to start from.
1.3 REGIONAL CLIMATE UNCERTAINTIES

There is an increasing demand by policymakers, the scientific community, and the public for realistic regional projections in order to assess the possible impacts of future climate change. The social interest of more accurate knowledge about regional trends and effects is obviously high. The quest for this knowledge, on the other hand, is not that evident as regional and local climate is generally much more variable than climate on a global scale (IPPC, 2001a).

The size of Belgium is too limited to enable irrefutable statements about Belgian Climate. Unlike, for example the KNMI in the Netherlands, we do not have a body making national predictions. Therefore, we need to broaden our focus first to the observations, evolutions and projections for Europe. Regional climate predictions are relatively difficult since small changes in spatial climate patterns can make a substantial difference on the regional scale. Moreover, year to year fluctuations in specific regions are generally more important than changes in the world average. On a larger scale, variations in one region are compensated, levelled out, by opposite variations elsewhere (Beersma, 2004; IPPC, 2001a).

1.4 EVIDENCE OF CLIMATE CHANGE IN BELGIUM

In order to show that climate change is happening and already influencing and determining life on earth we want to provide some evidence of climate change in Belgium.

Leysen and Herremans observed that in 2004 the arrival date of the 15 species of migratory birds in their study was on average nearly 8 days earlier than in 1985. The Chiffchaff even arrived even 20 days earlier (MIRA, 2005).

De Bruyn found that as a result of increasing temperatures several species of southern dragonflies very recently became much more frequent in Flanders (MIRA, 2005).


During the summer of 2003, an extreme drought and heat wave hit Europe with enormous adverse social, economic and environmental effects. In Belgium that heat wave would have caused between 1258 and 1297 lives, most victims being elderly people (UNEP, 2004; Sartor, 2004).
2 PRIMARY IMPACTS OF CLIMATE CHANGE

2.1 CLIMATE PROJECTIONS FOR BELGIUM

2.1.1 Temperature

During the 20th century the global average surface temperature has increased by about 0.6°C, the average for Europe being even higher with a calculated increase of 0.95°C. In Europe, the 1990’s has been the warmest decade in the instrumental record. In the northern hemisphere, warming during the past century was the highest of the last 1000 years (EEA, 2004; IPCC, 2001; Marbaix and van Ypersele, 2004).

As already mentioned, the last two decades in Belgium were marked by very high yearly average temperatures. This trend is clearly reflected in the figure below which indicates the evolution of the average temperature in Uccle since instrumental record. The statistical analysis of the temperature data distinguishes four periods. Between 1833 and 1909 the yearly average temperature was 8,8 °C. Between 1910 and 1942 and between 1943 and 1983 the yearly average temperature amounted to respectively 9,5°C and 9,7°C. From 1984 onwards, the yearly average is about 10.4 °C. The warming trend for Belgium is thus well established.
Based on different models and for different scenario’s, which serve as an input for impact studies, a global average temperature rise from 1,4 to 5,8 °C is calculated for the 1990-2100 period. A moderately optimistic scenario about the greenhouse gas emissions would lead for example to an increase of about 3 °C in average world temperature by 2100. It is very likely that surface air temperature will increase faster than the average. If the projected temperature increase during the 21st century will occur, this temperature increase will be without precedence during the last 10000 years (IPCC, 2001c; Marbaix and van Ypersele, 2004).
For what concerns the projections of climate change, no special calculations for Belgium exist. Nevertheless, it is possible to shed some light on the expected temperature increase in Belgium based on the IPCC data for Europe, the KNMI 2006 climate scenarios and the projections made within the framework of the PRUDENCE project.

The IPCC expects annual temperatures over Europe to warm at a rate between 0,1 and 0,4 C° per decade. This warming is greatest over southern Europe and northeast Europe and least along the Atlantic coastline of the continent (IPCC, 2001b).

The KNMI projections use 4 scenarios ranging from a moderate one to a scenario named “warm +”. In the moderate scenario, average Dutch winter and summer temperature will rise with 0,9 C° by 2050 compared to 1990. In the latter one, average summer and winter temperature increase respectively by 2,3 and 2,8 C° over the same period. Although one cannot simply use these data for Belgium or Flanders it does provide a quite good order of magnitude. The value of these projections for the area south of the river Meuse and Samber however is much less certain (KNMI, 2006).
In the framework of the CCI-HYDR project the Royal Meteorological Institute of Belgium and the K.U. Leuven Hydraulics Division are currently carrying out high resolution climate change projections for Belgium. Their simulations will be based on many regional climate models provided by the PRUDENCE project.

However, the predicted temperature increase for Europe will be weakened as the Gulf Stream, which transports heat from the tropics to higher latitudes, might slow or stop as a result of global warming. Especially in Northern and Western Europe this may lead to considerable cooling (Marbaix and van Ypersele, 2004).

2.1.2 Precipitation

Historical records in Europe demonstrate very different regional evolutions in annual precipitation. Indeed, between 1900 and 2000, precipitations have increased in the north of Europe by 10 to 40% while in the south of Europe they have decreased by 20% (EEA, 2005a).

Analysis of historical records in the Meuse basin over the last century show a slight increase in annual and seasonal average precipitation volumes (Wit et al., 2001). Nevertheless, data series used are considered as relatively short for precipitation, which are characterized by an important natural variability.

In Belgium, expected future evolutions of precipitation vary drastically between winter time and summer time.

Despite some differences between results from various studies, it can be concluded that projections for the evolution of winter precipitation during the 21st century show a moderate increase. The change has been quantified to be in-between 6 and 23% (Marbaix and van Ypersele, 2004). Another study (Beersma, 2004) mentions an increase of winter precipitation by 3-13% in 2050 (FLOODSITE, 2006), while other authors expect that precipitation will rise by 10% in winter (d'Ieteren et al., 2004).

On the contrary, precipitations in summer seem to decrease in Belgium but quantitative results diverge significantly: from status quo to a decrease by 50% (Marbaix and van Ypersele, 2004). A recent synthesis states that summer precipitation would decrease by maximum 3% or remain constant (d’Ieteren et al., 2004).

Such a possible decrease in precipitation combined to an increase in temperature would lead to losses of availability of water.

Those seasonal differences are clearly illustrated by Figure 3 (Commission Nationale Climat, 2006), which shows the expected relative changes in winter and summer precipitation (as well as temperature) between 1961-1990 and 2071-2100. Results are shown for two emissions scenarios, from five general circulation models and for a set of regional climate models (Commission Nationale Climat, 2006). It appears that precipitation in winter is likely to increase by 3 to 30% by the end of the 21st century, while summer precipitation change lies in-between “status quo” and a drop by 50%.
Figure 3: Mean climate change over an area approximately equivalent to Belgium, for the period 1961-1990 to 2071-2100. Results are shown for two emissions scenarios (“○”: “short term politics” and “×”: “politics more oriented towards a sustainable development”), from five general circulation models (coloured symbols), and for a set of regional climate models (the error bars relate to uncertainty in regional change) (Commission Nationale Climat, 2006).

Considerable uncertainties in prediction of precipitation changes are a consequence of both the limits of contemporary models and the important natural variability of precipitation, especially in summer (Marbaix and van Ypersele, 2004). In particular, the evolution of precipitation is likely to be affected by more uncertainty than other climate parameters, because precipitation has a higher natural variability (d'Ieteren et al., 2004).

More specifically, results from GCMs show that the Meuse basin will be affected by global warming in a similar way, i.e. through an increase in average winter precipitation and a decrease in average summer precipitation (Wit et al., 2001).

2.1.3 Climate variability and extreme weather phenomena

Given a certain climate, extreme events such as heat waves, droughts or storms have a proper probability distribution. Small changes in climate may, but will not necessarily, have a clear impact on the probable occurrence of extreme events and on their intensity. Social and natural systems are often particularly vulnerable for such changes. This is why one needs to pay ample attention to changes in the likeliness of extreme events (IPCC, 2001).

A. Rainfall and storms

Although the impact of global warming on the occurrence of extreme regional meteorological conditions, and as a result extreme hydrological conditions, remains uncertain (Wit et al., 2001), a tendency towards more frequent extreme events is considered as likely but is not yet quantified (IPCC, 2001b; EEA, 2005).

Since 1976, an increase in the number of very rainy days has already been observed in the north and centre of Europe (EEA, 2005), provoking thus a higher flood risk (EEA,
2005). Similarly, precipitation records show that extreme values increased between 1946 and 1999.

The same goes for projections at the global scale. Indeed, IPCC (IPCC, 2001b) considers more frequent heavy rainfall as “very probable” in the future (Marbaix and van Ypersele, 2004).

In many European regions, the future trend towards extreme rainfall is also expected to be more pronounced than the average change. Studies already revealed that in wet areas, the changes in the high intensity events are larger than expected on the basis of the changes in the average precipitation amounts, implying an amplified response of the wet extremes (Tank, 2004).

In Belgium, although the frequency of heavy rainfalls is expected to rise, additional studies will be needed to quantify this evolution, between insignificant and substantial (Commission Nationale Climat, 2006).

Statistical analysis of long observation records (1911-1912) for the Meuse basin showed that, although the annual number of wet days (>1mm/day) has only slightly increased from 1972 onwards, the associated precipitation amounts have significantly increased since 1980 (Tu et al., 2005a). Moreover, both annual and winter (November to April) very wet days (>10mm/day) in the basin have also considerably increased since 1980, roughly by 20% compared to the pre-1980 period, while the precipitation events in the summer half-year (May to October) have changed little (Tu et al., 2005a). Those results emphasize that the wet days in the Meuse basin have become wetter over the recent two decades.

According to Können (2001), in 2100, Flanders and Zeeland are expected to experience an increase of number and intensity of rain showers by 10 to 40% (FLOODSITE, 2006).

Storm frequency has increased in recent decades, but recorded storm intensities are no higher than they were early in the 20th century (IPCC, 2001b). Wave heights around the shores of northwest Europe also show large variability, but no long-term trend emerges (IPCC, 2001b).

Concerning storm projections, uncertainties remain particularly important. Nevertheless, a future increase in their intensity and/or frequency is regarded as probable (Marbaix and van Ypersele, 2004).

One scenario of climate change indicates that storm in Northwest Europe could increase by 1-9% (Dorland et al., 1999). Another study (Können, 2001) predicts an increase of number and intensity of storms (wind speed and wave height) by 2100 in Flanders and Zeeland (FLOODSITE, 2006).

A statistical model, based on recent storms in the Netherlands, shows that an increase of 2% in wind intensity by the year 2015 could lead to a 50% increase in storm damage to houses and business (Dorland et al., 1999). However the effect of climate change on the maximum gust speeds remains highly uncertain, although a 2% increase in the maximum gust speed (which greatly influences the damage) in 25 years is held conceivable (Dorland et al., 1999).

Nicholls has analysed the implications of sea-level rise and socio-economic scenarios on changes in flooding by storm surges (Nicholls, 2004). Scenarios are derived from the IPCC Special Report on Emissions Scenarios (SRES). The conclusions reveals that the
incidence of flooding would change, even without significant sea-level rise, due to growing exposed population; but these changes are strongly controlled by assumptions on protection measures (adaptation).

**B. Heat waves and drought**

The assessment reports of the IPCC recognise that the warmer mean temperatures increase the probability of extreme warm days. It is also indicated that standard deviation of temperature is likely to change. This means that increased temperature variance raises the probability of higher extreme temperatures as it adds to the already higher mean temperatures. The Third Assessment Report concludes that higher maximum temperatures and more hot days are likely to occur over all land areas (IPCC, 2001b).

If the observed temperature fluctuations between one year and another stay the same as during the 20th century, than it will be very likely that the higher mean temperature will increase the likeliness of extreme hot summers, marked by more serious heat waves. As some researches found that the yearly fluctuations in temperature might become even more pronounced, an increased occurrence of heat waves seems likely. However there is still much uncertainty about this issue (IPPC, 2001a; Marbaix and van Ypersele, 2004).

The impact of the higher summer temperatures and the possible increase in the occurrence of heat waves is partly a function of precipitation. Unless the projections of summer precipitation are subject to quite some uncertainties an increase is most unlikely. It is clear that the expected status quo or decrease in summer rainfall will add to the severity of future climate related impacts in summertime.

Besides substantial effects on human health, exceptionally hot and dry summers can have also devastating impacts on the natural environment and economic activity. Given the likely increase in the occurrence of heavy rainfalls the dry soils in summertime will be prone to intense rainfall events. Recreational activities at our latitude, on the other hand, might benefit from hot and dry summers.

### 2.2 DIRECTLY LINKED EFFECTS

#### 2.2.1 Sea level rise

Based on tide gauge data, global average sea level rose between 10 and 20 cm during the 20th century (IPCC, 2001). Tide gauge data for the Belgian coast indicate a relative sea level rise from 2 mm/year for high water, 1.5 mm/year for mean sea level and 1mm/year for low water over the past century (Van Cauwenberghe, 2000). The change in sea level is mainly induced by two mechanisms: on the one hand by changes in water temperature and on the other hand by the melting of ice caps and glaciers (den Ouden et al., 2004).

As water warms, its density decreases and thus water volume increases. As a result of global warming, the oceans are warming too. When heat is taken up more readily by the ocean surface and passed on to the ocean interior, climate change is retarded, but sea level rise will be more pronounced (IPPC, 2001).

It is calculated that when the ice caps on Greenland and Antarctica would melt completely this would raise the global sea level by 7 m and 60 m respectively. Although
this scenario will not occur in the near future, it does indicate that even small changes in
ice volume would have major impacts on sea level. The meltdown of glaciers, in the
worst case, can add about 0.5 m to global sea level rise. The current contribution of the
decline in glacier volume, as a result of climate change, on the global sea level rise is
still not exactly known as too little data exists. In Europe, on the other hand, all glaciers
decreased in volume during the last 150 years. It even seems that since a few decennia,
an increased meltdown of the European glaciers can be observed. For sea level rise as a
whole, there is no evidence of an accelerated trend yet. Ice will keep on contributing to
sea level rise for thousands of years after climate would have stabilized (den Ouden et
al., 2004; MIRA, 2005).

In the 21st century, temperature induced expansion of the oceans is expected to make
the largest contribution to sea level rise. Depending on the scenario, the predicted
global sea level rise between 1990 and 2100 ranges from 0.09 to 0.88 m. Although sea
level rise is very likely to continue in the future, regional realities can be quite diverse.
Sea level rise in Western Europe will not deviate much from the world average.
However, one needs to take into account that the Belgian surface will decline with
about 5 cm over the next century (Beersma, 2004; IPCC, 2001a; Marbaix and van
Ypersele, 2004).

