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# ITERATIVE CLIMATE RISK MANAGEMENT AS EARLY ADAPTATION IN AUSTRIA – POLICY CASE STUDY “PUBLIC ADAPTATION AT THE FEDERAL & PROVINCIAL LEVEL”

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### Abstract

In this report we investigate public adaptation measures and the associated costs at the federal and provincial level by focusing on disaster risk in Austria as a case study. Despite considerable uncertainties regarding the attribution of disaster losses to anthropogenic climate change, rising losses from extreme events, such as floodings, have highlighted the need for tackling climate-related risks in any case. As highlighted by the Third UN World Conference on Disaster Risk Reduction in Sendai in early 2015, in practice this requires to address risk comprehensively by linking climate change adaptation (CCA) to disaster risk management (DRM). We test the relevance and implications of operationalizing the emerging concept of Climate Risk Management (CRM) to that end for the case of Austria, a country that has been subject to recurrent flooding, leading to massive losses and considerable stress to public finance. We suggest and employ an approach building on multiple lines of evidence and various methods, comprising of an extensive literature review, expert interviews, public budget analyses, exchange workshops with key stakeholders and risk-based economic modeling involving fiscal stress testing. We find that (1) in the current Austrian DRM practice climate change considerations are not explicitly taken into account. However, the DRM practice in Austria can be seen as early adaptation to climate change. (2) Recent extreme events have already put Austria's major risk financing instrument – the disaster fund – under severe pressure and made budget diversions necessary. (3) Under future climate and socioeconomic developments climate related risks are expected to increase substantially, leading to potentially even stronger fiscal implications in the future. To proactively address future contingent climate-related fiscal liabilities, we suggest to foster linking climate adaptation with DRM in practice by implementing a comprehensive CRM approach. In such an approach a mix of policy measures is needed, tailored to the particular requirements of different layers of climate related risks.

# Contents

## 1. Aim of the working paper

The purpose of this working paper is to contribute to the assessment of public adaptation measures and the associated costs at the federal and provincial level in Austria in terms of a policy case study. In the present case study we look into extreme event risk, with a special focus on flood risk, which is the most relevant natural hazard for Austria. The importance of extreme event risk is highlighted by the inclusion of "Protection from natural hazards" and "Disaster Risk Management" as two out of 14 activity categories in the National Adaptation Strategy (NAS). The case study addresses current as well as medium to long term disaster risk by engaging in a broad stakeholder dialogue with Austrian disaster risk management experts and practitioners, conducting comprehensive budget analyses, and employing state of the art economic flood risk modelling. Furthermore, we test the relevance of the concept of climate risk management (CRM) for the Austrian practice, which allows for comprehensively addressing disaster risk by linking climate change adaptation (CCA) and disaster risk management (DRM).

The research is conducted within the project PACINAS "Public Adaptation Costs: Investigating the National Adaptation Strategy", funded by the Austrian Climate Research Programme ACRP and is coordinated by the Wegener Center for Global and Climate Change, University of Graz. Two case studies on public adaptation costs are carried out: one for the federal and provincial level and a second for cities (see Figure 1).

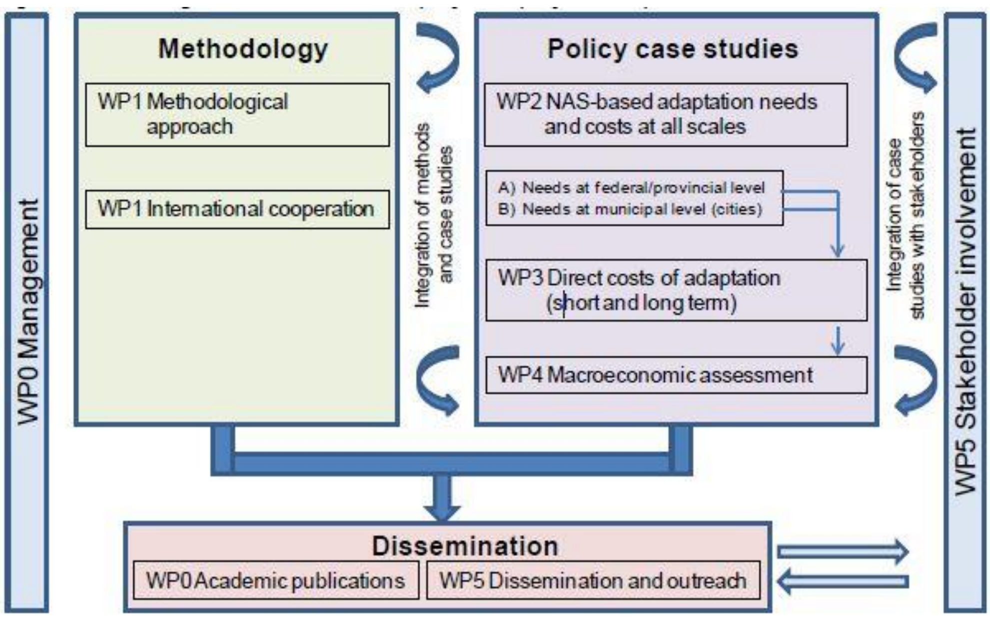


Figure 1: PACINAS project – project components and their interaction. Source: PACINAS Project Partners (2014)

## 2. Introduction and background

Much of the concern about climate change is related to projected shifts in the occurrence of events linked to weather and climatic extremes such as floods and droughts. While weather extremes and associated losses have been concerns for a long time, with losses and impacts from extreme events in Europe rising sharply in recent decades the issue has risen to the top of the agenda in Europe and elsewhere. Yet, although science has identified climate change to alter frequencies, durations and intensities of many natural hazards - heatwaves, droughts and heavy precipitation on a global scale (IPCC, 2014) as well as for heavy precipitation events on the national scale in Austria (APCC, 2014) - the case for climate change increasing economic impacts associated with natural hazards, commonly called losses, has not yet been made (Bouwer, 2011; IPCC, 2012; Mechler et al., 2014). The rise in losses has so far been primarily attributed to socioeconomic trends, rising exposure of people and capital at risk, while acknowledging that an influence of climate change on trends in losses cannot be excluded (IPCC, 2012). Despite (and because) of these considerable uncertainties, recent disasters in Austria and Europe have highlighted the need for fostering climate risk management (CRM) in the present and in the future, and the concept of CRM featured prominently in scientific studies and policy reports (EC, 2009; UNISDR, 2009; Watkiss et al, 2014; Jones et al. 2014).

Yet, while the potential of CRM has been understood and various conceptualizations suggested, there is a sore lack of operational methods which can provide decision-support. As one conceptual contribution, analysts have suggested that CRM means comprehensively reducing, preparing for and financing risk, while tackling the underlying risk drivers, including climate-related and socio-economic factors (Mechler et al. 2014). Watkiss et al. (2014) see a key role for CRM in terms of serving as a blueprint for early action on CCA. This implies a significant overlap between current practice of DRM and CCA activities. Both pursue a similar goal, namely the reduction of negative impacts of climate change and disasters, respectively, on the natural environment, human society and economies by anticipating risks and uncertainties and addressing vulnerabilities (IPCC, 2012). Consequently, there have been calls to subsume both CCA and DRM within a broader CRM concept and to mainstream CRM into both development practice and planning at the sub-national, national and international levels (IPCC, 2014).

Despite these strong calls and expressed needs for employing and mainstreaming comprehensive CRM in practice, little research has been done in various dimensions within this domain to inform the practical implementation of CRM: (i) Even though Watkiss et al. (2014) present a conceptualization of an iterative framework for climate change adaptation, their approach falls

short of discussing present and future challenges in a more comprehensive notion of climate risk management; (ii) there is a lack of clarification regarding the operationalization of the CRM concept; (iii) empirical evidence of actors employing the concept and related methods is largely missing; (iv) an explicit risk-based consideration of climate extremes that distinguishes between frequent (average) and infrequent (fat-tailed) risks (Steininger et al., 2015).
The following discussion aims at contributing to filling these gaps in terms of providing an operational definition of CRM, providing evidence generated while using a CRM approach with adaptation policymakers, and reflecting on the pros and cons of the concept and associated methods.

We focus our CRM discussion on the case of Austria, a country that has been subject to recurrent flooding, and which was just recently hit by large-scale flooding in 2013, which led to massive losses (estimated at EUR 0.9 billion; BMI, 2014) and substantial stress to public finance. Austria has been a forerunner in analytical approaches for dealing with climate-related risks. As one of the first comprehensive national assessments of climate change, the Austrian Panel on Climate Change (APCC) showed that warming in Austria is stronger than the global average, leading to increasingly severe risk and the need to upgrade adaptation efforts (APCC, 2014). A country-wide assessment of the costs of climate change was conducted in 2015, demonstrating large cost implications of unmitigated climate change for public and private actors already today (Steininger et al., 2015). Also, in 2012, the Austria Council of Ministers adopted the national adaptation strategy and action plan (BMLFUW, 2012), which was co-generated with a large set of stakeholders and identifies many options, which are now being prioritized in terms of their costs, benefits and potential to reduce impacts and risk. "Protection from natural hazards" and "DRM" are two of 14 activity categories that are covered in the Austrian national action plan and which we consider here in the context of the comprehensive CRM discussion.

Overall, our main research question we set out to answer by looking into the case of Austria is whether the iterative CRM conceptualization serves as a useful concept to address the existing adaptation deficit and the uncertainties associated with future climate change impacts, losses and damages in policy and practice. As one important element, we tackle the highly policy relevant topic of natural hazards' impact on countries fiscal vulnerability and what a country like Austria can do to cope with economic impacts of climate risks. To answer this research question, we employ an approach building on multiple lines of evidence and various methods, comprising of an extensive literature review on the current CCA practice dealing with extreme events and natural hazards in

Austria, analyses of the Austrian public budget, expert interviews with stakeholders in Austria, climate risk-based economic modelling, and robust adaptation pathways.

### 2.1. Shifting paradigms: towards climate risk management

The role of risk in responses to climate change has seen heightened attention, particularly with the publication of IPCC's 5th assessment report. While being discussed strongly in all the contributions by working groups I, II and III, particularly working group III took thinking on risk and risk management strongly forward. The foundational chapter by Jones and colleagues (Jones et al., 2014) suggested a balanced perspective organized around three framings of risk, that all need attention with different emphases: (1) Idealized risk – the conceptual framing of climate change risk under the UNFCCC as dangerous anthropogenic interference with the climate system, represented by the Reasons for Concern as the dominant framework for informing mitigation and the 2 degree target; (2) perceived risk - the subjective judgment people make about an idealized risk for informing adaptation; as well as (3) calculated risk - the product of a quantitative risk analytical exercise based on a mixture of historical (observed) and theoretical information for informing both adaptation and mitigation questions. Jones et al. (2014) suggest that while the focus has been on (1), (2) and (3) are seeing increasing attention. We build on this and suggest that a shifting discourse informing policy and practice needs to be based on all three framings of risk and hence consider the following three aspects: (1) iterative CRM (2) transformation from re-active disaster response to pro-active risk management (3) and finally, moving from implicit to explicit budgeting of climate risks.

Even though the current state of scientific knowledge does not provide robust, quantifiable evidence that climate change is at the moment the unique, not even the most important direct driver of losses and damages linked to climate-related disasters (Bouwer, 2011; IPCC, 2012), it can be argued that CRM is indispensable for managing the existing adaptation deficit. This existing adaptation deficit results from existing climate variability and extremes and does not factor in potential future developments initiated by climate change. Hence, the current DRM practice can be seen as an early adaptation measure within an iterative climate risk management approach (Figure 2): first addressing the existing adaptation deficit and by iteratively integrating new scientific knowledge on climate change (e.g. emerging early trends and changes in variability that exacerbate existing risks or create new risks), acknowledging the uncertainties associated with climate change and paving the way for mainstreaming climate change in disaster risk management (Watkiss et al., 2014). This gradual approach allows for an adjustment of decisions over time with evidence and eventually contributes to increase the robustness of policy response pathways to deal with the impacts of climate change.

