PUBLIZIERBARER ENDBERICHT

A) Projektdaten

Kurztitel:	COIN
Langtitel:	Costs of Inaction
Programm inkl. Jahr:	ACRP5, 2012
Dauer:	01.01.2013 – 30.09.2014
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Schlagwörter:	Climate Impact, Climate Change Damage, Economic Evaluation
Projektgesamtkosten:	beyond 500.000 € (including own contributions of research institutions)
Fördersumme:	377.648 €
Klimafonds-Nr:	B286216
Erstellt am:	10.12.2014

Project Summary / Projektübersicht

1 Kurzfassung

Das interdisziplinäre Projekt COIN (Cost of Inaction – Assessing Costs of Climate Change for Austria) evaluiert die ökonomischen Auswirkungen des Klimawandels für Österreich. Dazu werden in den 12 Schlüsselsektoren sektorintern und –übergreifend mittels Szenarien mögliche Auswirkungen von Klimaänderungen in Kombination mit sozioökonomischen Entwicklungen analysiert. Szenarien sind plausible alternative zukünftige Situationen, deren Analyse es erlaubt, Bandbreiten zwischen negativen und positiven Auswirkungen abzuschätzen sowie kritische Konstellationen zu erkennen. Im Projekt COIN geht das Hauptszenario für den Zeithorizont 2050 von einer globalen Erwärmung innerhalb der 2-Grad-Grenze aus. Diese Annahme setzt eine stärkere als derzeit beobachtbare Klimapolitik voraus. Die hier vorgestellten Analysen berücksichtigen bereits Anpassungen des Einzelnen und zeigen nur jenen Ausschnitt aller möglichen Auswirkungen, der bereits quantifi zierbar ist. Es besteht weiterer Forschungsbedarf insbesondere auch für die nach aktuellem Forschungsstand noch nicht quantifizierbaren Auswirkungen.

Der interdisziplinäre Ansatz: Im Projekt COIN arbeiteten 42 ForscherInnen aus

18 Forschungsgruppen aus Österreich und anderen europäischen Ländern unter Federführung der Klimaökonomik in Forschungskooperation mit Agrarökonomik, Forstwirtschaft, Wasserwirtschaft, Gesundheitsökonomik, Tourismusforschung, Verkehrswissenschaften, Biologie, Energieökonomik, Produktionsökonomik, Stadtplanung, Risikoforschung und Meteorologie ein gutes Jahr lang zusammen, um auf konsistente und damit vergleichbare Weise die ökonomischen Auswirkungen des Klimawandels quer über alle Bereiche zu bewerten. Die Ergebnisse wurden durch ein Internationales Scientific Advisory Board unter der Leitung von Paul Watkiss (Universität Oxford) geprüft sowie zwei Review-Prozessen durch 38 internationale Gutachter unterzogen, demgemäß weiter verbessert, und sind im Buchhandel erhältlich als

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.

Was bewertet wurde: Die Bereiche der Klimawandelauswirkungen sind in der Österreichischen Strategie zur Anpassung an den Klimawandel (BMLFUW, 2012) nach Handlungsfeldern gegliedert. Das Projekt COIN verwendet dieselbe Gliederung und untersuchte die Auswirkungen somit für Landwirtschaft, Forstwirtschaft, Wasserwirtschaft, Tourismus, Elektrizitätswirtschaft, Heizen und Kühlen (Gebäude), Gesundheit, Ökosysteme und Biodiversität, Verkehrsinfrastruktur, Handel und Fertigung, Stadt und Raumordnung, Naturgefahren und Katastrophenmanagement (wobei die letzten beiden genannten und in BMLFUW (2012) separaten Bereiche hier jeweils in einen Bereich zusammengefasst wurden). In jedem dieser Bereiche wurden die ökonomisch relevanten Wirkungsketten identifiziert, sowie jener Ausschnitt aus diesen Wirkungsketten auch quantitativ (d. h. in Euro) bewertet, für den dies nach aktuellem Wissensstand bereits belastbar möglich ist.

Die Ergebnisse:

Während es bisher für Österreich bereits – meist jedoch regionsspezifische – Untersuchungen in einzelnen Bereichen gab, fokussiert COIN auf eine österreichweite Bewertung aller Bereiche. Zudem ist die durchgängige Ermittlung der jeweiligen Folgewirkungen für den Rest der Volkswirtschaft ein zentraler Mehrwert des Projekts. So führen etwa die Produktivitätsverluste in Fertigung und Handel, ausgelöst durch mehr Hitzeperioden, durch die wirtschaftliche Verflechtung dieser Sektoren zu Folgeschäden auch in anderen Sektoren, die zu insgesamt mehr als vier Mal höheren gesamtwirtschaftlichen Verlusten führen. Dieser gesamtwirtschaftliche »Vergrößerungseffekt« einzelsektoraler Schäden beträgt – je nach Sektor – zwischen 60 % (makroökonomische Folgewirkungen der Übernachtungseinbußen im Tourismus) und dem genannten mehr als Vierfachen. COIN bietet erstmals eine derartig umfassende Abschätzung. Erst die Berücksichtigung dieser gesamtwirtschaftlichen Rückwirkungen ermöglicht belastbare Aussagen zu den Auswirkungen auf öffentliche und private Budgets, wie sie für alle Bereiche vorgenommen wurden.

Wie werden gesamtwirtschaftliche Auswirkungen gemessen? Am Beispiel von Hochwasserschäden wird schnell ersichtlich, dass zwar einerseits durch Produktionsausfälle die Messgröße Bruttoinlandsprodukt (BIP) reduziert, sie aber andererseits durch Wiederaufbauarbeiten gesteigert wird. Netto erhöhen (klimabedingte) Extremereignisse zumindest kurzfristig vielfach das BIP, während erst langfristig etwa auch der verlorengegangene Kapitalstock mindernd durchschlägt. Sind wir also am »Wohlbefinden « der österreichischen Bevölkerung interessiert, so haben wir auf eine Messgröße zu fokussieren, die die bloße Wiederherstellung von zuvor vorhandenen (und erst durch Klimawandel zerstörte) Bestände nicht als Zuwachs des Wohlstandes wertet. Daher hat das Projekt COIN zusätzlich zur BIP-Veränderung auch einen um diese Effekte bereinigten Wohlstands-Indikator ermittelt. Sowohl die Größenordnung der Entwicklung des Wohlstandsindikators ist eine andere als die des BIP, als in einigen Fällen auch sogar die Richtung (wie am Beispiel Hochwasser gezeigt). Mangels geeigneter Daten und Methoden wurden nicht-marktliche Folgeschäden weitgehend nicht bewertet. So wurden beispielsweise die durch Hochwasser verursachten Kosten psychischer Folgen wie das emotionale Leid beim Verlust von Erinnerungsstücken nicht berücksichtigt.

Während zu den einzelnen Detailergebnissen nach Sektoren Fact Sheets auf der Projekthomepage http://coin.ccca.at bereitstehen, und ebenso überblicksartig in Abschnitt 4 im Folgenden dargestellt werden, werden an dieser Stelle im Folgenden lediglich kurz die aggregierten Ergebnisse reflektiert (auch dafür gilt: nähere Infos auf der Projekthomepage).

Die Klimaerwärmung ist schon beobachtbar, dieTemperatur ist in Österreich im Jahresmittel seit 1880 um knapp 2 Grad gestiegen. Die wetter- und klimabedingten **Schäden** belaufen sich damit **bereits heute** in Österreich auf **jährlich** durchschnittlich rund **€ 1 Mrd.** (vgl. Tabelle 1). Diese Zahl berücksichtigt nur bedeutende Naturkatastrophen sowie hitzebedingt-frühzeitige Todesfälle. Diese Schäden werden weiter steigen, insbesondere wenn es nicht zu signifikanten Emissionsreduktionen kommen sollte. Das Projekt COIN zeigt, dass die gesellschaftlichen Schäden – zunächst für ein mittleres Klimawandelszenario, **bis zur Jahrhundertmitte** – auf durchschnittlich **jährlich € 4,2 Mrd. bis € 5,2 Mrd.** (heutiges Preisniveau) steigen werden.

Im Projekt COIN wurden zudem alternative Klimaszenarien und sozioökonomische Szenarien untersucht, aus deren konsistenter Anwendung über alle Sektoren sich auch **ein geringerer und ein höherer Schadensbereich** abschätzen lässt. Demgemäß können wir damit rechnen, dass die heute bereits quantifizierbaren **Gesamtschäden** – und zwar quer über die zuvor genannten Felder, von Land- und Forstwirtschaft bis Tourismus – zur Mitte des Jahrhunderts insgesamt innerhalb einer **Bandbreite von jährlich durchschnittlich € 3,8 Mrd. bis € 8,8 Mrd.** liegen werden. Bei diesen Zahlen gilt es Mehreres zu bedenken: Sie betreffen lediglich den zuvor dargestellten und schon **belastbar** monetär **bewertbaren Ausschnitt an Wirkungsketten**, die in Österreich ihren Ausgang nehmen; es sind darin zudem keinerlei Rückwirkungen globaler Auswirkungen auf Österreich berücksichtigt; an Extremereignissen werden einzig Hochwasserschäden an Gebäuden berücksichtigt (und diese nur im Mittel).

Dazu kommen dann die **Schäden durch** die hierin noch nicht berücksichtigten Klimafolgen (siehe die Fact Sheets für die wichtigsten nicht einbezogenen Wirkungsketten). In die vielerorts verwendete Maßgröße BIP fließen Aktivitäten wie der Wiederaufbau nach Hochwasserschäden (der allerdings nur den ursprünglichen Wohlfahrts-Zustand, zumindest teilweise, wieder herstellt) als steigernd ein, daher ist der Verlust in BIP gemessen übrigens kleiner.

Die bisher genannten Schadenszahlen beziehen sich zudem jeweils nur auf den jährlichen Mittelwert. Gesellschaftlich relevant ist jedoch nicht nur dieser Mittelwert aus möglichen Schadensszenarien, sondern auch in welcher **Häufigkeit und Intensität Extremereignisse** auftreten können. Die Ergebnisse aus COIN zeigen dies für drei Beispiele: Ein 100-jährliches **Hochwasser** wird zur Mitte des Jahrhunderts allein zu **Gebäudeschäden** in Höhe **von € 3 bis € 7 Mrd.** führen, **zum Ende des Jahrhunderts** in Höhe von **€ 8 bis € 41 Mrd.** (ein 20-jährliches dann zu Gebäudeschäden in Höhe von € 3 bis € 16 Mrd., heutiges Preisniveau), je nach gewähltem Klima- und sozioökonomischen Szenario (nur direkte Schadenskosten wie Wertverluste und Reparatur, jedoch noch ohne Berücksichtigung von volkswirtschaftlichen Folgeschäden). **Hitzewellen**, wie sie bereits zur Mitte des Jahrhunderts im Schnitt alle 20 Jahre auftreten, erhöhen die dadurch ausgelösten **Todeszahlen** dann **auf 6000 bis 9000**; **Dürreperioden**, wie sie zur Mitte des Jahrhunderts bereits jedes dritte Jahr auftreten, verursachen

allein in der **Landwirtschaft Produktionsausfälle** in Höhe von rund **€ 1,3 Mrd.**.

Da wir beim Phänomen Klimawandel mit einer solch großen Bandbreite an Extremereignissen konfrontiert sind, müssen wir als Gesellschaft die Frage beantworten, ob es in der erwarteten Bandbreite Ereignisse gibt, die wir jedenfalls vermeiden wollen. Und dann die entsprechenden Schritte – in Emissionsminderung und Anpassung – setzen.