Extreme high water levels will occur with increasing frequency as a result of sea level
rise. Their frequency may be further increased when extreme events, like storms, will
become more frequent or severe. A higher sea level increases therefore the probability
eo f erosion and inundations along the coast line. In Belgium, the sea breaking through
the coast line, induced by sea level rise, could bring about flooding up to 20 km inland,
potentially affecting 200000 people. Protection of the coast line, as a response to sea
level rise, however, will inevitably affect existing habitats too. Besides, sea level rise
might induce intrusion of salt water which can affect the quality and the quantity of fresh
water reserves, ecosystems and food production. As sea level rise influences tidal rivers,
these impacts also play inland. The increase in high water levels in the river Scheldt
caused by sea level rise is several times larger than sea level rise itself (IRGT-KINT,
2004; MIRA, 2005).

After the inundations of 1976 along the river Scheldt, induced by a violent northwest
storm in the North Sea, the authorities launched the Sigma plan in order to protect the
tidal part of river. The recent update of the plan took into account a sea level rise of 60
cm by the year 2100 (MIRA, 2006; Sigmaplan, 2006).

2.2.2 Flooding

River discharges and groundwater quantities are determined by many factors: climate,
land use, soil type, flow regulation. This complex system of numerous factors interacting
with each other will obviously be affected by the changes of temperature, precipitation
and evapotranspiration, resulting from climate change (IRGT-KINT, 2001).

Across much of Europe, flood hazard is considered as likely to increase, as shown by
Figure 4 (EEA, 2005a), with substantial rises in flood risk in coastal areas (IPCC, 2001b).

In particular, climate change will lead to increased winter floods in much of Europe.
Indeed, winter precipitation will more and more take the form of rainfall (due to higher
temperature) and will hence provoke rapid run-offs and a higher flood risk (EEA, 2005a).
Evaluations of climate change impact on European rivers have been presented during the research project RIBAMOD (Samuels, 1999), with different results. For example, increases in flood peaks of up to 10% were predicted for a basin in Italy, while changes of up to 20% are expected for two basins in Great Britain.

Those changes in flood frequency and intensity will provoke important life and financial losses all over Europe (EEA, 2005a). In particular, for Great Britain, studies stress that inundation risk would reach “unacceptable” levels, with serious socio-economical consequences (Marbaix and van Ypersele, 2004).

In Belgium, changes in mean river discharges are found to be either positive or negative, according to diverse climate change scenarios. The result depends on the balance between increased precipitation and higher evapotranspiration. This annual drainage change may be in-between 5% increase and 30% decrease (Commission Nationale Climat, 2002).

Regarding extreme events, the frequency of recorded floods in Belgium has already increased during the last decades. Major inundations took place in 1995, 1998, 2002, 2003 and 2005. Land use planning is obviously partly responsible for those floods, but variations in winter precipitation and increased frequency of heavy rainfalls will still amplify flood risk (Commission Nationale Climat, 2006).

Other recent studies (e.g. Tu et al., 2005a) report that flood peaks in the Meuse River and some of its tributaries have significantly increased since the end of the 1970s or the early 1980s, mainly as a consequence of causal precipitation.

Hence, future increases in groundwater levels and river discharges are expected to take place, especially in winter, as a result of the change in precipitation (Commission Nationale Climat, 2002; Marbaix and van Ypersele, 2004). Similarly, though it remains...
difficult to quantify the potential changes in flood frequency, more precipitation on a soil saturated with water in winter and spring is very likely to lead to a higher flood frequency (IRGT-KINT, 2001).

Although more studies are needed concerning the detailed effects of climate change on flood risk in Belgium, various analyses provide already an insight into the most probable evolutions.

Können (2001) states that in 2100, Flanders and Zeeland will experience “an increase in the river peak discharges” (FLOODSITE, 2006).

A specific study on the river Meuse upstream of Borgharen in Belgium and France predicts a small decrease of average discharge (~5%) but an increase in extreme discharge and variability (5-10%) (Booij, 2003).

The effect of climate change on the discharge regime of the Meuse has also been specifically studied by means of hydrological simulations performed on the Meuse basin in the framework of the Dutch National research Program on Global Air Pollution and Climate Change (Wit et al., 2001).

Monthly averaged time series have been used for climate parameters and no changes have been introduced in the time distribution of rainfall (though in reality this too is likely to be modified). Results are presented as monthly average discharge change values, which result from both precipitation and evapotranspiration changes. The latter are partly increases due to higher temperatures but also decreases in summer as a result of reductions in soil moisture content (caused by lower precipitation).

It has been concluded that climate change would lead to an increase in the average discharge at the end of winter and at the beginning of spring, while a decrease of the average discharge is expected in autumn. However, natural variability of the Meuse discharge is large and differences over long time intervals are rather small, so that it becomes hard to clearly quantify those long term changes.

The results reveal a damping effect. Indeed, changes in the discharge regime are found to be less pronounced than those in the precipitation regime. This lower sensitivity can be explained both by the increase in the evapotranspiration and by the natural storage capacity of the catchments.

Uncertainties are mainly attributable to the selection of the climate change scenario used to perform the simulation. Indeed, the difference in the predicted change of the average monthly discharge regime that results from using different hydrological models is smaller than the difference that results from using different climate change scenarios.

Recent studies show that the increase in the flood peaks in the Meuse River since the 1980s needs to be explained mainly by climate variability rather than by land-use changes (Ashagrie et al. 2006, Tu et al. 2005b). Nevertheless, de Wit et al. (2001) have show that, in terms of future discharge regime in smaller rivers such as Ourthe or Mehaigne, the impact of changes other than climate induced ones (e.g. changes in land use...) may be as important as impacts resulting from climate change. This suggests that relevant adaptation measures (land use changes, water management, flow regulation, ...) could reduce peak discharges.

For eight Belgian catchments, Gellens and Roulin (Gellens and Roulin 1998) have simulated impacts of climate change on surface flow as relative values of monthly
differences. Relative values enable to compare impacts on rivers with very different discharges but the effects are inevitably enhanced during low flow stages.

According to this study, regarding flood frequency, the Belgian catchments present an increase for most climate change scenarios. Besides, all Belgian catchments with prevailing surface flow are undergoing an increase in flood frequency during winter months.

As an example of results, Figure 5 illustrates the damping effect already mentioned above. Indeed, though the “GFDL mixed (stationary)” scenario is characterized by a high increase in temperature and a slight rise in summer precipitation, the simulated results show a small decrease in surface runoff due to the highest rise in effective evapotranspiration simulated.

![Figure 5: Relative change in monthly values of surface flow, for eight Belgian catchments, under climatic change conditions: scenario “GFDL mixed (stationary)” (Gellens and Roulin, 1998).](image)

The computed impacts (Gellens and Roulin, 1998) have been demonstrated to be strongly catchments dependent (Wit et al., 2001), because they depend not only on the selected climate change scenario but also on the properties of the catchment itself, as shown by Figure 4.

The Dijle catchment (Scheldt basin) is characterized by a low runoff coefficient (< 20%) whereas in the Berwinne catchment (Meuse basin) and in the Zwalm catchment (Scheldt basin) surface runoff ranges from 40 to 60%. In the Dijle catchment, a high increase in spring precipitation (simulated by “NCAR scenario”) and a high decrease in summer precipitation (simulated by “Hadley scenario”) result in small changes of the surface flow, as can be read on Figure 6. On the contrary, the same two changes in precipitation result in much greater responses in the Berwinne and the Zwalm catchments (+ and – 30%).
Hence, catchments which are characterized by a dominance of fast runoff component, are more vulnerable with respect to both floods and low flows. Those catchments are located in the regions of rocks (eastern upper part of Chiers and Semois) and in the Ardennes massif (upper Ourthe, Lesse Vesdre and Amblève) (Wit et al., 2001).

The increase in flood frequencies during winter months for the catchments where surface flow prevails is the only common response to the different scenarios investigated by Gellens and Roulin (Gellens and Roulin, 1998). As a conclusion, the effect of climate change on river discharges must necessarily be studied for each catchment specifically (IRGT-KINT, 2001).

In terms of number of flood days, different rivers also show a very different sensitivity, as can be seen on Figure 7. For baseline conditions, on the catchments Ourthe and Semois almost no flood occurs from May to September, while the Herk and the Dijle catchments present a flatter monthly distribution. Taking into consideration the effect of climate change, the numbers of flood days of Ourthe and Semois present a much lower sensitivity to climate change, whereas the Herk and the Dijle catchments present a higher one (Gellens and Roulin, 1998).
Analysis of impacts on discharge of a large number of rivers confirms the main distinction between the catchments with high infiltration rates, where the impacts are damped by the large groundwater capacities, and the catchments with prevailing surface runoff which are more sensitive to the climate changes (Gellens and Roulin, 1998).
3 SECONDARY IMPACTS OF CLIMATE CHANGE

3.1 INTRODUCTION

Climate change will have diverse impacts - some positive, most negative. In this chapter we will first define what we call secondary impacts. Three broad categories of secondary impacts are identified: economic, ecological and social effect. Before we focus on each of these secondary impacts of climate change in Belgium their interconnections and the role of adaptive capacity therein will be discussed.

3.2 GENERAL DESCRIPTION OF SECONDARY IMPACTS

3.2.1 Definition of secondary impacts

Secondary impacts as defined in the proposal are those derived from primary impacts as documented in the previous chapter. Most literature sources, however, talk about “impacts on natural and human systems”.

WP1: General study and evaluation of potential impacts of climate change in Belgium
- 17 -
The scheme below provides an overview of the climate change issue and indicates the place of secondary impacts therein. Three broad categories of impacts can be distinguished: impacts on the economic system, ecosystem and the social system. The chosen division between, economic, ecological and social effects is, as any division, a human attempt to classify a complex system. These categories are highly interconnected and thus mutually influencing.

Figure 8: The place of secondary impacts in the climate issue
3.2.2 Interconnections between secondary effects

We have various reasons for treating the economic, ecological and social impacts of climate change separately. First, we took this subdivision in order to align this chapter as much as possible to the subdivision in following working papers. Secondly, as it is our aim to provide a clear picture of the impacts of climate change in Belgium. We believe that, given the limited scope of this study, this division is the best way to orderly cover all relevant aspects.

The prediction of the possible impacts of climate change on human and natural systems is even more complex than predicting climate change itself. Apart from physical phenomena a lot of socio-economic factors and human decisions enter into the game. Moreover, the impacts of climate change are very often multidimensional and mutually intensifying. This only adds to the complexity and importance of addressing the issue in a systematic and holistic way (MIRA, 2005).

The analysis of climate change impacts by the second working group of the IPCC for example does not explicitly make the division between economic, ecological and social impacts. The contribution of the second working group studies impacts across a range of systems and sectors, but also tries to address a number of issues which cut across the various sectors and systems. Where many other studies choose to focus on several human systems which are prone to climate change such as agriculture and food safety, coastal zones, fisheries, industry, health, public services, human settlements, biodiversity etc. (which are only fractions of the full story) we want to hand the building blocks for an integral analysis. The challenge is to cover insights in the economic, ecologic and social dimensions of climate change in order to value each dimension as a part of a highly complex picture.

3.2.3 Adaptive capacity and prevention

Adaptive capacity, as defined in the Third Assessment Report of the IPCC, is the potential or ability of a system, a region or community to adapt to or sustain the adverse effects or impacts of climate change. It deals with the opportunities for and barriers to adaptation. Adaptation is the adjustment, both natural and human-induced, in economic, ecological and social systems in response to the actual or expected climatic change and its impacts. Discussing adaptation and adaptive capacity is important when studying the impacts on natural and human systems. It sheds a slightly different light on the secondary impacts considered below and therefore needs to be discussed here. This is also an important issue in the light of the questions which will be treated in the following working packages. On the one hand, it relates directly to the assessment of impacts and vulnerabilities and on the other hand, it is implied in the development and evaluation of response options.

Figure 8 situates also the place and role of adaptive capacity and adaptation in the climate change issue. As indicated, the level of the secondary impacts is function of the adaptive capacity of a system or community, its sensitivity and its degree of exposure. No matter the nature of the impacts, whether they are rather economic, ecologic or social it is all function of a systems vulnerability to the primary impacts of climate change and its direct linked effects.

2 (IPPC, 2001b)
Along with mitigation which tries to influence human activities in order to limit the emissions of greenhouse gasses and ultimately climate change, adaptation constitutes an important response option. Mitigation and adaptation are complementary response strategies to concerns about climate change. However the dynamics of adaptation in human systems are little studied one can distinguish autonomous and planned adaptation. Autonomous adaptation takes place without the deliberate intervention of a public agency. Planned adaptation acts upon the vulnerabilities and thus the impacts and can be either reactive or anticipatory. Besides, it may also influence the socio-economic development paths underlying human activities.

The potential danger of climate change, in terms of impacts and effects, depends on the change itself and the capacity of the society exposed to adapt to it. Planned, anticipatory adaptation holds the potential to significantly reduce vulnerability and even to realise opportunities. Therefore the recognition and examination of the impacts, whether natural, economical or social, is very important in order to limit the severity of and costs related the effects of climate change.

The assessment of the vulnerability to and the impacts of climate change need to take into account the predictions and estimates of likely future adaptations. The degree to which future climate change risk is dangerous depends greatly on the likelihood and effectiveness of adaptations in that system. As a result, assessment studies that neglect adaptation are likely to overestimate the net impacts and vulnerabilities. Knowledge about adaptation is therefore necessary to make informed judgements on the vulnerability of sectors, regions or communities.

Adaptation to climate change is not limited to change in average conditions, but also to change in variability. Most systems, sectors, regions and communities are able to adapt to changes in average conditions, especially if they are gradual. However, they are particularly vulnerable to changes in the occurrence and the intensity of extreme events. Enhancement of the capacity of systems to adapt to the impacts of climate change therefore can be a wise and cost-efficient strategy to cope with the actual change and uncertainties in climate.

The propensity and ability of a system to adapt depend largely on its characteristics. A system’s adaptive capacity can be described in terms of its economic resources, technology, information and skills, infrastructure, institutions and wealth. These determinants vary widely between regions, groups, as well as over time. This is why responses to climate change are not universally or equally available.