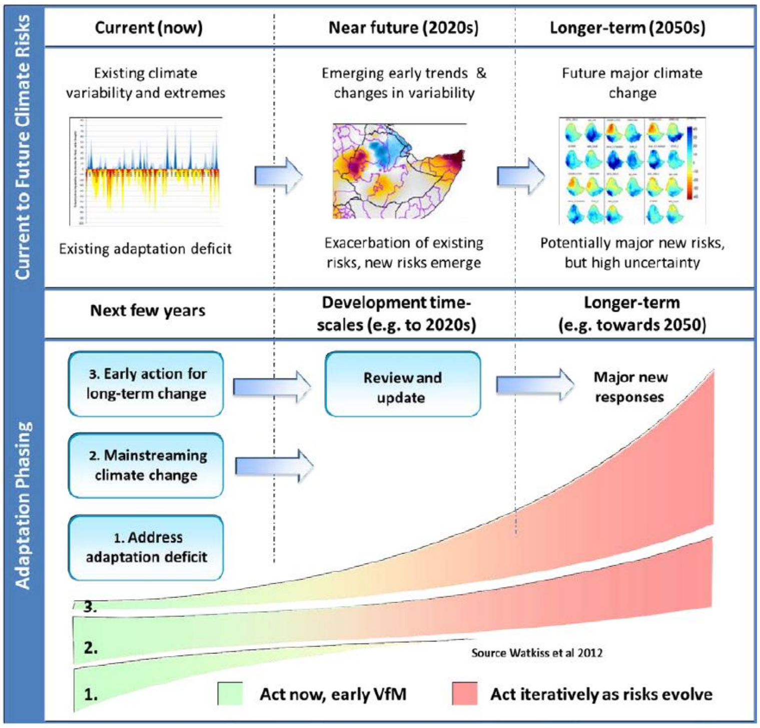


Figure 2: Iterative framework for adaptation; Source: Watkiss et al. (2014)

Over the last decade there has already been a paradigm shift in the choice of policy instruments to address disasters towards a more pro-active approach, putting a stronger emphasize on ex-ante DRM (Linnerooth-Bayer et al., 2005). Risk management systems which strive to reduce, pool and financially share risks have been devised and to some extent also employed. This new notion of pro-activeness in the DRM community relates to the concept of pro-active – or planned – adaptation in the climate change discourse. In contrast to re-active climate adaptation, which can be described as a gradual coping with the consequences over time as a response to certain events, pro-active climate adaptation refers to actions preparing for risks before events materialize. Especially adaptation to extreme weather events, such as floods and droughts, requires an anticipatory approach.

Comprehensive CRM requires joint effort by the private and the public sector. We focus here on the crucial role of the public sector in the provision of DRM as early action on climate change. As DRM and CCA constitute local public goods (Tiebout, 1965) – their benefits can only be enjoyed by residents in the local community directly affected by these measures –, one key actor of concern is the public sector. The public sector has to step in to guarantee the local provision of DRM by planning ahead for extreme event risk. Taking this long term view is not an easy proposition for the public sector, as disaster risk constitutes a contingent liability, i.e. costs that accrue only in case of an event. However, not considering these contingent liabilities ex-ante in the public budgeting process may eventually lead to severe fiscal stress once an extreme event occurs. Progress in public sector risk planning has been achieved based on tools available to systematically assess and manage risks in the fiscal balance sheet (fiscal risk and hedge matrices Schick & Polackova Brixi, 2006; Mechler and Hochrainer-Stigler, 2014). Austria, our point in case, with its disaster fund, already has an instrument in place to take some of the implicit climate risks out of their balance sheets and make these contingent climate related liabilities more explicit.

## 3. Methodology

The methodologies employed in the present case study comprise of an (i) extensive literature review on the current CCA practice dealing with extreme events and natural hazards in Austria, (ii) expert interviews and workshops, (iii) public budget analyses and (iv) climate risk-based economic modelling. These multiple methodological perspectives enable a comprehensive discussion of the current CRM practice in Austria, potential future climate risk and their impact on Austria's fiscal position, and are eventually integrated to identify robust adaptation pathways for Austria.

### 3.1. Expert interviews and expert workshop to assess the current DRM practice in Austria with respect to Climate Change Adaptation

We carried out semi structured open ended interviews with relevant Austrian stakeholders at the federal and provincial level to gain insights regarding the framing of the current CRM practice in Austria and to identify current and past public expenditures for CRM. In a first step it is necessary to identify all units that are involved in the management of risks linked to extreme weather events across sectors and levels of government. However, there is no uniform regulation in the Austrian legislation concerning the protection from natural hazards. Legislative and executive powers are ascribed to different administrative bodies depending on the specific circumstance. The resulting fragmentation of responsibilities leads to difficulties in identifying the relevant administrative bodies and in ensuring a consistent approach regarding the identification of fundable measures and their costs across Austria. The operating area "Protection from Natural Hazards" (in German "Schutz vor Naturgefahren") within the Federal Ministry of Agriculture, Forestry, Environment and Water Management was introduced to foster the strategic interaction of all public agencies working in the DRM field. However, according to the Austrian audit court, still no optimal coordination of all responsible organizational units has been achieved (Rechnungshof, 2008).

Table 1: Public agencies involved in the Austrian DRM practice

| Public agency | Superordinate ministry | Detailed description |
|---|---|---|
| Austrian Service for Torrent and Avalanche Control (in German "Wildbach und Lawinenverbauung" (WLV)) | Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) | The WLV analyzes and assesses hazards and risks, plans and conducts preventive and protective measures in Austrian Alpine regions. It is thereby focusing on different Alpine hazards such as floods, mudflows, avalanches, slope movements and rock fall. These hazards constitute a major security risk in many regions of the Alpine country Austria. The WLV's overall objective is to improve and enhance society's preparedness for future natural disasters. |
| Federal Water Engineering Administration" (in German "Bundeswasserbauverwaltung" (BWV)) | Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) | The implementation of the different affirmative actions according to "Wasserbautenförderungsgesetz 1985" rests in the domain of the governors of the Austrian provinces. The BWV is responsible for flood protection in Austrian river valleys, with the exception of torrents (these fall under the competences of the WLV), and the Danube and the border rivers March and Thaya (for which the bmvit, more precisely the Via-Donau, is responsible). The BWV is fostering *active flood control* through measures like river regulations, dikes and retention basins and *passive flood control* by, for example, keeping flood discharge and retention areas clear. |
| viadonau – Austrian waterway Ltd. (in German „Österreichische Wasserstraßen-Gesellschaft mbH") | Federal Ministry for Transport, Innovation and Technology (bmvit) | The viadonau is tasked with the maintenance and development of the Danube waterway. The viadonau's main objective is to ensure the availability of an efficient and reliable waterway infrastructure. With respect to flood risk, viadonau constructs and operates flood control dykes and facilities to protect the residents of the areas concerned. |
| Federal Crisis and Catastrophe Protection Management (in German "Staatliches Krisen- und Katastrophenschutzmanagement" (SKKM)) | Federal Ministry of the Interior (BMI) | The SKKM is not only in charge of the co-ordination in matters of national disaster protection management but also of national crisis management and international disaster relief. The Federal Ministry of the Interior is responsible for managing catastrophes and crisis situations of the most different kinds. This objective requires, amongst others, setting measures for the protection against natural disasters. |

The operating area "Protection from Natural Hazarads" identifies the key institutions dealing with catastrophic impacts and risks of natural hazards in Austria as being located in three ministries, the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW), the Federal Ministry of the Interior (BMI), and the Federal Ministry for Transport, Innovation and Technology (bmvit). Within these ministries we identified the following public agencies which are responsible for the implementation of DRM measures in Austria as our prime target group for the expert interviews: the Austrian Service for Torrent and Avalanche Control (in German "Wildbach und Lawinenverbauung" (WLV)), the Federal Water Engineering Administration" (in German

"Bundeswasserbauverwaltung" (BWV)), the viadonau – Austrian waterway Ltd. (in German „Österreichische Wasserstraßen-Gesellschaft mbH"), and the Federal Crisis and Catastrophe Protection Management (in German "Staatliches Krisen- und Katastrophenschutzmanagement" (SKKM)) (for more details see Table 1).

The four public agencies involved in the Austrian DRM practice are characterized by different approaches to DRM, depending on at which stage of the disaster management cycle they primarily operate. The WLV, the BWV and the viadonau are mainly operating in the phases prevention, mitigation and preparedness and to some degree in the reconstruction phase after an extreme event has destroyed or harmed the protective structures. Hence they are mainly implementing construction measures which are dealing ex-ante with flood risk. The SKKM on the other hand is primarily operating in the emergency and response phase of the disaster management cycle. Hence its measures are ex-post in nature.

A further important player in the Austrian DRM practice is the ministry of finance (BMF). Via the Austrian disaster fund the BMF finances to a large degree the measures implemented in the Austrian DRM practice. In the interview and workshop phase of the case study the BMF contribution provided valuable insights from the perspective of the financing entity in contrast to the implementing entities.

During the expert interviews we discussed questions dealing with both, the status quo and the medium term future of the Austrian DRM practice. The key questions, which represent the loose structure of the interview guideline used for all interviews, are listed in **Error! Reference source not found.** in the Appendix. As a follow-up to the expert interviews, we hosted a stakeholder workshop bringing together researchers and relevant experts from the different public agencies involved in the Austrian DRM practice (see Workshop Agenda and list of participants in the Appendix). The aim of this workshop was to discuss the empirical findings regarding the public costs of DRM and CCA (as discussed in the following), the potential future impacts of climate related disasters on the fiscal position in Austria and to identify potential entry points for a iterative and robust CRM strategy in Austria.

Also at the provincial level, expert interviews with representatives from province departements responsible for regional road infrastructure, water management and DRM in Upper Austria and Styria were held in late 2015, 2016 and early 2017.

## 3.2. Empirical analysis of budgeting processes

Disaster statistics are of immediate importance for policy making. A systematic collection of information on risk management expenditure, in combination with data on disaster losses, allows policy makers to evaluate the effectiveness of implemented measures in reducing the negative impacts of disaster events and eventually to assess the level of resilience against current and future disaster risks. Moreover, disaster statistics increase transparency and may contribute to the promotion of disaster risk management within a country. However, as in many other OECD countries, Austria does not have a central repository (such as national accounts) that clearly distinguishes and accounts for DRM expenditures. Moreover, if data does exist, no clear cut distinction between ex-ante and ex-post DRM measures can be drawn and to an even lesser degree expenditures relevant for CCA can be identified.

Based on the information gathered in the literature review and in cooperation with the interviewed DRM experts, we identified the relevant data sets covering current and past CRM expenditures in Austria. By comprehensively analyzing these data sets we strive to identify those expenditure items in the Austrian DRM practice that constitute one element of public costs of early CCA in Austria.

On the provincial level, we assessed the budgets and expenditures with respect to impacts of prior extreme events in the provinces Upper Austria and Styria. The budgets of the last 10 years, especially the "extraordinary budgets" (="Ausserordentlicher Haushalt") were assessed by exploring annual budgets and expenditures for single province departments responsible for catastrophe aid finance, extreme event impact mitigation, etc. We assume that deviations between approved budgets and actual expenditures for particular budget sections for covering extraordinary costs indicate a climate impact, if these costs can be related to extreme weather events in the respective year.