Auf diese Bandbreite an möglichen Folgen zu reagieren heißt für die Anpassung auch, dass sie zeitgerecht und flexibel angelegt werden müsste, und dementsprechend umfassender, wenn wir den Klimaschutz nicht oder nicht ausreichend schaffen sollten.

Die Ergebnisse aus COIN zeigen auf, dass für ein gesellschaftlich adäquates Umgehen mit Klimawandel ein frühes Intervenieren im Sinne der Anpassung in vielen Bereichen nötig ist, wenn einerseits bereits jetzt auftretende Schäden gemindert werden sollen und andererseits Anpassungen mit langen Vorlaufzeiten bereits jetzt eingeleitet werden sollen (vgl. z. B. Forstwirtschaft, Gesundheit oder

Verkehrs- und Gebäudeinfrastruktur). Freilich gilt, dass auch mit Klimawandelanpassung Residualschäden im Allgemeinen nicht zu vermeiden sind.

2 Executive Summary

The objective here is to cover *as broad a* field of impacts as possible at the national level within a single comprehensive cost evaluation. To create such information at the national level, the present volume presents (a) a toolbox for deriving future climate impacts and arriving at related monetary quantification at the sectoral level, (b) the means for doing so consistently across all fields of impact, (c) a framework for impact integration in terms of a consistent macroeconomic framework in order to quantify economic feedback effects, (d) an approach for dealing with non-market impacts, e.g. impacts related to human health and biodiversity and (e) appropriate methods for considering extreme events and their ‘fat tail’ distribution.

Methodologically speaking, the approach presented combines a scenario-based impact assessment across all fields of impact, a computable general equilibrium (CGE) analysis so as to capture cross-sectoral linkages and economy-wide effects, and a qualitative analysis to capture additional non-market effects where monetization is not considered appropriate.

The project results first give an overview of climate costs at the European level. Impacts are found to amount to several percentage points of GDP by the end of the century, and are characterised by large differences in the patterns of impacts across Europe. For example, due to a combination of enhanced climate signal and higher local vulnerability, there are more negative impacts in South-Eastern Europe and the Mediterranean area.

In general, available national assessments of climate change risks and adaptation planning follow one of two approaches, i.e. either the use of top-down global Integrated Assessment Models (IAMs) which are then downscaled to reflect the national or regional scale, or the use of bottom-up sectoral impact assessments which are scaled up to capture the regional or national level. On comparing the national evaluations undertaken in the UK, France, Germany and Switzerland, it becomes clear that the approach presented in this volume can indeed generate complementary information. Specifically, the new approach is helpful in the following three important areas: (a) it explicitly considers uncertainties through high impact case narratives (i.e. damage-enhancing socioeconomic developments and high-damage climate change scenarios), (b) it applies consistent socio-economic scenarios and shared policy assumptions across various sectors, and (c) it advances the state of the art with respect to the assessment of cross-sectoral, indirect, and macroeconomic effects.

The national scale evaluation approach is designed specifically to deal with the following issues:

- provision of a consistent overall framework
- derivation of local indicators from climate model ensembles
- development of shared socioeconomic pathways necessary to ensure consistency across sectoral evaluations
- creation of a toolbox for economic impact evaluation ensuring consistent evaluation
- development of the macroeconomic modelling framework
- macroeconomic integration of sectoral impacts while taking sufficient account of feedback effects.

We consider the methodological approach as comprehensive regarding the fields of impact and the relevant aspects of climate change costs. However, we are aware that the quantification of costs has to leave many open questions and relevant impacts which could not be quantified in this work.

In order to exemplify its use, the set of tools is applied to a single country, i.e. Austria. The following results were derived:

With respect to observed welfare damage of climate and weather induced extreme events in Austria insurance data reveal annual average sums of € 97 million (m) in the 1980s, € 129 m in the 1990s, and € 705 m in the last decade. However, these figures are covering large events (catastrophes of class 5 and 6) only, and are of incomplete coverage even for this subcategroy pre-2002. In the past, the most significant damage at the national scale in Austria was related to riverine flooding, valued at € 3.5 billion in 2002 and € 2.3 billion in 2013 (which amounted to 1.4% and 0.7% of GDP, respectively; all monetary values given in this summary are at prices of 2010). Non-market impacts of premature heat-related deaths can be evaluated at a current annual average € 150 m to € 390 m. Thus, the current welfare damage of climate and weather induced extreme events in Austria is an annual average of about € 1 billion (large events only).

We find that this has the potential to rise to € 4 to 5 billion by mid-century (annual average, known knowns of impact chains only), with an uncertainty range of € 4 to 9 billion. When extreme events and the tails of their distribution are included, even for a partial analysis focused on extremes, damages are seen to rise significantly, e.g. with an estimated increase to € 40 billion due to riverine flooding events alone by the end of the century. These highlight the need to consider the distribution of impacts, as well as the central values.

In contrast, traditional economic measurements, such as those assessing climate change impacts on GDP, provide, at best, only a partial picture. For example, GDP losses do not account for losses in stocks (e.g. buildings) due to climate change events.

3 Background and Objectives

The infrared absorption capacity of greenhouse gases is inducing a warming of the earth's atmosphere. Already in 1979 the World Meteorological Organization found "that it is now urgently necessary for the nations of the world: [….] to foresee and to prevent potential man-made changes in climate that might be adverse to the well-being of humanity", and that "it is possible that some effects on a regional and global scale may be detectable before the end of this century and become significant before the middle of the next century." (WMO, 1979).

In various assessment reports published since 1990, and most recently in 2013/14, the Intergovernmental Panel on Climate Change (IPCC), has confirmed the findings presented in the scientific literature that climate change has led to a global mean temperature increase of almost one degree Celsius since 1880 and that it is predominantly caused by human activities (IPCC, 2013, 2014). The IPCC also reports that, left unabated, future emissions will lead to a temperature increase by the end of the 21st century of 3.2 to 5.4 degrees Celsius. Even the most ambitious mitigation scenarios could potentially lead to dangerous climate change; i.e. even if global average warming is limited to two degrees Celsius relative to pre-industrial levels (the current international goal agreed, noting that this is unlikely to be met). For most regions, particular land-locked mountainous and continental climate zones, this implies a more substantial increase, e.g. a 4.5 to 6.6 degree Celsius increase by 2100 is projected for the Alpine region and thus for a country such as Austria (Jacob et al. 2013).

Due to the inertia of the climate system societies are thus confronted with the need to adapt to climate change and – in order to avoid a further increase that gets increasingly unmanageable in the future – the need to engage in attempts to agree on and implement greenhouse gas emission mitigation policies. For both types of decisions, adaptation and mitigation, well-informed decision making requires knowledge on the type and magnitude of climate change impacts expected, and on the type of information available and deducible.

During the last two decades a rich body of literature has thus developed on climate change impacts, with results put into perspective most recently in IPCC (2014). In this literature two strands can be distinguished. One is employing aggregated impact functions, within so-called Integrated Assessment Models, which have been applied mainly at the global level in order to quantify the social costs of carbon (the additional damage of an extra ton of GHG emitted). A second strand builds upon physical impact assessments, often extended by related economic valuation.

All of these studies indicate the high demand for evaluations at the national and sub-national level, as this is where climate change materializes and where administration and governance of adaptation takes place. This also lends force to the IPCC´s demands for disaggregated studies and scenarios capable of allowing for more appropriate impact assessment at the national to local level. To date, however, studies at the national and sub-national level have tended to focus solely on a few selected fields of impact (i.e. on those considered the most important).

This clear gap in the literature provides the motivation for the present volume. The objective here is to cover *as broad a* field of impacts as possible at the national level within a single comprehensive cost evaluation. To create such information at the national level, the present volume presents (a) a toolbox for deriving future climate impacts and arriving at related monetary quantification at the sectoral level, (b) the means for doing so consistently across all fields of impact, (c) a framework for impact integration in terms of a consistent macroeconomic framework in order to quantify economic feedback effects, (d) an approach for dealing with non-market impacts, e.g. impacts related to human health and biodiversity and (e) appropriate methods for considering extreme events and their 'fat tail' distribution.

4 Content and Results

Book with full project details and results published with Springer:
One objective of COIN was an international publication of its results in the Springer publishing house. For this purpose, a 4 step review process was conceived and set up, including comments of the international project scientific advisory board, the project consortium itself, of 38 international sectoral experts and finally of an independent project subgroup. By this means, a peer reviewed analysis featuring Austrian results based on an internationally transferable methodological framework for a consistent interdisciplinary analysis was provided.

The costs of climate change in Europe
Climate change has the potential to lead to major impacts and economic costs in Europe. An overview is reported on a recent regional assessment—the ClimateCost project—which has combined sectoral assessments and wider economic analysis to derive such estimates. The results reveal potentially high economic costs from climate change in Europe, though these vary with the emission scenario and time period. While many of these impacts are projected to be adverse and lead to economic costs, there are also economic benefits. The results also show large differences in the patterns of impacts across Europe, with more negative impacts in South-eastern Europe and the Mediterranean, due to a combination of the enhanced climate signal and the higher vulnerability in these regions. The analysis of different scenarios shows that mitigation (towards a 2 degree C stabilisation scenario) would reduce these costs significantly, but only in the medium-long term (after 2040). There will therefore be a need for adaptation as well as mitigation, but given the high future uncertainty, this is likely to be best advanced through a framework of adaptive management.
While this European wide view is important, this analysis also shows there is a need for country level analysis—as developed for the first time in this detail for any country in this project —to capture national context and insights, to allow analysis of country specific risks, and to provide national-level information to start planning for adaptation.

A consistent framework for the national level evaluation
Impact assessment at the national level requires sectoral detail, economy-wide integration, and a consistent framework and toolbox to do so. The project discussed the issues, and derived the requirements for climate scenarios and local indicators, shared socioeconomic pathways, and economic evaluation to allow for and ensure consistent integration. Finally, a methodological check-list for national level quantitative climate impact assessment has been provided.

Climate change effects
An ensemble of 31 climate change scenarios of different GCMs and RCMs, forced by four different emission scenarios have been prepared. The core of this ensemble is a high resolution regional model run forced with the A1B emission scenario, which were bias corrected and localized on a daily basis to a 1x1 km raster. This model is assumed to be the "mid-range" at the end of the 21st century in terms of the climate change signal for temperature and precipitation.
Local observations and the climate change scenario for the all of Austria on a daily basis and on a 1x1 km raster have been used to calculate more than 60 impact related meteorological indicators based on temperature, precipitation, radiation, and snow. All indicators are calculated on the NUTS3 level. Temperature depending indicators were additionally calculated on elevation bands (500 m) within the NUTS3 regions.
To assess the range of the potential climate change within the 21st century, a statistical method was developed to estimate the "peak over threshold" type indicators (e.g. heat days) from monthly mean data. For this type of indicator, the highest and lowest indicator values could be estimated for selected time frames from the extreme scenarios of the whole ensemble.
All climate scenarios indicate a warming within the 21st century. The mid-range scenario belongs to the colder realisations within the first half of the century with a warming of less than 2°C in summer and 2°C in winter compared to the reference period of 1981-2010. At the end of the century, the warming is in the order of 4°C in both seasons. The whole ensemble indicates a

warming of 0.5 up to 4 degrees till 2050 and at the end of the century the warming reaches from ~ 2°C up to 6°C in winter and up to 9°C in summer. The low border stems from models forced with the RCP 4.5 emission scenario and the high border from models forced with RCP 8.5.
The climate change signal for precipitation is not that clear. The annual sum shows no clear trend. For summer precipitation, the majority of the model indicates a decrease till minus 20 % and in winter an increase of the same magnitude.
The derived indicators reflect the same trends. In general, it can be said that temperature depending indicators at the middle of the century derived from the hottest realisations have a similar climate change signal as the "mid-range" scenarios at the end of the century. The extreme warm realisations at the end of the century really show a different world. More than 100 heat days in Vienna on average are unimaginable. Precipitation depending indicators highlight a higher frequency of dry spells in summer and an increase in daily precipitation intensities.