Unlike developing countries, which are in general very vulnerable to climate change, a country like Belgium with well-developed social institutions supported by higher levels of capital and a vast pool of high educated people tend to have greater adaptive capacity. In Belgium however, certain regions, social groups and natural ecosystems are more vulnerable to climate change as their adaptive capacity is constrained. In the light of sustainable development, these issues should therefore get special attention. Besides, present uncertainties with regard to the magnitude of the impacts and gaps in knowledge about the underlying causes of vulnerability often will hinder adaptation. Accordingly, further research about the evaluation of the feasibility, costs and benefits of potential adaptation options and capacity is still needed (EEA, 2005).
3.3 ECONOMIC ASPECTS

This part is composed of the description of the potential impacts of climate change in Belgium throughout the climate change policy and a wide range of economic sectors:

- The services sector was studied after the analysis of tourism, energy, transport and financial services, … .
- The production sector was examined by way of the study of agriculture, fisheries, the automobile industry and to a lesser extent the building industry, … .

Certain impacts could not be analyzed for Belgium owing to their strong integration/dependence on a more global scale as was the case for the financial services. Elsewhere, it is important to specify that the economic and social impacts generated by climate change are strongly are linked.

3.3.1 The economy and linkages to climate change policy

Governments have deployed measures which aim at reducing the effects of climate change as well as tackling them both at a national and an international level. These decisions obviously have economic consequences for each individual but also for all of the industrial companies together. The ensuing effects could either be felt positively or negatively.

Three types of measures allow for a reduction in greenhouse gas effects (Guesnerie R., 2003):

- Improved technologies with a view to restricting gas emissions;
- Technology transfer, i.e. replacing the technologies that pollute the most with those which pollute the least (for example, using renewable energies more frequently, changing from coal to gas, thereby allowing for a reduction in carbon emissions);
- Incentive, via the price system, towards the consumption of a product whose manufacture is less polluting.

Overview of some political measures

The Kyoto protocol was signed in 1997 on the reduction of the emissions of six greenhouse gases (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, perfluorinated hydrocarbons and hydrofluorocarbon) for the period 2008-2012, taking the level of the emissions in 1990. This agreement was ratified by 156 countries and came into force on 16 February 2005. It is to be remembered that the United States withdrew from this process in 2001, owing to fears of a decrease in their economical growth and to probable difficulties in reaching their goals without calling their lifestyle into question. For this agreement, each country remains its own boss in the choice of the means that will allow them to
reach their goal in reduction by implementing policies and economic measures and/or by the purchase of emissions permits on the international market.

A European market of CO₂ quotas was developed at a European level. The first phase covers the period 2005/2007, and a second phase is planned for the period 2008/2012. This market deals with emissions from more than 11 000 installations from six industrial sectors (more than 40% of the European GHG emissions). The units involved in this market must respect a certain quota on a yearly basis. Where quotas are exceeded, the units must buy quotas from other units who have succeeded in reducing their emissions below the threshold of the compulsory quotas. These quotas were set up in each country via the national plans of quota allocation for the period 2005/2007 and on the basis of the European directive relating to the quotas. In 2008, the European system of quotas will have to be integrated in the international system.

At the Belgian level, the different levels of power (Federal and Regions) intervene according to their competence in setting up political measures to reduce the emissions, with regard to their priorities. These different policies are coordinated by various organs of which the national Climate Commission is the most important.

The question of the cost analysis of policies on climatic change poses a number of complex problems. In fact, many models have been elaborated but none has the capacities for representing the totality of the problem at the same time as giving well-defined analyses on the main activities and technologies, which are sources of atmospheric pollutants. Because of this, models generally have very varied approaches. “Bottom-up” models define the energy system and its technological options, but do not integrate the system to the macro-economic level. “Top-down” models study the macro-economic sphere, but do not allow technological options to be defined. There have also been hybrid models. Currently, it is still difficult to be able to estimate the economic impacts of the climate change for fine spatial scales (Criqui et al., 2003).

The ex post facto analysis of the European market of CO₂ quotas shows certain differences compared to the forecasts established by the experts. The price of the CO₂ ton has, in fact, fluctuated widely. It has therefore passed from € 8,5 in January 2005 to nearly € 30 at the beginning of the month of July 2005, to be stabilised then around € 22 during the second part of the year 2005; it then increased to around € 30 up until April 2006, before falling to around € 13 in May 2006. Various factors can explain the variations in price, such as political factors, meteorological factors, and the price of fossil fuel (Choquette et al., 2006).

On the level of the relation between the impact of the European market of CO₂ quotas and the economical competitiveness of businesses, the analyses of several teams tend to show certain stability in profits for businesses, except for sectors at risk, such as aluminium (Maréchal, 2004). The impact would therefore be nothing globally, but it is important to specify that internal fluctuations are probably foreseeable. In addition, positive spin-offs can arise in certain sectors, as a result of the decrease in emissions in another sector and this because of their technological nesting (dependence). Nevertheless in a globalised market, it is important to follow the impacts of the directive
on the CO₂ quotas and to examine the dangers represented by the countries who do not dispose of any constraint on carbon.

As for the economical assessment of damage in monetary terms, it is very difficult to give statistics this for the different sectors and also on the Belgian scale. Nevertheless at world level, recent studies have presented the macro-economic weight that would result from man’s inactivity in the face of the threat to the climate (Ackerman and Stanton, 2006; Stern³, 2006). According to these studies, the risks incurred as a result of non-commitment could cost humanity very dearly. According to the STERN report⁴, the world GDP could decline somewhere within a range of 5% to 20%, until the end of the century. According to another report (Ackerman and Stanton, 2006), entitled "Climate Change - The Costs of Inaction" by Tufts University, which uses an estimation from the German Institute for Economic Research (DIW), the cost of annual economic damages could reach 20 000 billion USD by the year 2100 (USD according to the rate for the year 2002), or 6 to 8% of the production world-wide for this period. In another part of this same estimation, the adoption of policies to tackle these changes would allow for the increase in temperature to be limited to 2°C and would mean a reduction of more than half the damages. Another estimation presented by the PAGE model, and included in this report, indicates that by the year 2200 the cumulative cost of the damages could reach 74 000 billion USD (USD according to the rate for the year 2000).

3.3.2 Human settlements

Since the beginning of time, the reason men have settled in a place comes from the facilities found in this place that are basic to their needs and enjoyment. Today, the relocation of populations and activities towards the interface « land-sea » has greatly increased since the industrial revolution, and has caused a reorganisation of land boundaries on a global level. Coastal zones are now at the heart of geopolitical and geoeconomic structures, linked to them by powerful exchange fluxes. Moreover, since the First World War, sea exchanges have developed together with a powerful technological revolution: the specialisation in ships and increase in cargo capacity. Jointly, industrialisation has grown up quite markedly along the banks of river mouths. In fact, there are two advantages in these: depths linked to the river’s outflow channels and with vast expanses of marshland and of mud flats. These regions of land which were of such little interest in the past have taken on new importance. The petrochemical industry, iron and steel industry and metallurgy processing have thus been set up in these zones. The concentration of people and goods which are found in the heart cities and in the most exposed areas, have since then become places of tremendous vulnerability in the face of climate hazards such as flooding, the rise in sea level, … .

³ Stern Review on the economics of climate change (see, http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm)
⁴ The publication of this review generated many comments, among which were those of Richard Tol (Tol, 2006), one of the most renowned experts on the economics of climate change. He expressed quite a lot of reserve on the conclusions of the Stern review. Several methodological points are highlighted by Tol:
• very selective choice of the studies on climate change which gives more weight to the more pessimistic ones
• use of a discount rate which is lower than the official recommendations by HM treasury
• misinterpretation of certain results
• no true cost-benefits analysis has been carried out
The category of human settlements unites many sectors of activities whose reaction to the effects of climate change are to be felt in different ways. According to the experts of the IPCC, human settlements can be solicited by the climate in three ways (IPCC, 2001):

- By modification of the production capacity of the economic sectors which sustain the human settlement or of the demand for local goods and services. The type of settlement is obviously an important factor in determining this occurrence.
- By direct impacts on certain physical infrastructures (distribution and transport networks), on apartment blocks, on urban services and on certain economic sectors such as tourism and construction.
- By direct impacts on the population (migration, health).

The modifications in climate run the risk of bringing in numerous modifications of a greater and more varied size at the level of human settlements, caused in part by their marked tendency to overlap. And so, it is possible to bring to light certain impacts of the global warming effect such as the temporary modification in the demand for energy (see 3.2.7), the increasing demand for water, the possible loss of productivity and the change in tourist demand (see 3.2.9). Elsewhere, following the example of ecosystems, human infrastructures (transport, production,...) will equally be affected by the direct impacts of climate change. The human settlements situated in a vulnerable area would thus be able to see the impacts increasing (flooded area) as a consequence of the increase in risks linked to extreme events,... These modifications are obviously felt in different ways on the level of each society. Elsewhere, the possibilities of response to these modifications will depend on each case and on the extent of each modification, within the limits of technical, economic, social and environmental constraints.

Globally, the various levels of authority integrate certain measures which aim at reducing the impacts of extreme events like flooding. These problems are integrated in many documents of spatial planning (Ruimtelijk Structuurplan Vlanderen, Decreet betreffende het integraal waterbeleid, Sigma Plan, Watertoets, Plans PLUIES, SDER, CWATUP, PRD,...). As we have already seen elsewhere, measures have also been taken to reduce GHG emissions. And in the same way, in the field of construction and restoration of public or private buildings, incentive measures have been set up to meet this objective by taking direct action on energy consumption. This kind of initiative is reflected in the many incentive subsidies offered to encourage the wise use of energy in the three regions of the country.

### 3.3.3 Industry

Climate change can affect industry in several ways. The main impacts (linked to climate change) are the demands for water and energy which will greatly increase during heat wave periods. The cost of the rise in demand will obviously increase too. Elsewhere, such extreme events will also have an impact on the production and the distribution of goods and products. And so, adverse weather conditions may bring about a failure in the supply of raw materials. In the same way, the transport of commuters to their place of work will also be hit by the weather (see 3.3.8 for more details about transport).
Disruptions to the production chain will be highly probably from then on, and they will obviously be felt at the sales level as well. In the same view, the distribution of products and their retail sale will also be disrupted by climate conditions. These disruptions could even generate changes in consumer behaviour (Baron, 2006). The resolution of the problem of relocation and economical losses potential is therefore a necessary condition towards the adoption of more ambitious objectives in the future.

3.3.4 Agriculture sector

The agricultural sector is one of the main economic sectors which will be influenced worldwide by climate change. In a general way, it has to be said that on account of global warming, agricultural returns should decrease. Obviously these modifications in climate should bring with them as many beneficial effects for certain crops as negative ones (DEFRA, 2004). Nevertheless, the benefits and costs that arise will not be homogenous, but will vary greatly according to region, crops, agricultural practices and the other activities (cattle breeding, horticulture, fruit farming). Generally speaking, the availability of water will represent one of the essential points of this sector with regard to future climate change.

The notable effect of global warming in our regions for about twenty years has allowed us to pick out eventual impacts linked to these new conditions. And so, the main recordings possibly attributable to this phenomenon are: a modification in the crops calendar by 10 to 20 days (Hanson, 2004); the significant advance in stages of development with regard to fruit trees (for example, the flowering season) (Seguin, 2005). Elsewhere, global warming also ought to have differing positive effects. And so simulations have shown slight increases in yield from models of corn and wheat crops. Cattle breeding should gain from a lengthening of the grazing period or from an increase in the number of animals in a defined space (Seguin, 2005). It is worth noting that in the case of major differences in climatic factors (extreme occurrences) the impacts will certainly be different. Looking more globally, if climate change is not too great, production systems and growing habits seem to be able to survive this rise in temperature.

With regard to the general yield from our temperate crops, the impacts seem to be under control, in as far as the rise in temperature does not exceed 2 to 3°C. Higher changes in temperature would provoke relocation of crop zones and modifications in the landscape itself. With this, and as for many other sectors, the stakes involved in using water resources would become greater. The dry periods that we have known in July of this year (2006) show how much water is important and how the lack of it can be a limiting factor for crops. As we have already seen during the dry period of the summer of 2003, the European agricultural sector was hit hard by the drought. By comparison with cereal harvests of the previous year, a loss of 23 Mt was recorded. For the year 2006, the European Commission published the results of their forecasts for crop yields. The conclusions from these analyses indicate that the extreme temperatures experienced in European countries have had tangible effects on yield. Compared to the forecasts for 2005, the main crops affected are: soft wheat (-4%), winter barley (-2%), grain-maize (-5,1%), potatoes (-4,3%) and sugar beet (-3%). In total, cereal production should be much less - around 9 million tons (-3,6%) - than what it was in 2005, which was considered to be a year of lesser yield. In the same way, the permanent grazing areas (pasture and grass), green crops used for fodder and green maize were also affected by
The ADAPT Project report
Climate change – Secondary impacts
Contract n°: SD/CP/O2A
Economics aspects

WP1: General study and evaluation of potential impacts of climate change in Belgium

- 26 -

the dry spell (European Commission, 2006\(^a\)). The European Commission’s forecasts for Belgium indicate that the crop yield for corn, barley and maize ought not to be identical to the average for the years from 2001 to 2005 (European Commission, 2006\(^b\)). On the other hand, potato crops should be affected much more severely by dry periods.

In conclusion, with reference to history, a slight modification in temperature (around 2-3°C) should not have interfere too much with crop yields, and should allow for them to adapt just as they did in the last century (Rounsevell et al., 2004; Seguin, 2005). If climate conditions became harsher, new choices would have to be made concerning these crops, taking into account the need to consider how water resources are laid out, in an integral way (irrigation being the most efficient method). Furthermore, this sector of activity must also follow the evolution of weeds, parasites and cryptogamic diseases, in the face of climate change. Crop yields could in fact be influenced by these factors in new ways (cycle, displacement / relocation, …).

3.3.5 Forestry sector

As a result of global warming, the different species present within the forest ecosystem will be affected in various ways. Conifers will gain to a lesser extent from the fertilizing effect of CO\(_2\) and from global warming compared to the deciduous species (Marbaix, 2006). With the exception of the beech, deciduous trees will profit from the lengthening of the growing season and the closing of their stomata, which will reduce their transpiration and weaken the effects of drought.