## 3.3. Probabilistic flood risk modeling

Generally speaking, two methodological approaches are available to estimate flood loss distributions, i.e. either via catastrophe modeling approaches or by using past loss events and applying extreme value theory. We refer for the latter method to Embrechts et al. (2007) and focus here on the more advanced catastrophe modeling approach, which is also applied in this analysis. It is common practice in catastrophe models to evaluate the direct damage via three components or modules, i.e. the "hazard", "exposure" and "vulnerability" module (Grossi and Kunreuther, 2005). A fourth "loss" module summarizes the results from these modules with the help of risk metrics or loss distributions, which inform about the probability that losses do not exceed a given level of damage.

Loss distributions are cumulative distribution functions where the x-axis represents the losses, e.g. monetary losses, annual losses in terms of GDP, or capital stock losses. The y-axis represents the probability that losses do not exceed a given level of damage. It therefore can be called the "event axis". For example, in Figure 3, a value of 0.98 on the event axis means that with a probability of 98 percent the losses do not exceed a given level of damage, say x2. In other words, with a probability of 2 percent the losses will exceed this level of damage. Note that a 2 percent probability can be interpreted as a (1/0.02=) 50 year event, e.g. an event that happens on average once every 50 years. The same principle can be used for all other events. The loss distribution function itself is very useful for risk management purposes because various risk measures can be calculated from it (see Pflug and Römisch 2007). For example, the average annual loss, which is the area above the loss distribution, the Value at Risk (VaR) which is defined as VaR(p)=F-1(1-p), where F-1 is the quantile function defined as the inverse of the loss distribution function, or the Probable Maximum Loss (PML) which is associated with a given probability of exceedance (see also Grossi and Kunreuther 2005).

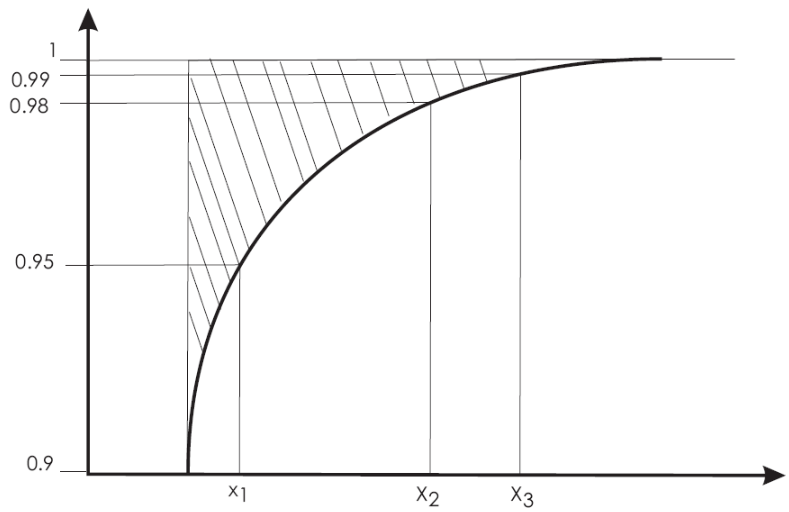


Figure 3: Generic loss distribution function

Several flood hazard models on the very local scale exist in Austria, however, currently only two flood risk modeling approaches provide flood loss distributions on the country scale. Full details of these models and discussion of them can be found in Prettenthaler et al. (2015). What is important for our discussion here is that in the first model (see Lugeri et al. 2010; Hochrainer-Stigler et al. 2014) the hazard module is not based on a dynamic hydrological model while the second one (Prettenthaler et al. 2015) performed the analysis from a bottom up-approach which did not include all exposure assets. We avoid both these limitations by using simulated losses based on the LISFLOOD hydrological model and an economic damage model (van der Knijff et al. 2010; Rojas et al. 2012). The flood loss data set has been validated in previous pan-European studies (Jongman et al. 2014) and provides therefore an ideal entry point for our analysis as we will be able to include climate change effects within one coherent approach. Note, flood risk estimates (here in the form of loss distributions) from catastrophe modeling approaches are usually only available on the GRID or basin scale (as in our case) and there is the additional challenge to up-scale these loss distributions to higher scales. Not until recently, information on larger scales on flood risk was only available for specific events or expressed in terms of average losses. Consequently, the full probabilistic risk information was not available anymore on these scales and risk management strategies could not be applied any longer (additionally averages do not give any information about the severity from extremes, see for a discussion Jongman et al. 2014).

We therefore perform a copula-based approach to derive probabilistic flood risk estimates on the country level for Austria. In more detail, we apply a structured coupling of probability loss distributions on the basin scale (derived from LISFLOOD) based on a method discussed in Jongman et al. (2014) and more recently in Timonina et al. (2015). Dependencies between river basins in Austria are estimated using different copulas (e.g. Clayton, Frank or Gumbel) and are based on maximum river discharges for the period 1990-2011. Afterwards, the loss distributions from each basin are coupled using the given copulas and a minimax ordering approach to finally derive a loss distribution on the country level. The details of the copula methodology, which is now seen as most appropriate to avoid underestimation of extreme risk (see Jongman et al. 2014), and a general algorithm to perform such coupling can be found in Timonina et al. (2015). To the authors' knowledge the only other model currently available for Austria employing a copula approach is the aforementioned one discussed in Prettenthaler et al. (2015), which, however, falls short in comprehensively including all exposed assets. The loss distributions for Austria, derived by the application of our LISFLOOD-based copula approach, form the basis for our discussion of the natural disaster fund and other climate risk management measures discussed in the following.

## 4. Results: Empirical evidence on climate risks and climate risk management in the short term at the federal and provincial level

### 4.1. Insight regarding framing and practice currently pursued in Austria: DRM as early adaptation in Austria?

The expert interviews and the expert workshop with stakeholders from the key institutions in the Austrian DRM practice have pointed out that **in the current Austrian DRM practice climate change considerations do not play a major role** and are not explicitly taken into account in the deliberations by the public agencies responsible for the implementation of DRM measures in practice, the WLV, the BWV, the viadonau, and the SKKM. As the main reason for that the interview partners stated the lack of a scientifically proven link between the climate change signal and extreme weather events, such as floods, in Austria.

The lack of scientific evidence is based on a **lack of spatially-explicit projections from climate models and the considerable uncertainties associated with modeling (regional) climate change**. In the past ten years various studies have been conducted to analyze the relationship between the climate change signal and an increase in the frequency and intensity of extreme floods in Austria. In contrast to some German regions (Baden-Württemberg and Bavaria), where hydrological studies (focusing on large-scale weather patterns) have shown a link between climate change and an increase in the frequency and intensity of extreme flood events (Hennegriff and Kolokotronis, 2007; Hennegriff et al., 2006), no statistically significant link has been identified for Austria until today (Prettenthaler et al., 2015, ZAMG und TU-Wien, 2010). For riverine flooding, which is one key concern in Austria, climate change is globally projected to increase the intensity and frequency of the flooding burden; however, due to numerous uncertainties there is only low confidence in projected changes (IPCC, 2012)[1]. On the other hand, there is high confidence that todays and future losses are rising as more assets and people are moving in harm's way also in Austria (Prettenthaler et al., 2015).

Hence, the interviewed experts argued, no explicit implications for the current DRM practice, such as the designing and dimensioning of preventive measures, can be derived from existing climate model results, while socioeconomic developments leading to higher exposure require careful attention. Nevertheless, the experts' statements in the interviews and the workshop revealed that climate change considerations are implicitly taken care of in the Austrian DRM practice (see Box 1).

In addition to the fact that climate change does not explicitly influence decisions on or conceptions of risk management measures in Austria, there is also no clear consensus in the Austrian DRM practice of which public expenditures can be regarded as relevant for CCA[2]. During the stakeholder process there was ambiguity in the context of defining costs of CCA, e.g. regarding the clear

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[1] The quantitative assessment of flood risk is complex, as such extreme event risk is characterized by few observations (low probability) associated with massive consequences (high impact), which by definition means substantial uncertainty around any estimates, particularly if future drivers, such as from climate change, need to be addressed as well (UNISDR, 2005; Grossi and Kunreuther 2005; Feyen et al. 2008; Global Assessment Report 2013).

[2] This ambiguity related to expenditures classified as costs of CCA is not unique to the field of DRM but is evident more generally in the Austrian climate risk discourse.

distinction between impact costs and costs of CCA, ex-ante and ex-post measures, extreme events and weather variability.

**Box 1: Implicit climate change considerations in the Austrian DRM practice**

The **WLV** is considering the climate change signal in so far that in the scenario analysis for specific WLV projects it is also carrying out a time series analysis of historic rainfall patterns. If this historic data already incorporates changes in rainfall patterns induced by climate change, climate change is implicitly dealt with. However, it is important to note that this does not constitute an ex-ante modeling of climate change or an explicit representation of climate change.

Experts from the **BWV** and the **viadonau** pointed out that in contrast to some German regions (Baden-Württemberg and Bavaria, see e.g. Hennegriff and Kolokotronis, 2007) where so-called "climate change markups" (up to 10-15%) are applied in the construction of protective structures, climate change considerations do not influence the dimensioning of protective buildings in Austria. However, after the flood events in 2005 the definition of an HQ100 event – and hence the requirements for protective structures – has been changed, based on new statistical data. This implies that similar to the WLV example above, any climate change signal – even though not explicitly detectable today – is implicitly considered in the construction of protective flood buildings.

The **BWV** furthermore pointed out that no-regret and low-regret measures (Watkiss et al., 2014), which do not primarily focus on CCA but may - as a co-benefit - also contribute to CCA in the longer term, are being regularly implemented. Such measures contribute to a reduction in current climate risks and build resilience e.g. by pursuing disaster risk reduction. Moreover, improved climate services (such as weather forecasts) create a more enabling environment for more explicit adaptation in the future.

For the **BMI**, which has a somewhat different approach to DRM than the other agencies, as it is mainly focusing on coping with disaster events, it is an open question whether climate change will even in the future have a relevant impact on Austria's ability to cope with the impacts from natural disasters. According to one expert from the BMI, even though climate change might increase the frequencies and intensities of natural hazards, Austria's coping capacity might still be sufficient to deal ex-post with the impacts of natural hazards. First, it is an open question to what degree climate change could increase the impacts from natural hazards and second, on a national scale, there are currently over capacities in the emergency services. Hence, an exacerbation of climate related risks might still be manageable with current emergency management capacities.

## 4.2. Expenditure and budget analysis regarding short term adaptation at the federal level

Due to these reasons, **no explicit public expenditures for CCA** are currently collected and provided in the areas of DRM and the protection from natural hazards. However, the interview partners' statements on the topic made clear that the Austrian DRM community does not neglect the potential impacts of climate change on future natural hazards. Even though they are not explicitly taken care of, climate change considerations are implicitly incorporated in the Austrian DRM practice. For example the implementation of no-regret and low-regret options can, according to the IPCC's SREX report, be seen as starting points for adaptation, as they have the potential to offer benefits now and lay the foundation for addressing projected changes in exposure, vulnerability and climate extremes." (IPCC, 2012) Moreover, by continuously reviewing and integrating new scientific knowledge on climate change (e.g. emerging early trends and changes in variability that exacerbate existing risks or create new risks) the practitioners are adjusting their decisions over time with evidence. Hence, **DRM in Austria can be seen as early adaptation to climate change, addressing the existing adaptation deficit** and **mainstreaming climate change** in decision processes (as e.g. required by the EU Flood Directive RL 2007/60/EG), **within an iterative CRM approach**.

