The Impact of Climate Change on Austria: An Economic Assessment of all Sectors and Cross-Sectoral Interactions

Framework and main results of the COIN research project

The framework

The interdisciplinary COIN project (COst of INaction – Assessing Costs of Climate Change for Austria) assesses the economic impacts of climate change on Austria. For this purpose, the project conducts a scenario-based analysis of possible climate change impacts in combination with socio-economic developments for and across twelve key sectors. Scenarios are plausible alternative future situations, and their analysis permits to assess critical constellations as well as the range of positive and negative impacts. The main scenario applied in COIN assumes global warming below 2 degrees for the pre-industrial to 2050 period. This assumption presupposes stronger climate policies than the ones currently in place. The analyses represented here already take into consideration the individual adapting and, importantly, they are restricted to that part of all possible impacts which is already quantifiable. Further research is warranted, especially regarding the impacts not yet quantifiable by current research.

The interdisciplinary approach

In order to consistently assess the economic impact of climate change on and across all sectors under scrutiny, and thus allowing for reasonable comparisons, the COIN project combined the efforts of 42 researches in 18 Austrian and European research groups who collaborated for about one year. Research was carried out under the auspices of climate economics in research cooperation with agricultural economics, forestry, health economics, tourism research, transport sciences, biology, energy economics, production economics, urban planning, risk research, and meteorology. The results have been audited by an international scientific advisory board headed by Paul Watkiss (University of Oxford) and underwent two review processes by 38 international reviewers; the accordingly improved findings have been published as

Steininger, K., König, M., Bednar-Friedl, B., Kranzl, L., Loibl, W., Prettenthaler, F. (eds.), Economic Evaluation of Climate Change Impacts: Development of a Cross-Sectoral Framework and Results for Austria, Springer, 2015.

What has been assessed?

The Austrian Strategy for Adaptation to Climate Change (BMLFUW, 2012) divides the areas of climate change impact into fields of action. The COIN project has adopted this structure and thus investigates climate change impacts on agriculture, forestry, water management, tourism, energy management, heating and cooling (of buildings), human health, ecosystems and biodiversity, transport infrastructure, manufacturing and trade, cities and spatial planning, as well as natural hazards and natural disaster management (the last two fields are treated separately in BMLFUW [2012] but have been subsumed into one respective field in COIN). **The project has identified the–in economic terms–relevant impact chains for each field and has conducted a quantitative evaluation (i.e., in Euros) of those impact chains where quantitative models are already available.**

What has not been assessed?

On a global level, climate change will have a range of impacts, many of which will reverberate on Austria. For example, it is expected that in some regions climate change will lead to an increase in agricultural yields by mid-century, yet that on a global level the overall yields will decrease significantly (IPCC, 2014a). Such climate-related change in crop yields can result in rising world market prices and ensuing import dependencies, which could ultimately result in food shortage. Further predictions are that climate change impacts will lead to increased poverty in most developing countries and that new poor segments will arise in highly unequal societies (IPCC, 2014a). This could in particular increase the already commencing flow of African refugees into Europe (and thus into Austria). As global climate change impacts and their effects on Austria are highly complex, and due to the relatively short project duration, these impacts were disregarded in the COIN study. **The project has only investigated climate change impacts on Austria which also originate in Austria.**

To what extent can trends and extreme events be evaluated?

The current state of knowledge, recently outlined in IPCC (2013, 2014a), allows for a reliable assessment of trend developments for Europe and Austria, which show that on a regional scale the remaining uncertainties in temperature change are significantly smaller than those in precipitation change. Conversely, it is much harder to derive reliable findings regarding the development and intensity of future extreme events based on climate scenarios; in this context, statements concerning extreme events of a large spatial/temporal scale (e.g., droughts or heat waves) are more reliable than statements regarding small-scale shorttermed events such as convective extreme events (including thunderstorms or hail storms as well as their respective consequences, i.e., mud- and landslides). Convective extreme events are nonetheless also highly relevant in terms of damages. Based on current state of knowledge, the COIN project has thus been able **to evaluate impact chains triggered by trend developments** (e.g., higher temperatures or regional and seasonal decrease in precipitation sums). Concerning the impact of extreme events, COIN has only been able to analyze a limited number of selected areas: agricultural droughts, damages to building stock as a result of large-scale multi-day flood events, and health impacts due to heat waves. However, when societal decisions on climate change mitigation (reducing emissions, adapting to ongoing climate change) are concerned, not only average (trend) developments are of relevance, but also, and especially so, events which do not occur every year but have even stronger impacts when they do occur. In this context, further research is especially warranted.

