EVALUATION OF THE SOCIO-ECONOMIC IMPACT OF CLIMATE CHANGE IN BELGIUM

STUDY COMMISSIONED BY THE NATIONAL CLIMATE COMMISSION

Summary for Policymakers

Koen De Ridder[1], Koen Couderé[2], Mathieu Depoorter[3], Inge Liekens[1], Xavier Pourria[3], David Steinmetz[3], Eline Vanuytrecht[1], Katelijne Verhaegen[2], Hendrik Wouters[1]

[1] VITO

[2] KENTER

[3] ECORES

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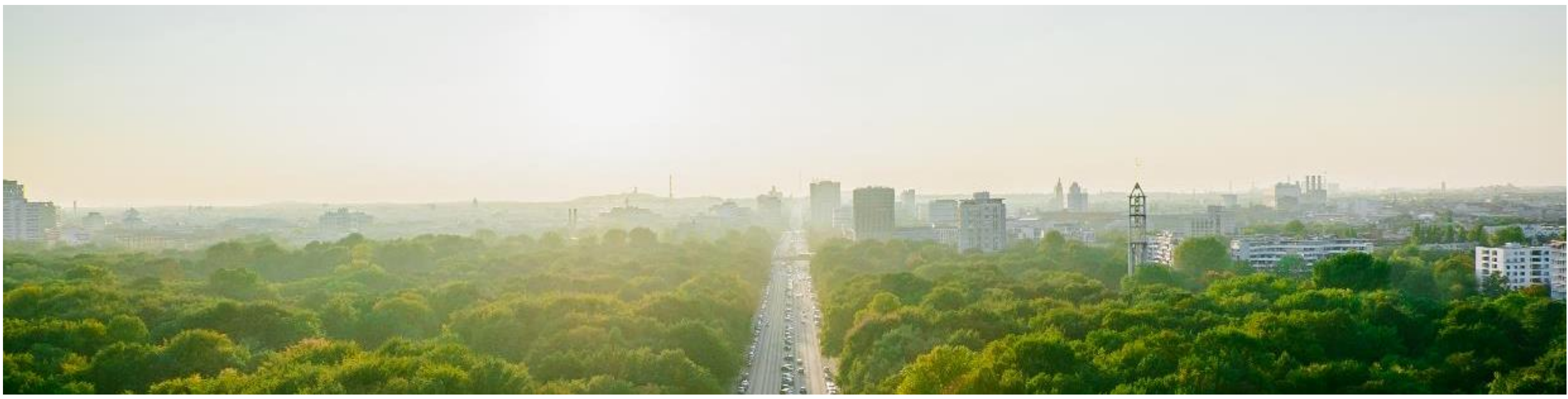

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INTRODUCTION

Today, the average global temperature has increased by more than 1°C compared to pre-industrial values. Over the same period, atmospheric CO_2 concentrations have risen from 280 to more than 400 ppm. At the current pace of emissions, the carbon budget that is left to stay below the 2°C target of the Paris Agreement will be depleted in a few tens of years. For the 1.5°C target, this budget will be exhausted before the decade is out.

At the same time, the impacts of climate change are becoming increasingly apparent. In recent years Belgium has experienced persistently mild winters, recurring drought episodes and a succession of hot summers, culminating in the unprecedented temperature extremes recorded during the summer of 2019. These phenomena have already affected agricultural yield, mortality figures and labour productivity loss, among other.

Realising that some level of climate change has become unavoidable, it is now important to direct considerable actions and resources towards adaptation, apart of course from pursuing efforts towards greenhouse gas emission reductions.

To develop relevant and effective adaptation plans and measures, it is of paramount importance to gain insight into the physical climate risk that is expected to affect society throughout different sectors. Moreover, to be able to compare climate risk and the associated damage across sectors, it is useful to quantitatively express damage in a harmonized fashion by expressing it as a monetary value[1].

This *Summary for Policymakers* provides a condensed overview of the socio-economic impact of climate change in Belgium, resulting from a literature-based study conducted between November 2019 and July 2020. It presents the main outcomes of the full report, which interested readers are referred to for a more detailed account, including the literature sources, the approach followed and the detailed results.

Below, first a presentation is given of the main characteristics of climate change scenarios for Belgium in terms of standard climatic indicators such as temperature and precipitation. Subsequently, a brief overview is provided of the main expected impacts of climate change considering several sectors and including economic cost estimates. Finally, the social aspects of climate change impacts are described, and a few concrete cases of such impacts are presented. It is important to realise that climate change impacts were estimated under the assumption of inaction, i.e., not accounting for additional adaptation measures.