At the level of phytogeographical distribution, the eventual trends generated by climate change are known. The most sensitive species are those least able to stand up to drought conditions. The species found at the southern limit of their distribution area are likely to be the most vulnerable. Landfalls can therefore be foreseen, in particular for the beech, the Norway pine or the spruce. According to simulations carried out in France, systems of intensive wood foresting and sites whose soil is very rich and highly productive are more sensitive to change (Loustau and Dupouey, 2005).

As for pathogenic factors in silvicultural systems, these should benefit from global warming, since parasitic species are usually limited by winter temperatures. Consequently, an epidemic risk might be foreseen after future global warming. Therefore there could be a rise in parasitic insects of certain population. Moreover, certain parasites could also affect species which have not been in contact with them before. All the same, the number of cases of diseases linked to water-related stress in the mother plant (cortical necrosis of the roots) should increase. In the case of global warming, parasites which depend on a more important water diet would be in regression, in contrast with other types.

3.3.6 Fisheries

It is difficult to foresee the consequences of climate change on the fishing industry in Belgium and Europe because of the number of influencing factors attached (rising temperature, physico-chemical evolution of the environment, …). These changes will obviously lead to modifications on the food chains (phytoplanktons, zooplankton, fish, …). Besides this, the overfishing seems to be the most critical factor in sustainable development in our regions (IPCC, 2001\(^b\)). Nevertheless, according to climate change,
certain trends can be identified as has been shown in a recent study on the evolution of fishing along our coasts (Gabriëls et al., 2005). The populations of fish currently trawled will undergo modifications in their geographic distribution due to changes in the ambient conditions. More southern species have appeared in the North Sea over the last few years, such as sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*), the meagre (*Argyrosomus regius*) and triggerfish (*Balistes carolinensis*). This study also points out that coastal fishing and particularly gray shrimp fishing (*Crangon crangon*), will incur problems in the near future following the slow warming of the North Sea. The moving of the geographic distribution of this species can already be seen towards the northeast. Consequently, new alternatives will be envisaged. Sea fishing fleets, composed mainly of trawlers intend for the fishing of demersal species such as sole (*Solea solea*), plaice (*Pleuronectes platessa*) and cod, will also suffer from the consequences of climate change. In fact, climate change has implications on the distribution of the demersal species and on their population dynamics. The recruitment\(^5\) of cod, saithe (*Pollachius virens*), plaice and sole will no doubt be more affected by these phenomena.

In a global way, climate change represents a new factor of pressure on the marine environment and who pronounced the impacts of the overfishing and the pollution.

### 3.3.7 Energy sector

The study of the energy sector can be analysed from a consumption aspect, but also from a production one. In fact, these two aspects are very likely to encounter certain modifications and adaptations as a result of climate changes over the years ahead.

**A. Production**

As in numerous other countries, Belgian energy producers make great use of water as a cooling agent in the technical production process (nuclear and thermal power plants). This use gives rise to the emission of water at a temperature higher than that of water drawn in the natural environment. These two processes of drawing water and disposing of it can only be done under certain constraints. In the Walloon Region, two limitations can be distinguished:

- The disposal temperature cannot exceed a maximum temperature of 28°C as it comes out of the power plant;
- The difference in temperature between the waters drawn for use and the waters to be disposed of cannot exceed 3°C.

In view of these limitations, a temperature higher than 25°C for surface water can become a problem within the context of energy production. Elsewhere, it is worth noting that the use of warmer water in the cooling circuit can also cause losses in production at the level of the turbines, their efficiency being reduced due to a rise in temperature (Electrabel, pers. com., 2006).

\(^5\) *Usually refers to the addition of new individuals to the fished component of stock. It may also refer to new additions to sub-components, e.g., ‘recruitment to the fishery’ refers to fish entering the actual fishery, and this is determined by the size and age at which they are first caught’ (source: [http://www.fishbase.org/](http://www.fishbase.org/)).*
Owing to high temperatures on the water surface, energy production must be restricted, because of the legal constraints on the use of water as a cooling agent. In order to avoid a discharge of water above the accepted levels, the producers may reduce their load capacity. Unfortunately, certain situations mean going beyond the accepted levels. In the Walloon Region, the producers are allowed to exceed the upper limit for a total of 7 days (accumulated throughout the year). After this, they must make a request for an exceptional case. This kind of situation has already been encountered in Belgium and in other European countries (Guyotat, 2003, Hopquin, 2003). During the summer of 2003, the German nuclear facilities situated on the Rhine and the Neckar had to decrease their production by 20% during the month of August for several days. The water had in fact reached temperatures in excess of 26°C (Hanson, 2004). After this kind of problem, the request was made for an exceptional case, in order to be able to draw water for cooling purposes and also restore it at temperatures higher than the norms in force, and this so as to avoid any break in the demand for energy. During this summer, 2006, the facilities in Walloon\(^6\) also suffered from the rise in water temperature, and the discharge norms were even exceeded for four days (Electrabel, pers. com., 2006).

In view of these remarks, and in case of global warming at water surface level, many questions of a technological, ecological and economic order are being asked.

Another technical problem could also affect the distribution of electricity resulting from the rise in temperature during the hottest months. In fact, high voltage cables have a temperature limit which should not be exceeded (around 85°C). When temperatures are very high, it may be necessary to reduce the current in the cables, so as not to go beyond this technical threshold. It is worth noting that this kind of event has already happened during the hottest periods, when a small part of the network requires servicing and thus causes an increase in current through the cables out with this section in order to maintain a consistent and even supply throughout the whole network (Electrabel, pers. com., 2006). The risk of overheating was reduced through lowering the current passing through these cables. In the years ahead, this phenomenon could therefore see a rise in the frequency of its occurrence during periods of very hot weather and high consumption.

B. Consumption

Climate change, and more particularly global warming which will probably come as a result of it, will bring about an antagonistic effect on energy consumption, it being sensitive to modifications in temperature (Marbaix, 2006). What with the colder seasons becoming milder and the calorific requirements in housing and buildings of all kinds (offices, schools,...) becoming less, energy consumption should be lower. At the other end of the scale, with the summer periods being subject to heat-waves, this will give rise to high increases in consumption, due to the need to keep cool (air conditioning system, fridges, ...). At the present time, it is difficult to be able to assess the impact of these two modifications

\(^6\) Also in Flanders (see: http://www.vrtnieuws.net/nieuwsnet_master/versie2/nieuws/details/060717doel/index.shtml)
3.3.8 Transport sector

An analysis of the transport sector shows that it is possible to pick out two types of consequences linked to climate change. The first one, labelled “direct” impact, is a result of meteorological conditions at the time of using transport itself. The second, identified as an “indirect” impact, is linked to the politics involved in the struggle against climate change.

With transport, it could be affected by climate change and its associated conditions (heat wave, weather stress,...). Furthermore, these modifications would affect the whole range of means of transport, all of this at different degrees, following the damage done to the infrastructures and because of poor transport conditions. Besides this, with regard to road traffic, the traffic conditions could be even more precarious in the direction of key destinations such as the sea or the Ardennes during sunny periods.

During heat waves, these disturbances would also be observed in rail and air traffic. As well as this, the transportation of goods by waterways could equally be affected to a lesser extent (Netherlands Environmental Assessment Agency, 2005). On the other hand, with winter conditions becoming more clement, disturbances associated with these conditions should be less important. The possible economic consequences of these impacts are still to be examined.

As for road traffic, the road networks most sensitive to inclement weather (tunnels, in the case of flooding) will bring about serious traffic problems such as was the case notably on the occasion of the flooding in Woluwe-Saint-Lambert in July and August of this year. The problem of flooding has already occurred on several occasions. For example, the tunnels located along the Meuse in Liege are often closed to traffic because of flooding after heavy rainfall.

Another difficulty can occur during the summer months: the high temperatures may damage the road surface (melting asphalt) and thereby cause traffic problems. A research study (Stern and Zechavi in London Climate Change Partnership, 2002) on a road affected by high temperatures shows that the hot climate conditions increased the risk of accidents.

The new climate conditions could be responsible in the future for more important disruptions in the public transport system than currently, such as the underground. In the case of heavy flooding or flash flooding, the underground system could be disrupted. This kind of event already took place in Brussels this summer during flash flooding. On July 28 2006, the underground traffic was interrupted at Roodebeek station because the lines were under water. The same phenomenon occurred again in the month of September of the same year. Similar occurrences could arise more frequently in the future, such as the rise of temperature in the underground stations. In the summer, during heat waves, the comfort of underground passengers will also be affected by the high level of the temperature in the stations.

As a result of climate change, the estimated increase in transport costs via waterways is limited to 2 to 4%, in Netherlands (Netherlands Environmental Assessment Agency, 2005). In the case of extreme conditions, such as those encountered in 2003, where the water level in waterways diminished remarkably, a considerable rise in transport costs was envisaged. Furthermore, given the combination of a weak rate of flow and a level of water that is not very high, the risks of complications for this means of transport are very...
probable. Along the inland waterways, it appears that the dry periods can disrupt river traffic. In the Walloon region, some restrictions were recorded along the stretch of water between Monceau and Liege (MET, pers. com., 2006). In Monceau's case, the only disruptions were a limit to the number of lockages and the grouping together of ships so as to maintain the waterline level upstream of the Monceau dam. In Liege's case, due to a reduced rate of flow, the stretch of water could have fallen below the water line in spite of the application of measures to restrict this. In 2003 and 2005, the draught of water allowed in the stretch at Liege (Ivoz-Ramet-Genk) had to be reduced, which brought about certain repercussions in the cost of transport.

As for the transport industry, and more particularly the manufacturers of road vehicles, indirect impacts will equally be felt. In fact, this sector of activity must take into account rulings which have settled with a view to diminishing greenhouse gas emissions. This is why the European Commission has decided to reduce the CO$_2$ emissions from new vehicles to 120g/km, by the year 2010 at the latest.

The problems associated with climate change are relatively new ideas for the automobile sector (Austin, 2003). These modifications have important financial impacts. Certain adaptation measures have already been taken on the level of several makes of car in order to reduce their CO$_2$ emissions. Within the European Union, commitments have been made along with European (European Automobile Manufacturers Association – ACEA), Japanese (Japan Automobile Manufacturers association – JAMA) and Korean (Korean Automobile Manufacturers association – KAMA) car manufacturers. The aim of these manufacturers is to reduce CO$_2$ emissions in cars by 25% for the period 1995-2008 (2009 for the JAMA and the KAMA) (European Union, 2006). This would bring the threshold of emissions to 140g of CO$_2$ per km covered. Elsewhere, in response to its aims to reduce emissions, the European Community has decided to play on two other measures: the taxation and the legislation of 1999 on labels concerning fuel consumption.

### 3.3.9 Tourism sector

On a worldwide scale, the tourism sector has a huge economic weight at its disposal. The criterion “temperature” is an important key in tourists’ space- and time-rating. The potential effects of climate change will be positive or negative according to the influence of the meteorological conditions in situ (beautiful weather, rain, snow, flooding,...) Elsewhere, these will also play a modifying role on the pleasant atmosphere and particularly on the evolution of the landscape and the environment.

Globally speaking, it is currently difficult to give a ruling on the consequences linked to this change as far as tourism is concerned. Nevertheless, certain trends can be concluded. So it is probable that both international and local tourism will be affected by the influence of climate change. The destinations towards the south run the risk of being less appreciated than at the present time, and with conditions becoming hotter in the north, more individuals will tend to stay in their own country during holiday time (Netherlands Environmental Assessment Agency, 2005). In addition, the inter-seasonal period could benefit from climate change, attracting more tourists because of higher temperatures. By way of comparison, the high season would be more affected. Moreover, international tourism will also be affected with regard to transport methods due to political measures aiming at reducing the greenhouse gas emissions. Currently,
the tourists have already been able to note an increase in costs of transport. Finally, the impact of the climate change will depend therefore for each country on an equation taking into account the proposed offer and the effects on the request.

As seen above, the temperature of a tourist site has an influence of the first order in the choice of destination for a trip or holiday. For example, an increase of 1°C in temperature in The Netherlands can generate an increase of 3.1% in the number of foreign tourists in the next few years (Netherlands Environmental Assessment Agency, 2005). All the same, concerning national (or internal) tourism, temperature is considered the best tourist indicator.

Modifications in climate could ruin certain destinations which depend highly on meteorological conditions. In the case of global warming below our latitudes, it would be interesting to examine the question of the impact of this rise in temperature on winter tourism linked to the boardsporting activities in Belgium. In fact, this sector is highly dependent on snow cover on the of ski slopes. Moreover, there must be snow cover at particular times of the year, such as school holidays or weekends. In the past, certain stations had their season ruined by the lack of snowfall. These activities could disappear from now on in the future (van Ypersele, 2004).

Moreover, other tourist activities could also be affected, such as those associated with such recreational areas as internal bathing waters and the coastal region (erosion). Some activities have seen a weakening in their economic productivity during dry spells on account of restrictive measures of taken due to a lack of water. This was in fact the case with kayaking along Walloon rivers in 2003 (Danze, 2003). On the other hand, the reduction in the rivers’ low water discharge can also generate a growing risk of a concentration of pollutants and pathogenic elements.

3.3.10 Financial sector

The whole financial sector is affected by the problems which modifications in climate have generated. According to several members of the United Nations Environment Programme (UNEP) consortium for financial institutions, the extent of the catastrophes caused by climate change could even ruin the stock markets and the world’s financial institutions (UNEP, 2002). Thus “the increasing frequency of severe climatic events, threatening the social stability or coupled with significant social costs, has the potential to exert pressure on insurance companies, reinsurance companies and banks to the point of impaired viability or even insolvency” (UNEP, 2002).

The analysis of this sector is approached from the point of view of banks (investment) and insurance companies at an international level.

A. The banking sector

This sector could be particularly sensitive to the increase in damage resulting from extreme events. Following the diversification of the financial services offered financial companies can find themselves facing a collection of risk effects for which climate change becomes a risk for their whole portfolio of activities. The companies which are unaware of this danger run a higher risk from then on. Moreover, several threats and opportunities can be brought to light for this sector. The UNEP consortium for financial institutions highlights a series of these positive and negative effects (see table 1).
Elsewhere, the sector for financial services of a banking kind has a role to play in the “climate – finance” relationship (investment, credit risk and new climate risk hedging products) which it must not neglect (Allianz group and WWF, 2005).