Shared socioeconomic pathways
Socio-economic pathways determine future climate impacts and costs thereof. Pragmatically, we have referred to a global reference Road socio-economic pathway (represented by SSP2 in the IPCC process) and derived figures for the core economic, demographic, land-use and (qualitatively) technological development in Austria, which again frame the sectoral development assumptions necessary to follow a scenario-based cost assessment approach. In principal, trend projections and existing studies have been used to describe a single country, here applied for Austria, in 2030/2050 that is growing slowly in terms of population (0.27 % p.a.) and medium in terms of GDP (1.65 % p.a.) and in which forests, meadows and settlements expand in the north-east-south crescent— at the cost of arable land, within which further intensification will take place. Policy assumptions as well as technological change have been set to a medium path, at which risk zoning put forward, the EU integration 'muddles through' and no technological wonders are taken into account. A reference scenario might be regarded as least uncertain—which is not true—but we might expect more volatile developments to equilibrate over some decades. The Austria we expose to climate change by 2050 is significantly different from nowadays: Its population is older and its public and private infrastructure density is higher—at least two factors that might influence future climate costs of inaction.

Agriculture
The analysis in the agricultural sector is mainly guided by three research questions: (1) what are potential impacts of climate change on the agricultural sector in Austria? (2) what are the costs induced by climate change at sector level and economy-wide if there is no planned adaptation, i.e. long-term adaptations implying major structural changes? and (3) which uncertainties need to be considered due to spatial and structural heterogeneity? The key findings can be summarized as follows:

1. **Climate change results in moderate increases in crop and grassland forage yields in the period 2036-65 on national average** due to moderate temperature increases, rather stable annual precipitation sums, and the CO_2 fertilization effect. Compared to the historical reference period, the model results indicate changes in average dry matter crop yields between -8% and +9% in the period 2016-45 and between -9% and +7% in the period 2036-65. Simulated changes in permanent grassland forage yields range between -3% and +33% in both scenario periods. Yield changes vary by region, crop, and crop management. Crops can utilize moderately increasing temperatures if sufficient water supply during the growing season is available. This is mainly the case for the western parts of Austria. In contrast, already existing water shortages in crop production may be exacerbated by increasing temperatures and induced evapotranspiration. This is mainly the case for the cropland dominated eastern parts of Austria. Crop and grassland forage yield increases are higher with irrigation and high fertilization intensity whereas extensive cultivation results in decreasing crop and grassland forage yields on average. The model results show that the impact of crop management exceeds the impact of climate change scenarios on average.

2. **Climate change leads to moderate increases in agricultural production value and variable costs in the period 2036-65 at aggregated national level.** This is mainly due to

moderate increases in crop yields and grassland forage yields. In total, moderate climate change is expected to increase production value by € 193 million and € 180 million in the periods 2016-45 and 2036-65 compared to the baseline scenarios without climate change. The results are driven by mixed effects for both, regions and crops. Productivity gains from climate change on grasslands are an important driver of increasing production values. Total production costs also increase by € 77 million and € 74 million under the investigated climate change scenario in the periods 2016-45 and 2036-65, respectively.

3. **The results are based on a moderate climate change scenario (mid-range climate change scenario in COIN)** predicting a rising trend in mean annual temperature of +1.05 °C (+2.02 °C) and in mean annual precipitation sums of +1.5% (-2.3%) between the historical reference period 1981-2010 and the first (second) scenario period 2016-45 (2036-65) in Austria. However, more severe changes are expected for the second half of the 21st century, which are likely to result in significant changes in crop and grassland forage yields as well as agricultural production values. Furthermore, we do not account for changes in economic and market conditions, land use, yield quality, technological advances, infestation pressure of pests and diseases, and sub-daily information on future climates.

Forestry

In mountain forests longer vegetation periods result in increased productivity, while at low elevations in the east and in the south of Austria, drought will negatively impact on forest growth. Assuming no suitable adaptation measures are taken, increases in bark beetle infestations and possibly also storms are likely to result in yield reductions. In addition, the investment needed to maintain protection functionality against gravitational hazards in spite of losses of protective forest cover is higher than that needed to compensate for productivity loss alone.

Ecosystem Services

Climate plays a major role here. Researchers have only just begun to derive the specific threshold values at which ecosystem services start to decline. In economic terms, the pollutant buffer capacities of soil and vegetation, erosion protection and the provision of drinking water are all extremely significant ecosystem services. In COIN, the only agricultural services that were investigated were insect pollination and biological pest control, and the results were taken into consideration as explained earlier for agriculture.

Human Health

Pathways by which climate change affects health are considered to be both wide-ranging and complex. Furthermore, the specific emergence of phenomena depends highly on geographic area, population density and degree of industrialisation.

In our work package we focussed on Europe, using Austria as a case study for estimations and discussions of heat waves which seem to be the most severe threat to human health. However, estimating future impacts requires some simplifications to be made, depending on the availability of cases analysed. In our estimates we focussed on old people aged 65 and older as well as on mortality. Estimates for morbidity were not possible. Both the empirical data base and estimation methods still lack the requisite level of maturity. Against this background, results presented are quite significant, with 640 to almost 3,000 deaths and 6,800 to 31,500 life years lost (YLL), depending on the scenario combination for one year in the 2050s. Results show that the considered variation in the climate signals matters far more than the considered socioeconomic assumptions (given our assumptions the result is about 3 times more sensitive to climate than to socioeconomic conditions).

An estimate for extremely hot years with an extension of the vulnerable groups to chronically ill the number of deaths will more than double for the period 2036 to 2065 compared to about 3,000 deaths of an average year of this period.

In the case of temperature-related mortality of old-aged people, monetization is highly uncertain, since the calculation depends only on dis-utility (value of a life year lost or of a life lost). Besides ethical concerns, results depend highly on the specific valuation; compared methods show a difference by factor 2, different assumptions reveal a difference by factor 14.

However, given the potential health effects, monitoring of temperature-related mortality and morbidity is required. Further to general heat information systems, more tailored approaches need to be developed to care for potentially vulnerable people ranging from old-aged persons to people with poor health conditions, especially when accompanied by weak ties to social networks. Furthermore, outdoor and indoor heat islands need to be both identified and mitigated.

There are many other pathways by which health might be affected. We limited our discussion to climate-sensitive communicable diseases with an emphasis on food-borne diseases (Salmonellosis) and on allergic health effects (caused by Ragweed).

Against the background that effective control and prevention programs have reduced numbers of cases significantly in Austria within one decade, it is likely that these will lead to further decreases in future. Climate change could slow down these improvements, however, this is to a degree difficult to predict since both the future effectiveness of programs and climate change-induced effects on Salmonella cases for Austria are highly uncertain. Studies are required to better understand the potential effects of climate change in Austria.

Allergies as non-communicable disease are strongly related to quantity and seasonality of pollen, which themselves are depend on climatic variables. Due to climate change, a rapid spread of highly allergenic Ragweed is observed in several parts of the world, including Europe and Austria. A recently published study estimates mean treatment costs for allergy within a range of about € 290 million to € 365 million annually up to 2050. This would offset the annual adaption costs of about € 30 million annually by factor 10.

Water

The water cycle of the WSS sector starts at the water resources like groundwater, spring water or surface water, includes abstraction, treatment to drinking water quality, transmission, storage and supply, consumption, collection and transport of wastewater, wastewater treatment including treatment sludge disposal and finally discharge of the water into the environment and thus back to the water resources, usually into rivers.

Besides the resource situation, the demand side has a strong nexus to weather and climate. Seasonal characteristics as well as the days of the week or time of the day show a clear influence on the consumer's behaviour. This includes the actual weather and its variability of temperature and precipitation. A change of frequency or duration of specific weather situations due to climate change, especially an increase of dry hot periods, will result in more frequent and intense peak demands. On the side of the wastewater treatment an increase of variation of the weather will lead to an increased number of Combined Sewer Overflow (CSO) events and thus to a higher total pollution of the environment. On the other hand, higher temperatures will increase the performance of the waste water treatment process by ways of an enhanced activity of microorganism responsible for degradation of pollutants within the treatment plant.

In order to adapt the long-lasting assets of the WSS sector in an efficient way, more and early information on the impacts and their magnitudes on the sector will be needed.

We consider a baseline scenario that reflects changes due to socioeconomic and demographic changes as well as a climate change scenario that reflects additional changes due to climate change. Based on changes of units such as changes in final demand, new built assets, enlargements, or replacement of assets; we attempt to give cost estimates for the WSS sector until 2050 (under the differentiation of the causal nexuses and exemplarily based on empirical data). Based on the estimated costs for the WSS sector, macroeconomic effects are calculated, including spill-over effects to other sectors, as well as effects on welfare, GDP and public budgets. Both scenarios are subject to various assumptions and considerably high uncertainties and therefore the underlying results must be interpreted with care.

We show that an increase of infrastructure damages in the WSS sector will be mainly caused by floods or landslides due to intense precipitation events. Even higher impacts will originate from changes in production costs (e.g. treatment effort, operation and maintenance etc.) due to climate change as more assets and labour will be needed to provide the same service as today or to meet an additional climate change induced consumer demand. In total, the adaptation to socioeconomic and demographic changes will be the bigger challenge than the adaptation to climate changes. However, the costs of climate change will only add up to the total costs for each customer. Despite all of the uncertainties involved, investigations on the effects of climate change suggest that there will be very few benefits and many different costs for the WSS sector.

Energy

The objective of this WP was to the assess cost of inaction for the sector "energy". This included the identification of cost relevant climate sensitivities, development of sector specific scenarios, application of cost-assessment tools (developed in WP2) and a consistency check (e.g. regarding cross-sectoral comparison). During the work on the project it turned out that it is more consistent to use the term "electricity" as a header for this work package, since other energy related issues (in particular heating and cooling) are covered in the next work package.

Thus, the WP investigates the impact of climate change on the electricity sector. We quantified two main impact chains:

(1) impact of climate change on electricity supply, in particular on hydropower and
(2) impact of climate change on electricity demand, in particular for heating and cooling.

The combined effects of these two impact chains were investigated using the optimization model HiREPS. This takes the hourly resolution of the electricity system into account and considers, in particular, the interaction of the Austrian and German electricity markets. The results show that by 2050 there is a robust shift in the generation of hydroelectric power from summer to winter periods and a slight overall reduction in hydropower generation. The absolute increase in electricity demand is moderate. However, the electricity peak for cooling approximately reaches the level of the overall electricity load in 2010. These two effects - decreasing hydropower supply and increasing cooling electricity peak load (see the following work package for the latter) - lead to moderate sectoral climate change costs in 2050 compared to the baseline scenario without climate change. Regarding macroeconomic effects coming from climate change impacts on the electricity sector we see negative impacts on welfare as well as GDP. However, significant uncertainties remain and the effect of extreme events and natural hazards on electricity supply and transmission infrastructure also needs further examination. The costs of a potential increase in black out risk may be orders of magnitude higher than the costs indicated in our mid-range scenario.

Construction and housing

The objective of this WP was to assess the costs of inaction for the sector "construction and housing". This included energy related effects, in particular on heating and cooling and non-energy related demands which refer to adaptations of buildings and technical. Finally, the estimation of the costs for heating and cooling and the costs for adaptation of infrastructure and housing to better cope with future climate conditions will be derived in order to examine the costs of inaction. During the work on the project we decided to call the related chapter "Buildings: Heating and Cooling". The main reason was that the non-energy related aspects were much more difficult to assess and were partly covered in other work packages.