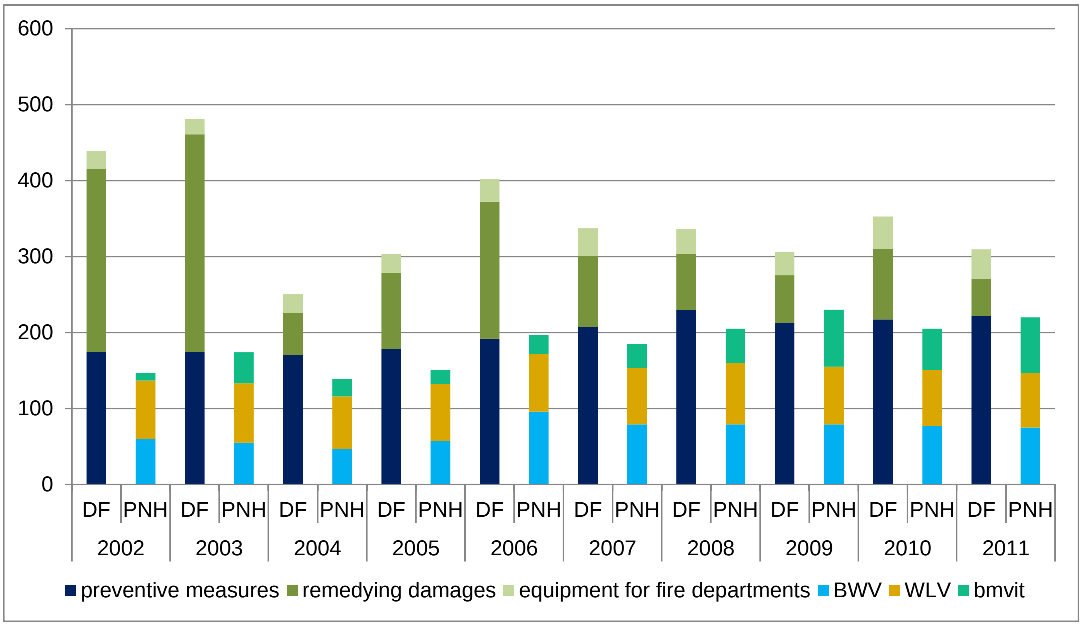


Figure 4: Comparison of payments from the Austrian disaster fund for preventive measures, remedying damages and equipment for fire departments (columns DF) with public expenditures for the protection from natural hazards (columns PNH), 2002-2011 (in million EUR)

In turn, the current and past public expenditures in the Austrian DRM field can be interpreted as **expenditures for no-regret and low-regret early adaption measures** and could give a first impression of **how much money is being spent today to address the current adaptation deficit**.

Knowing the existing information and data limitations we have to rely on the best data available to identify these past and current public expenditures. We base our empirical analysis on officially available data by the operating area "Protection from Natural Hazarads (PNH)" (BMLFUW and bmvit, 2012). Figure 4 visualizes the expenditures for the protection against natural hazards by the three key public agencies in Austria: viadonau, WLV and BWV over the period 2002 to 2011, as collected by the operating area PNH (columns PNH).

The literature review and the expert interviews revealed that the public expenditures for the protection against natural hazards are mainly financed by the Austrian disaster fund – Austria's main vehicle in coping with catastrophic events – and correspond to the disaster fund's expenditures for preventive measures (see columns DF in Figure 4)[3]. Hence, we will dig deeper into the bi-annual reports of the Austrian disaster fund in the following subsection to get a better understanding of the nature of these expenditures. To eventually be able to say something about the disaster fund's expenditures relevance for CCA in Austria we have to go another step further. We set out to disentangle the aggregated data provided in the bi-annual reports of the Austrian disaster fund by relying on detailed data from the three public agencies investing in measures that address flood risk in Austria, the WLV, the BWV, and the viadonau.

### 4.3. Financing expenditures to protect against natural hazards: The Austrian disaster fund

The Austrian constitution does not define a federal jurisdiction for dealing with natural hazards and natural disasters. Hence, remedying damages after natural disasters falls under the jurisdiction of the federal provinces. However, a devastating avalanche catastrophe in 1951 required public support to the federal provinces – in the form of a special law –to raise the required funds. Further special laws were issued in the following years to deal with other natural disasters. Only by 1966, after two devastating floods in 1965 and 1966, the first permanent disaster fund was established on the basis of the law "Katastrophenfondsgesetz 1966". After various amendments of the original law, the issuance of a new law in 1985 followed by yet further amendments, the currently legal basis for the Austrian disaster fund, the "Katastrophenfondsgesetz 1996" was issued. (BMF, 2012)

Since then, the key instrument for financing public disaster risk management in Austria constitutes the **Austrian disaster fund** (in German "**Katastrophenfonds**"). While the Federal Ministry of

[3] The deviations between the payments from the Austrian disaster fund for preventive measures and the public expenditures for the protection from natural hazards (see Figure 4) are based on two reasons: (1) Expenditures for preventive measures according to the disaster fund also comprise expenditures which are not managed by the BMLFUW and the BMVIT and hence cannot be ascribed to the public expenditures for the protection from natural hazards collected by the operating area PNH and (2) until 2014 additional federal funds were laid out by the BMLFUW for the protection from natural hazards.

Finance administers the resources of the disaster fund, two other federal ministries – the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) and the Federal Ministry for Transport, Innovation and Technology (bmvit) – as well as the nine Austrian federal provinces are responsible for the implementation of measures regarding the protection from natural hazards. Within the BMLFUW it is the public WLV and BWV that are charged with this task. Within the bmvit the viadonau is the responsible unit.

### 4.3.1. Deposits to the Austrian disaster fund

The greater share of the Austrian disaster fund's resources constitutes of a percentage share of the federal income tax, wage tax, capital yield tax (on dividends), and corporate income tax revenues. The exact percentage and hence the level of annual federal deposits to the fund are defined by the currently in force fiscal equalization scheme (for the most recent year 2014 the percentage share was 1.1%). Further resources for the disaster fund are drawn from investments and repayments by the Austrian hail insurance. Additionally, until 2013 the fund accrued interest yields from the invested disaster fund reserves. Since 2013 the reserves are no longer invested but only treated as an accounting component[4]. Hence the endowment depends on the overall economic development and, as can be seen in Figure 5, reflects macroeconomic developments such as the financial crises in 2008 and 2009.

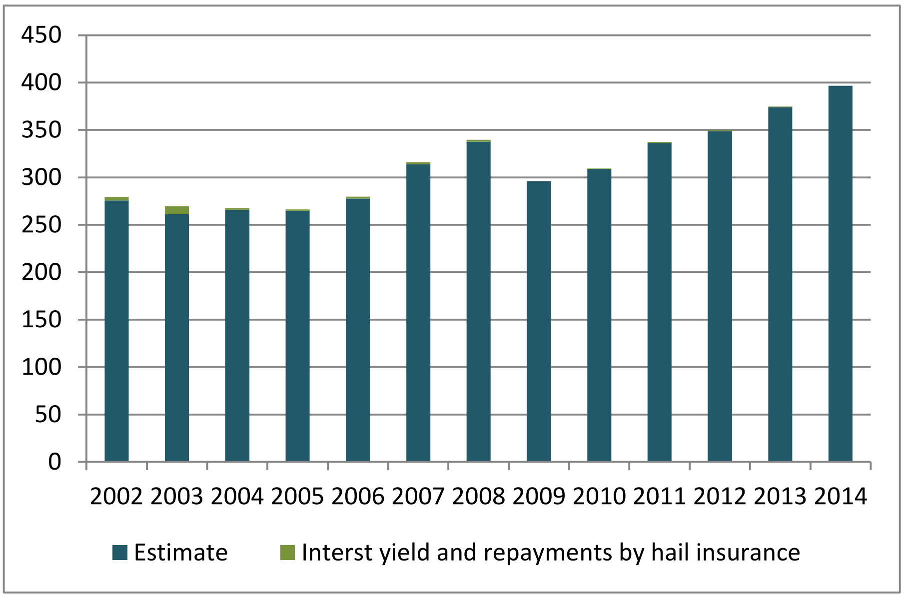


Figure 5: Deposits to the Austrian disaster fund 2002-2013 (million EUR); Source: Source: Own illustration based on bi-annual reports of the Austrian disaster fund (see e.g. BMF, 2014 for the reporting period 2012-2013)

[4] Since 2010, the fund gets additionally endowed with annually EUR 10 million drawn from the federal corporate income tax revenues. This amount is however earmarked for the remedying of damages to state roads (more precisely in German "Landesstraßen B").

In addition to these resources, which are dependent on tax revenues and hence on the overall economic development in Austria, the fund can also draw from a built up reserve. Originally truly accumulating in nature, the accumulation of reserves has been capped with the issuance of the current disaster fund law in 1996 at a level of EUR 29 million until 2012 and EUR 30 million since 2013. Thus, in years where it was not necessary to withdraw funds from the reserve (as there were no major catastrophic events taking place in Austria or additional funds for ex-post payments were available from extraordinary increases), surpluses from the disaster fund (deposits minus expenditures) were redistributed to the general budget as the buildup of the reserve was capped (for the development of the reserve over time see Figure 6).

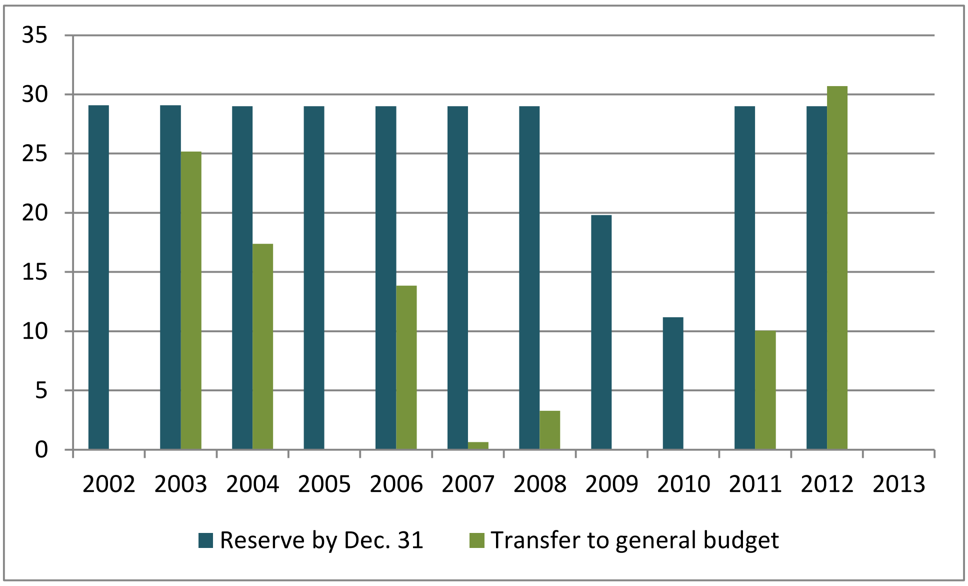


Figure 6: Reserve of the Austrian disaster fund and transfers to the general budget (million EUR)

Severe floods in 2002, 2005 and 2013 – with cost estimates for the 2002 and 2013 floods amounting to more than EUR 3 billion (Habersack et al., 2004) and EUR 0.9 billion (BMI, 2014) respectively – led to the situation that the fund's usual resources (including the reserve) were not sufficient to cope with the damages of these catastrophic events. Hence, special-laws were enforced which provided an ad-hoc increase of resources for the disaster fund. Since 2008, according to the fiscal equalization scheme 2008 ("Finanzausgleichsgesetz (FAG) 2008"), an ad-hoc increase in resources for the fund does not anymore require issuing a special law. A resolution by the federal government is sufficient to deposit additional funds (in line with § 9 Abs. 2 Z 2 FAG 2008). Figure 7 visualizes how the increases based on the special laws in 2002 and 2005 as well as the later increases based on resolutions by the federal government have been put to use[5]. As a first reaction by the Austrian government, the federal funds provided via the disaster fund to the BMLFUW alone (i.e. to the agencies BWV and WLV) will be increased to annually 200 million EUR over the next five years (BMLFUW, 2014).