What are central findings in the individual fields?

Potential average Austrian crop yields ***in agriculture*** will rise for the Austrian average (mostly due to temperature-related contexts such as longer growing periods, but also due to the CO_2 fertilisation effect); this will hold true at least until mid-century. However, especially (periods of) extreme weather events, increasing investment expenditures (e.g., for irrigation), and disruptions of ecosystem services (the project investigated the pollination performance of insects and biological pest control) tend to offset (partially or fully) such a crop yield increase. The agricultural sector would benefit less from the (uncertain) potential increase in yield than the food and retail sectors.

In ***forestry*** with its long rotation periods, prolonged vegetation periods do not result in increased productivity, as bark beetle calamities will increase in warmer summers. An additional impact of droughts, especially in the southern and eastern parts of Austria, and higher peak wind speeds during gales could negatively impact forest growth, if no targeted adaptation measures are taken. Preserving the functions of protective forests would require investments that exceed the losses in productivity.

The climate has a strong impact on ***ecosystem services***. Research into determining thresholds, the crossing of which greatly reduce ecosystem services, has only just started. Protection from erosion, the pollutant buffer capacities of soil and vegetation, and the supply of drinking water are – in economic terms – highly relevant ecosystem services. The only agricultural services that COIN has investigated were insect pollination as well as biological pest control. These results were taken into consideration as explained earlier for agriculture.

Human health: More frequent and intense heat waves will increase the number of deaths in the growing share of the elderly (approx. 1.000 additional average annual deaths in the 2036–2065 period). More extreme years, where the group of those vulnerable is extended to include the chronically ill, could result in a six-fold increase in health impacts compared to the mid-range assumptions above.

In the area of ***water supply and sanitation management*** it has, likewise, only been possible to quantify the impact chains in part. Here it becomes evident that for a mid-century year the already significant additional capital expenditures would increase by at least another 10 % due to climate change (the added increase amounting to at least € 170 mn aggregated up to 2050).

Floods already pose one of the biggest climate- and/or weather-related economic risks in Austria. Climate change poses an additional challenge for ***disaster management***, especially as regards reducing vulnerability. However, since extreme events are always deviations from standard weather patterns, forecast uncertainties are naturally high. While average annual flood damages amounted to approx. € 200 mn during the 1981–2010 period, the forecast for annual damage-related losses for the 2036–2065 period ranges between € 400 mn and € 1,800 mn. Compared to the 1977–2006 period, damage-related losses from 100-year flood events are estimated to roughly double for the 2036–2065 period as a result of climate change and increases in wealth. Hence, such events could cause damages of € 4 to € 7 billion (at current prices).

Already, precipitation-induced mass movements and washouts cause considerable damages to ***transport infrastructures*** (€ 18 mn p.a. for road infrastructure), and in future the extent of these damages will be directly linked to how road and transportation networks develop. Traffic network exposure will increase according to respective network expansions, and regionally varying dispositions towards damage events (e.g., mudslide, washout, and windthrow hazards, or proneness to landslides) have to be considered. The indirect consequences of traffic interruptions (production and time losses) can exceed the direct repair and maintenance costs by far, depending on the duration of interruptions and on detour options.

As regards energy consumption in the context of ***buildings***, fossil fuel savings during the heating periods will outweigh additional (electrical) energy demands during cooling seasons by mid-century. However, the widening gap between (the in Austria mainly hydropower-based) ***electricity generating capacity*** in summer and a concurrent increase in cooling energy demands proves critical. New summer peak demands for electricity thus coincide with limited production volumes during summer drought periods, which have to be balanced by imports and alternative power plant capacities, respectively. Imports (especially by southern EU countries) cause additional burdens for the European electricity grid and strongly increase the risk of highly expensive blackouts.

Climate change impacts on the ***manufacturing and trade*** sector are very diverse and range from changing requirements for cooling and cold chains during production and transport to extreme events impacting on the transport network, which is, inter alia, essential in the context of intermediate inputs for production. Losses in labour productivity due to increasing periods of heat were consistently evaluated across all branches of the manufacturing and trade sector: up until mid-century, annual losses for the manufacturing and trade sector alone will reach € 140 mn.