While energy savings in buildings is among the key prerequisites for a low-carbon future, our ability to maintain temperatures in buildings within a specific comfort range, and thus our demand for heating and cooling energy, are also highly sensitive to climate change. We quantify two main impact chains:

(1) a higher temperature in winter leads to a reduction of heating energy demand and
(2) a higher temperature in summer leads to an increase in demand for cooling.

The demand for cooling energy depends largely on the future uptake of air conditioning in the building sector and is subject to considerable uncertainty. On quantifying these two impacts for the example of Austria for the period around 2050 a net saving of about € 230 million per year is found, triggering slightly positive effects on welfare and GDP. The result is depending on the development of energy prices and in particular by the ratio of electricity to fuel price in the heating sector. The results show that, in absolute terms, the energy reduction in heating is much higher than the increased energy demand for cooling for the time horizon and the geographical location investigated. This stems from the fact that energy demand for air conditioning in Austria in 2008 was only 0.4-0.5 % of the final energy demand for heating. The impacts and costs resulting from a strong increase in electricity peak loads in summer are investigated in the previous work package (energy).

Transport

Even today, damage to transport infrastructure, primarily resulting from landslides or from road and rail undercutting (or washouts) caused by heavy precipitation, is already considerable, amounting to 18 million euros p.a. for road infrastructure). The extent of future damage depends directly on how traffic networks develop. Network exposure depends on the nature of network extensions. Local aspects need to be considered (e.g. geological conditions determining landslide potential, slope gradients, the risk of damage through undercutting (washouts) or wind). Depending on the duration of the disruption and on the availability of alternative routes, the indirect impact of traffic disruptions (losses in production and time) may easily exceed the direct costs of repair.

Manufacturing and Trade

The sector "Manufacturing and Trade" exhibits relatively high climate sensitivity as it depends on climate sensitive raw materials and intermediary inputs (such as agricultural products, timber and energy). In addition, changes in climatic stimuli (such as in temperature and relative humidity) may also influence production processes and/or the productivity of workers.

For this sector all these effects are discussed qualitatively. The productivity losses of workers, however, are also estimated on the basis of a quantitative model using a relationship between the Wet Bulb Globe Temperature (WBGT) index and the productivity of workers. The Human Capital Approach (HCA) and a GDP per employee approach are used for monetizing the direct productivity losses. Changing working conditions can have serious effects on the productivity of workers and thus on companies. Depending on the climatic development and the degree of adaptation the degree of damage caused can vary significantly. The direct climate impacts observed in the sector "Manufacturing and Trade" are magnified fourfold by associated macroeconomic feedback effects. For the mid-range climate scenario, there is a decline in economic welfare of 6 million euros for the period 2016–2045 (and 54 million euros for 2036–2065). For the high-range climate scenario respective welfare losses amount to 58 million € (296 million €). As declining demand also triggers price declines, losses in GDP are stronger, about 1.5 times the welfare losses. Note, however, that we only estimate the effects of productivity changes within the sector "Manufacturing and Trade". Similar productivity changes could affect the remaining sectors of the whole economy as well, and thus could increase the economy-wide effects of climate-induced productivity changes above those quantified in the present chapter.

Catastrophe Management, natural disaster protection, spatial planning

To manage the economic impacts of future flood events appropriate financial funds have to be provided. For such a fund one has to know two important quantities: (i) The average damages caused by flood events; and (ii) the money that is needed to compensate the damage of a future flood event. We concentrated on riverine flooding as an example to calculate these quantities.

Therefor three different methods were used. The first method combines flood risk areas of the HORA project with building stock to estimate losses of flood events. Further results of the ClimateCost study and AdamCost study are considered to provide results under different model specifications. Quantiles could only be computed by the AdamCost and HORA based model. Estimated annual losses (in M€) for the base period are provided in Table 1, and the change of these in losses under a climate change scenario in Table 2 (in M€). For the AdamCost based model some uncertainties in the method were considered and hence an interval is provided.

Since for different methods we get different baselines we provide the average annual damage for the different baselines. For the HORA-based method the baseline is 288 M € for Ø 2016-45 and 405 for Ø 2036-65 and for the ClimateCost method the baseline is 479 M € for Ø 2016-45 and 820 for Ø 2036-65. Since AdamCost does not consider changes in the socioeconomic variables, the baseline is the same as the base period. Finally the 99%-quantile for the yearly flood damage distribution is provided in Table 3. We should note that a large part of the differences can be explained by different statistical methods of how to implement climate change, different socio-economic assumptions, different spatial resolutions considered for the evaluation of the extent of floods and the consideration of different damages. It should be noted that the results are showing high uncertainties and therefore these results have to be treated with caution.

Table 1 Average annual climate-triggered economic impacts in (annual losses) for the sector catastrophe management up to now (in M€). For the AdamCost some uncertainties in the method were considered and hence an interval is provided.

economic impact in the base period		HORA-Based	ClimateCost	AdamCost
Ø 1981-2010	costs	207	337	[149-195]
	benefits	-	-	-
	net effect	-207	-337	-[149-195]

Table 2 Average annual climate-triggered economic impacts (annual losses) for riverine flooding. Difference to baseline scenario in the future (in M€). For the AdamCost some uncertainties in the method were considered and hence an interval is provided

future economic impact		climate change triggered additional damage		
		HORA-Based	ClimateCost	AdamCost
Ø 2016-45	costs		461	-
	benefits	8	-	-
	net effect	8	-461	-
Ø 2036-65	costs	25	966	[848-1100]
	benefits	-	-	-
	net effect	-25	- 966	-[848-1100]

Table 3 The 99 % quantile of the estimated flood damage distribution (in M€).

period\method	HORA-Based (M€)	ClimateCost (M€)	AdamCost (M€)
Ø1977-2006	3,220	-	2,350
Ø 2016-45	4,356	-	3,718
Ø 2036-65	6,894	-	4,948

We additionally collected data on disaster protection, including e.g. operating hours for the fire brigades, and conducted interviews with external experts. However, the data obtained was not rich enough to complete conclusive analyses.

Tourism

To main objective was to assess the costs of inaction for the sector "Tourism" and to identify potential differences between Austrian regions. Since tourism is a strongly demand-driven sector, quantifying the climate-induced change in final demand was chosen as method for assessing the costs of inaction in the tourism sector. For this purpose we (i) used dynamic multiple regression models to quantify the sensitivity of overnight stays towards year-to-year weather variability for each NUTS 3 region and various seasons, (ii) applied the resulting sensitivities on climate change scenarios – based on a general tourism development scenario – and (iii) transformed the resulting impacts on overnight stays into monetary terms using average tourist expenditures.

Table summarizes the final outcome of the sectoral cost assessment, i.e. direct sector impacts (costs and benefits) due to climate change without feedback effects from other sectors. For the purpose of illustration, results –principally available at NUTS 3 and monthly/seasonal level – were aggregated to national and annual level. Hence, the figures in Table show the average annual economic impacts on future tourism demand due to changes in average climatic conditions, differentiating between up to three different climate change scenarios. Potential impacts due to changes in climate variability are not taken into account.

Assuming socioeconomic pathway parameters as in the reference scenario[1] and a change in the climate as indicated by the mid-range scenario, average annual climate-triggered future economic losses in the tourism field are estimated at € 104 m (€ 316 m) in the first (second) scenario period, of which € 101 m (€ 291 m) are attributable to the winter season. Average annual climate-triggered future economic benefits, on the other hand, are estimated at € 37 m (€ 106 m), of which € 32 m (€ 90 m) are attributable to the summer season. Hence, an average annual future net loss of almost € 70 m or 0.3% (€ 210 m or 0.6%) is expected compared to a situation without climate change. Thus, outcomes suggest predominantly negative impacts on winter tourism and mainly positive impacts on summer tourism, with the net impact being negative.

Whereas net impacts aggregated to national and annual level seem rather small due to counteracting effects, impacts on particular regions during specific seasons may be more pronounced. In the case of Carinthia, results for the winter season for instance suggest average annual climate-triggered future economic losses of almost 3% (over 6%) in the first (second) scenario period. Assuming climate change according to the high-range scenario, these losses rise to almost 7% (about 10%).

Table 4: Average annual climate-triggered economic impacts on tourism demand arising from socioeconomic development and climate change in the future (in M€)

future economic impact relative to Ø 1981-2010		**climate change** low-range	mid-range	high-range
Ø 2016-45	costs	75	104	213
	benefits	54	37	15
	net effect	-21	-67	-199
Ø 2036-65	costs	n.a.	316	n.a.
	benefits	n.a.	106	n.a.
	net effect	n.a.	-210	n.a.

Not adjusted for rounding differences

It is important to note that the presented estimates on the costs of inaction exhibit various uncertainties, not only with respect to climate change scenarios, but also for instance regarding future socio-economic development, future tourist preferences and weather/climate sensitivities.

[1] I.e. an average annual nationwide growth rate of overnight stays of about 0.8%, an annual growth rate of real tourist expenditures per overnight stay of 0.8%, and weather sensitivities of tourism demand as observed in the past.

Cities and Urban Green

In urban environments climate change is expected to have a significant impact upon levels of thermal comfort. Several impact chains have been identified. The economic cost evaluation of

[1] I.e. an average annual nationwide growth rate of overnight stays of about 0.8%, an annual growth rate of real tourist expenditures per overnight stay of 0.8%, and weather sensitivities of tourism demand as observed in the past.

damages arising thereof faces multiple difficulties. Thus in Wp16 we deal with preventive costs, as estimating direct costs of damages of climate change induced rise in urban heat islands (heat stress, implications thereof, cooling demand, etc.) is too complex to get quantitative results on so far. These costs refer to an increase of open green to supply the growing built up area achieving a similar open green share for the larger city as well as to mitigation measures against urban heat island effects through enlargement of open green space and – to increase the open green share to improve thermal comfort through shading and evapotranspiration, both enhancing cooling. Where no additional open green space can be established - planting of trees in streets can serve as substitute.

The following key messages can be summarized:

1. **Cities, urban heat island effects and urban green**

A critical topic in cities is - with respect to global warming - the urban heat island effect, which will be even more important in the coming decades. The climatic factors which accelerate urban heat island phenomena are high irradiance, high temperatures accompanied by nocturnal cloud cover and low wind speed, which both reduces flux of urban heat load to upper atmospheric layers . Thus we have to consider the influence of the built urban environment and the influence of the open spaces between, both a result of urban design, which either trap heat load or support cooling.

2. Urban green space within cities and the need for additional park areas because of settlement growth

Growing urban areas (the baseline scenario) requires additional green space within the urban fabric causing costs for buying lots and for constructing new parks. To keep costs low, we have not considered the identical green space ratio for the additional urban fabric area but just 50 % assuming that the new settlement area is closer to the neighbouring rural surroundings which provide the inhabitants with green environment in the vicinity.

3. Adapting cities to a changing climate by increase of open green space within the built up area

Additional investments as preventive expenditures may increase the number and size of open green spaces in the cities to reduce the urban heat island effect under higher temperatures, to secure the current local thermal comfort - to keep the health conditions of the inhabitants stable and to enhance the attractiveness of the city for visitors during the hot summer months. Additional costs for intensifying the maintenance of urban green because of climate change is judged to be less important as climate stress is surpassed by environmental stressors due to activities and properties within the city.