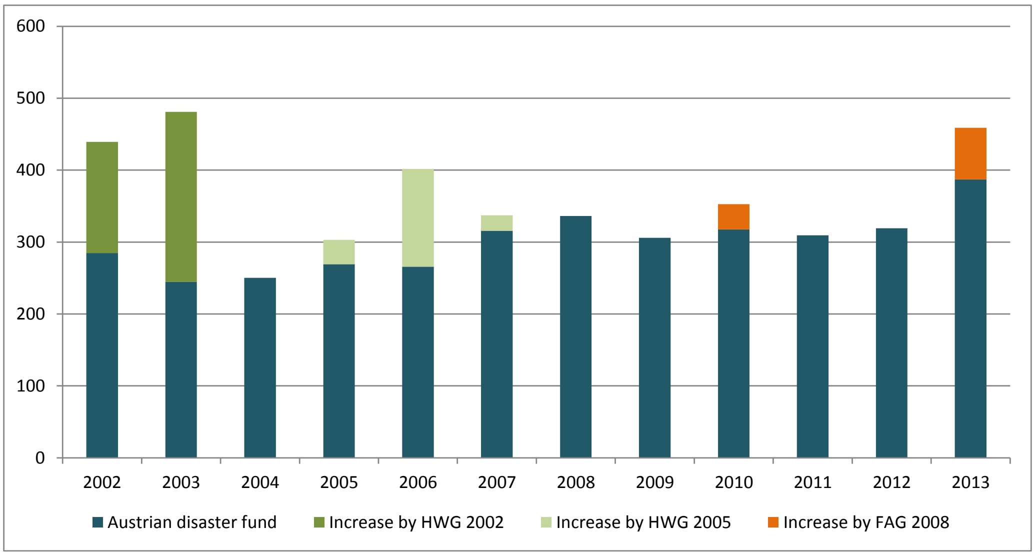


**Figure 7: Payments by the Austrian disaster funds basic budget and by increases based on special laws (in 2002 and 2005) and federal government resolutions (since 2010), 2002-2013 (in million EUR) . The extraordinary allocations were dispersed in the year of the event and in subsequent years.**

### 4.3.2. Payments by the Austrian disaster fund

Since the first disaster fund law was issued in 1966, the scope and mechanisms of the law have been regularly amended. In its current legal form, the disaster fund's resources are allocated to serve mainly three purposes:

- Preventive measures (73,27%)
- Remedying of damages due to exceptional catastrophic events (17.84%)
- Equipment for fire departments (8.89%)

As disaster management in Austria lies within the competences of the federal provinces, financial assistance for remedying damages to assets owned by natural and legal persons (with the exception of regional and local authorities, i.e. "Gebietskörperschaften") from extraordinary catastrophic events is at first granted by the federal provinces. In a second step the federal government regularly refunds the federal provinces 60% of the financial assistance provided by the federal provinces (in line with the maximum level assistance according to § 3 Z 3 lit. a KatFG 1996). The impaired private party regularly receives an assistance of 20-30% of the incurred damages, in some cases of hardship

[5] While the funds from the increases based on the special laws in 2002 and 2005 had to be put to use within two and, respectively, three years, the increases based on the more flexible decision process as implemented by the 2008 fiscal equalization scheme had to be used in the very same year.

up to 80%[6]. In addition to damages to assets owned by natural and legal persons, the federal government might refund up to 50% of the costs of measures to remedy damages from extraordinary catastrophic events to assets owned by regional and local authorities. The funds for the procurement of equipment for fire departments by the federal provinces are allocated to the federal provinces based on the number of inhabitants.

The annual allocation of funds eventually depends on the level of damages in the respective years and on the point in time of the application for financial assistance by the federal provinces. Particularly in years of catastrophic events, such as 2002, 2005, and 2013, as well as in the subsequent years, the ex-post payments have increased dramatically (Figure 7).

The actual payments from the disaster fund do not reflect the estimated allocation of funds for the preventive measures (73.27%), remedying damages (17.84%) and equipment for fire departments (8.89%) in every year (Figure 8). The annual allocation of funds eventually depends on the level of damages in the respective years and on the point in time of the application for financial assistance by the federal provinces. Particularly in years of catastrophic events, such as 2002, 2005, and 2013, as well as in the subsequent years, the ex-post payments have increased dramatically.

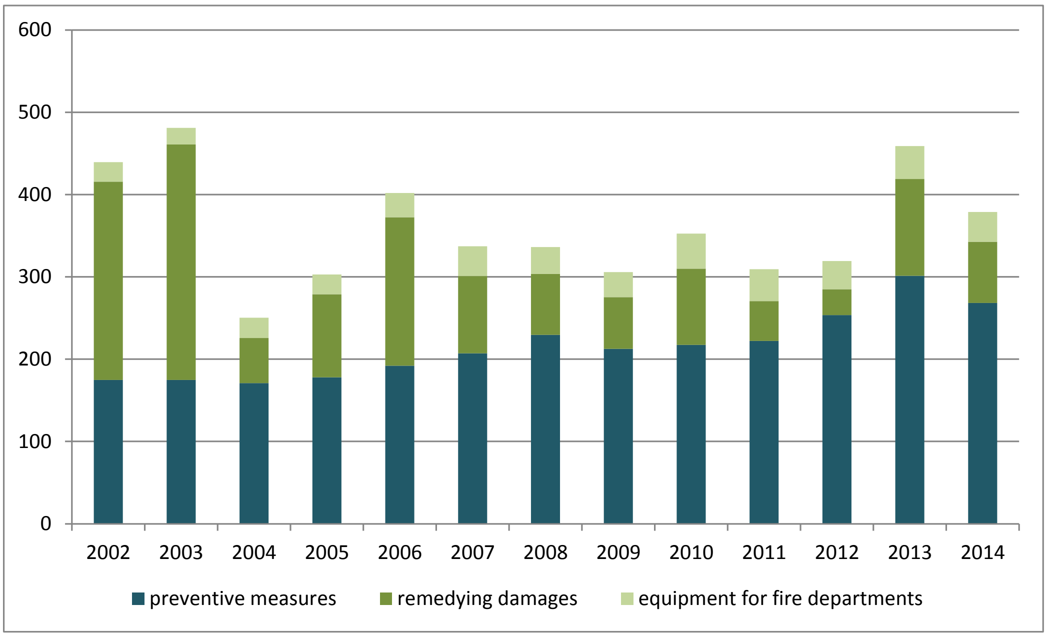


Figure 8: Payments by the Austrian disaster fund for preventive measures, remedying damages, and equipment for fire departments, 2002-2013 (in million EUR)

[6] An important detail regarding early adaptation in this context is that the financial assistance provided by the disaster fund does only cover the instauration of a damaged asset according to its pre-catastrophe condition, i.e. its pre-catastrophe present value. Thus, building-back-better damaged assets, which could serve the purpose of increasing resilience against future natural hazards, is not foreseen under the current form of Austria's disaster fund.

In contrast to the expenditures for remedying damages after catastrophic events, which have regularly been higher than the initial estimate over the period 2002-2014, expenditures to finance preventive measures have usually not been put to their intended use exhaustively (Figure 9). According to the Austrian audit court (RH, 2008), the reason is that the bmvit does not fully exhaust its allocated funds. The BMLFUW on the other hand does make use of all allocated funds and e.g. in 2006 it was for the first time possible to redistribute some of the funds from the bmvit to the BMLFU to force investments in preventive measures within this ministry. The audit court suggested already in 2008 to make sure that unused funds allocated to one ministry can be transferred and put to use in the other ministry on a general basis (RH, 2008).

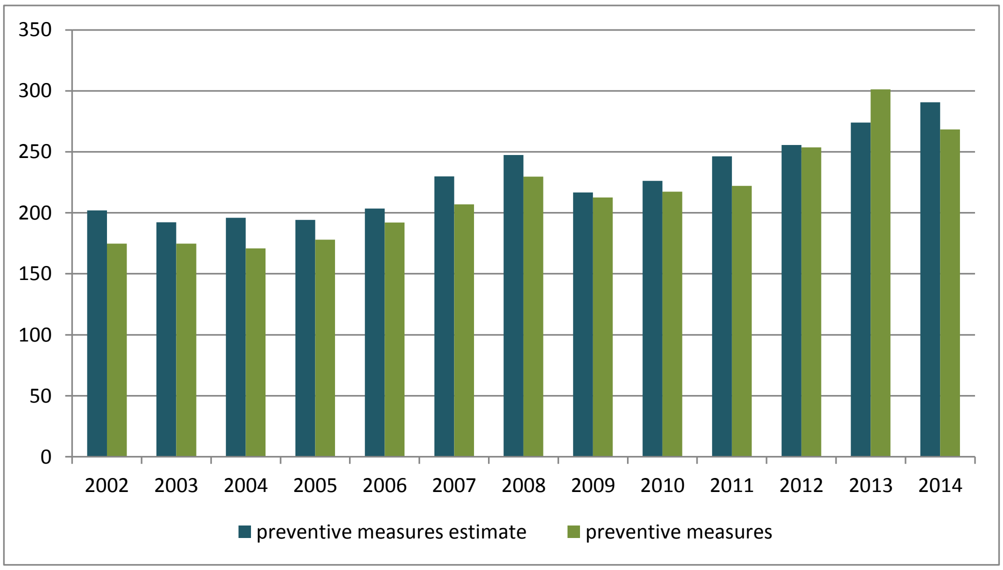


**Figure 9: Estimate for expenditures Vs. actual expenditures to finance preventive measures, 2002-2013 (in million EUR)**

When digging deeper into the bottom-up data bases of the three public agencies implementing the measures financed by the Austrian disaster fund to inform the identification of expenditures for early adaptation measures in the Austria, we find that not all payments by the three public agencies can indeed be classified as truly preventive in nature, as the Austrian disaster fund data base would suggest. The bottom-up analysis of the three respective data bases shows that the expenditures by the WLV, the BWV and the viadonau have to be further disentangled into *immediate measures* dealing immediately after a flood event with damages to the assets of the three public agencies, *building measures*, and *planning and maintenance measures*. Figure 10 visualizes the actual annual payments by the three public agencies BWV, WLV and viadonau for the protection against natural hazards, financed by federal funds. These numbers, collected in a bottom-up manner, with data available on a project basis for the WLV, on the level of municipalities for the BWV and on the level of federal provinces for the viadonau (more details in the next sections), correspond very well to the top down data on preventive public expenditures (see footnote 3 for an explanation of deviations between bottom-up data and disaster fund data) derived from the annual disaster fund reports (see Figure 10 for the years 2010-2013, as there is no data on WLV expenditures prior to 2010 available).