The value of businesses is now subject to new factors of assessment, such as the new policies and regulations set up to tackle the greenhouse effect, the development of an environmentally-friendly technology, evolution in climate, the growing consumer-consciousness in the face of these questions.

From now on, financial institutions must integrate the impacts associated with greenhouse gas reduction policies on the level of businesses into their own economics analysis policies. In fact, financial investors must take into account the costs associated with the new regulations and with the impact of these on the companies in which an investment has been made. On account of this statement and according to the experts’ opinion, the financial sector has therefore an indirect role to play in tackling climate change. The areas most targeted are the sectors of investment, the risk analysis and prevention.

Table 1: Summary of Threats and Opportunities for the Finance Industry (Innovest Strategic Value Advisors and UNEP Finance Initiative Climate Change Working Group, 2002)

<table>
<thead>
<tr>
<th>FINANCE SUBSECTOR</th>
<th>POTENTIAL THREATS</th>
<th>POTENTIAL OPPORTUNITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Macroeconomic downturn hurts business volume</td>
<td>Development of new markets and demand for new products related to greenhouse gas emissions reductions and/or adaptation to climate change creates new momentum for economic expansion</td>
</tr>
<tr>
<td></td>
<td>Uncertain and unpredictable impacts on global markets</td>
<td>Public/private partnerships in green municipal funds, etc.</td>
</tr>
<tr>
<td></td>
<td>Greater pressure on public purse for disaster relief and infrastructure rebuilding</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compounding risk across entire portfolio of converging activities (asset management, insurance, reinsurance)</td>
<td></td>
</tr>
<tr>
<td>Corporate &amp; Retail Banking and Project Finance</td>
<td>Property damage risks to project finance and real estate finance</td>
<td>Financing clean energy technology development</td>
</tr>
<tr>
<td></td>
<td>Cancelability of real estate insurance exposes property lender</td>
<td>Financing of infrastructure development arising from adaptation</td>
</tr>
<tr>
<td></td>
<td>Unanticipated GHG emissions mitigation costs at project level</td>
<td><em>Enhanced</em> project returns from sale of credits</td>
</tr>
<tr>
<td></td>
<td>Impaired value of GHG-intensive capital stock</td>
<td>Lending by commercial banks to customers for energy efficiency-related projects</td>
</tr>
<tr>
<td></td>
<td>Physical damage to corporate assets</td>
<td>New markets in, e.g., political/regulatory risk transfer</td>
</tr>
<tr>
<td></td>
<td>Regulatory and political risks</td>
<td></td>
</tr>
<tr>
<td>Asset Management</td>
<td>Macroeconomic disruptions impair long-term asset appreciation</td>
<td>Outperformance from investing in climate leaders and best-in-sector securities</td>
</tr>
<tr>
<td></td>
<td>Hidden carbon liabilities affect market value of securities</td>
<td>Hedge funds investing in GHG credits</td>
</tr>
<tr>
<td></td>
<td>Real estate holdings impaired by weather events, increased energy costs</td>
<td>Innovative climate-related theme funds e.g., new energy</td>
</tr>
<tr>
<td>Private Equity</td>
<td>Reduction in competitiveness of GHG-intensive business</td>
<td>Growing demand for low carbon technologies and related goods and services</td>
</tr>
<tr>
<td>Other</td>
<td>Compounded carbon risks for diversified fund managers, e.g., hedge funds</td>
<td>Hedging services for uninsured GHG credit and energy price risks</td>
</tr>
<tr>
<td></td>
<td>Potential deterioration of project economics and investment viability due to national financial policy responses to climate change</td>
<td>GHG credit brokerage and trading</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Consulting and advisory services</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Macrobias opportunities in developing countries</td>
</tr>
</tbody>
</table>
B. The insurance sector

Due to the increase of people and goods in the zone at risk, due to a greater concentration of industries in this zone, due to the rise in the number of losses when extreme climatic events occur, the insurance sector is tending to take new options as to insurance-related possibilities. In fact, within insurance companies the rise in real and insured losses has on the one hand generated a decrease in the cost-effectiveness of their product, and on the other hand, has led to the bumping up of their rates, the suppression of certain forms of cover and a growing demand for compensation and help from the State. As a result of these heavy pressures on the financial capacities of the reinsurance sector, a substantial decrease in the availability of insurance against catastrophes was recorded these last few years (OECD - Organisation for Economic Co-operation and Development, 2004)

In a general way, it has to be acknowledged that the increase in losses due to natural catastrophes is partly caused by socioeconomic factors (demographic growth, increasing wealth, urbanisation in the zones at risk) and partly by climatic factors, such as the progression observed in rainfall, flooding and drought (IPCC, 2001). Faced with these risks, the market for catastrophe insurance, which has grown rapidly, has introduced new solutions via international diversification and important financial means. In this way, the offer for cover has been recently extended by loans called “catastrophe obligations” (“cat bonds”). According to Swiss Re (Swiss Re, 2004), this insurance market could be quite large. One of the characteristics of this type of insurance is that certain potential forms of damage turn out to be greater than the total capacity of insurance world-wide.

As with the banking sector, the UNEP consortium for financial institutions has set up a panel of the opportunities and threats which come from climate change in the context of insurance and reinsurance companies (see table 2).
Table 2: Summary of Threats and Opportunities for the Insurance Industry (Innovest Strategic Value Advisors and UNEP Finance Initiative Climate Change Working Group 2002)

<table>
<thead>
<tr>
<th>INSURANCE SUBSECTOR</th>
<th>POTENTIAL THREATS</th>
<th>POTENTIAL OPPORTUNITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENERAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>New and existing markets become unviable as climate change increases regional exposure</td>
<td>Use of pre-existing insurance tools (e.g., Errors and Omissions insurance to protect against errors in forward selling of climate-influenced contracts; Business Interruption insurance to be better prepared than competitors)</td>
</tr>
<tr>
<td></td>
<td>Asset management risks; loss of long-term value in securities affected by adaptation/mitigation regulations and measures</td>
<td>Technology insurance and/or contingent capital solutions to guard against non-performance of clean energy technologies due to engineering failure</td>
</tr>
<tr>
<td></td>
<td>Compounding risk across entire portfolio of converging activities (asset management, insurance, reinsurance)</td>
<td></td>
</tr>
<tr>
<td>PROPERTY / CASUALTY</td>
<td>Physical damage to insured property from extreme/more frequent weather events unbalancing insurer’s assets and liabilities</td>
<td>Increase in demand for underwriting services as weather risk increases</td>
</tr>
<tr>
<td></td>
<td>Liquidity problems due to same</td>
<td>Insurance of GHG offset and clean energy projects and related financial services eq professional indemnity for carbon credit guarantors and certifiers</td>
</tr>
<tr>
<td></td>
<td>Increases in population and infrastructure density multiply size of maximum potential losses from extreme weather events</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Regulatory change, for example relating to design standards</td>
<td></td>
</tr>
<tr>
<td>LIFE/HEALTH</td>
<td>Increased risks to human health (thermal stress, vector-borne diseases, natural disasters)</td>
<td>Increase in global demand for L/H insurance as human health risk increases</td>
</tr>
<tr>
<td>OTHER</td>
<td>Business interruption risks becoming unpredictable and more financially relevant.</td>
<td>Collaboration with others in pooling capital to expedite Kyoto mechanisms</td>
</tr>
<tr>
<td></td>
<td>Disruptions to construction/transportations sectors</td>
<td>Microinsurance</td>
</tr>
<tr>
<td></td>
<td>Increased losses in agro insurance</td>
<td>Weather derivatives</td>
</tr>
<tr>
<td></td>
<td>Political/regulatory risks surrounding mitigation</td>
<td>CAT Bonds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Consulting/advisory services</td>
</tr>
</tbody>
</table>

3.3.11 Conclusions towards work package II

During this study it was not possible to consider all economic sectors. This results in the objective of this first part of the project, to synthesize the various climate impacts in Belgium in order to examine in more detail the specific case of flooding in the second part of this study.

A number of fields of economic activity proved to be subject to repercussions resulting from climate change. Generally speaking, the whole economic sector is not affected by these changes in the same way; some sectors are affected mainly by extreme events, others by the modifications in climate on a more global scale, and still others by the combination of these two phenomena. In general terms, many sectors will undergo damages in a direct or an indirect way. Consequently, these phenomena will affect the whole Belgian economy and in more globally the world economy.

Despite the numerous damages caused by climate change, these will not necessarily have only harmful effects. In fact, some sectors might even gain from the modifications in climate conditions in our regions, alongside the damages undergone. By far the best example of this is the agricultural sector where production depends directly on the productivity coming from natural capital. This is also one of the main sectors where meteorological "whims" are felt. The agriculture sector could therefore benefit from the rise in temperature allowing for the development of certain crops.
Over and above the damages passed on to the different economic areas, climate change will also increase the conflicts of interest between these various activities during certain periods. This is notably the case of the use of water during drought periods. Its consumption/use involves an important number of actors who form the population for drinking water, these being the industries that use water as a cooling agent, farming, for the watering of crops and the leisure and recreation sectors, which are directly dependent on water for their activity. Obviously all of these actors do not have the same end use objective and because of this, it will be necessary to make choices in managing this.

Finally, like the whole of the earth's ecosystem, the economic sphere is also confronted by the consequences of climate change. And just like each individual in an ecosystem, this sector must adapt to the new modifications in its surroundings. This phenomenon will depend on its capacity to “acclimatize” to this new environment as well as on the apathy of its reaction and the speed of the changes in progress. Changes and modifications in the economic landscape will consequently be possible.
3.4 ECOLOGICAL ASPECTS

3.4.1 Impact of climate change on natural ecosystems and associated services

Ecosystem services are the beneficial outcomes from ecosystem functions i.e. primary production, nutrient cycling, soil formation. Some examples of ecosystem services are support of the food chain by harvesting of animals or plants, the provision of clean water and scenic views as a recreational value (MA, 2005). Thus conserving, restoring and preventing further loss of ecosystems, can improve the socio-economic development or otherwise deterioration of ecosystems may put constraints on further socio-economic development.

In the last decades the scientific community indicated that effects of climate change on ecosystems should be considered on top of other human caused impacts on ecosystems (ICPP 2001, EEA 2005). Natural ecosystems already under stress, e.g. by water and air pollution, will have a diminished capacity to adapt to climate change. Over the last 50 years, humans have used ecosystems more intensively than in any comparable period of time in human history (MA, 2005). Because of the complexity of natural ecosystems, effects of climate change presents a series of important and immediate challenges to nature conservation and restoration (Birds, 79/409/CE, and Habitat, 92/43/CE, Natura 2000). When subject to multiple stresses, natural environments can exhibit symptoms that indicate reductions in resilience, resistance, and regenerative capabilities. Therefore climate change is likely to further stress sensitive ecosystems which are already adversely affected by a variety of other human impacts, such as altered flow regimes and deterioration of water quality and biodiversity (Hare, 2005). Even if emissions of greenhouse gasses stop today, these changes would continue and in case of sea level for centuries. Therefore, in addition to emission reduction measures, it is essential to develop adequate adaptive responses to avoid the risk posed by, and to take advantage of the opportunities arising from global change.

Freshwater systems are closely connected to climatic processes, by influencing or even driving global atmospheric processes that may influence climate. Because freshwater ecosystems integrate atmospheric and terrestrial events, they may be sensitive early indicators of climate change. Moreover, they are essential contributors to biodiversity and productivity of the biosphere. They also provide a variety of goods and services to the human population, including water for drinking and irrigation, recreational activities and habitat for economically important fisheries (Postel and Carpenter, 1997; Meire et al., 2005). In addition to the challenges posed by land-use change, non-point source pollution and water use, freshwater systems are expected to respond to the added stress of climate change.

Taking into consideration the socio-economical importance (see 3.3 and 3.5) and the ecological values (especially biodiversity and ecosystem functions), we focused on the impact of climate change on freshwater ecosystems. Those ecosystems have historically responded to climate change and we assume that they will continue to do so. Hereby
we include wetlands, lakes, streams and rivers, and estuaries as separate biota because of their distinctive biodiversity and functions.

3.4.2 Wetlands

A. Impact on functionality of wetlands

Wetlands are important regulators of water quantity and water quality. Several types of wetlands are known to act as hydrological buffers. For example, floodplain wetlands store water when rivers over-top their banks, reducing flood risk downstream. The value of these services may be considerable and often technical alternatives to regulate the quantity of flow are much more expensive. Wetlands not only regulate the quantity of water flow but also regulate its quality (Ramsar COP7, 1997; MA, 2005).

In Belgium, wetland responses to climate change are still poorly understood and are often not included in global models of the effects of climate change (Meire et al., 2005). Therefore, only a general assessment of the relationships between wetlands and climate change can be given in this phase. It is generally understood, however, that increases in temperature, sea-level rise, and changes in precipitation will degrade those benefits and services. These changes will likely affect waterfowl that are dependent wetlands as habitats, and may contribute to desertification processes. It is important to realize, though, the degree of uncertainties associated with projections of the consequences for wetland ecosystems resulting from climate change. For most regions the projections for changes in precipitation and temperature, are highly uncertain. Further uncertainty includes the increase in frequency and intensity of extreme events, such as storms, droughts, and floods. The ability of wetland ecosystems to adapt will be highly dependent on the rate and extent of these changes.

B. Impact on wetlands biodiversity

Europe is predominantly a region of fragmented natural or semi-natural habitats in a highly urbanized, agricultural landscape. A significant proportion of remaining semi-natural habitats of high conservation value is enclosed within protected sites, which are especially important as refuges for threatened species (MA, 2005). Nature reserves form an important conservation investment across the whole of Europe. However, species distributions are projected to change in response to climate change (MA, 2005), and valued communities within reserves may disassociate, leaving species with nowhere to go (MA, 2005).

The observed changes in the climate system (e.g., increased atmospheric concentrations of carbon dioxide, increased land and ocean temperatures, changes in precipitation and sea level rise), particularly the warmer regional temperatures, have affected the timing of reproduction of animals and plants and/or migration of animals, the length of the growing season, species distributions and population sizes, and the frequency of pest and disease outbreaks.

Temperatures are expected to increase as a result of increasing greenhouse gas concentrations (IPCC, 2001a). Temperatures are projected to increase by 1.5 to 5.8 by 2100 (IPCC, 2001a). This increase will affect plant communities in a number of ways. Direct response to climate through altered reaction kinetics, which could lead to increased primary production especially in regions where carbon assimilation is limited.
by low temperatures (Larcher, 2003). Indirect effects of temperatures increase include changes in resources availability and competitive interactions (De Valpine and Harte, 2001).