CLIMATE SCENARIOS FOR BELGIUM

To the extent possible, the climate scenarios and sectoral impacts described below have been based on the CORDEX.be (euro-cordex.be) high-resolution climate simulations for Belgium, which are themselves based on the Representative Concentration Pathways (RCP) approach used in the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

Compared to the period 1850-1899, average temperature in Uccle has increased by more than 2°C, although a portion of this observed increase can be attributed to an increasing urbanization. Since the 1970's the observed temperature rise has been occurring at an enhanced rate of 0.24°C per decade. Towards the end of the century, compared to the period 1976-2005, temperature is expected to further increase by up to 3°C in winter (hence reducing cold episodes) and 3.6°C in summer, under scenario RCP8.5.

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[1] Monetary estimates are expressed in M€/yr (million euros per year), using English-style notation: a comma separating thousands (e.g., 1,000 meaning one thousand) and a period ('.') as a decimal separator.

Extreme summer temperature maxima are expected to increase more than the average values: at the end of the century and under RCP8.5, the highest daily temperature occurring in a year is expected to increase by 4.1°C, and the maximum value occurring once every five years by 4.6°C, with respect to the 1976-2005 time frame.

With increasing temperatures, heatwaves are occurring increasingly often: while a few decades ago a heatwave occurred once every few years, recently we have been confronted with several heatwaves occurring each year. Detailed projections show that, ***compared to the 1981-2014 baseline period, the number of heatwave days per year is expected to increase from about 1 to almost 27 heatwave days per year for the period 2041-2074 under scenario RCP8.5. In cities, the temperature increment associated with the urban heat island phenomenon pushes the number of heatwave days to 41 per year.*** This urban effect is very important for Belgium, given that most inhabitants live in cities and towns, hence cities weigh in heavily when assessing population exposure to heat (and flooding, see below).

Observations show a small but steady increase in annual precipitation values, annual rainfall currently being higher by 92 mm compared to the start of the measurements in 1833. Precipitation is expected to further increase towards the end of the century. However, climate projections find a clear seasonal dependence in future precipitation amounts, with increasing winter precipitation and reduced summer precipitation. At the end of the century and under RCP8.5 these changes in precipitation are projected to amount to +18% (winter) and –10% (summer).

Moreover, ***it is expected that a considerable share of summer precipitation will fall during intense but short-lived bursts associated with thunderstorms***, which cause a rather limited infiltration of water into the soil, resulting in a lower groundwater table. Conversely, such events generate high overland flow (runoff), which – especially over impermeable urban surfaces – may induce flooding. It is also expected that hailstone size will increase in the future, thus amplifying the damaging effect of these hydrometeors.

As is the case for temperature, for precipitation it is also expected that the increase of extreme values will be larger than that of the average amounts. ***The number of days per year with heavy rainfall (> 20 mm) has increased from an average of 3 in the 1950's to 5-6 today***. The increasing trend for heavy precipitation is expected to continue: ***by the end of the century, under scenario RCP8.5, daily extreme precipitation values occurring only once every five years are expected to increase by 37% in summer and 34% in winter***. Again, as was the case for temperature, the high share of impermeable surfaces in cities will induce enhanced flooding.

In recent years Belgium has been confronted with recurring drought. In particular, ***the past three years (2017-2019) and the spring of 2020 were distinctively dry.*** This trend is expected to continue: summer precipitation amounts are expected to decrease (see above) and ***the number of wet summer days is expected to decrease by 16% towards the end of the century under RCP8.5.*** Moreover, the short-lived and intense character of summer precipitation will generate enhanced runoff, which also constitutes a loss. In addition, higher temperatures induce an enhanced potential evaporation, further depleting the amount of available water. ***It is expected that potential evaporation will increase by about 261 mm/yr towards the end of the century under RCP8.5.*** Reduced rainwater infiltration, combined with higher levels of potential evaporation, will induce more frequent and more severe droughts and a reduction in (ground-)water supply.

Observations from the past 30 years do not show a clear trend in the occurrence of extreme wind speed values in Belgium. Also, projections for the daily average wind speed in Europe do not show a clear trend towards the future. This appears to be also the case for Belgium, although ***it is expected that the wind speed during the most intense storms may increase by up to 30%***.