In ***urban areas***, climate change will intensify the impact of urban heat islands (due to buildings, sealed areas, and a lack of cooling vegetation cities are several degrees warmer than the surrounding rural areas).

As far as ***tourism*** is concerned, especially summer tourism will benefit from rising temperatures and precipitation decrease, which, at the same time, have a negative impact on winter tourism in its current form. The forecasted annual decrease in winter overnight stays of 1.5 million by far exceeds the gains in summer tourism. This net drop in demand alone leads to direct average annual losses of approx. € 300 mn. In addition, there are macroeconomic consequences (see the following section), changes in the sector's cost structure (e.g., irrigation costs, demand for artificial snow, airconditioning systems, etc.), and impacts of increased extreme weather events.

What will be the repercussions on the overall national economy?

While there have already been (mostly regionspecific) investigations into individual sectors in Austria, COIN's focus is on a nation-wide assessment of all sectors. In addition, the ***consistent determination of the respective impacts on the overall national economy*** is a key added value of the project. Thus it is, for instance, that as a result of the interdependencies between the sectors productivity losses in the manufacturing and trade sector caused by an increase in heat waves lead to four times higher economic losses at the national level. This **overall economic »magnification effect« of damages in individual sectors** ranges between 60 % (macro-economic impact of tourism losses from decreasing overnight stays) and the aforementioned quadruplication. COIN is the first project to present such a comprehensive assessment. Also, it is only possible to make reliable statements on the impacts on public and private budgets, as COIN has done for all sectors, when considering these overall economic feedback effects.

How is the overall economic impact measured?

The example of flood damages makes readily apparent that the gross national product (GNP) may decrease due to production outages, but that, on the other hand, it will re-increase due to reconstruction demand. (Climate-related) extreme events often cause at least a short-term GNP increase, while losses in capital stock will impact the GNP only in the long-term context. If we are interested in the Austrian population's »wellbeing«, we thus need to focus on **an indicator** which does **not classify the replacement of pre-existing stocks and assets (damaged by climate change) as welfare increase**. In addition to the GNP changes, the COIN project has therefore also determined a welfare indicator adjusted for this effect. **Developments regarding the GNP and the welfare indicator differ in magnitude**, and **in some cases** (such as flood damages) they **even develop in opposing directions**. Due to lack of appropriate data and methods, non-market related consequential damages were mainly disregarded; expenditures to cover flood-related psychological consequences, such as distress due the loss of memorabilia, have thus, for instance, not been considered.

How can the results be put to use?

The highly detailed analysis of the impact chains and the consistent assessment of potential damages to all areas (directly to the individual sectors, to the overall economy, to public budgets) provide **useful orientation knowledge for the further development of the climate change adaptation strategy**. On this basis, priorities can now be set, and more specific directions for action can be developed as an essential input to its further development.

What is the range of total damage costs?

Global warming can already be observed, and the average annual temperature in Austria has risen by almost 2 °C since 1880. Thus, in Austria weather- and climate-related **damages already** amount to an **annual** average of approx. **€ 1 billion** (see Table 1). This figure only takes into account major natural disasters and heat-related premature deaths. Damages of this and similar nature will further increase, especially if no measures are taken towards significantly reducing emissions. The COIN project shows that (under a moderate climate change scenario, **up until mid-century**) social damages will increase to the average annual level of **€ 4.2 to € 5.2 billion** (current price level; see Table 1).

Moreover, the COIN project has investigated alternative climate and socio-economic scenarios, whose consistent application across all sectors also provides the means of assessing **wider and narrower damage areas**. Accordingly, it can be expected that by mid-century the already quantifiable **total damages** (across all sectors mentioned above, from agriculture to forestry and tourism) will on **average range at € 3.8 to € 8.8 billion p.a.** (see Table 1). With regard to these figures, several aspects ought to be noted: they only apply to the above described part of impact chains which can already be reliably **assessed** in **monetary terms** and originate in Austria (see Table 2); the figures do not reflect any feedback effects of global impacts on Austria; regarding extreme events, only (the average) flood damages to building stock are considered. Thus all damages from climate change impacts which are not yet included in these quantifications need to be added (see Table 3 for the most important impact chains not included).

The GNP as a much applied indicator is positively influenced by activities such as reconstruction measures after flood damages (even though these only restore the initial welfare level – at least to some degree); incidentally, this is also why losses measured in GNP terms are lower.