The vulnerability of wetlands to dessication, depends in large on the sources of water supply (precipitations, groundwater discharge, surface water flows) (El Kahloun et al., 2005). In general wetlands fed by precipitation are the most likely to lose wetlands characteristics in a drying climate. In groundwater dependent wetlands or fens, drought may induce internal eutrophication (Van Haesebroeck et al., 1996). The increase in nutrient availability may stimulate biomass production and induce decrease in biodiversity (Boeye et al., 1997; El Kahloun et al., 2000; El Kahloun et al., 2003).

C. Greenhouse gasses

Greenhouse gas emission has resulted in significant changes in important aspects of our climate (IPCC, 2001b). By 2100, global surface temperature is projected to warm by 1.4 to 5.8, and sea level to rise by 9 to 88 cm in relation to 1990 (IPCC, 2001b). Temperature is likely to induce profound changes in the functioning and services of European’s natural and human systems (EEA, 2004). Even if emission of greenhouse gases stop today, these changes will continue for many decades due to the time lags in the response of climatic and oceanic systems to changes in the atmospheric concentration of the gases (Wigley, 2005). Therefore, there is a need to understand the function of the ecosystems related to carbon dioxide (the most important greenhouse gas).

i. Wetlands: a sink and/or source of carbon?

Wetlands, coastal wetlands and peatlands represent the largest terrestrial biological carbon pool (Dixon et al., 1995). Therefore they play an important role in the global carbon cycle (IPCC 1996). Due to their anaerobic character and low nutrient availability, wetland carbon stocks increase continuously. However, as soils warm in response to climate change, mineralization generates considerable carbon emission (Maltby and Immirzy, 1993). In order to properly assess the source and sink potential of natural wetlands, the flows of carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) have to be taken into account. Kasimir-Klemedtsson et al. (1997) showed that wetlands in northern Europe accumulate between 0.16 - 0.25 t C ha⁻¹ yr⁻¹ but if methane emissions are taken into account these wetlands become a net source of 0.43 - 1.1 t C ha⁻¹ yr⁻¹. The effects of climate warming on ecosystem carbon (C) storage remain uncertain. The role of wetlands in the global carbon cycle is poorly understood, and more information is needed on different wetland types and their function as both sources and sinks of greenhouse gases.

ii. Wetlands loss is likely to result in additional release of CO₂

As reported previously, wetlands store large amounts of carbon and when these wetlands are lost or degraded, CO₂ and other greenhouse gases are released into the atmosphere in large quantities. Therefore, conserving wetlands is a viable way of maintaining existing carbon stores and avoiding CO₂ and other emissions. The conservation strategies may include a multitude of activities related to innovative natural resources exploitation, legislation, enforcement, incentive measures, impact assessment, capacity building and awareness raising. An additional mitigation strategy is the creation
of human-made wetland ecosystems. Creation of constructed wetlands can compensate to some extent for the loss of natural wetland functions, such as flood storage and water quality buffering (Kusler and Kentulla, 1990) and provide opportunities to store carbon.

3.4.3 Lakes, streams and rivers

A. Impact on functionality of lakes, streams and rivers

In temperate Europe, the potential for precipitation decreases that result in lower flow rates could have major implications for lakes and streams. This could lead to changes in habitat and breeding locations of aquatic flora and fauna. These hydrological changes have the potential to be more significant for freshwater organisms than a temperature increase. The effect of warmer winters that lead to less extensive ice cover of lakes is expected to affect Europe’s temperate lakes and streams as discussed above. Aquatic ecosystems support delicate, deeply interconnected webs of life which are highly adapted to the physical (and biochemical) characteristics and cycles of the rivers themselves. Changes in precipitation patterns may alter seasonal flow and volume patterns in streams and rivers.

B. Impact on Biodiversity of lakes, streams and rivers

The life processes of most aquatic species are temperature-dependent, warmer water can increase primary production. In streams and rivers, aquatic invertebrates may mature more rapidly and reproduce more frequently (Arnell et al., 1995), increasing food resources for fish. However, increasing water temperatures may also stimulate microbial activity and decreases of organic matter are expected, which may to the contrary result in less food availability for fish (Meyer and Edwards, 1990).

A temperature rise due to global warming is expected in all freshwater biota, i.e. in lakes, streams and rivers. Rare and endangered plant and animal species with sensitivity to small temperature changes often have no alternative habitat, especially in isolated areas such as those in alpine wetlands. Besides the warming effect, Talling and Lamolle (1998) have pointed to the possibility of increased mixing of stratified water bodies due to increased storm activity, which could result in the large-scale die-off of fish species.

The projected increase in biomass productivity in terrestrial systems and increase in runoff would affect lakes, streams and rivers because of alterations in the amount and quality of water and solid material inputs. Organic matter inputs are expected to increase and would be beneficial for algae and cyanobacteria, which are less favored by secondary consumers.

3.4.4 Estuaries

A. Impact on the functionality of estuaries

Sea-level rise can cause several direct impacts, including inundation and displacement of wetlands and lowlands, coastal erosion, increased storm flooding and damage, increased salinity in estuaries and coastal aquifers, and rising coastal water tables and impeded drainage (Bijlsma et al., 1996). Climate change and sea-level rise would impose serious impacts on the natural environment and human society in the estuarine zone. Primary impacts of sea-level rise are listed as inundation, exacerbation of flooding,
beach erosion, changes in nutrients fluxes, habitats loss and salt water intrusion to rivers and groundwater aquifers.

**i. Water purification and nutrient fluxes**

Due to a long residence time of the water and the intense interactions between water, soil and atmosphere, tidal areas also play an important role in nutrient cycling and the self-cleaning capacity of estuarine rivers (Mallin and Lewitus, 2004; Middelburg et al., 1995; Van Damme et al., 2005). In Belgium, increase in precipitation will likely induce higher freshwater discharges that can further influence the Scheldt estuary ecology by decreasing water and nutrient residence time in the main channel. Nutrient and organic material are transferred more rapidly to estuarine waters, and important ecological processes (denitrification, nitrification, mineralization, nutrient uptake) in nutrient cycling have less time to act upon the large volumes of nutrients, which could lead to alterations of fluxes of N, P and Si from downstream to coastal waters (Struyf et al., 2004).

**ii. Habitat loss**

Estuaries are the main transition zones or ecotones between the riverine and marine habitats. They are composed of a mosaic of subtidal, intertidal mudflats, intertidal sandflats, marshes, shingles, rocky shores, lagoons, sand-dunes and coastal grasslands (Davidson et al., 1991). Estuaries in Europe contain large human populations and significant socioeconomic activities (EEA, 2005). They also support diverse ecosystems that provide significant habitats and sources of food.

During the past centuries, dike construction and land reclamation for agricultural, urban, industrial or port developments have dramatically reduced the estuarine areas throughout the world, both in surface and in quality. Many estuaries suffer from a loss of habitat and degradation, the latter mainly due to anthropogenic pollution (Nicholls and Klein, 2004). In Europe risk of flood hazard will be substantial for coastal areas where flooding will increase erosion and loss of coastal habitats, this would have serious consequences for biodiversity, particularly for wintering shorebird and marine fish populations (Beniston et al., 1998; Nicholls and Klein, 2004).

Further loss of habitat is now restricted due to legislation and if losses are inevitable they must be compensated for, at least in some parts of the world. In the USA compensation has a strong tradition, but now also in Europe due to habitat (92/43/EEC) and bird directive (79/409/EEC) it is a hot topic. However climate change and sea-level rise would impose serious loss of habitats in the coastal zone.

**iii. Inundation**

Changes in the estuarine morphology can cause a substantial rise of the tidal amplitude, often leading to an increased risk for flooding. Sea level rise would double the global population at risk from storm surges (from around 45 million up to 90 million). Examples of particularly sensitive areas include small island states, Bangladesh and other states in Southeast Asia, north-western Europe, the southern Atlantic coast and the Gulf of Mexico in the United States. In the scope global change and sea level rise, protection against storm surges will become more and more important.
After the inundations of 1976 along the river Scheldt, induced by a violent northwest storm in the North-sea, the authorities launched the Sigma plan in order to protect the tidal part of river. Recently a new philosophy is emerging, combining safety, economy (harbour) and nature (Maris et al., 2006). Giving more space to the river through controlled inundation areas offers the opportunity to protect against flooding and restore the ecological functioning of the estuary without obstructing the economic development of neither harbours nor navigation. One specific way to combine ecology and safety is the creation of a Flood Control Area (FCA) with a Controlled Reduced Tide (CRT) (Meire et al., 2005). The CRT principle can create a favourable tidal regime for tidal wetland restoration in a FCA, regulated by a simple but well-designed system of in- and outlet sluices that needs no further steering, regulating or pumping (Cox et al., 2006). These specific areas however, will differ in many ways from fully tidal wetlands, mainly because of the different flooding regime, which is now also the function of the case specific inlet-outlet sluice design. But besides the tidal regime, also water quality can be a function of the chosen CRT design.

**iv. Erosion**

Impacts on the Natural and Human systems: One of the most significant impacts of sea-level rise is acceleration of coastal erosion as well as inundation of mangroves, wetlands. Coastal erosion is considered to be one of the main impacts of sea level rise. (Boorman, 1990; IPCC, 2001b). Increased coastal flooding, loss of habitats, an increase in the salinity of estuaries and freshwater aquifers, and changed tidal ranges in rivers and bays, transport of sediments and nutrients, patterns of contamination in coastal areas are amongst the main effects of coastal erosion.

The threat that climate change will add to erosion is real. Especially poorly vegetated soils are vulnerable to possible increases in rainfall intensities, storms, wind velocity or droughts as a result of climate change. Changes in land use (whether driven by economic, demographic, social, technological pressures and/or even climate change) are particularly important for soil erosion. At the one hand, soil erosion can reduce the quality and depth of soils, possibly leading to important productivity losses, and at the other hand it might cause off-site pollution or damage. The latter effect is particularly well documented in Belgium.

On a global scale, Belgian climate cannot be called erosive as rainfall with high erosive power is often very local. In Belgium, the risk of erosion is highest during in summertime due to intense thunderstorms, these “extreme” events are much more determinative for soil erosion than normal rainfall intensities. There is a consensus that higher precipitation and rainfall intensities will bring about greater rates of erosion (IPCC, 2001b; IRGT-KINT, 2005).

Very dry soils with a bad structure are many times more sensitive to erosion than humid ones. As a result of an increase in temperature, evaporation and dry periods soils might even get dryer during summertime. This reality will therefore contribute to the expected adverse effects of increased rainfall amounts and intensities on erosion (IRGT-KINT, 2005).

Highest rainfall induced erosion rates in Belgium occur south of the Meuse and the Samber. Average soil loss in Flanders amounts to 1.18 ton/ha a year, erosion being highest on the loamy and sandloamy regions in the south of Flanders. In these regions,
which extend over the North of Wallonia, yearly soil loss can be higher than 10 ton/ha (0.74mm). Based on models, the sediment exports to the Flemish watercourses is estimated at 0.26 ton/ha, and at 0.8 – 1.0 ton/ha to the Walloon watercourses (IRGT-KINT, 2005).

In the centre of Belgium, intense rainfall produces regularly inundations of a muddy character. This is particularly the most important downstream consequence of soil erosion in Belgium. About 53 percent of all communities in that region state to suffer from this kind of inconvenience, 15 to 20 percent being affected several times a year. In the long term, sedimentation of watercourses and flood retention basins becomes also an important consequence, causing problems with the navigability and, above all, increases the risk of flooding (IRGT-KINT, 2005).

Insofar the chance of soils getting dryer during some periods of the year increases, soils will become more susceptible for wind erosion. However, the KMI observed a steady decline in average annual wind speed in Uccle, a trend which is consistent with Dutch observations (IPCC, 2001; RMI, 2006; Smits et al., 2005).

For quite a long time, a large part of the Belgian coast is subject to erosion, affecting the natural coast defence. Storms can take away substantial amounts of sand, damaging beaches and dunes. If the number of heavy storms would increase, erosion will probably do so too. Besides, one also believes sea level rise will intensify erosion (IRGT-KINT, 2004; Marbaix and van Ypersele, 2004).

v. Salinity intrusion

During extended droughts by increasing temperature, decreased river flow will likely allows the saline water to migrate up the estuary. A rise in sea level will also cause saltwater to immigrate upstream.

In Belgium the longitudinal salinity profile of the Scheldt estuary is primarily by the magnitude of the river discharge, with the transition between fresh and salt water being particularly variable (Soetaert et al., 2005, Van Damme et al., 2005). Scheldt freshwater discharges will likely increase up to 28% during the next century (pers. com. from AWZ, Flander Waterways and Maritime Affairs Administration). This will certainly affect the transition between fresh and salt water.

B. Impact on biodiversity of estuaries

Fish and shellfish species that use estuarine ecosystems as nursery habitats are also sensitive to temperature conditions. As temperature increase by climate change, many species will be forced to shift their geographic ranges toward suitable thermal rearing environment for their young (Kennedy, 1990).

One of the potential negative effects of increased runoff in estuarine zones is an increase in nutrients inducing eutrophication. Nuisance algal blooms and low oxygen in bottom waters kill fish and shellfish (Kennedy, 1990). Increased runoff will also lead to problems with toxic pollutant (heavy metal, organic chemicals) with concurrent negative impacts on biodiversity. In Belgium, high freshwater discharges by increased precipitation can influence estuarine ecology by decreasing water residence time in the main estuarine channel. The upstream tidal freshwater regions are likely to be most affected by changing freshwater discharges as the impact of marine waters is negligible.
(Struyf et al., 2004). Muylaert et al. (2001) have shown how short-term freshets can result in the flushing of entire diatom communities from freshwater reach.

3.4.5 Conclusions towards work package II

As we mentioned in the above analyses ecological impacts of climate change are multiple, complexes and incompletely studied. We try to summarize the potential impacts of climate change on the biodiversity and the functionality of the most vulnerable ecosystems in Belgium. However, impacts may differ from local, regional, national and international levels. To make progress on climate change adaptation, there is a need to improve climate models and scenarios at a detailed regional level, especially for extreme weather events, to reduce the high level of uncertainty.