At Ostend, sea level has risen by 11.5 cm between 1951 and 2013. It is expected that by the end of the century, sea level will additionally rise by 69 cm compared to the period 1991-2010. From these trends, it is expected that the impact of storm surges will increase considerably towards the end of the century.

SECTORAL IMPACTS

HEALTH

In Belgium, as in most temperate climate zones, ***heatwaves claim more victims than any other weather-related disaster. Heatwaves currently cause tens to hundreds of excess deaths per year, especially among the elderly and in people with underlying disease.*** Considerably higher values are observed during exceptional years, such as the year 2003 with its extremely hot summer that led to an estimated excess mortality of between 1200 and 2000.

Future projections of excess mortality yield an estimate of approximately 1900 excess death per year at the end of the century under RCP8.5, i.e., an annual excess mortality with a magnitude at least similar to that experienced in 2003, on average. It should be noted that this figure for excess mortality was obtained under the assumption of no socio-demographic changes (such as, e.g., an increasing population number or a larger share of elderly in the society), but also assuming that no physiological adaptation takes place in the population. ***For mid-century conditions (2050) under a high climate scenario (RCP8.5), excess mortality would reach a figure of 926 per year.***

From national monitoring data it emerges that ***Brussels has a higher relative (per capita) excess mortality than the Flemish and Walloon Regions.*** In general, it is to be expected that, owing to the enhanced exposure to high temperatures (urban heat island effect), together with an enhanced vulnerability profile, mortality should be higher in cities.

Assigning an economic cost to this excess mortality is not straightforward. ***When applying the Value of a Statistical Life (VSL), which is based on the willingness-to-pay concept, one obtains heat related excess mortality costs in the range of 2,600-5,200 M€/yr. For mid-century conditions (2050, RCP8.5), the figure ranges from 1,380 M€/yr to 2,740 M€/yr.*** While these are very high values, they are consistent with international studies in which mortality often constitutes the largest share of sectoral costs. ***Using another approach, based on the concept of Value of a Life Year (VOLY), yields lower values, in the range of 630-1,270 M€/yr by 2100.*** The difference with the VSL-based value clearly illustrates the large uncertainty associated with these estimates.

High ambient temperature also causes illnesses such as heat exhaustion and heat stroke and aggravates several common cardiovascular and pulmonary conditions. A rough estimate yields up to 60,000 additional hospital admissions per year related to heat stress during warm summers in the future. Moreover, heatwave episodes have been linked to mental health issues, including a higher number of mood disorders, attempts to commit suicide, increased aggression and violence. Patients with pre-existing mental disorders are particularly vulnerable.

The economic cost of heat-related morbidity was estimated based on excess hospital admissions, together with typical hospital stay costs, yielding a value between 95 M€/yr and 188 M€/yr. This estimate does not include the impact on the wider economy by its effect on labour productivity loss, which is dealt with below.

Exposure to cold can lead to direct effects such as hypothermia, or indirect pathologies such as cardiovascular disorders or respiratory infections. While global climate change leads to hotter summers, it also leads to milder winters. As a result, ***it is expected that wintertime mortality and morbidity, which currently are much higher than summertime mortality and morbidity, will decrease.*** However, international studies conclude that, with climate change, the reduction of deaths from winter cold will be compensated by the rise in heat-related mortality during the second half of the century. Related to this, we find that, towards the ened of the century, ***the avoided cold-related health cost, when applying the VSL approach as above for heat, reaches a***

very similar value of 2,600-5,200 M€/yr of cost reduction thanks to milder winters. For mid-century conditions, the figure is 1,760 M€/yr to 3,510 M€/yr.

Climate change also induces other health related impacts, including vector-borne disease, food/water contamination, and an increasing incidence of allergenic disease. These aspects have not been included as, with the current knowledge, they are difficult to estimate.

LABOUR PRODUCTIVITY

High temperatures and heatwaves adversely affect labour productivity. While this is particularly the case for outdoor work (e.g., agriculture, construction), indoor (e.g., office) work is also impacted. This is important in a country like Belgium where the 'services' sector – a large portion of which relies on indoor work – constitutes the single largest sector in the national economy.

Based on urban climate simulations, ***certain areas in Brussels experienced up to 11% of working hours potentially lost under the conditions of the hot summer of 2003 and considering the 'heavy work' (outdoor) category.*** Here also, the urban heat island phenomenon plays an important role by adversely affecting heatwave intensity.