4. Expected open green area increase and related costs:

The examined provincial capitals show today a built up area of 85,000 km2. Till the 2030ies expansion of 66 km2 and till 2050 expansion of 94 km2 built up land is expected (baseline scenario). So because of urban expansion for 2030 an open green space growth of 163 ha and till 2050 a growth of 235 ha is assumed. Taking into account adaptation for climate change (mid range scenario) an open green space growth of 224 ha and till 2050 a growth of 357 ha is assumed. The total investment costs for new park areas are estimated with 3,208 M € till 2030 and with 4,698 M € till 2050, which is annual costs of 189 M till 2030 respectively additional 127 M € till 2050. The costs for planting additional street trees are estimated for the mid range climate scenario with 19 M € till 2030 and 25 M € till 2050 which is annual costs of 1.12 M € till 2030 and of 0.95 M € till 2050. The costs for maintaining 163 to 235 ha additional park area are estimated for the mid range climate scenario with 6,52 M € till 2030 and 9,38 M € till 2050 which ranges between 0,58 M € per year till 2030 and 0,39 M € as annual average till 2050.

Cross-sectoral overlaps and consistency

Finally, the consistency of the cross sectoral assumptions and possible sectoral overlaps within the previous fields were monitored and checked in order to avoid double counting of damage costs across sectors. This analysis was based on a consistency matrix, indicating all direct and indirect effects of each considered impact chain (compare Fig.1).

UNIT(S) OF EXPOSURE	(semi-) quantitative	qualitative only	climate damage stimuli (cf. matrix for thresholds and regional scope)	DIRECT (PHYSICAL) IMPACT [incl. INDICATOR]	NEXT-ORDER impact: changes in cost structure (supply-side)	NEXT-ORDER impact: changes in demand (incl. investments)	NEXT-ORDER impact: knock-on effects (macro-economic)
winter cereal (wheat) (details: Changes in crop yields and in the stablity of crop yields; focus regions: North eastern area of plains and hills , Alpine foreland, Wald and Muehlviertel)	x		lenght of VP mean T in VP and variation mean P in VP and variation number of hard frost events w/o snow cover drought period/climate water balance in VP strong P events hail events in VP late frost events in VP heat wave in VP	Changes in crop yields [in tons per hectar]	increased use of irrigation of 10% in North eastern plains and hills . Increase of pesticide input (+ 10 %).	Optimization of the basic conditions for a successful national breeding community and cultivar evaluation system [indicator?]	Changed agricultural production affects food and processing industry and availability of feeding stuff; this has possible impacts on the trade balances (for agricultural goods, for food products)

Figure 1: Schematic illustration of one impact chain (winter wheat in the Agriculture field of activity) including its related climate stimuli and an empirical assessment of direct and indirect (trans-sectoral) impacts.

We furthermore developed a project manual for key terms, key concepts (compare Fig. 2) and common graphical presentation templates which were applied for the final Springer application.

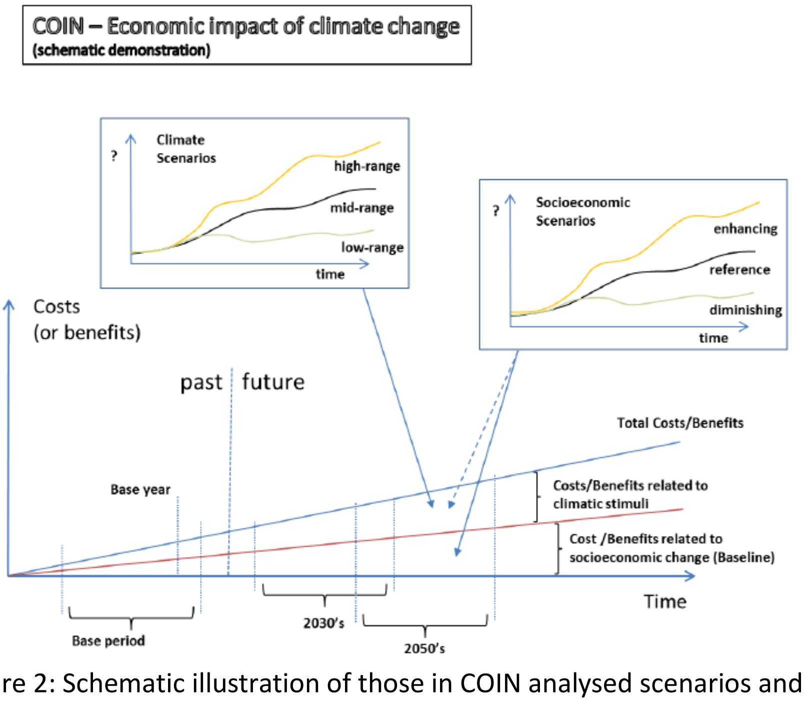

Figure 2: Schematic illustration of those in COIN analysed scenarios and periods.

Based on cross checked sectoral damages WP18 also assessed a grand total range of possible costs up to 2050. Considering all analysed impact chains, a mid-range climate scenario and a reference socio-economic development would result in additional macroeconomic average costs of 330 million euros per year in 2030 and additional 830 million euros per year in 2050. Using a different evaluation measure the project assumptions would reduce the average annual welfare by 1 billion euros in 2030 and by 2 billion euros in 2050. Assuming more extreme conditions COIN also assessed possible ranges of future costs. Induced by altered and more extreme future socio-economic changes e.g. considering changed heat conditions ranges of total average costs of 2 to 4 billion euros per year in 2030 and between about 4 and nearly 9 billion euros in 2050 were estimated (compared to damage numbers of 1 billion euros already observed today).

Macroeconomic evaluation: a comparison across impact fields and total effects

The aggregate macroeconomic effects of the quantifiable impact chains in ten impact fields were evaluated for Austria: agriculture, forestry, water, buildings (with a focus on heating and cooling), electricity, transport, manufacturing and trade, tourism, catastrophe management, and cities and urban green. First, the costing methodology used for each impact chain as well as the respective interface to implement them within the macroeconomic model are reviewed and compared across impact fields. The main finding here is that gaps in costing are mostly the consequence of insufficient data and for that reason, the two important impact fields ecosystems and human health could not be assessed in monetary terms for costs arising to the economy. Second, for the subset of impact chains which could be monetized, a computable general equilibrium (CGE) model is then used to assess the macroeconomic effects caused by these. By comparing macroeconomic effects across impact fields, we find that the strongest macroeconomic impacts are triggered by climate change effects arising in agriculture, forestry, tourism, energy, and buildings. The total macroeconomic effect of all impact chains—which could be quantified and monetized—is modest up to the 2050s: both welfare and GDP decline slightly compared to a baseline development without climate change. This is mainly due to (a) all but two impact chains refer to trends only (just riverine flooding damage to buildings and road infrastructure damages cover extreme events), (b) impacts are mostly redistribution of demand, while stock changes occurring as a consequence of extreme events are basically not covered and (c) some of the precipitation-triggered impacts point in opposite directions across sub-national regions, leading to a comparatively small net effect on the national scale.

Assessment of the Costs up to 2100 and Barriers of Adaptation

A quantification of climate damages or the costs of inaction faces the inherent uncertainty of future climate scenarios and socio-economic developments. For the appraisal of the long-run cost of inaction in COIN we therefore applied the Delphi technique until 2100 that offers a qualitative assessment by recognised experts rather than quantitative results. The Delphi results suggest pronounced increases in the damage costs in the second half of the twenty-first century. For half of the sectors addressed, there is unanimous consensus among experts that climate damage costs in 2070 will be higher than in 2050. A further increase in costs after 2070 is expected for the majority of sectors. Economic and social developments are considered the most important cost drivers in the long run. Despite this judgement, however, uncertainty of future social, economic and thus cost development is rated considerably high. Extreme events might be key determinants of the long-term cost of inaction.

Disseminiation and outreach

Presentation of the COIN project as well as the preparation of the project results were coordinated and executed. A project corporate design, including logo, and homepage (coin.ccca.at) were developed. The homepage in combination with and a project flyer functioned as information provision channels in English and German language. The project flyer was also intended to attract stakeholders to participate and support the project with their expert knowledge and useful data for the analysis. Emphasis was put on the conception and production of fact sheets for each individual sector. In strong collaboration with a communication expert key statements were deduced with the help of the lead authors and fact sheets with a maximum length of 2 pages were developed. The fact sheets feature a common structure and target interested non-experts using a comprehensive language. The storyline of each fact sheets comprises the presentation of the considered impact chains but also the listing of what has not been analyzed, the presentation of the results including regionally interesting specifications and finally cross sectoral implications as well as the impacts of the sectoral findings for the Austrian GDP or welfare. To get an overview of the entire project results an overview fact sheet was also generated summarizing the background, assumptions and main findings COIN on 7 pages. All COIN fact sheets are provided on the COIN homepage as well as on the CCCA homepage (www.ccca.ac.at)

5. Conclusions and Recommendations

Climate Scenarios

All climate scenarios indicate a warming within the 21st century. The whole ensemble indicates a warming of 0.5 up to 4 degrees till 2050 and at the end of the century the warming reaches from ~ 2°C up to 6°C in winter and up to 9°C in summer. The low border stems from models forced with the RCP 4.5 emission scenario and the high border from models forced with RCP 8.5. The climate change signal for precipitation is not that clear. The annual sum shows no clear trend. For summer precipitation, the majority of the model indicates a decrease till minus 20 % and in winter an increase of the same magnitude.

The derived indicators reflect the same trends. In general, it can be said that temperature depending indicators at the middle of the century derived from the hottest realisations have a similar climate change signal as the "mid-range" scenarios at the end of the century. The extreme warm realisations at the end of the century really show a different world. More than 100 heat days in Vienna on average are unimaginable. Precipitation depending indicators highlight a higher frequency of dry spells in summer and an increase in daily precipitation intensities

Agriculture

The analysis in the agricultural sector is mainly guided by three research questions: (1) what are potential impacts of climate change on the agricultural sector in Austria? (2) what are the costs induced by climate change at sector level and economy-wide if there is no planned adaptation, i.e. long-term adaptations implying major structural changes? and (3) which uncertainties need to be considered due to spatial and structural heterogeneity? The key findings can be summarized as follows:

1. **Climate change results in moderate increases in crop and grassland forage yields in the period 2036-65 on national average** due to moderate temperature increases, rather stable annual precipitation sums, and the CO_2 fertilization effect. Compared to the historical reference period, the model results indicate changes in average dry matter crop yields between -8% and +9% in the period 2016-45 and between -9% and +7% in the period 2036-65. Simulated changes in permanent grassland forage yields range between -3% and +33% in both scenario periods. Yield changes vary by region, crop, and crop management. Crops can utilize moderately increasing temperatures if sufficient water supply during the growing season is available. This is mainly the case for the western parts of Austria. In contrast, already existing water shortages in crop production may be exacerbated by increasing temperatures and induced evapotranspiration. This is mainly the case for the cropland dominated eastern parts of Austria. Crop and grassland forage yield increases are higher with irrigation and high fertilization intensity whereas extensive cultivation results in decreasing crop and grassland forage yields on average. The model results show that the impact of crop management exceeds the impact of climate change scenarios on average.

2. **Climate change leads to moderate increases in agricultural production value and variable costs in the period 2036-65 at aggregated national level.** This is mainly due to moderate increases in crop yields and grassland forage yields. In total, moderate climate change is expected to increase production value by € 193 million and € 180 million in the periods 2016-45 and 2036-65 compared to the baseline scenarios without climate change. The results are driven by mixed effects for both, regions and crops. Productivity gains from climate change on grasslands are an important driver of increasing production values. Total production costs also increase by € 77 million and € 74 million under the investigated climate change scenario in the periods 2016-45 and 2036-65, respectively.