Furthermore, the damage figures presented thus far only refer to the respective annual averages. However, not only the mean value derived from possible damage scenarios is socially relevant, but also the **frequency and intensity of extreme weather events**, which the COIN results delineate for three examples: a 100-year **flood** at mid-century will cause **damages to building** stock alone that amount **to € 4 to € 7 billion**; **at the end of the century**, the damages will come to **€ 8 to €41 billion** (and in case of a 20-year flood to € 3 to € 16 billion; current price level). The figures depend on the respective socio-economic and climate scenarios (only direct damage costs, such as losses of value or expenditures for repair measures, not yet considering consequential damages to the national economy). **Heat waves**, as they will typically already occur every 20 years by mid-century, **will lead to 6,000 to 9,000 heat-related deaths**; **drought periods**, as they will already occur every fourth year by mid-century, will cause **production losses of approx. € 56 mn for the agriculture sector** alone.

As we are faced with such a wide range of extreme events in the context of climate change, we as a society have to answer the question of whether there are any particular events within the anticipated range we want to avoid at any rate, and consequently we need to take the respective actions (the reduction of emissions and respective adaptation). In terms of adaptation, responding to this range of possible consequences also means that we need to take adaptation measures timely, that they need to be flexible, and that they have to be more comprehensive, should we not be able to provide (adequate) climate protection.

Can we take out insurance against climate change-related damages?

On a human time scale, climate change is irreversible, and it poses the most global, most long-term, and in its dimension the most uncertain problem for our society. Currently, we are only aware of, and can merely quantify, a (possibly even rather small) part of consequential damages from climate change. Insurance companies are not designed to insure against damages that are very likely to occur. Rather, they focus on contingencies such as the small chance of a house catching fire. Unfortunately, chances are much higher that climate change will have dramatic impacts. The current 10 % chance of an existential, planetary, climate change-related disaster to happen (Wagner and Weitzman, 2015) is much too high for traditional insurance concepts to apply. A conventional »climate change insurance« would work in such a way that we would regularly deposit money into an account, so we would be prepared for a case of emergency, i.e., for climate-related damages to occur. However, this would not suffice to compensate climate-related damages. For what good is a high account balance, when throughout many re-gions in Austria there are no living environments safe from floods or mudslides? Having sufficient funds is only effective as long as there is also sufficient building stock, provisions (and other goods) to satisfy the basic human needs. With this in mind, **taking out insurance means solving the basic problem and preventing the concentration of greenhouse gases in the atmosphere from rising further**. The situation lends itself to the metaphor of a sick patient: adaptation to climate change will at best alleviate the symptoms, while climate protection/the reduction of emissions will address the causes.

Table 1:
Climate- and weather-induced damages, Austria, disregarding global feedback effects, only impact chains that can be reliably quantified (impact chains disregarded: see Table 3), **annual average** as well as lower and higher damage ranges, for both the 2016–2045 and 2036–2065 periods

Damage in million €, Ø per annum (at 2010 prices)		
A) Damages already observable		
Total	**850 to 1,090**	
Market damages		
Annual average of damages from climate- and weather-related events (Münchner Rück, Ø 2001–2010)	705	
Non-market damages:		
Heat-related premature deaths	145 to 385	
B) Additional future damages	**2016–2045**	**2036–2065**
Damages from additional climate change (decrease in welfare)	**995**	**1955**
[range: more/less severe damages]	[890 to 1,211]	[1,825 to 2,280]
Additional damages from socio-economic developments	**270** [268 to 314]	**825** [800 to 1,080]
Non-market damages:		
Heat-related premature deaths	**95 to 255**	**570 to 1,300**
Assessment employing value of Life Years Lost (€ 63,000 per LYL)	95 [82 to 580]	570 [285 to 1,840]
or assessment employing Value of Stat. Life (€ 1.6 Mio. per SL)	255 [210 to 1,535]	1,300 [640 to 4,350]
C) Total annual damages (already observable damages plus additional future damages)	**2,210 to 2,610** [2,090 to 4,150]	**4,200 to 5,170** [3,760 to 8,800]

Annotations:
Figures in **bold type: mean average of trend scenario***;* in square brackets [higher (lower) damage sums]: different socioeconomic developments and less (more) intense climate change: for details see Fact Sheets for the individual fields of action].
VSL and LYL figures from Watkiss (2011), heat-related premature deaths: see Fact Sheet »Human Health«.