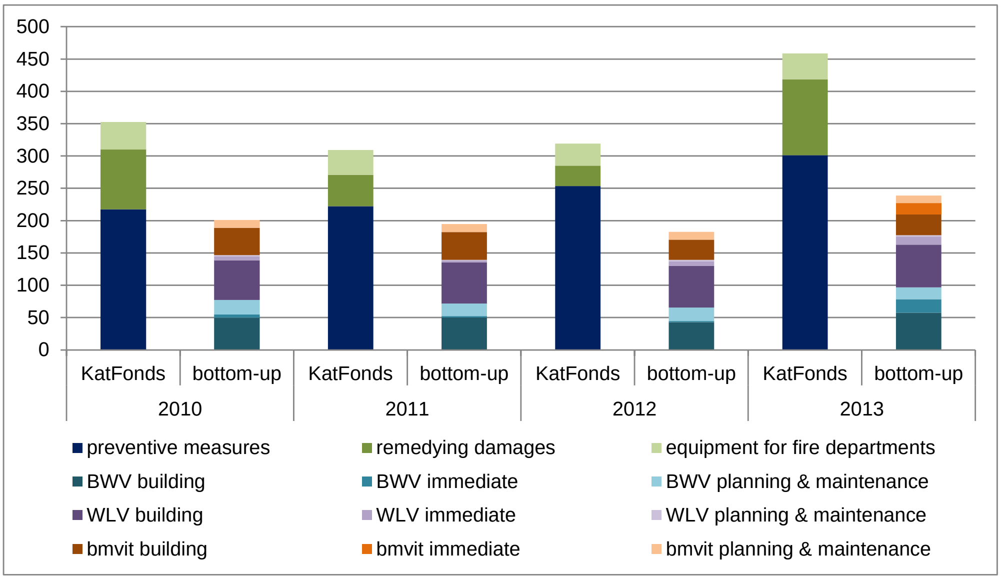


Figure 10: Comparison of payments from the Austrian disaster fund for preventive measures, remedying damages and equipment for fire departments with a bottom-up analysis of the expenditures by the BWV, WLV and viadonau for the protection from natural hazards, distinguishing between building measures, immediate measures and planning & maintenance measures, 2010-2013 (in million EUR)

As there was no clear consensus achieved on the definition of what is considered as early adaptation measure in the context of DRM during the stakeholder process, we distinguish here between four different expenditure levels in each year (Figure 11):

(1) Employing a narrow definition of early adaptation expenditures, covering only building measures presented in the bottom-up data bases of the BWV, WLV and the viadonau, leads to expenditures for the years 2010-2013 amounting to 153 million EUR, 156 million EUR, 139 million EUR, and 156 million EUR, respectively.
(2) Adding the expenditures for immediate as well as for planning and maintenance measures as reported in the BWV, WLV and viadonau data bases would increase total expenditure levels for the years 2010-2013 to 201 million EUR, 195 million EUR, 183 million EUR, and 239 million EUR, respectively.
(3) Starting top-down from the disaster fund perspective, early adaptation measure could be defined by the fund’s expenditures to finance preventive measures. This would include further preventive expenditures according to the Katastrophenfondsgesetz (§3, Z4) beyond the ones managed by the BMLFUW and the viadonau and result in total expenditures for the

years 2010-2013 amounting to 217 million EUR, 222 million EUR, 254 million EUR, and 301 million EUR, respectively.

(4) Employing an even broader scope for early adaptation measures, one could argue that in addition to financing preventive measures also the other two elements of the disaster fund's expenditure side – financing equipment for fire departments and expenditures to remedy damages after a catastrophic event – are relevant expenditures to deal with climate and weather events in the context of an iterative DRM approach. This would in turn result in total early adaptation expenditures for the years 2010-2013 amounting to 353 million EUR, 309 million EUR, 319 million EUR, and 459 million EUR, respectively.

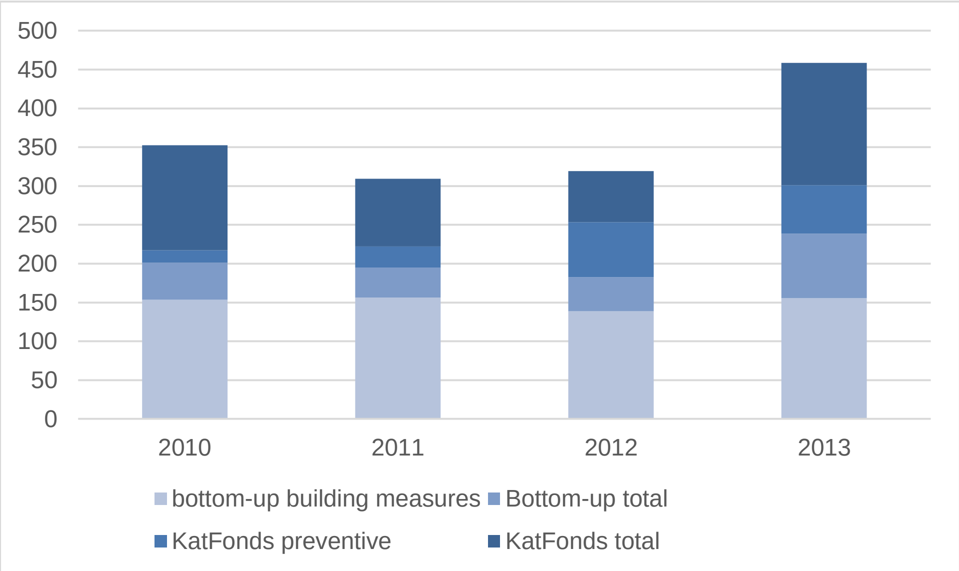


Figure 11: Expenditures for early adaptation in Austria, 2010-2014 (in million EUR)

## 4.4. Expenditure and budget analysis regarding short term adaptation at the provincial level

The budgets of the provinces of Upper Austria and Styria were assessed in terms of their extraordinary budgets. In addition we assessed in interviews adaptation relevant budget items.

**Province of Styria**

As explained above, the budget of Styria was assessed in terms of climate adaptation relevant costs. We now focus on the example of regional road infrastructure. For example in the year 2016, around 53.5 million EUR were available in the ordinary budget for repairs of provincial road infrastructure, 28.8 Million € for the construction of new regional roads and 7 million EUR for maintenance.

Who provides funding for provincial roads? Provincial roads and former federal roads (category B) are first paid for by the province and depending on the road category, federal funds are also provided. This covers a share of 50/50 for provincial roads (category L). In the case of category B, a basic allowance of 2.5 million EUR is provided. Above that, a total amount of 10 million EUR is shared among all nine Austrian provinces in % share.

In terms of events, eight events were reported for the period between between 2005 and 2016, comprising seven floods and one ice-rain event. The following events occurred in the year 2005 – flood event in the municipality of Gasen, 2009/2014 – floods in the districts of Feldbach, Radkersburg, Graz-Umgebung, Fürstenfeld and Liezen, in 2011/2013/2014 – floods in the disctict of Liezen and in 2016 – floods in the municipalities Breitenau, Stanz, Gasen and Anger/Weiz. Ice rain occurred in the year 2013 in the districts Feldbach and Radkersburg.

For provincial roads in Styria, the following damages related to the before mentioned events are presented in Table 2 in the years from 2012 to 2015 caused costs between 3.6 million EUR and 5.4 million EUR. In contrast to flood events, drought events have not caused any damages to regional roads in Styria until today. In addition, financial resources were provided by the disaster fund, which can be depicted in Table 3.

**Table 2: Damage repair costs for provincial roads in the province of Styria between 2012 and 2015**

| Year | Road repair costs (in EUR) |
|---|---|
| 2012 | 5,477,383 |
| 2013 | 4,044,879 |
| 2014 | 4,450,778 |
| 2015 | 3,682,050 |
| 2016 | N/A |

Due to past flood events, different risk mitigation or adaptation measures have been implemented. This covers for example highly stable asphalts to avoid damages due to heat. Also risk management measures and central deposits for emergency equipment like sandbags and concrete guide walls were built. Due to the implementation of these risk mitigation or adaptation measures rapid coping at the initial stage after extreme events is now possible.

**Table 3: Financial support from the diasater fund for provincial roads in Styria between 2012 and 2015**

| Year | Financial support from the disaster fund (in EUR) |
|---|---|
| 2012 | 1,345,358 |
| 2013 | 1,551,437 |
| 2014 | 1,379,839 |
| 2015 | 1,219,596 |
| 2016 | N/A |

Detailed data was also provided by the civil protection agency of the province of Styria. Here a certain combination of financial efforts between the federal level, province and municipality exists.

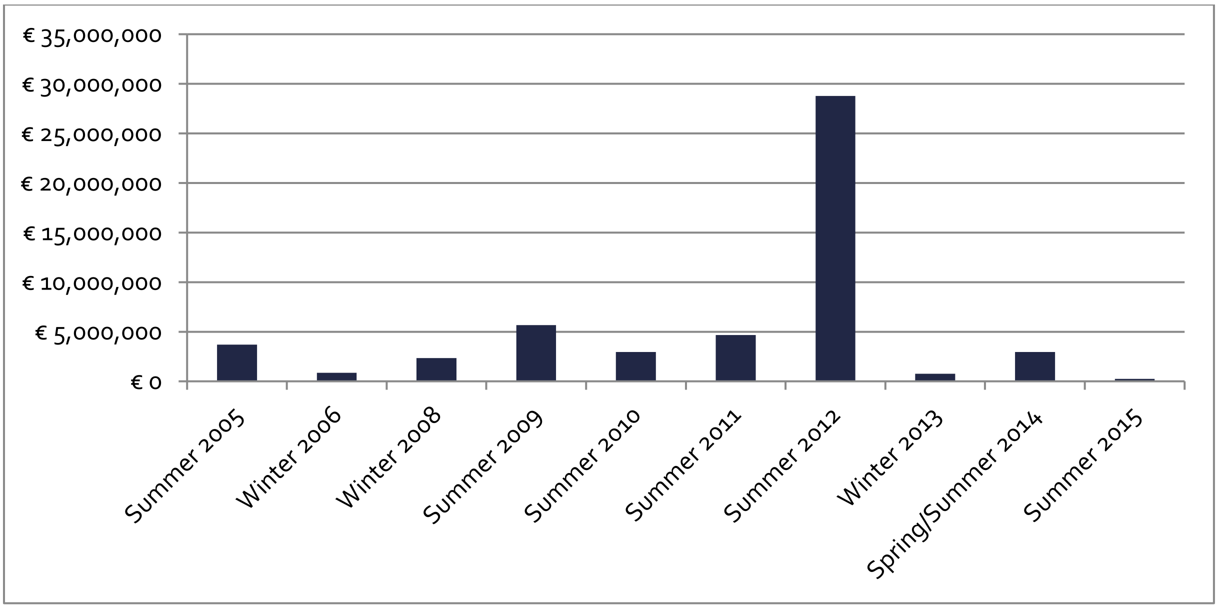


**Figure 12: Emergency relief fund-expenses in Styria between 2005 and 2015, data from the Styrian civil protection administration (in EUR)**

The public administration body in charge of civil protection is in charge of the so called "priority 1 – immediate support measures" (in German "Soforthilfemaßnahmen"), meaning that relief funds are provided after an events stroke for immediate financial support. Figure 12 shows the expenditures for this priority 1 – emergency relief measures between 2005 and 2015, based on the season of the related year.

Financing of the measures took place under the annual building program in Styria with finances from the national, provincial and local level. Financing at the provincial level came partly from the ordinary and partly from the extraordinary budget. The following measures with regard to flood protection measures were planned and implemented: more than 2.5 million EUR after the 2002 events, more than 20 million EUR after the events in the area of Graz between 2006 and 2016, and 6.5 million EUR after the events of 2012 were invested respectively.

Financing of flood protection measures and immediate relief is financed by the disaster fund. Also for the financing of private property, budget from the catasrophy fund is used. The unit 10 of the provincial government of Styria operates the funds to the beneficiaries. Figure 13 showcases the disaster funds payments for fire brigardes and civil potrection related equipment between 2006 and 2015.