Furthermore, the amount of ecosystems alteration directly attributed to climate change will be difficult to ascertain because of the human interaction. The critical uncertainty in projecting future ecosystem response to changing climate is how human will interact with these ecosystems as climate changes. Therefore an integrated socio-economical, ecological and hydrological study is needed to predict the degree and range of the possible impacts of sea-level rise and climate change. This will provide as a basis for preparing response strategies and measures. To identify the most vulnerable sectors and areas from multiple viewpoints is another important task.
3.5 SOCIAL ASPECTS

3.5.1 Society and linkages to climate change

“Drought provokes food crisis in Puri District, Angola”\(^7\), “Hundreds killed in North Korean floods”\(^8\), “Soldiers redeployed on the streets of New Orleans to fight crime in the aftermath of Hurricane Katrina”\(^9\). These news items illustrate that human and society cannot get round to the effects of certain weather events. A WHO study states that every year 150 000 people die because of raising temperatures, heat waves, storms, floods etc. (WHO, 2005). Actually, these weather events are nothing new. During history, these weather events also occurred and had affected many people. Then, why are we just starting to worry so much during the last decades? Because we expect that the climate will change globally. Climate refers to weather as observed over a long period. Climate trends that are already observed, are the increase in average temperatures, the rise of sea level, the increasing variance in seasonal rainfall and the occurrence of more extreme weather events, like droughts, hurricanes, storms, heat waves and floods (Ochoa et al., 2005); These weather events are projected to occur more frequent and become more intense. It is expected that more people will be affected, since also regions that have never experienced these weather events, will be threatened. Furthermore, the direct and the indirect impacts of these climate changes are projected to endanger human basic needs like food, water, housing, basic furnishing, employment and safety (Douglas et al., 1998). Adding the aspect of uncertainty about the climate change scenarios, our worries can be justified.

Like the economic and the ecological system, society is able to cope with climate conditions that deviate from the average conditions, but only to a certain degree. Too extreme events may turn society into a disaster area (Smit and Pilifosova, 2003). The link between climate change and societal impact is illustrated by the following formula (based on Hilhorst, 2004):

\[
SI = E \times V_p / C_s
\]

SI: social impact of climate change
E: exposure to direct climate change and its indirect impacts
V\(_p\): vulnerability of people
C\(_s\): adaptive capacity of the society

This formula states that the extent of the impact of climate change on society (SI) depends on the exposure (E) to the climate changes, the vulnerability of people (V\(_p\)) and the adaptive capacity (C\(_s\)) of the society. The figure beneath illustrates that the number of natural disasters has increased in the past. Especially the numbers of floods and

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windstorms have increased significantly during the past twenty-five years. But also droughts had been experienced more and more. And climatologists project that this number of extreme weather events may continue to grow in the future (Emergency Disasters Database, 2006).

![Number of natural disasters reported](image)

Figure 9: Numbers of natural disasters 1900-2005 (source: EM-DAT, 2006)

Shortly, the climate might change more profoundly. There is consensus that this is for the greater part due to human activity. Mitigation policy that tries to eliminate emissions will never stop the occurrence of extreme events, but will only reduce the climate variability. Nevertheless, we are still emitting and thus we will be exposed to the projected climate changes.

Remarkably, effects of climate change of the same intensity cause different impacts on different people. For instance, Bangladesh and the Netherlands are both low-lying countries where a large part of the population lives in the coastal areas and near the rivers. The problem is that these areas are at sea level, or in the case of the Netherlands even below sea level. Nevertheless, a sea level rise of 60 cm may cause a larger social impact in Bangladesh, than on the Dutch society. The different vulnerability of the people and the level of adaptive capacity of the society explain this (Germanwatch, 2004). Vulnerability refers to the characteristics of a person, a group or a region in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (Blaikie et al., 1994). Vulnerability has four properties. Firstly, it is constructed by social, political, economic and cultural factors (Cutter et al., 2003). Secondly, it is a differential concept, since vulnerability varies across regions and across social groups.
Furthermore, vulnerability is scale-dependent because more negative impacts may be felt at the local level than at the national level. And lastly, vulnerability is dynamic, since people that are vulnerable to climate change today, may be less vulnerable in the future (O’Brien et al., 2004). Within our social scope, we consider the vulnerability of people or social groups like the poor, the elderly, the ill, the immigrants; these people experience the negative aspects of climate change the most. The adaptive capacity of society is the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2001b). Some societies have a large adaptive capacity, due to their wealth, their access to technology, the stability and efficiency of their institutions, their information system, the equal distribution of power and their well-functioning of social system (Smith et al., 2003). Others have not.

Exposure, vulnerability and adaptive capacity are the factors that induce social impacts. It is important to note that society is not only exposed to the direct impacts of climate events, but also to the indirect impacts of climate-induced changes in the economic, ecological and social system itself. These may be even more profound and may result in long-term changes (Cutter et al., 2003). Assessing the social impacts of climate change is a complex task because of the uncertainty that is inherent in every aspect of the process. Firstly, there are uncertainties about the climate scenarios. We do not know exactly which climate events will happen and when it will happen. Furthermore, the adaptive capacity of the society is uncertain and we are not sure whether the whole population can resist the climate events. And lastly, this report will deal with the most known social problems Belgium might be confronted with because of climate change. But this list is non-exhaustive and climate change still can generate non-projected impacts.

3.5.2 Unequal distribution of the effects: winners and losers

Although most researches focus on the negative impacts of climate change, it may also cause some positive effects. Problematic is the unequal distribution of these positive and negative effects within and across national borders and over time. Depending on the characteristics of the climate change, impacts may be felt in a different way at individual, sectoral, regional and national level. Some people, sectors or countries may benefit from climate change, although many will suffer from the impacts. In Belgium for instance, warmer summers are profitable for coastal tourism, but the disappearing of snow will endanger employment in the skiing sector in the Ardennes (Marbaix and van Ypersele, 2004). And at the European level, northern European countries may enjoy positive effects on agriculture, but southern and eastern European agricultural productivity may decrease (IPCC, 2001b). Besides, also within the group of losers, there may be a significant variance of the impacts. Important to recognize is that the proportion of winners and losers is dynamic and can change spatially and temporarily (O’Brien and Leichenko, 2003). Recently, a general study on the sectoral distribution of the impacts in Belgium was performed by UCL (Marbaix and van Ypersele, 2004). But more profound research is not available about the distribution of the impacts between social groups and between regions in Belgium. This is necessary to develop appropriate adaptation policy.

The unequal distribution of climate change impacts may generate several social problems. At first, climate change may particularly threaten socially subordinated groups, like the poor, the migrants, and the invalids. The impacts may further skew
existing societal inequalities and may increase unequal income distribution. Besides, these social groups often do not possess sufficient financial, material or social resources to prevent the impacts. Some people are able to adapt easily to climate changes, while others will become marginalized (O’Brien and Leichenko, 2003; Tol et al., 2004). We may expect that more people will need financial or material support to cope with the impacts of climate change. Like for instance, households who have suffered a flood and farmers who have lost their crops because of long-term drought.

The second problem deals with the responsibility. Often, the people who are negatively affected are not the main contributors to the emissions of CO$_2$. This unequal relation between provokers and the affected people might be perceived as unfair and unjust. This raises the questions who will have to take responsibility for the losses of the losers and who will have to pay for adaptation? The affected people themselves, the polluters or the ones that have the ability to pay (Future International Action on Climate Change Network, 2004)? Within a liberal world, the private sector will have the main responsibility and individuals will take measures themselves in order to protection to climate change impacts. This strategy will promote innovation, but may exclude some groups that require support the most. In a collective world, the government will take the lead in offering support. Through this, a basic security is guaranteed, but the market might be hampered (Workshop Nederlands Klimaatbeleid, 2005).

The third problem is about the way to reduce the impacts of the losers. This is a complex task, since policy itself can generate distributional effects that might be unacceptable for the winners. Furthermore, when government will take measures like heightening dikes, creating a disaster fund or compensating farmers for their lost crops, many financial assets are required which may be received from the taxpayers or from other policy domains. In the last case, there will be more competition regarding the governmental budget and possibly financial cutbacks in social programs, what may affect the living standard to certain degrees (Redefining Progress, 2006).

### 3.5.3 Less welfare, more poverty

Climate change may increase the number of people into poverty and may reduce welfare. This may occur directly or indirectly. At first, some people may die because of extreme weather events, sometimes leaving behind families. A source of income might be lost, what might cause financial problems. Furthermore, extreme weather events may damage property or reduce the value of property, as for instance houses and cars. People who rent a house, may be excluded and may have to find another place to live, which is often of lower quality. Besides, climate change may be disadvantageous to some economic sectors. Some enterprises might have to face increased costs, eventually causing them to go bankrupt. In particular cases, this may result in more unemployment, reduced income, more people with financial problems and more poverty. However, these social impacts might be visible only during a short period, especially after extreme events as for instance floods or droughts. Within the spirit of the Belgian welfare state, policy makers would have to take measures to take care of these people. This may increase the burden on income supporting services. But also whole communities may be confronted with damaged infrastructure. It might take a lot of time and money before this is rebuilt (Redefining Progress, 2006; Richards, 2003; London Climate Change Partnership, 2002).
Indirect impacts that harm welfare are for instance the projected reduced economic growth of some regions and sectors. Besides, living costs may go up. Water, electricity and food prices may increase, because of scarcity and increasing competition. This is in particular a problem for people who already have financial problems, since they need to spend a larger part of their income on these necessities. Then, health risks make more people susceptible; in particular people who live in less hygienic circumstances. More illness may generate more financial costs of health care in certain cases (Redefining Progress, 2006; Richards, 2003).

The problem is that often the ones, who are already poor, are hit the most. They do not have the required financial, material or social resources to cope with climate change impacts (O’Brien and Leichenko, 2003). People with financial problems often might opt for no or for a low insurance, which possibly do not cover all the costs. Furthermore, they often live in less expensive houses, being of low quality and sometimes situated in risk areas. Besides, some people are isolated and can not rely on a social network during hard times of recovery (The Heinz Center, 2002; Klinenberg, 1999).

3.5.4 More health risks

Health is an essential component for human well-being. Illness, and especially long-term diseases, may result in reduced working capacity, temporal economic inactivity, unemployment, social isolation and financial problems (Lindholm et al., 2002). Many studies conclude that climate changes will contribute to the increase of human health risks in every part of the world. Also the Belgian population may encounter several health effects in the short-term as well as in long-term.

A. Heat-related health effects

The human physiology is able to adapt easily to small deviations from the mean temperature. The optimal temperature for man is 16.5 °C. More alarming are thermal extremes, as there are heat waves and cold spells. These larger deviations from the optimum may exert pressure on human health (Huynen et al., 2001).

Climatologists project more frequent heat waves. Heat waves can cause heat cramps, heat fatigue, sunstroke, heat syncope and overheat. In particular baby’s, elderly, people with respiratory problems, the urban poor and socially isolated people are the most susceptible to heat waves (FOD Volksgezondheid, Veiligheid van de Voedselketen en Leefmilieu, 2005). Furthermore, there is significant evidence that heat waves can cause excess mortality. This is demonstrated by several researches on the excess mortality during the heat wave of 2003. In Belgium, the excess mortality numbered 1297 (Sartor, 2004), in the Netherlands, the number was 1400 (de Beer and Harmsen, 2003) and France counted to 14 947 persons (Poumadère et al., 2005). Mortality is caused by cardiovascular, cerebrovascular and respiratory problems (Haines et al., 2005). These numbers are large and make clear that these countries are at this moment not yet well prepared to cope with “unexpected” extreme heat. In addition, heat waves are often paired with high concentration of ozone. Too high concentrations of ozone may result in respiratory problems, headache and eye and throat irritation (FOD Volksgezondheid, Veiligheid van de Voedselketen en Leefmilieu, 2005).

On the other hand, milder winters and less cold spells are projected. A Dutch research states that this may reduce the excess mortality due to extreme cold, what may be a
positive impact of climate change on health (Netherlands Environment Assessment Agency, 2005). This evolution is very likely to take place in Belgium too.

B. Allergies

Because of climate change, the number of people suffering from allergies may grow. Increases in temperatures, CO$_2$ levels and certain weather conditions may influence the timing and the duration of the pollen season$^{10}$. These factors also affect the quantity of pollen in the air and the geographical distribution of flowering plants. Consequently, Belgium may expect an increase in the prevalence of hay fever and asthma within its population, as well as in the seriousness of these allergies.

In addition, temperature changes may be paired to changes in relative humidity, what might result in the increase of in-house allergens, as for instance dust mites. Persons, who are allergic to dust mites, suffer from eye irritations, hay fever, asthma and eczema (Netherlands Environment Assessment Agency, 2005).

Another allergen that may appear more frequent in Belgium is the processionary caterpillar. In the spring of 2006, several villages in Belgium were troubled by nests of the processionary caterpillars. Originally, these caterpillars come from Central Europe. Their appearance is often explained by the changing climate. Unfortunately, these caterpillars can harm human health. Contact with the hairs of the caterpillar with skin, eyes and airways result in itch, rash, difficulties in breathing and irritation of the eyes$^{11}$.

C. Food-borne and water-borne diseases

Food-borne and water-borne diseases are favored by warm temperatures. Research within the scope of the cCASHh project has cleared out that the number of salmonellosis-cases rises by 5-10% for each one-degree increase in weekly temperature for ambient temperatures above about 5°C$^{12}$ (D’Souza et al., 2004). Also the food-borne disease botulism increases because of temperature rises. Animals but also humans are vulnerable to several types of botulism. Symptoms of botulism infections are double vision, blurred vision, drooping eyelids, slurred speech, difficulty of swallowing, dry mouth and muscle weakness. If not treated, the symptoms may cause paralysis of the arms, legs, trunk and respiratory muscles$^{13}$.

Because of climate changes, more attention must be paid to water-borne diseases, in particular to cryptosporidiosis. Man can be infected by the parasite by drinking surface water or by contact with soil and food that is contaminated with the parasite. Symptoms of the disease are dehydratation, weight loss, stomach cramps, fever, nausea or vomiting$^{14}$. Outbreaks of cryptosporidiosis are associated with heavy rainfall events$^{15}$. The increase of temperature also contributes to the growth of bacteria in coastal, river and recreational waters. Cyanobacteria grow optimally in water of 20°-30°C. Contact with cyanobacteria generates skin irritation, gastric disorder, headache and fever.