To what extent do the COIN findings justify investments in mitigation?

The COIN results show that in order to deal with climate change in an adequate way it is necessary

Table 2: Climate change impact chains considered in damage quantification

Field of action	Impacts considered
Agriculture	• temperature rise: prolonged growing periods; however, water availability as an increasingly limiting factor • changes in precipitation and soil erosion, precipitation damage to plants
Forestry	• prolonged growing period • aridity • bark beetle
Ecosystem services and biodiversity	-
Human health	• heat-related premature deaths
Water supply and sanitation	• reduced groundwater recharge and well yield • heavy precipitation events and associated infrastructure damages as well as adaptations • increased water extraction • increased winter wastewater volumes • increase in sedimentation during arid periods
Buildings	• heat load reduction • increase in cooling loads
Electricity production	• changes in discharge fluctuation for hydropower • changes in wind speed and solar irradiation • increasing cooling demand in summer and decreasing heating demand in winter and according changes in electricity demand
Transport and mobility	• reconstruction costs for road infrastructure due to floods, landslides, and mud-slides
Manufacturing and trade	• changes in labour productivity
Urban regions	• loss of climate comfort (and preventing such loss by expanding green spaces, respectively)
Disaster management	• damages to building stock after riverine floods
Tourism	• changes in overnight stays in both winter and summer tourism due to changes in snow conditions, precipitation totals, and temperature

to intervene at an early stage and make adjustments in many areas. This holds true for reducing damages that already occur to date, and also if adaptations requiring long lead times are to be initiated at present (e.g., in the forestry, health, or transport and building infrastructure sectors). It is, of course, fact that residual damages are generally unavoidable, regardless of adaptation to climate change. It is essential that adaptation is not justified by gradual climate change-related climatic developments alone, but also by damages owing to extreme events/natural disasters and weather variability. Establishing closer relations between natural hazard management and climate change adaptation is currently discussed at EU-level and can also be improved in Austria. This could mitigate the economic impact of climate change. The Austrian adaptation strategy reflects these requirements and outlines an initial action framework. This framework advocates planning and ecosystem stabilising measures which are in accordance with emission reduction targets on the one hand, and with further political goals, such as resource protection, biodiversity, and sustainability, on the other.

Table 3: Climate change impact chains disregarded in the quantification of damages (excerpt/selection)

Field of action	Impact chains disregarded
Agriculture	• irrigation costs • additional pest control • heat-induced labour productivity losses • heavy rain events • flood damages
Forestry	• storm events • change in the species composition due to temperature rise • heat-induced work and labour productivity losses
Ecosystem services and biodiversity	No impacts were monetised (thus neither the loss of pest control nor of pollination services, or species loss, etc. were considered).
Human health	• heat-related illnesses • extreme precipitation events • air pollution • water- and foodborne diseases • vector-borne diseases • impacts of relocation
Water supply and sanitation	• reconstruction costs after floods • changes in water quality due to temperature increase • droughts and resulting investments • increase in water treatment due to lower surface water renewal rate • contamination after flooding • reduced oxygen solubility in surface waters
Buildings	• decreased thermal comfort due to summer heat • increased frequency of storms
Electricity production	• changes in discharge fluctuation and water temperature • natural events (storms, floods, other extreme events) and their impacts
Transport and mobility	• transport network disruptions • water transport (reduced water levels) • storm events • temperature-related deformation of road surfaces • rail transport • air transport • passenger comfort in vehicles
Manufacturing and trade	• changes in the production process due to temperature and extreme events • cooling and heating • damages to the infrastructure • shifts in the area of consumption
Urban regions	• decrease in climate comfort • city tourism • heat-related damages to pavements, tram tracks, etc.
Disaster management	• disaster relief personnel • disaster relief volunteers • storm events • droughts
Tourism	• changes in water and energy demand • changes in the availability of environmental resources important for tourism • extreme events (including business downtime)

References:

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Detailed information (Fact Sheets) on the fields of

- Agriculture
- Transport and Mobility
- Tourism
- Manufacturing and Trade
- Human Health
- Water Supply and Sanitation
- Urban Regions
- Disaster Management
- Energy and Electricity supply
- Forestry

are accessible online at **http://coin.ccca.at**

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