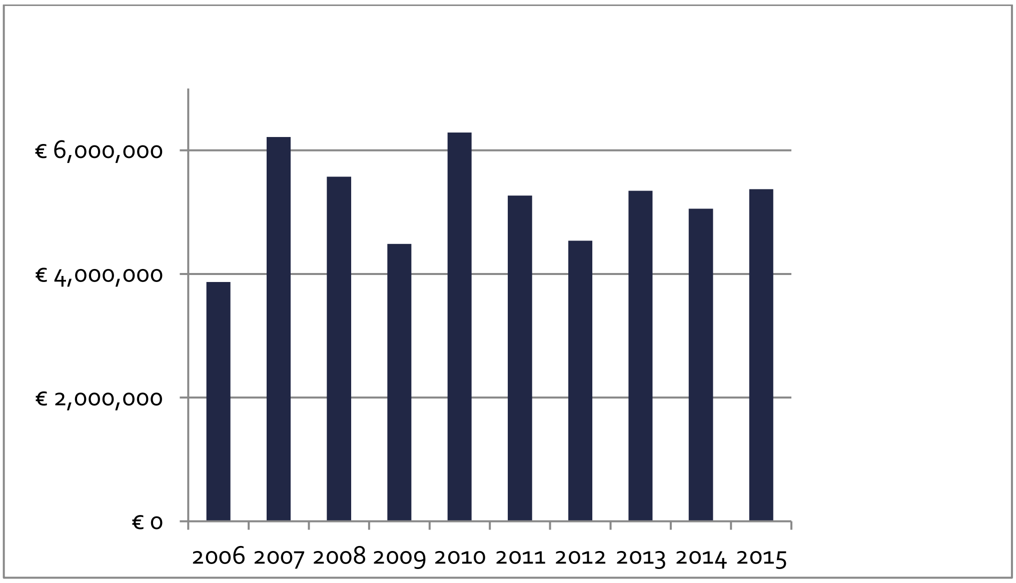


**Figure 13: Disaster fund aid provided to fire-brigardes and civil protection related equipment between 2006 and 2015 for the province of Styria.**

The measures taken along the creek of Schöckelbach in the municipality of Weinitzen (surrounding the city of Graz) is an example for expenditures for protective hydraulic engineering visualized in Figure 14. This is a storage reservoir built and finalized in 2012. After its realisation, the storage reservoir was already filled three times, which avoided the flooding of the district of Andritz in the city of Graz. The avoided damage already increased the construction costs.

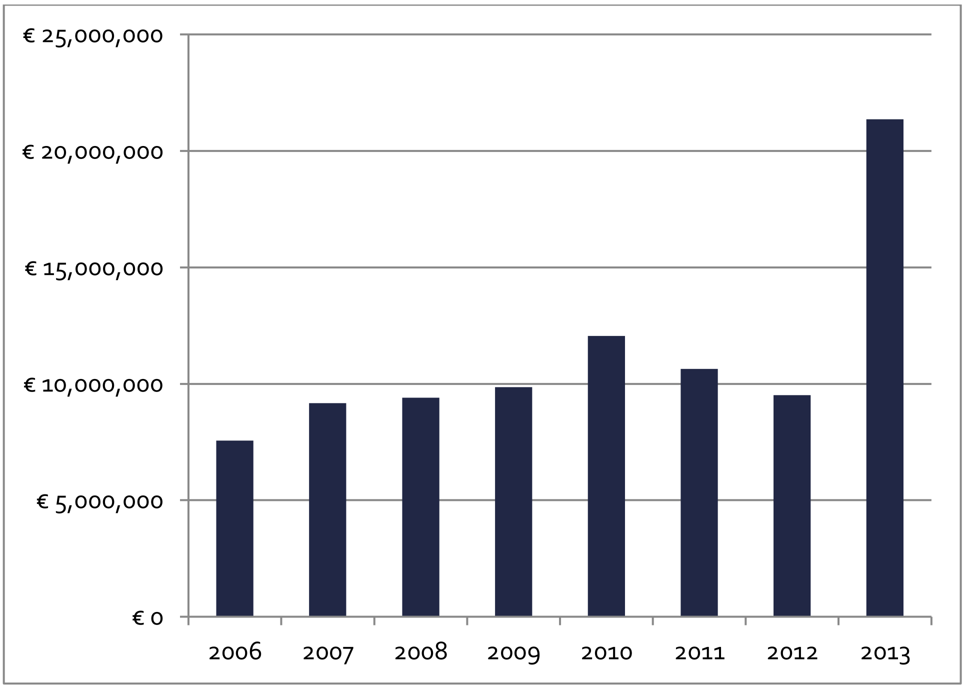


**Figure 14: Protective hydraulic engineering in the province of Styria**

**Province of Upper Austria**

Especially the big flooding events of the years 2002, 2012 and 2013 had an impact on the province of Upper Austria. As an example, the costs of relief measures and regular measures in the years 2013 and 2014 have been provided and can be viewed in the following table. The budget for the relief measures related to the 2013 floods, were permitted in the year 2013 by means of a supplement budget.

Table 4: Relief measures budget and regular measures budget in the years 2013 and 2014 in Upper Austria

| Measure/Year | 2013 | 2014 |
|---|---|---|
| Relief mesures (costs in EUR) | 3,147,000 | 3,412,000 |
| Regular measures (costs in EUR) | 6,204,800 | 13,221,000 |

## 5. Results 2: Climate risks in Austria up to 2030 and 2050

### 5.1. Modelling the fiscal impacts of flood risk at the federal level in Austria up to 2030 and 2050

With increasing evidence that climate change will alter the frequencies and intensities of extreme weather events in the future (IPCC, 2013; IPCC, 2012), in combination with socioeconomic developments that will increase the exposure of communities and assets to natural hazards, Austria has to become aware of the fact that the public ex-ante and ex-post DRM expenditures will likely have to increase accordingly to guarantee a sufficient level of protection from natural hazards and to remedy damages after a catastrophic event has occurred. In this section we employ the risk based modeling tool, the IIASA CATSIM model presented in section 2, to estimate future direct economic losses of extreme weather events and their repercussions on the Austrian federal budget.

We find that in the base year of 2015, the fund's endowment dedicated to the compensation for damages due to extraordinary extreme events, amounting to EUR 72 million, is not sufficient to cover the expected direct losses of EUR 258 million for this year (Figure 15). The model then estimated the future expected annual flood losses in 2030 and 2050 in Austria and compared this to the business as usual funding of deposits in the Austrian disaster fund. The analysis found that the business as usual endowment of the Austrian disaster fund dedicated to the compensation for damages will not be sufficient to cover expected annual losses of EUR 354 million for 2030 and EUR 511 million for 2050. Severe stress could be put on the disaster fund's financial resilience and additional ad-hoc budget payments would become necessary more frequently.

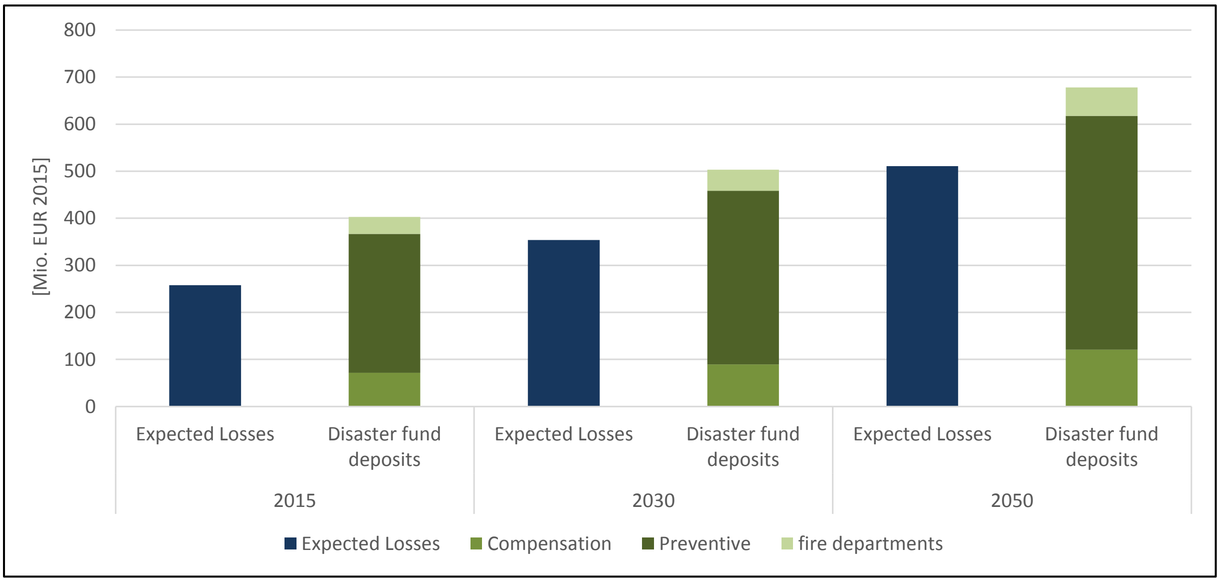


Figure 15: Development of expected annual flood losses from 2015 to 2030 and 2050 under current levels of flood protection (in blue) compared to the development of disaster fund deposits (in green) under business as usual (assuming a real GDP growth rate of 1.5 % p.a.) (in million EUR 2015).

The results for different flood loss return periods show an increase of losses over the future (Figure 16). It should be noted that the results are mainly driven by socioeconomic developments, leading to higher exposure of assets to flood risk, while climate change impacts are not found to be large in the near to medium future, e.g. 2030 (the relative importance of climate change, exposure and vulnerability in driving risk is now a very active research area, see for example Mechler and Bouwer 2014 for a discussion).

As discussed in the previous section, our flood loss estimates are based on a catastrophe modeling approach. However, as in most flood models today, they do not incorporate actual protection standards and therefore likely overestimate losses, especially for more frequent events. Ideally, one would use detailed information on the very local level to determine for each location the specific protection level which actually exists. However, this is not possible on higher scales (e.g. country level) as such comprehensive information is not systematically available yet. To circumvent this problem, we use protection levels estimated in Jongman et al. (2014) which defined flood protection standards as the minimum statistical probability of discharge that leads to flooding. The assessment was based on a large pan-European literature survey and modeling effort to establish estimates on the basin level for all European countries and therefore were also used here.

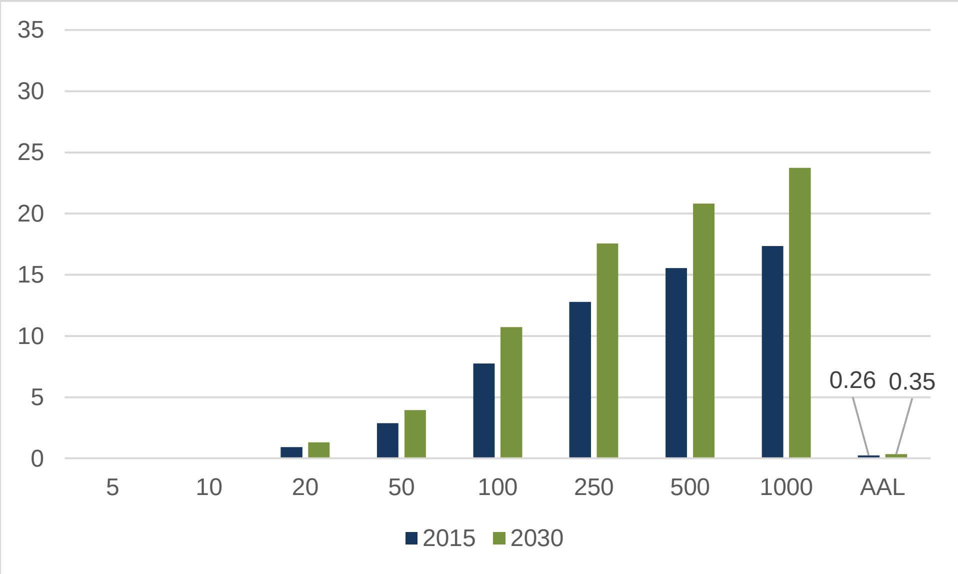

Figure 16: Probabilistic projections of flood losses (with flood protection measures) for different return periods in Austria calculated with a copula approach (in billion 2012 EUR)

The probabilistic modeling results can extend the analysis of risk by giving not only information about the changes in average losses but also about changes of the tails, i.e. extreme risk. While AAL are expected to increase from 258 million EUR in 2015 to 354 million in 2030, policy makers should also pay attention to the full loss distribution, particularly the tails of the distribution. When talking about catastrophic events it is the low probability, high impact events that should matter most in decision making, as in case of occurrence such events could impose severe stress on federal budgets and can overburden risk instruments, such as the Austrian disaster fund, exactly at the moment when they are needed the most.