3. **The results are based on a moderate climate change scenario (mid-range climate change scenario in COIN)** predicting a rising trend in mean annual temperature of +1.05 °C (+2.02 °C) and in mean annual precipitation sums of +1.5% (-2.3%) between the historical reference period 1981-2010 and the first (second) scenario period 2016-45 (2036-65) in Austria. However, more severe changes are expected for the second half of the 21st century, which are likely to result in significant changes in crop and grassland forage yields as well as agricultural production values. Furthermore, we do not account for changes in economic and

market conditions, land use, yield quality, technological advances, infestation pressure of pests and diseases, and sub-daily information on future climates.

Forestry

From available climate change impact results (forest productivity, damage from bark beetle disturbance regimes) we had to select those where the climate drivers matched the COIN climate change scenarios as closely as possible. Relative changes in productivity could be directly used to derive absolute changes in timber production in Austrian Federal Provinces. Simulated bark beetle damages in provinces in course of the 21st century were combined with aggregated species data from the Austrian Forest Inventory to derive area of damaged Norway spruce forests (Picea abies).

Energy

The change in the electricity generation mix is modelled in the optimisation model HiREPS (Totschnig et al., 2013), (Kranzl et al., 2013), (Totschnig et al., 2014). The HiREPS model is a dynamical simulation and optimization model of the electricity and heating system. The model focuses on analyzing the integration of fluctuating renewable electricity generation into the power system, and specifically uses an approach whereby important system constraints are treated endogenously. For the investigation in the project COIN the model was applied to the electricity system in Austria and Germany. After optimising the model for both countries, the individual effects for Austria were then separated out for use as input in the HiREPS model. The latter addresses these aspects endogenously by using spatially and temporally highly resolved wind, solar and hydro inflow data, and by including a detailed model of hydropower and pumped storage, thermal power plants (including startup costs and efficiency losses during part-load operation), interaction of the electricity and heating systems, load flow calculation (including thermal limits of the electricity grid), and hourly temporal resolution. Therefore, it is highly suitable to deal with the question of climate change impact on the electricity sector and assessing the cost of climate change in this sector.Change in river run-off levels, wind and PV power generation are taken into account in the model HiREPS via the hourly climate data described in 4a (Mid Range Climatic scenario for electricity) and on a monthly basis the derived results for river run-off in Austrian water basins. Increased cooling energy demand in summer and decreased heating energy demand in winter are considered in HiREPS via the total change of annual final energy demand as well as the change in hourly load profiles and thus also the changes in peak loads.

Climate change leads to a shift in both the supply and demand curves. The area below the supply curve corresponds to the overall electricity generation costs. The main indicator for monetary evaluation is the difference between the respective electricity generation costs in the baseline case and those in the mid-range scenario. This difference is derived on an hourly basis for the simulation year 2050. In addition to the above effect, there is also a change in the final demand for electricity. As this is covered in WP9 (Buildings: heating and cooling) and is not considered here.

Biodiversity

Identification of the responses of selected organisms (pollinators, generalist predators in the agricultural landscape, vertebrates) related to climate change. This requires a literature search and a review on the main work related to this topic. This includes also changes in land use as a consequence of climate change, and their effects on the organisms mentioned above (Rosinak 2008). These changes in land use types and habitats will be evaluated in their effect on every species. In a first step, we categorise the effects of climate change on habitat types (increase in area quality, reduction in area, quality). In the next step, we estimate the effects of these habitat area (quality) changes on the selected organism groups (pollinators, e. g. honey bees, bumble bees, hoverflies; generalist predators, e. g. ground beetles, rove beetles, ladybird beetles, lacewings). Effects of a worst case/ best case land use change scenario (e. g. loss of all species-rich flowering semi-natural grassland) on pollinators and generalist predators. Some of these changes are triggered by agricultural demand and agri-economical conditions rather than climate change. This is why land-use and socio-economic scenarios play a vital role for species exposure and thus sensitivity of ecosystem services.

results:

With some certainty, climatic change will lead to newly assembled pollinator and pest control communities, which might impact ecosystem services. However, land-use changes and the combination of stressors will produce a much stronger negative influence on both of these services. On regional level, a diverse landscape including semi-natural habitats is the most important background supporting a sustainable pollination rate for wild as well as cultivated plants, and also an assemblage of pest antagonists capable of keeping pest outbreaks in check. Further loss of semi-natural habitat will entail a reduced pollination rate and a reduced pest control efficiency which reduces agricultural production. If agricultural area is enlarged to compensate for production losses, the situation will be aggravated.

Among the impact chain, range shifts and asynchrony between parasitoid and pest cycles can be expected with some reliability. This will lead to newly formed species assemblages and probably a reduction in ecosystem services, at least temporarily. It is less clear whether species relevant for pest control and pollination services will become extinct and to what degree a possible reduction in species richness will impair ecosystem services.

Declines and local extinctions of some pollinator species (butterflies, hoverflies, honey bees and wild bees including bumble bees) have been proved for some European countries. However, it is still unclear to what extent climate change compared to other pressures is responsible for these species decline. Neither was it possible to quantify the losses in agricultural production which might be attributed to a change in climatic parameters.

The value of the ecosystem services pest control and pollination for agricultural production can be assessed based on published data and calculation methods as well as specific assumptions for the dependency of plant productivity on insects providing these services. However, it is not possible to make a scientifically sound quantification of impacts on these services attributed to raising temperatures. Obstacles to such quantifications are lack of knowledge regarding (1) species reactions to altered climatic conditions, (2) the compensation capacity within the species community (including alien species), (3) the importance of various insect species compared to other species to provide pest control and pollination service to agriculture, and (4) the degree of combined impacts on ecosystem services.

In the light of published knowledge of climate change and its effects on pest control organisms and pollinators, a scenario with a slight but relevant reduction of pest control and pollination with observable effects on agricultural production output appears to be the most likely one. The amount of these effects can only be estimated on the basis of several assumptions and are hypothetical. At present, it is not possible to predict the temporal trajectory of those impacts.

Calculations of insect contributions to pest control and pollination – published in the literature and provided in this chapter – prove their economic value for the agricultural production output. Therefore, observed declines of these ecosystem services at the global and European scale should evoke measures to counter climate change effects as well as land-use changes in an appropriate way. Loss of appropriate habitats due to raising intensity of agricultural use, fragmentation of landscapes and excessive use of fertilisers and pesticides are deteriorating foraging and nesting conditions for most of the insects being responsible for providing ecosystem services. These pressures seem to impair insect community networks at least to the same extent as changing climate parameters.

To reduce uncertainties, more niche modelling analyses, in particular addressing species that are responsible for pest control and pollination services, are needed. Currently, invertebrate distribution data are often incomplete and poorly suited for such analyses. The relationship between species richness and ecosystem services should be explored in closer detail. Exclusion experiments could help to elucidate the role of natural pest control in maintaining yield numbers.

Catastrophe Management, natural disaster protection, spatial planning

We used three methods to evaluate flood risk in Austria:

- The principle idea of the HORA based method is to use risk maps to evaluate the number of buildings that are affected by a flood with a given return period. The number of affected buildings together with a damage function dependent on the return period of the flood is then used to estimate the total damage. Finally risk maps under a changed climate were created using existing ones and the change of the distribution of extreme precipitation. In this method only results on residential buildings where used.
- The second data set used here is taken from the ClimateCost Project which analyzed the costs and benefits of adaptation for river flood damages in Europe using the LISFLOOD model. They focus on the mean ensemble results within the SRES A1B scenario, i.e. a medium-high emission scenario. Direct losses on residential, agriculture, transport, commerce and industry sector due to river flooding are considered only, i.e. intra-urban flooding as well as coastal flooding is excluded
- Further results from the ADAM project. The project uses static flood hazard maps and attaches probabilities to different flood depths which afterwards are coupled with corresponding losses for residential, agriculture, transport, commerce and the industry sectors. The resulting GRID based loss distributions are then upscaled to the country level using a hybrid convolution approach. In this way it was possible to derive a loss distribution on the country level. The flood curves are then changed using changes in flood hazard frequency over the period 2010-2100 for a 100-year event for the A1B storyline based. The additional time periods needed here (e.g. 2030) are derived by using the relative changes in expected losses within the ClimateCost study as an approximation of changes in losses over previous periods not reported in AdamCost.

Tourism

Many studies that deal with impacts of climate change on tourism in Austria focus on the supply side by examining the change in the climatic potential for particular tourism types, but do not explicitly take the relationship between weather/climatic conditions and tourism demand into account. However, since tourism is a strongly demand-driven sector, quantifying this relationship seems an essential task for assessing the (monetary) impacts of climate change and the costs of inaction. Hence, in order to assess direct impacts of climate change on tourism demand (represented by overnight stays), we applied a four-step-procedure:

Weather sensitivity of tourism demand: In a first step, the sensitivity of tourism demand towards weather variability was quantified based on historical data and the method of multiple regression analysis. Analyses were carried out for each Austrian NUTS 3 region as well as being separated into winter season (Nov.-Apr.) and single summer months (May-Oct.).

Climate change impacts on tourism demand: In a second step, the region- and season-specific weather sensitivities were applied to climate change signals (1981-2010 vs. 2016-45 and 1981-2010 vs. 2036-65), resulting in the assessment of the pure impacts of “average weather” conditions without considering any socioeconomic changes. Results of step 2 were given as percentage change in overnight stays.

Integrated scenario: In step 3, scenarios on future tourism development were taken into account additionally.

Monetary evaluation: In the last step, physical impacts were translated into monetary terms using average tourist expenditures per overnight stay.

To sum up, quantifying the climate-induced change in final demand was chosen as method for assessing the costs of inaction in the tourism sector.

Manufacturing and trade

Developments within society and economy are crucial for exposures in almost all sectors. In fact, demand for goods and services from all sectors are steered by socioeconomic developments. A surplus in welfare will alter demand for energy, water, wood products, food, tourism infrastructure and industrial products as well as the discount rate. Thus, the development of a coherent socio-economic scenario was crucial.

The distributions of human beings within the age pyramid as well as scenarios for migration within Austria and from the outside determine the spatial distribution of potentially sensitive populations and thus determine the exposure of the sector health.

Technological development is crucial for the exposure of certain sectors. Plausible technology assumptions have been elaborated for the following sectors: energy, construction and housing as well as industry and retail.

Setting up plausible land-use scenarios was based on plausible land-use shares and hints on distributional patterns for Austria. The time slice for land-use scenarios will cover the first half of the century only. Land-use patterns have explicitly supported exposure assumptions for the following sectors: agriculture, forestry, biodiversity and ecosystems, cities/urban green spaces, transport and mobility as well as energy results:

Pragmatically, we have referred to a global reference Road socio-economic pathway (represented by SSP2 in the IPCC process) and derived figures for the core economic, demographic, land-use and (qualitatively) technological development in Austria, which again frame the sectoral development assumptions necessary to follow a scenario-based cost assessment approach.

In principal, trend projections and existing studies have been used to describe a single country, here applied for Austria, in 2030/2050 that is growing slowly in terms of population (0.27% p.a.) and medium in terms of GDP (1.65% p.a.) and in which forests, meadows and settlements expand in the north-east-south crescent – at the cost of arable land, within which further intensification will take place. Policy assumptions as well as technological change have been set to a medium path, at which risk zoning put forward, the EU integration 'muddles through' and no technological wonders are taken into account. A reference scenario might be regarded as least uncertain – which is not true – but we might expect more volatile developments to equilibrate over some decades.

The Austria we expose to climate change by 2050 is significantly different from nowadays: Its population is older and its public and private infrastructure density is higher – at least two factors that might influence future climate costs of inaction.