10 http://www.natuurkalender.nl
11 http://www.natuurkalender.nl
12 http://www.who.dk/ccashh/water/20020610_1
13 http://www.cdc.gov/NCIDOD/DBMD/diseaseinfo/botulism_g.htm
14 http://www.cdc.gov/index.htm
15 http://www.euro.who.int

WP1: General study and evaluation of potential impacts of climate change in Belgium
- 49 -
D. Vector-borne diseases: TBE, Lyme disease and malaria

There is strong evidence that climate change may contribute to conditions that favor tick activity. The problem is that ticks can be carrier of various diseases. Man catches tick bites in covered areas, grasslands and parks. In particular children are vulnerable to tick bites, since they often play outside.

The first disease is Tick-Borne Encephalitis (TBE). There are significant findings that ticks, carrying Tick-Borne Encephalitis are moving up to northern areas, due to mild winters and extended autumn activity (Lindgren and Gustafson, 2001). People can be infected with TBE by tick bites, but also by drinking raw milk from goats, sheep or cows. The disease is most often manifested as meningitis (inflammation of the membrane that surrounds the brain and spinal cord), encephalitis (inflammation of the brain) or meningoencephalitis (inflammation of both the brain and meninges). These diseases can even result into death\(^{16}\).

The second disease is the Lyme disease. Lyme is an infection that is caused by Borrelia burgdorferi. About 10% of all ticks are carrier of the Borrelia bacterium. An increase in patients, suffering from Lyme disease, is registered in Belgium. In 1991, only 42 patients were diagnosed with the Lyme disease. While in 1997, 300 patients were suffering and in 2003 already 722 cases were recorded in Belgium (Marbaix and van Ypersele, 2004). The same trends are also observed in the Netherlands and in France\(^{17}\) (den Boon et al., 2004; Letrilliart et al., 2005). The first symptom of the Lyme disease is the “erythema migrans”, a red rash that appears around the bite. Then other symptoms may appear, as there are joint pains, chills, fever and fatigue. A few weeks till months after the contamination, the lime disease spreads through the body and symptoms as severe fatigue, pain in arms and legs, facial palsy, a stiff, double vision and cardiac arrhythmia. In the end, the patient will suffer from swelling of joints, severe headaches, painful arthritis and chronic nervous disturbances, leading to cognitive disorders\(^ {18, 19}\).

The transmission potential of vector-borne diseases is closely related to climate change. Although research reveals that the endemic areas of potential transmission of malaria may increase too, the chance that Belgium will be confronted with an alarming increase of malaria incidences is extremely small (Martens et al., 1997; Van Lieshout et al., 2004; Marbaix and van Ypersele, 2004); Nevertheless, one must be careful with an increase risk of imported malaria from developing countries (Netherlands Environment Assessment Agency, 2005).

E. Extreme weather events

More extreme events are projected. In Belgium, more floods, heavy rainfalls and droughts may occur. These weather events may cause death and injury in a direct way. But there are also some indirect effects related to unhygienic and overcrowded circumstances or due to the lack of medical aid. Natural disasters may decrease the nutritional status of the victims in the case food and water are not available, maybe resulting in malnutrition. Besides, living in flooded areas may cause respiratory and diarrhoeal diseases. Also the risk of water-related diseases may increase because of

\(^{16}\)http://www.cdc.gov

\(^{17}\)http://www.natuurkalender.nl

\(^{18}\)www.iph.fgov.be

\(^{19}\)www.aldf.com
disruption of water supply or sewage systems. Floods disseminate in certain cases dangerous chemicals from storage sites and waste disposal sites. Contact with these substances may affect health too. And last but not least, many disaster victims suffer from mental problems, such as post-traumatic stress disorder, which can even last for years (IPCC, 2001b; EEA, 2004).

F. Climate change and the ozone layer

Although climate change may not be confused with the problem of the ozone layer, there are evidences that the healing of the ozone layer may be delayed at the two poles because of the greenhouse-effect, while at temperate latitudes it might be enhanced. In this way, health will be indirectly affected as a result of increased or decreased exposure to ultraviolet radiation (UV). Furthermore, an increase in warmer and drier summers is expected. Consequently, the chance of a greater exposure to sunlight and UV radiation will increase the health risk like skin cancer, cataract and weakening of the immunity system (Netherlands Environmental Assessment Agency, 2005).

3.5.5 More social distress

Too abrupt and too large divergence from average temperatures and mean rainfall may make havoc of the society. Firstly, coping with floods, heat waves, droughts and storms demands re-organization by households and communities. Additional coping tasks must be assigned, what may increase stress within households. During a first experience with an extreme weather event, many people do not know what to do, what might cause confusion. Secondly, in certain cases there is a lack of water, electricity or food. During a certain period, human basic needs are not met. Furthermore, the normal household tasks may be hampered by this temporarily lack of water, electricity or food or by the destroyed community infrastructure. Both contribute to the increase of the workload and one may experience more emotional stress and interpersonal conflicts. Thirdly, when the additional tasks require too much time or when people have to be evacuated, the leisure activities may be put to a stop for a while, resulting possibly in a temporarily withdrawal from the community. Also during heat waves, outdoor activities are restricted to a minimum and social gatherings are hampered. Besides, the more people are confronted with extreme weather events, the less safe they feel in their home environment. Furthermore, crime and burglary may increase during and after these weather events, because of open windows during heat waves or because of empty houses after flood evacuation. A reduced safety feeling may affect social life and may even result in dislocation, creating unoccupied houses and deteriorating community life. And finally, government may be reluctant to take into account the needs of the victims or to take measures to prevent a second event. This might generate alienation of the victims and mistrust regarding the government, resulting in a divided community. These situations of social distress may even continue months after the extreme weather event.

3.5.6 Changing risk perception and difficult policymaking

Several research results have indicated that climate change will increase the risk of flooding, droughts, heat waves and hurricanes etc... Belgium will run risks too, although

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20 These results are based on qualitative research of various case studies (see bibliography)
concrete information on the extent and characteristics of climate change risks is lacking today.

The Netherlands, but also other countries, are confronted with the problem of communication between the experts on the one hand and the policymakers and the public on the other hand (Klimaatconferentie Rotterdam, 14-09-2006). The way experts assess the risks of climate changes is considered to be a “real” risk, because it is measured objectively, analytically and rationally (Slovic, 2000). A lot of research is performed on climate change, but research results of experts rarely reach the public and they are sometimes interpreted in a wrong way. Society perceives risk differently. This public risk perception is socially constructed, subjective and differs according to prior experience, voluntariness of exposure and dread quality of the risks (Jasanoff and Wynne, 1998). There might be a discrepancy between the expert risk assessment and the perception of risk by the public. In a situation where risk perception of the public conflicts with expert risk assessment, policymaking will be hampered and measures are delayed. But policymaking may also be difficult because of uncertainty regarding the projections, lack of human capacity or the limited financial assets to enforce adaptation policy (Klimaatconferentie Rotterdam, 14-09-2006). In order to formulate adequate adaptation policy regarding the perceived climate change risks, it is necessary that the risks perceptions of the public and the experts are brought into closer alignment (Jasanoff and Wynne, 1998). Therefore, it is important that the expected risks are correctly communicated from the expert to the public and policymakers, if necessary through intermediates as institutions, news media, social organizations, opinion leaders, personal networks or public agencies (Kasperson et al., 2000). The public must come to accept the scientific claims and legitimate policy. Then, these adaptation issues can be put on the agenda. Communicating risk correctly is an intricating process since trust needs to be built between experts, public and policymakers (Jasanoff and Wynne, 1998; Van Aalst, 2006). In particular on climate change impacts, this process is complex due to the uncertainty of the potential impacts and the skepticism of some interest groups.

A public survey about climate change, performed by the Belgian Federal Ministry of Environment, has revealed that Belgian citizens are quite aware of the potential climate change risks. 65% states that climate change impacts are already tangible in Belgium. 57% argues that climate change threatens daily life. 66% says that climate change is a current problem. Remarkably, the public has a large confidence in the information given by independent researchers. The trust in governmental agencies scores moderately. Nevertheless, the survey reveals several gaps in public knowledge on the causes, the consequences and the mitigation measures (Tobback, 2005).

3.5.7 More international instability

Climate change may influence international stability in three ways. At first, climate change is a problem that is caused globally and affects people over the whole world. Therefore, it is a key issue in international environmental diplomacy. Climate change is a difficult matter to “solve”, as is demonstrated by the 15-years of discussion before making a deal regarding CO2-emission reduction. This is due to the aspects of unequal distribution of the impacts, unequal vulnerability and responsibilities that are inherent to climate change: those who suffer most and first from climate change, are not those who have caused the problem. Although they are not the main contributors of CO2, many developing countries are at risk of extreme climate events, but are lacking the capacity
to cope with it. Furthermore, they consider obliged reduction as an obstruction to their economic development. But industrialized countries are reluctant to take measures without cooperation of the developing countries. These divergences of views are a threat to political resolution and may polarize even more the North-South debate. But if action is delayed, adjustment will be more painful when serious climate change finally occurs (Repetto and Lash, 1997; Parks and Roberts, 2006).

Secondly, people decide to migrate because of declining income, increasing risks or deteriorating social circumstances. Climate changes are projected to contribute to these motives for instance because of sea level rise or decreasing agricultural productivity. A strong increase in the number of environmental refugees may be expected. One predicts a growth of environmental refugees to 50 million by 2010 and estimates that in 2050 about 150 million people will be looking for a new place to live. This huge number could be problematic, since environmental refugees are not internationally recognized as refugees and cannot obtain asylum. Problems of frontier-running, illegal migration, exploitation and employment at the black market may become worse (Lovgren, 2005; Wets, 2001).

Finally, climate change may increase the risks to social instability and even to violent conflict. Pretending that climate change is the cause of violent conflict is rather far-reaching. But circumstances that are deteriorated by climate change in combination with poverty, natural resource scarcity, demographic pressure, ignorance, inequity and ethnic hatred, may trigger violent conflict. An example is the current war in Darfur that is caused by drought and the fight for water resources. The projected conflicts may have an intrastate character and in particular African and Asian regions are at risk of violent conflicts. Belgium may experience these conflicts in its trade balance and in the international diplomacy and also investments of many years in development assistance may be nullified in no time (Nordas and Gleditsch, 2005; Barnett and Adger, 2006; Rayner and Malone, 1998).

3.5.8 Conclusions towards work package II

Socio-political impacts of climate change are rarely studied. In the above analysis, a short summary of potential social impacts that Belgium may encounter in the future is described. But not every individual will experience these impacts. It is important to recognize that vulnerability differs across people and is dynamic over time. Some will win, other will lose and some will not be affected. Regarding adaptation policy to be effective, it is important to study which section of the population will suffer most from floods. Moreover, the impacts that the local level may experience, are different from these on the regional, national or international level. A level-based impact division may direct responsible actors at the appropriate level. The above impact assessment summarizes already a list of issues that request adaptation:

- The unequal distribution of climate change impacts and the growing injustice
- The increase in people in search for income support and compensation for damage
- The increase of health risks
- The reduction of welfare
- The increase of social distress prior, during and after extreme climate events
- The difficult communication between expert and policy makers
- The potential growth of environmental refugees
- The complex climate change diplomacy

This non-exhaustive list contains some current, but also some new problems. Some impacts are well understood, others very weakly, and no doubt, there are many complex connections that may magnify or dampen impacts that we have not even recognized (Dessler and Parson, 2006). It is also important to study the opinion of the social groups regarding acceptable risks and adaptation measures before they are implemented.

Adaptation to climate events is nothing new. Throughout history, people have learnt to live with weather events and have tried to adapt their society to climate variability. Consequently, the climate change that we might experience in the future should no longer be seen only as a threat. Adaptation policy aims to reduce the negative impacts and to increase the benefits. The adaptation to the impacts of climate change also generates opportunities for technological, institutional and societal innovations, which may reduce the disastrous impacts of extreme events. Measures should be taken to reduce the risks, although creating zero-risk situations will be unrealistic. Society should be climate proof. This means that on the one hand hard infrastructure should be used to reduce risks to a level that is accepted by society and economy and on the other hand “softer” measures should be required such as insurances, evacuation plans and crisis communication. The challenge for policymakers regarding adaptation is to decide how to cope with the increased climate risks, when to take measures and how to create consensus between the stakeholders about the implementation of the policy. Climate change adaptation should be a true integration across scientific disciplines, economic sectors and stakeholder groups. Moreover, it requires participation at all levels, including citizens (Kabat and Vellinga, 2005). In this process, special attention must be given to the communication of the potential impacts and the acceptance of the proposed measures by the different stakeholders.
4 CONCLUSIONS

The impacts of our changing climate are still coupled with a high level of uncertainty. Regardless of the effects elsewhere, the effects may be important for any individual country in the world. It is, however, important to recognize that vulnerability to climate change differs greatly across space, people and sectors and is dynamic over time.

Despite the fact that the expected effects of climate change on Belgium may be relatively ‘limited’, they will be considerable. The unequal distribution of impacts across social groups, locations and economic activities only adds to the importance of the issue. Given the nature and magnitude of the expected effects adaptation really does make sense. The rationale behind the need for adaptation is as well economical as social and ecological.

Adaptation to climate is nothing new. Throughout history, people have always tried to adapt their systems to changing conditions. Adaptation is about reducing the negative impacts and increasing the benefits. To a certain extend adaptation occurs spontaneously. However, even with important reductions in greenhouse gas emissions the expected evolutions in rainfall amounts and intensities, temperatures and sea level rise will persist for quite some time. Hence, the development of planned adaptation strategies to deal with the risk of climate change becomes a necessity.

The increased risks from climate imply considered decisions from society. Given the complexity of the issue this requires a proper assessment of the economic, social and ecological costs and benefits of possible adaptation options.

To this end, there is a need to first identify the most important effects of climate change for Belgium. A timely response can help to minimize the potential costs of these effects which are disproportionately faced by the most vulnerable sectors and ultimately by society as a whole. To this end the development of a decision tool, based on an integrated assessment of the cost and benefits of adaptation measures, is an important action.

In the light of the importance of climate change induced flooding in Belgium we propose flooding in the main two Belgian river basins as a case study. Given the clear impact of climate change on flooding and the existence of a series of possible adaptation measures, the subject of flooding is an interesting field to develop a methodology to guide decision on adaptation measures.
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