Extrapolating from a study conducted for the Antwerp area, it is found that, ***considering all sectors, labour productivity loss in the period 2081-2100 (RCP8.5) is expected to cost Belgium 610 M€/yr during the coolest year in this period, and 9,000 M€/yr during the warmest year***. For the middle of the century, the cost ranges from 170 M€/yr to 4,960 M€/yr.

An independent estimate, using data from a European study, yields a comparable range of labour productivity loss values of 865-7,970 M€/yr at the end of the century (RCP8.5). Hence, while there obviously is a large uncertainty (range of values) associated with these estimates, they appear rather robust, suggesting that the risk of heat related economic production loss in Belgium is to be taken seriously.

The productivity <u>gain</u> caused by warmer winter temperatures, under RCP8.5 at the end of the century, is estimated to range between 232 M€/yr and 364 M€/yr. In 2050, the range is 116-182 M€/yr. These figures, established using estimates of the effect of winter warming on absenteeism, are much lower than the projected heat related productivity losses presented above, although all labour productivity estimates (both heat and cold related) are fraught with a considerable level of uncertainty.

INFRASTRUCTURE (FLOODING)

Average damage costs in case of significant inundations have varied in the past between 40 and 75 M€/yr. In Flanders, ***reported damages due to inundations amounted to about 48 M€/yr in the period 2011-2019***. Of course, these costs are not evenly distributed over time.

Based on international studies, the future ***annual cost of fluvial (river) flooding in 2050 (RCP8.5) in Belgium is estimated to be situated somewhere between 134 M€/yr and 290 M€/yr***.

Larger costs are associated with coastal (including estuarine) flooding. For 2050, there seems to be a reasonably good correspondence between different studies, suggesting ***an additional expected annual damage cost associated with coastal flooding of approximately 200 M€/yr to 650 M€/yr***. For 2100, all studies indicate a sharp increase in damages. This may be due to the fact that sea level rise (and its impacts) are not linear; existing coastal defences may be overwhelmed somewhere after the year 2050. Taking a conservative stance, and accounting for adaptation measures that have already been decided (but not fully executed), towards the end of the century ***cost levels are found to be in the range of 2,400 M€/yr to 5,300 M€/yr.***

Simply adding up the figures for fluvial and coastal floods ***the expected total annual damage due to flooding in Belgium ranges between 343 M€/yr and 940 M€/yr in 2050 and between 2,534 M€/yr and 5,590 M€/yr in 2100***. Differences between the 2050 and 2100 figures are exclusively due to sea level rise, but are subject to major uncertainties. An important caveat is that these figures do not account for pluvial flooding (flash floods), which in Belgium may be an important damage factor.

Moreover, the above figures do not include the costs of indirect impacts, related to, e.g., service disruption or delays. Studies conducted abroad appear to suggest that this could induce a doubling of the economic costs, depending on the sector affected.

INFRASTRUCTURE (DROUGHT/HEAT)

Drought affects the navigability and traffic on waterways, hence affects inland shipping. In the Netherlands and Germany, ***costs associated with the impact of the exceptionally dry summer of 2018 on inland shipping, including costs related to delays or non-delivery, have been estimated to amount to several hundred millions of euros***. Moreover, drought can affect roads by inducing damage caused by the cracking of pavements when soil moisture underneath the pavement evolves towards a new regime.

Heat is also known to affect infrastructure, leading to impacts such as the buckling of railway tracks, melting of asphalt, and damage to the electricity network (e.g., through overheated transformator units). The direct damage costs associated with such effects appear to be rather modest in comparison with the effects of flooding. However, indirect costs of heat are expected to be much higher. Based on information from a recent heatwave in Australia, and assessing that this heatwave is representative for conditions in Belgium towards 2050 (under RCP8.5), ***indirect heat-related costs involving infrastructure (e.g., service disruption, delays) amounting to 153-766 M€/yr are found***.

ENERGY

For energy, the RCP8.5 scenario is combined with a business-as-usual scenario regarding future energy provision established for Belgium.

With respect to ***centralized production of electricity in power plants, drought and higher temperatures are expected to lead to an extra production cost of 44 M€/yr by 2050***. The impact of climate change will also induce a ***cost related to a reduced transport and distribution efficiency, which is expected to amount to 91 M€/yr***.