Cities and urban green

A critical topic in cities is - with respect to global warming - the urban heat island effect, expected to be more important in future decades. Investments to enlarge the open green areas in cities are preventive expenditures, helping to mitigate the urban heat island effect under higher temperatures, to secure the current local thermal comfort - to keep the health conditions of the inhabitants stable and to enhance the attractiveness of the city for visitors during the hot summer months. Additional costs for intensifying the maintenance of urban green because of climate change is judged to be less important as climate stress is surpassed by environmental stressors due to activities and properties within the city.

Climate Change Impacts at the National Level: Known Trends, Unknown Tails, and Unknowables

Economists attempting to evaluate the impacts of climate change are often caught between hard theory and exceedingly rocky empirics. Impact assessment models are necessarily based on highly aggregated—and sometimes highly simplified—damage functions. This study takes an alternative approach: a bottom-up, physical impact assessment and respective monetization, attempting to cover a much broader set of impact fields, feeding directly into a macroeconomic and welfare analysis at the national level. To ensure consistency, our approach applies impact assessment at the sectoral impact chain level using shared socioeconomic pathways, consistent climate scenarios, computable general equilibrium evaluation, and non-market impact evaluation. The approach is applied to assess a broad scope of climate impacts in Austria. Results indicate significant impacts around 'known knowns' (such as changes in agricultural yield from climatic shifts), with uncertainty increased by 'known unknowns' (e.g. changes in water availability for irrigation, changes in pest and diseases) but also raises the question of unknowns and unknowables, which may possibly dominate future impacts (such as exceedance of critical ecosystem function for supporting agriculture). Climate change, ultimately, is a risk management problem, where insurance thinking warrants significant mitigation (and adaptation) action today.

Analysis of the study result indicate that the current welfare damage of climate and weather induced extreme events in Austria is an annual average of 1 billion euros (large events only). This has the potential to rise to 4–5 billion euros by mid-century (annual average, known knowns of impact chains only), with an uncertainty range of 4–9 billion euros. When extreme events and the tails of their distribution are included, even for a partial analysis focused on extremes, damages are seen to rise significantly, e.g. with an estimated increase to 40 billion euros due to riverine flooding events alone by the end of the century. These highlight the need to consider the distribution of impacts, as well as the central values.

B) Project details

6 Methods

International Peer-Review of results

In order to care for the best possible scientific quality of the sectoral results a peer review process was conceived and implemented within COIN. In order to produce an internationally published Springer publication a four step review process was implemented. In this context national and international experts commented on the scientific quality, the innovation of the applied methods and the transferability of the presented results and methods to the international scale as well as on the language and the result's presentation. Respective comments were integrated by the project team and approved by an editorial team. In order to guarantee the intercomparison and readability across sectoral explanations, commonly applied key terms and concepts as well as graphical templates were developed within COIN.

Economic evaluation framework

The first step in an economic assessment of climate change impacts at the country level is the identification of so called "impact fields". These fields can be either single economic sectors, parts of sectors or aggregates of sectors. For the case of Austria that is explored in this project, 12 impact fields are identified and investigated regarding climate change impacts and the resulting economic costs and benefits. As impact fields are often of very different character, the mechanisms of climate change impacts are different and, therefore, also the costing methods to obtain costs and benefits of climate change are diverse. Hence, depending on the impact field, one or several of the following costing methods are applied: Changes in production technology and subsequent production cost structure, changes in productivity, changes in final demand, changes in investment, changes in public expenditures, and, finally, as an indirect cost measure, level of replacement cost. By applying these methods we obtain the direct costs by impact field.

As a modern economy is characterised by a strong specialisation across activities and sectors, there are strong interdependencies between different economic sectors 20
(e.g. the food sector relies heavily on agriculture). For that reason, indirect effects on other sectors may contribute to total costs (or benefits) for the economy as well. A framework is needed which is able to capture these interactions between economic sectors. For that reason we here employ a computable general equilibrium (CGE) model as it depicts linkages between economic sectors as well as agents and is therefore able to cover interaction between different climate impacts occurring in different sectors. Relevant model outputs are changes in welfare, changes in sectoral activity (output), changes in value added and GDP, as well as in public budgets.

Agriculture

Δ Climate signal	
Model & data	Statistical climate change model (ACLiReM) COIN-climate change data (COIN-CCD)
Indicators	Ø Temperature (°C) Ø Precipitation (mm)

↓

Bio-physical impacts	
Models	Bio-physical process model EPIC Meta-models of yield responses
Results	Ø Yields at NUTS-3 level (changes in %)

↓

Economic impacts on the agricultural sector	
Calculation	Economic gross margin calculation
Results	Ø Production values at NUTS-3 level (changes in %) Ø Production costs at NUTS-3 level (changes in %) Ø Productivity changes

↓

Macro-economic impacts	
Model	Computable general equilibrium (CGE) model
Results	Ø Welfare (changes in M€) Ø GDP (changes in M€) Ø Unemployment rate (changes in % points) Ø Public budget (changes in % points)

Fig. 1 provides an overview on the methodological steps of the climate change impact assessment in the agricultural sector. We have developed statistical meta-models of yield responses to match results from the bio-physical process model EPIC (Environmental Policy Integrated Climate; Williams, 1995) with the mid-range climate change scenario of the COIN project. Climate induced crop and grassland forage yield impacts are derived for five major crops including grain maize, winter wheat, winter rape, soybean, and temporary grassland as well as for permanent grassland. The economic impacts are driven by changes in crop and grassland forage yields as well as yield driven changes in production costs. An economic calculation is applied to estimate average annual changes of production values and production costs for the periods 2016-2045 and 2036-2065. The results feed into a computable general equilibrium (CGE) model to assess economy wide effects on welfare, GDP, employment, and public budget. Non-monetized impacts (e.g. sub-daily extreme precipitation events) are evaluated qualitatively. Uncertainties are discussed and are mainly because of high spatial and sectoral aggregation as well as unknown autonomous adaptation behavior of farmers.

Δ Climate signal	
Model & data	Statistical climate change model (ACLiReM) COIN-climate change data (COIN-CCD)
Indicators	Ø Temperature (°C) Ø Precipitation (mm)

Bio-physical impacts	
Models	Bio-physical process model EPIC Meta-models of yield responses
Results	Ø Yields at NUTS-3 level (changes in %)

Economic impacts on the agricultural sector	
Calculation	Economic gross margin calculation
Results	Ø Production values at NUTS-3 level (changes in %) Ø Production costs at NUTS-3 level (changes in %) Ø Productivity changes

Macro-economic impacts	
Model	Computable general equilibrium (CGE) model
Results	Ø Welfare (changes in M€) Ø GDP (changes in M€) Ø Unemployment rate (changes in % points) Ø Public budget (changes in % points)

Fig. 1. Methodology to assess climate change impacts in agriculture.

Ecosystems/Biodiversity

POLLINATION

To estimate the total economic value of the pollination service for the agricultural production in Austria only those pollinator-dependent agricultural products were selected which are directly used for human food. A further selection criterion was the availability of published figures for production output and producer prices. The economic value of each of the products was calculated according to the formula used by Gallai et al. (2009): Economic value = Production output x production price. In order to assess the pollinator dependent production output and the corresponding producer prices we attributed an average pollination dependence coefficient to each of the products following Klein et al. (2007).

PEST CONTROL

Losey & Vaugham (2006) assess the value of pest control ecosystem services by predators and parasitoids to be 65% of the value of agricultural goods, based on the consideration that natural pest control by parasitoids and natural predators reduced the amount of infested agricultural products to 35%. This is consistent with the finding that exclusion of polyphagous invertebrate predators from aphid-infected plants can increase the number of aphids by 31% (Holland & Thomas 1997). Since the value of agricultural plant products in 2008 has been calculated to be 3 001 million € (Statistik Austria 2009), the value of pest control ecosystem services by predators and parasitoids can be calculated to 1 885 million €.

Human Health

Past impacts and the present understanding of future developments shape the focus of this work package. Amongst the numerous possible pathways by which climate change might affect human health, heat waves seem to be by far the most severe threat to human health in Western and Southern Europe, especially when employing the assumption that adaptation to climate change will not take place (see also EEA 2012).

The methods for estimating health impacts of heat waves consider different climate and socio-economic scenarios for Austria for an average year during the 2016-2045 and 2036-2065.

The following steps were applied to arrive at the results:

1. The estimates presented here are based on Moshammer et al. (2006). Hence we used the Austria-specific postulated (investigated) interrelationship between Kyselý days (for a definition please refer to the book chapter) and excess mortality.
2. Projected Kyselý days were taken from climate model results (see relevant work package) on NUTS 3 level in accordance with the population assumptions.
3. Population: We only considered the population fraction aged above 65. Data were taken from the Statistics Austria database (see work package shared-socio-economic pathways).
4. Two different calculations were performed: Firstly, excess mortality because of Kyselý days including continuous temperature increase and secondly, excess mortality solely because of continuous temperature increase.
5. Calculations: Each calculation was performed for an average year in both the 2030s & 2050s and for three different socioeconomic and three different climatic scenarios.

Morbidity caused by heat waves was not calculated. Impacts can be expected to be much smaller than for mortality and uncertainties to be much higher. So far, no study for Austria has performed such estimates (Moshammer et al. 2006 collected data but did not analyze these). Michelozzi et al. 2009 investigated 12 European cities including Ljubljana, Budapest and Paris. Results were not appropriate to enable estimates for Austria.

Water

First, the baseline scenario calculates the differences between todays WSS sector and the future WSS sector of the the periods 2016 to 2045 and 2036 to 2065 without the influences of the anticipated climate change. The current estimations of total assets, units (water consumption / wastewater) and on costs are based on existing empirical data (Neunteufel et al. 2009, 2011, 2012a, 2012b and 2013a, Ertl et al. 2013). The future estimations of total assets and costs involved in the WSS sector are based on an extrapolations in accordance with the population growth, subsidy development (see shared socioeconomic pathway – chapter 7) and anticipated change of asset rehabilitation (Neunteufel et al. 2012b) and consumer behaviour (Neunteufel et al. 2012a).

Second, the climate change scenario calculates the differences between the future WSS sector (baseline without climate change) and the future WSS sector of the periods 2016 to 2045 (calculation for 2030) and 2036 to 2065 (calculation for 2050) with the influences of climate change. The estimations for the future climate change situation are based on expert assumptions with regard to the impact chains listed in Table 13.1 and Table 13.2.

However, several non-quantifiable impact chains are not included within the calculation of the climate change scenario. Therefore the results of the quantification are undervalued for sure at a certain magnitude that can't be estimated based on easy available information.

Nevertheless the considerations point out a possible was how to estimate climate change impacts and show

Construction and housing

The following steps were carried out to assess the costs of the two impact chains space heating and space cooling:

- Development of a reference scenario as well as scenarios with diminishing and enhancing heating and cooling energy demand. First, these scenarios are calculated ignoring the impact of climate change, and then taking climate change into account. This includes the uptake of renovation measures and changes in the mix of heating and cooling technologies. This step was carried out using the model Invert/EE-Lab (see e.g. www.invert.at). The scenarios are based on the project PRESENCE (www.eeg.tuwien.ac.at/presence, Kranzl et al., 2013b).
- For the cost evaluation, the costing method "change in final demand" was selected according to the overall tools in the economic framework. The scenarios were evaluated in terms of costs of energy carriers for heating and cooling, calculated on the basis of energy prices and energy demand for all energy carriers as well as regarding required investment

- costs for cooling and ventilation units, derived from the specific costs of cooling systems and the installed capacity in the different building categories.
- The costs of inaction are calculated by taking the difference between the costs in the climate change scenario and those in the baseline scenario (i.e. no climate change).
- To gain input for the macro-model and to assess feedback from other sectors the effects have been divided into the following sectors, corresponding to the related macro-economic sectors: Costs for biomass fuels, costs for heating oil and coal, costs for natural gas, electricity and district heating, costs for air conditioning and ventilation devices

Urban Green

We started with estimating urban expansion of the 6 Austrian major cities which show population numbers near or above 100.000 (Klagenfurt, Linz, Salzburg, Graz, Innsbruck, Wien).