The costs are less for decentralised (renewable) production. ***Hydropower, which suffers from reduced river flow rates because of enhanced drought conditions will incur a cost (reduced production) of 2 M€/yr***. In the case of ***solar energy, given that photovoltaic panels become less efficient at higher temperature, there is an estimated production loss of 17 M€/yr.***

The largest economic impacts are found in the field of energy demand. It is expected that milder winters will induce a ***reduced heating demand, resulting in an avoided energy cost for an amount of 220 M€/yr***. Conversely, ***hotter summers will induce an increased demand for cooling energy, by an amount of 88 M€/yr***.

Overall, there is a large tendency for these cost (and gain) figures to compensate, mainly because of the reduced heating demand in winter. Adding up all amounts of the individual impacts described above yields a ***net cost of 22 M€/yr***.

AGRICULTURE

The recurring drought and heatwaves observed in recent years are already taking their toll. For instance, in the Flemish Region, ***the drought and heatwave episodes of 2018 led to a reduction in production volume by 31% for potatoes, 13% for sugar beet, and 10% for cereals***, following which claims amounting to 150 M€ were submitted to the Flemish Disaster Fund.

Climate change is expected to induce a range of (sometimes opposite) effects. On the one hand, crops can benefit from CO_2 fertilization due to increased atmospheric concentrations to increase their productivity; and higher average temperatures will lengthen the potential growing season.

On the other hand, extended drought periods, crop sunburn, lethal temperatures, flash floods and hailstorms will cause damage. Moreover, persistent high temperatures and drought are expected to reduce livestock productivity through negative impacts on grassland yield and animal health.

By 2050, under scenario RCP8.5, the combined effects of climatic changes (altered rainfall, soil water availability and temperature) and atmospheric CO_2 concentration on mean crop productivity in our country could yield gains up to 10-20% as compared to 1981-2010, that is, if the CO_2 fertilisation effect can manifest itself under optimal fertility conditions. Crops like maize benefit much less from the CO_2 fertilization effect, since this crop functions already with maximal efficiency at current CO_2 levels.

At the same time, interannual yield variability caused by extreme weather events, and the associated risks for farmers, will also increase in the future. Even though the mean productivity may increase, farmers will face years with difficult conditions and see their production and income fall. ***By 2050, in years with unfavourable weather conditions, crop yields could drop well below recently (1981-2010) observed minimum levels (decrease by 35%), especially for potato and maize. For poultry, cattle and pig production, production losses up to 2-5% are likely.***

Taking all the above into account, ***by 2050, under scenario RCP8.5, the total agricultural (plant and animal) production value change compared to 2019 is expected to range between***

- ***an increase by 45 M€/yr, which is mainly related to the CO_2 fertilization effect, and***
- ***a decrease by 606 M€/yr when accounting for climate-related land loss (e.g., through salinization, erosion, flooding) and when accounting for climate-related price reductions on the international market.***

Towards the end of the century, especially under scenario RCP8.5, it is expected that the adverse effects of climate change will outweigh the beneficial impact of CO_2 fertilisation and lengthened growing season, yielding a net negative impact even when not accounting for land loss and/or price changes.

FORESTRY

Drought adversely affects growth rates in forests, causing forest stands to be harvested before they reach optimal maturity. ***The effect of this for beech (Fagus sylvatica), spruce (Picea abies) and oak (Quercus robur) is estimated to cause a yield loss in Belgium of 76.7 M€/yr towards the middle of the century (2041-2070) under scenario RCP8.5.***

In addition, drought together with mild winters and heatwaves predisposes trees to attack by bark beetle (*Ips typographus*). Given that favourable climatic conditions were met in the years 2018-2019, bark beetle has been breeding rapidly and abundantly, causing 1.6 million m^3 wood to be cut and taken out to avoid further spreading. ***The cost of bark beetle-related wood loss and quality reduction is estimated to amount to 64 M€/yr.***

Drought also leads to enhanced forest fire risk. The Fire Weather Index (FWI), which is used to estimate this risk, currently (1981-2010) exhibits a value of around 10-15 for Belgium. ***The FWI is expected to increase by 30-40% (and more than 40% in the Belgian Ardennes) towards 2071-2100 under RCP6.0.*** Associated to this increase, and considering the value of forest stands together with replantation costs, ***fire related logging losses and costs are expected to amount to 14.3 M€/yr under RCP8.5 by 2071-2100***, and half that amount by 2050. As to the impact of extreme winds, ***it is expected that logging by storm winds will cause damage costs amounting to 2.2 M€/yr.***

It should be noted that, apart from wood production, forests also provide several other ecosystem services such as recreation, water filtration and carbon sequestration, which in the scientific literature have been estimated to carry up to a tenfold monetary value per hectare compared to the value of sole wood production. Such aspects will be dealt with in the ‘ecosystem services’ section.

ECOSYSTEM SERVICES

Healthy ecosystems play an important role in carbon sequestration, i.e., the capturing and storing carbon from the atmosphere. In fact, currently around 50% of global anthropogenic CO_2 emissions are absorbed by the terrestrial biosphere, which puts a strong brake on global warming. It is estimated that in Belgium, by 2050 and under climate scenario RCP8.5, ***the monetary loss associated with the reduced functioning of carbon storage in ecosystem soils may amount to 172 M€/yr***, representing a decrease in avoided CO_2 emission reduction cost.

Degraded ecosystems and reduced functioning will induce ***a loss of 67.7 M€/yr owing to a reduced capacity to filter fine pollutant particles*** from the atmosphere. Moreover, ***recreational and health value of ecosystems in Belgium are expected to decrease by 27.7 M€/yr and 122.5 M€/yr, respectively***. The ecosystem service of ***pollination is expected to decrease by 23.7 M€/yr***.

Finally, the services delivered by freshwater ecosystems are numerous and include enhanced water quality, flood control and water supply. ***Freshwater ecosystem service delivery is expected to decrease by 695 M€/yr***.

Taken together, with climate change, the reduced functioning of ecosystem services and their capacity to deliver benefits is expected to induce an ***overall cost of 1,108 M€/yr***, which represents the monetary cost related to the non-delivery of these services. It should be noted, though, that the uncertainty associated with these numbers is extremely large, and that they do not include the complete ecosystem value.

INSURANCE

Floods, windstorms, hail and drought are the main climate related hazards affecting the insurance sector in Belgium.

In the period 2011-2019, weather-related insurance claims on average amounted to ***172 M€/yr for storms*** (winter storms as well as summer thunderstorms including with hail) and ***48 M€/yr for flooding***, or 220 M€/yr for the two categories combined. A striking aspect is the very high inter-annual variability in the amounts claimed. Little information is available to estimate future values for these cost categories, but information from a study conducted in the UK suggest ***a doubling towards 2050, hence an increase by 220 M€/yr***.

The costs associated with extreme hail events (e.g., car coach work dented, damaged greenhouses in the horticultural sector) rank among the highest costs in the sector, the year 2014 standing out with more than 500 M€ costs largely associated with the Pentecost hail storm. Based on a study conducted in the Netherlands, ***it is expected that by 2050 under the RCP8.5 scenario, hail related car damage claims will increase by 33%, and claims related to damaged greenhouses by 219%***.

Climate change raises concerns regarding the affordability of insurance in the future. Moreover, climate-related risk is increasingly seen as a potential threat to the insurance sector. The largest risk may reside in the inherent unsteadiness and variability (and unpredictability) of extreme weather.

TRANSBOUNDARY IMPACTS

Climate impacts in a temperate country like Belgium are rather modest compared to the impacts expected in Southern Europe and in many tropical countries. However, the export from such countries, which is expected to substantially decline with global warming, may affect foreign trade, hence indirectly affect the Belgian economy. From recent studies it arises that ***climate change related import reductions from outside Europe may induce a GDP decrease in Belgium by an amount in the range of 1,000-2,200 M€/yr***.

Moreover, it is expected that in developing countries, climate change may trigger large migration streams, caused by agricultural drought and sea level rise, but also caused by the increasing occurrence of deadly heat waves.

SOCIAL ASPECTS

Climate change impacts do not affect all citizens in the same way. ***Extreme events like flooding from heavy rainfall or urban heat often cause worse impacts on certain vulnerable groups, such as those suffering from poor health, low income, inadequate housing, or lack of mobility***.

Poor social networks are identified as an important factor increasing vulnerability, as isolated people are less likely to receive information and help. Social isolation increases the risk of death as a result of extreme weather events such as heatwaves. In addition, the physical characteristics of urban neighbourhoods can affect the extent to which people are impacted by a flood or heat wave event or experience other forms of climate impacts.

There is a very strong common spatial component to vulnerability and hazard. For instance, for the city of Gent, the spatial distribution of the number of people receiving a basic income allowance matches very strongly with parameters of heat stress, as poverty is concentrated in many of those city sectors that are also characterised by intense summer heat. Since the physical and social structure of many cities in Belgium are comparable to the situation in Ghent, one can expect that the relations between socio-spatial vulnerability and climate impacts will be applicable on a wider scale within Belgium.