Based on the current built-up area – urban green ratio additional open urban green area expansion has been estimated between 3.7 and 6.8 (till 2030) respectively between 5.5 and 10% (till 2050) for the baseline scenario. To mitigate urban heat effects due to more frequent and severe heat episodes as expected in the mid-range scenario open green space expansion was assumed considering additional climate induced growth rates between 1 and 4.5% (till 2030) respectively between 1.5 and 4.5% (till 2050). To keep additional park area small planting of additional street tress was suggested by expanding the street tree density per ha between 1 and 3 % (till 2030) and 3 to 5% (till 2050).

Costs have been estimated as investment costs and as maintenance costs. Investment costs have been calculated based on the cities' average lot prices and the construction costs on cost per unit basis (reported from the cities' gardening departments and from literature). Costs for open green area maintenance have been taken from the cities' particular "budget sector 8150", which contains all costs for "parks, gardens and childrens' playgrounds" and relating the cost numbers to the currently maintained park area. The calculation of the expenditures increase for open green space maintenance assumes that the total costs will grow like the open green space expansion.

Shared Socio-economic Pathways (SSP) for Austria

Setting up demographic, economic, technological and land-use scenario was primarily done by desk study and statistical analysis. Explicitly demographic and economic scenarios were raised on existing studies and material (e.g. Statistik Austria, BMF, OECD, FAO, IEA) while existing material for technological assumptions was very poor and accordingly only qualitative descriptions could have been raised. For the land-use scenarios, more detailed statistical analysis was performed based on socioeconomic and demographic trends at NUTS3 level. Settlement areas, mainly urban sprawl, as well as agricultural and forest area were projected Austria-wide at NUTS3 level.

Consistency

The implementation of a consistency framework within COIN was one major project highlight which enabled the project consortium to intercompare the sectoral climate related impacts on a monetary basis and to provide a grand total considering the different impact chains. For this purpose, all sectors used the same climate scenario as well as socioeconomic assumptions provided in WP1 and WP16. The provision of a guideline on the agreed methodological application of scenarios and a common wording within WP18 also enabled to overcome different transdisciplinary concepts and therefore the targeted intercomparison analysis.

Dissemination

The transformation of scientific project result into understandable and applicable information presents one major research challenge in the field of climate change impact research. Although a broad range of scientific knowledge is available in the scientific community action is missing in the respective decision making committees. Within this project the translation and condensation of the one year project results into fact sheets with a maximum length of 2 pages was accomplished by the strong collaboration of the scientific project team with a communication expert and an intermediate service team enabling this mutual knowledge transfer and preparation process. By this mean and based on several iteration steps the ratio between content and comprehensibility was developed.

References (sections 1-6)

BMLFUW (2012), Die Österreichische Strategie zur Anpassung an den Klimwandel, BMLFUW, Wien, 2012.

EEA European Environment Agency (2012) Climate change, impacts and vulnerability in Europe 2012 - An indicator-based report. EEA, Copenhagen

IPCC (2013) Climate Change 2013: The Physical Science Basis, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Oxford University Press.

IPCC (2014a) Climate Change 2014: Impacts, Adaptation, and Vulnerability, Summary for Policy Makers, IPCC.

IPCC (2014b): Climate Change 2014: Impacts, Adaptation, and Vulnerability, Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Oxford University Press.

IPCC (2014c) Climate Change 2013: Mitigation of Climate Change, Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Oxford University Press.

Jacob, D. et al. (2013), EURO-CORDEX: new high-resolution climate change projections for European impact research, Regional Environmental Change, doi: 10.1007/s10113-013-0499-2

Moshammer H, Hutter H P, Frank A, Gerersdorfer T, Hlava A, Sprinzl G, Leitner B (2006) Einflüsse der Temperatur auf Mortalität und Morbidität in Wien. StartClim2005.A1a

Michelozzi P, Accetta G, De Sario M, D'Ippoliti D, Marino C, Baccini M, Biggeri A, Anderson HR, Katsouyanni K, Ballester F (2009) High temperature and hospitalizations for cardiovascular and respiratory causes in 12 European cities. American Journal of Respiratory and Critical Care Medicine 179(5):383–389

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

Wagner, Gernot and Martin L. Weitzman (2015). Climate Shock: the Economic Consequences of a Hotter Planet, Princeton University Press.

Williams, J.R. (1995). The EPIC Model, in: Computer Models of Watershed Hydrology, Water Resources Publications. Singh V.P., pp. 909–1000.

WMO (1979): Declaration of the World Climate Conference, World Meteorological Organization.

7 Work- and Time Schedule

The project was granted end of December 2012, the kick-off took place in January 2013, covering all 18 research groups involved and the international advisory board. A dens network of interlinkages and interface management ensured consistency across the twelve inpact fields, and with the methods in shared socio-economic pathways, climate scenarios and economic evaluation methods. In October 2013 the overall results of the project were presented to the Scientific Advisory Board. All results were further harmonized and revised, with final drfat chapters ready for review by December 2013. International review reports came in in early 2014, chapters were revised accordingly, in some cases twice, until acceptable for publication. In summer 2014 the chapters (and Online supplementary material) was submitted to Springer (after having passed also their quality control), with proofs ready in late November 2014, and corrected proofs delivered early December 2014, such that the book covering all project results will be on the market in early 2015.

8 Publications and Dissemination

(1) Publications:

Author(s)	Title	Publisher
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.
Paul Watkiss	The Cost of Climate Change in Europe	in Steininger et al (2015), Springer.
Reimund Schwarze	On the State of Assessing the Risks and Opportunities of Climate Change in Europe and the Added Value of COIN	in Steininger et al (2015), Springer.
Karl W. Steininger, Martin König, Birgit Bednar-Friedl, and Herbert Formayer	Climate Impact Evaluation on the National Level: The Interdisciplinary Consistent Framework	in Steininger et al (2015), Springer.
Herbert Formayer, Imran Nadeem, and Ivonne Anders	Climate Change Scenario: From Climate Model Ensemble to Local Indicators	in Steininger et al (2015), Springer.
Martin König, Wolfgang Loibl, Willi Haas, and Lukas Kranzl	Shared-Socio-Economic Pathways	in Steininger et al (2015), Springer.
Gabriel Bachner, Birgit Bednar-Friedl, Stefan Nabernegg, and Karl W. Steininger	Economic Evaluation Framework and Macroeconomic Modelling	in Steininger et al (2015), Springer.
Hermine Mitter, Martin Schönhart, Ina Meyer, Klemens Mechtler, Erwin Schmid, Franz Sinabell, Gabriel Bachner, and Birgit Bednar-Friedl	Agriculture	in Steininger et al (2015), Springer.
Manfred Josef Lexer, Robert Jandl, Stefan Nabernegg, and Birgit Bednar-Friedl	Forestry	in Steininger et al (2015), Springer.
Klaus Peter Zulka and Martin Götzl	Ecosystem Services: Pest Control and Pollination	in Steininger et al (2015), Springer.
Willi Haas, Ulli Weisz, Philipp Maier, and Fabian Scholz	Human Health	in Steininger et al (2015), Springer.
Roman Neunteufel, Reinhard Perfler, Dominik Schwarz, Gabriel Bachner, and Birgit Bednar-Friedl	Water Supply and Sanitation	in Steininger et al (2015), Springer.
Lukas Kranzl, Marcus Hummel, Wolfgang Loibl, Andreas Müller, Irene Schicker, Agne Toleikyte, Gabriel Bachner, and Birgit Bednar-Friedl	Buildings: Heating and Cooling	in Steininger et al (2015), Springer.
Lukas Kranzl, Gerhard Totschnig, Andreas Müller, Gabriel Bachner, and	Electricity	in Steininger et al (2015), Springer.

Birgit Bednar-Friedl		
Birgit Bednar-Friedl, Brigitte Wolkinger, Martin König, Gabriel Bachner, Herbert Formayer, Ivo Offenthaler, and Markus Leitner	Transport	in Steininger et al (2015), Springer.
Herwig Urban and Karl W. Steininger	Manufacturing and Trade: Labour Productivity Losses	in Steininger et al (2015), Springer.
Wolfgang Loibl, Tanja Tötzer, Mario Köstl, Stefan Nabernegg, and Karl W. Steininger	Cities and Urban Green	in Steininger et al (2015), Springer.
Franz Prettenthaler, Dominik Kortschak, Stefan Hochrainer-Stigler, Reinhard Mechler, Herwig Urban, and Karl W. Steininger	Catastrophe Management: Riverine Flooding	in Steininger et al (2015), Springer.
Judith Köberl, Franz Prettenthaler, Stefan Nabernegg, and Thomas Schinko	Tourism	in Steininger et al (2015), Springer.
Claudia Kettner, Angela Köppl, and Katharina Köberl	Assessment of the Costs up to 2100 and Barriers to Adaptation	in Steininger et al (2015), Springer.
Gabriel Bachner, Birgit Bednar-Friedl, Stefan Nabernegg, and Karl W. Steininger	Macroeconomic Evaluation of Climate Change in Austria: A Comparison Across Impact Fields and Total Effects	in Steininger et al (2015), Springer.
Karl W. Steininger, Gernot Wagner, Paul Watkiss, and Martin König	Climate Change Impacts at the National Level: Known Trends, Unknown Tails, and Unknowables	in Steininger et al (2015), Springer.
Steininger, Themessl, Bednar-Friedl	Presentation of the COIN project	KLIEN annual report, 2014
COIN Team	COIN project info flyer	COIN project team
COIN Team	COIN Übersicht Fact Sheet	
Auswirkung des Klimawandels auf die pflanzliche Produktion	H. Mitter et al.	CCCA
Auswirkung des Klimawandels auf die Straßeninfrastruktur in Österreich	B. Bednar-Friedl et al.	CCCA
Auswirkungen des Klimawandels auf die Nächtigungen von Touristen in Österreich	J. Köberl et al.	CCCA
Auswirkungen des Klimawandels auf die Arbeits-produktivität in Fertigung und Handel in Österreich	H. Urban et al.	CCCA
Auswirkungen des Klimawandels auf die Gesundheit des Menschen	W. Haas et al.	CCCA
Auswirkungen des Klimawandels auf den österreichischen Wasserversorgungs- und Abwasserentsorgungssektor	R. Neunteufel et al.	CCCA
Auswirkungen des Klimawandels auf den Temperaturkomfort in Österreichs Städten	W. Loibl et	CCCA

Auswirkungen des Klimawandels auf die durch Fließge- wässer bedingte Hochwassergefährdung in Österreich	F. Prettenthaler et al.	CCCA
Auswirkungen des Klimawandels auf die Energie- und Stromversorgung in Österreich	L. Kranzl et al.	CCCA
Auswirkungen des Klimawandels auf die Holzproduktion in Österreich	M.J. Lexer et al.	CCCA

(2) Dissemination

Title	Event	Location	Presentation by
COst of INaction	Klimatag 2014	Innsbruck, April 2014	Karl Steininger
Kosten des Klimawandels für Österreich	Pressekonferenz mit BM Rupprechter zum Projekt COIN	Vienna, 15 January 2015	Karl Steininger
Kosten des Klimawandels	Dissemination Workshop COIN	Vienna, 22 January 2015	Full COIN team

Further dissemination activities to follow after the press conference with Minister Rupprechter.

Further publications in preparation (e.g. Formayer, H., Nadeem, I., (2015): Statistical method to derive “peak over threshold” indicators from monthly data. In preparation)