Another interesting insight arises from relating the share of population living in a dwelling not comfortably cool during summertime to income. From this comparison it emerges that in Belgium, the lowest 20% income category is 1.5-2 times as likely to live in an uncomfortably warm house, compared to higher income categories.

When costs of basic amenities such as food or energy (heating/cooling) change as a result of climate change, impacts on low income households will be much larger because they spend a larger proportion of average household expenditure on such amenities. For food an increase in prices is expected towards the middle of the century, through the adverse impact of climate change across the globe on international food prices. With respect to energy: while it is expected that wintertime heating demand will decrease (hence become less costly) summertime cooling requirements will increase rather strongly. This will exacerbate social inequity between those who can and cannot afford cooling apparatus and its energy cost, especially as the less well off, on average, already occupy uncomfortably warm houses, as mentioned above.

Given that, overall, the physical impacts of climate change are expected to induce economic damage, one would expect a (relative) loss of employment opportunities, affecting the less well-off segments of society more. Yet, this is to be balanced by considering that European and Belgian climate action (mitigation and adaptation) policies are expected to bring substantial positive effects to employment.

EXAMPLE CASES

While the macroscale economic overview based on large sectoral groups constitutes relevant input for policymaking, it is instructive also to focus a little closer on a few specific sub-sectors. Below, an overview is provided of climate change impacts to the sectors of French fries production and beer brewing, both highly iconic for Belgium.

Regarding French fries: 88% of Belgians eat them at least once a week. Belgium is also the largest exporter of pre-cooked frozen potato products, with exports to more than 150 countries. The increasing impact of drought on potato cultivation is the main concern for the French fries industry, the drought episode occurring in 2018 having caused a potato shortage and subsequent price increase by 23%. The industry is now reacting by shifting towards potato varieties that are more resistant to heat and water stress. The processing and storage of potato fries is also affected by climate change. The processing requires copious amounts of water, which may become a problem given the adverse impact of climate change on freshwater resources. Increasing temperatures will increase the cooling temperature energy requirements for storage.

Beer brewing is vulnerable to climate change through the impact on the ingredients. As for fries, drought is a problem. One of the main ingredients, barley, is primarily (97.53%) imported, hence depends on climate conditions and impacts in the source regions. An international study has found that drought and heat related yield declines in barley-growing regions worldwide may lead to an average world loss in barley production estimated between 3% (RCP2.6) to 17% (RCP8.5). Belgium would figure among the countries most hit by the supply decrease, with reductions of several tens of percent, and with beer production falling by 10 % (RCP2.6) to 40% (RCP8.5). As to hop, another beer ingredient, climate change is also expected to affect supply levels, with a decrease of the order of 7-10%. As for fries, the availability and quality of drinking water in the production process is an issue. Storage is also expected to experience the adverse effects of climate change, as electricity consumption for chilling power will rise due to higher summer temperature. Finally, Lambic brewers are confronted with a climate related challenge at a wholly different level. The brewing process being critically dependent on ambient temperature, Lambic producers are now facing a decline in the length of the producing season by more than 10%. The traditional Lambic beer production was the unique way to brew since ancient times, until the early twentieth century. The loss of the few traditional Lambic brewers left in Belgium today as a result of climate change has perhaps little economical weight, but would certainly put a blow to Belgium's unique beer heritage and tradition.

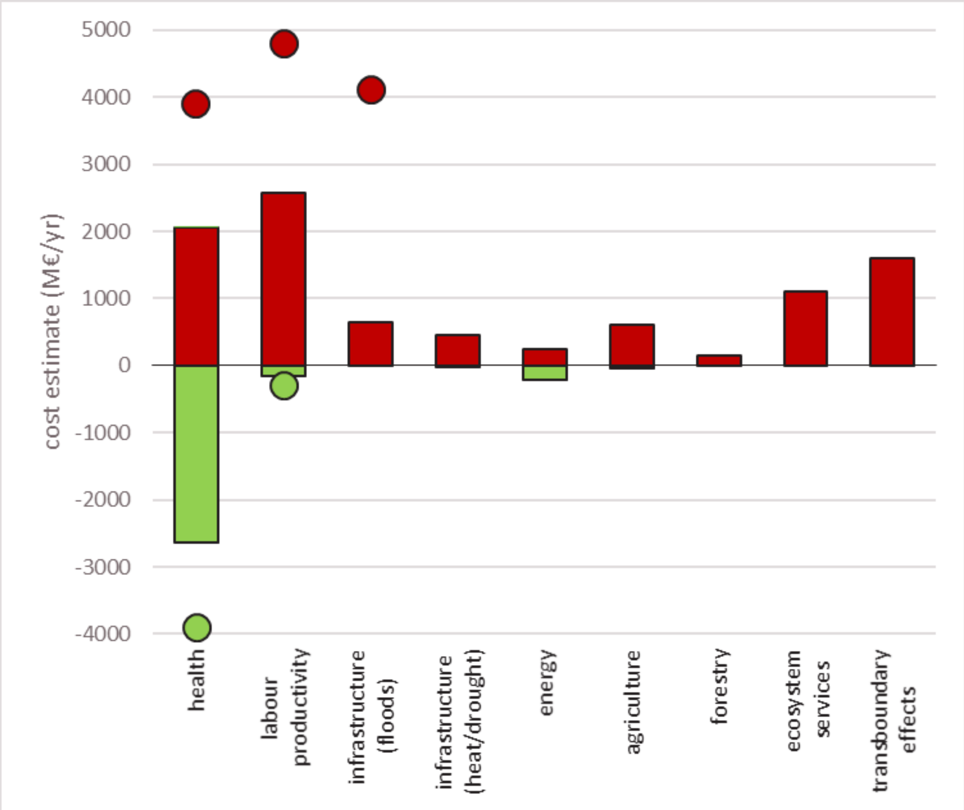
CONCLUSIONS

In Belgium, climate change is expected to induce ***hotter and dryer summers and milder and wetter winters***. ***Heatwaves, flooding and drought*** appear to constitute the main share of climate hazard. ***Vulnerability to these hazards in Belgium is enhanced given the large proportion of urban areas***, which exacerbate the adverse effects of heating (urban heat island effect) and flooding (impermeable surfaces). It is expected that ***groups within society that already today exhibit vulnerability (people with poor health, low income, or inadequate housing), are often also the most vulnerable to climate change effects***.

Climate change is also expected to affect a large number of economic sectors in Belgium, inducing large costs but sometimes also gains, the figures ranging from several hundreds to thousands of M€/yr, as shown in the figure below. In 2050 and under scenario RCP8.5, ***the total costs, which are mainly caused by extreme heat, drought and flooding, amount to nearly 9,500 M€/yr***, which is approximately 2% of the Belgian GDP. Conversely, ***the gains, which are associated with milder winters, approximately reach 3,000 M€/yr***, or 0.65% of the GDP. While the picture is incomplete, ***towards the end of the century the sectors representing the largest costs show a trend of a stronger increase in the costs than in the gains of climate change***.

It should be noted that the high share of heat-related labour productivity loss in the total economic costs constitutes a somewhat unexpected result. It is wholly related to the inclusion of the services sector in the assessment. Indeed, while often this sector not accounted for and while the impact of heat on the services sector is less important than on sectors based on outdoor work (agriculture, construction), the high share of the services sector in the national GDP more than compensates for this lesser climatic sensitivity.

To put these cost figures into perspective, it is enlightening to compare them – just by way of example – to (perhaps) more familiar costs, such as the annual budget of the Federal Public Service of Justice in 2019 (1,950 M€), the burden of COVID-19 measures on the budget of the Walloon Region in the spring of 2020 (1,800 M€), the annual budget of the Flemish Region for Mobility and Public Works in 2019 (4,100 M€), or the cost of 3,800 M€ for the purchase of 34 fighter jets F-35.



Estimated economic costs (red) and gains (green) of climate change per sector, as compared to present-day conditions, considering climate scenario RCP8.5 and the year 2050 (stacks) and 2100 (dots). The numbers contained in this figure represent average values of the cost ranges provided in the main text. Note that the health costs pertain to heat/cold impacts only.

It is important to realise that the figures and cost estimates presented above are not forecasts; instead they constitute scenarios and projections. Also, as mentioned before, they represent the costs incurred in the absence of any additional climate adaptation measures.

Finally, it should be realised that the cost estimates are characterised by a high level of uncertainty, related to the uncertainty on the climate information itself, the assumptions to assess the physical impacts of the changing climate and the unit economic cost assigned to this damage. Nevertheless, at the time of writing the impacts and cost estimates presented above constitute the most complete and detailed overview of the socio-economic impact of climate change in Belgium, thus constituting a firm basis to inform future climate policy and actions.