Our analysis thus leads to the conclusion that the current, static approach to financing DRM with the disaster fund is not an appropriate approach to manage low-frequency, high-impact events such as extreme floods and other climate risks in a broader understanding of CRM.

## 5.2. Expected future impacts, measures and costs at the provincial level

At the provincial level we were on able to derive qualitative insights regarding expected future impacts, measures and costs. To that end semi-structured, qualitative Interviews were performed with actors from the provinces of Styria and Upper Austria. In general, the outcomes of the four interviews on the level of the provinces Styria and Upper Austria showed that the implications of future climate related extremes are not expected to have an impact on the current budgeting practice. Also an increase of the current disaster fund in terms of volume is seen as very unlikely. To some regard, an increase of heavy precipitation events is expected by public administration experts, but not an incease in therms of bedgets for risk prevention or recovery. The consensus is that funds are made available shortly after events happen and lots of funds are already now used for risk prevention, based on the low number of interviews performed on the provincial level.

**Province of Styria – Interview results for expected future impacts, measures and costs**

Three qualitative Interviews were performed with experts from the field of disaster management and prevention, water management and provincial roads. The qualtitative insights gained are summarized in the following text-box.

**Climate Change and changes in risks/impacts**

Results of the qualitative interview showed that there might be changes in terms of the probability of 1 in 100 year events in the light of climate change. Thus there will be a likely increase in the future and thus the annuality will have to be adapted. Since a changing climate also changes the energy-balance of the atmosphere, thus extreme events will become more frequent and more intense (Kendon, et al 2014 ). There is an increase of extreme precipitation events and an increased appearance of flash floods and extreme surface runoff (pluvial floods), on top of flood events from rivers and creeks. Changes in precipitation intensity are expected with shorter, but more intense precipitation.

**Adaptation measures**

Preventive adaptation measures (e.g. flood defence) exhibit a net-positive return already now, but additional measures need to be taken to reduce the potentially increasing future impacts of extreme events. Along road infrastructure drainage infrastructure needs to be extended (e.g. storage basins). Thus the focus shall be on soft and green measures, like more retention space for rivers for improved flood protection. In some geographical areas, like in alpine valleys characterized by high settlement pressure, technical measures such as protection of rock-fall, debris flow, mud-slides and flood protection shall be implemented. It also needs to be taken into consideration that besides climate change also soil sealing, river straightening and settlements in risky zones lead to an enormous contribution for damage potential of singular events. Thus the structural change is a risk and chance and spatial planning is a key instrument to reduce loss potential.

**Future budget planning**

Current extreme events do, until now, not influence the budget planning of provinces, since after singular events, emergency relief funds and the disaster fund cover a big amount of the impact.

No changes in the current budgeting practices are to be expected for the coming years, especially when the current structures are not changeing. If extreme events increase, the risk-prevention or risk transfer mechanism remains a question for the insurance industry and future engagement of the public sector in terms of loss coverage via public budgets. In the long term, risk management measures and climate change adaptation measures will adapt to the new conditions.

**Adaptation Efforts and awareness**

Styria is one of the leading provinces in Austria with a climate mitigation plan since 2010 and an adaptation strategy since 2015. Thus a certain level of awareness and the need to implement long-term climate adaptation measures in the public administration has started. The current awareness of climate change impacts and relevant adaptation measures as well as the responsibility for its implementation in the public administration is still low. Due to working groups for all departements, awareness increased substantially. For example, for the department for provincial roads implemented a new risk management system in late 2015/early 2016. Yet, no awareness is given to climate-related adaptation costs or its future development.

**Awareness in the general public**

Also climate change has reached the general public in terms of negative impacts. Especially in terms of mitigation, measures reached the level of individuals with energy-efficient heating, insulation of buildings, pholtovoltaik and solar-heating-systems and more climate friendly nutrition.

The awareness of the public regarding climate change impacts is still quite low, but in areas that were impacted in the last years (e.g. district of Andritz and Sankt Peter in the city of Graz), certain awareness is visible. Due to media coverace in the last years, the general public became more aware, thus the importance and understanding for preventive measures will increase even more. More emphasis shall be placed on public relations in terms of risk awareness and adaptation measures to improve the current status.

**Province of Upper Austria – expected future impacts, measures and costs**

One qualitative Interview was performed with an expert in the field of water management and flood protection. The result is summaries in the text-box below.

**Positive experience with implemented measures**

The already implemented measures for flood protection along the Danube in Upper Austria proofed its use in reality (Danube flood in June 2013). Only in two areas, additional measures were foreseen after the flooding event hit in June 2013.

**Climate change and changes in risks/impacts**

Due to the increase of the intensity of heavy precipitation events, an impact on future extreme events is expected for Upper Austria.

**Implications on the budget planning in the past, due to extremes**

The flood events of 2002, 2012 and 2013 already had an impact on the budget and led to additional costs. Additional ex-post relief had to be provided by the federal and province level by means of budget diversion.

**Future budget planning**

No impact on the current budgeting practice is to be expected in Upper Austria since extremes (and related catastrophes) are not planable in terms of time and special occurance. The current instrument of the disaster fund and EU solidarity fund – relief aid budgets is seen as the future instrument for financing of catstrophes.

Risk-transfer mechanisms like insurance might lead to a lower risk-perception.

**Awareness in the general public**

Extreme events lead to an increased interest of the public over a short period. Especially the media coverage of catastrophes leads to an increase in the public debate. If this increased the risk-awareness in the long-term is not clear.

Especially awareness-building measures are performed continuesly on the public administration side, especially since individuals at the level of the regional government are in charge of this topic.

Risk-reduction measures are taken and implemented, if the individual is directly impacted and a certain risk-awareness is established. There is the general impression that many citizen take measures to reduce their risks.

## 6. Discussion: The way ahead- building blocks of an iterative climate risk management strategy for Austria

Irrespective of the potential contribution of climate change to recent natural disaster losses or future increases in losses and damages from extreme weather events in Austria, in an iterative approach to CRM, already the most recent flood losses reveal the urgency for early adaptation, i.e. to deal with the current adaptation deficit based on current climate variability and weather extremes. As part of an iterative CRM strategy, the Austrian DRM practice will have to deal with these current and future climate risks in any way. In the medium to longer term, as new significant scientific evidence – particularly in the research area focusing on attributing natural hazards and associated losses to climate change – is found, climate change considerations might be incorporated in an iterative manner in the development of a robust Austrian adaptation pathway. Not only the way how to deal with damages from catastrophic events ex-posed but also future investments into preventive and protective ex-ante measures have to be reconsidered, as the eventual aim of ex-ante DRM measures is to reduce ex-post public liabilities.

The fact that the damages caused by the floods in 2002, 2005 and 2013 put Austria's main vehicle to finance DRM – the disaster fund – under pressure, can be seen as a first evidence that the current approach to financing DRM in Austria is not sufficient to sustainably cope with catastrophic climate related events like the ones in 2002 and 2013. The diversions from the general federal budget, which have become necessary to provide additional resources for the Austrian disaster fund, put additional stress on the Austrian federal budget. In fact, the Austrian government is, implicitly (through moral obligations) and explicitly (through entitlements), taking over more and more climate risks for society. In combination with a potentially even reduced financial coping capacity under future socioeconomic and climate change developments, a continuation of this re-active approach to financing DRM in Austria would likely result in a reduction of Austria's fiscal space and may eventually lead to high opportunity costs as other socially desirable investments have to be forgone. Hence a revision of this budgetary procedure is necessary.

One option could be to link the development of deposits of the disaster fund to ex-ante estimates of future expected annual losses in order to sustain a positive balance over the long run. However, as, e.g. the example of Mexico shows, this would not increase a countries resilience against major natural disasters with losses substantially exceeding AAL (Cardenas et al., 2007). Another strategy could aim at reframing the fund's reserve to a truly accumulating, un-capped reserve. As the buildup of reserves in the Austrian disaster risk fund is capped, excess resources are distributed back to the general budget in years without major disasters. Without a static, absolute cap on the level of the Austrian disaster fund's reserve, the fund would have been able to accumulate more financial resources over the period from 2002 to 2013 (Figure 17). This would have allowed the fund to cover all ex-post expenditures for remedying the damages of the 2013 floods, amounting to approximately EUR 118 million with its own resources, which could have summed up to an amount of approx. EUR 130 million. No extraordinary increases by diversions from the general budget would have been required and hence no additional stress would have been put on the federal budget in 2013[7].

[7] Of course, this result would look different if also the damages from the floods in 2002 and 2005 would not have been remedied by issuing special-laws that provided increases to the disaster fund's general budget. Taking into account the relatively high frequency (three times within the last 12 years) of ad-hoc interventions would even strengthen the argument for a truly accumulating reserve to deal with the impacts of catastrophic events. Particularly as climate science predicts an increase in the frequencies and intensities of extreme events.

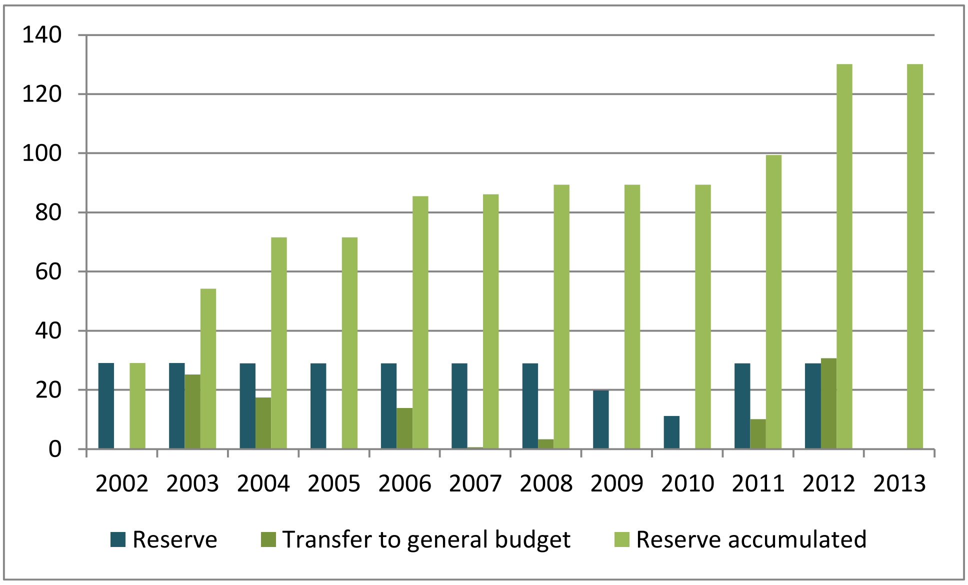


Figure 17: Development of the disaster fund's reserve by Dec. 31 with and without an absolute cap, 2002-2013 (in million EUR)

There are caveats linked to an uncapped reserve as well, mainly arising in the form of opportunity costs associated with the funds set aside. Instead of having this reserves sitting idle in anticipation of by definition low probability catastrophic events, they could have been employed instead to finance other socially and environmentally desirable investments. Eventually, these foregone investments could even have indirectly contributed to a reduction in climate related risks.

Instead of relying on a single risk management tool, we suggest to employ a more comprehensive and integrative approach to CRM. As there are different kinds of climate related risks, some occurring frequently with only minor impacts while others rather infrequently but devastating (low and high return period events, respectively, Figure 18), countries should employ a varied portfolio of instruments, each carefully chosen to be applicable for a certain layer of climate related risk (Mechler et al., 2014) and iteratively adjusted over time with evidence. For low layers of climate risk – characterized by high probability of occurrence but comparably low impacts –, risk reduction is often the most effective and cost efficient way forward. Ex-ante preventive measures, such as constructing flood barriers, could be financed e.g. through a disaster fund as in Austria.

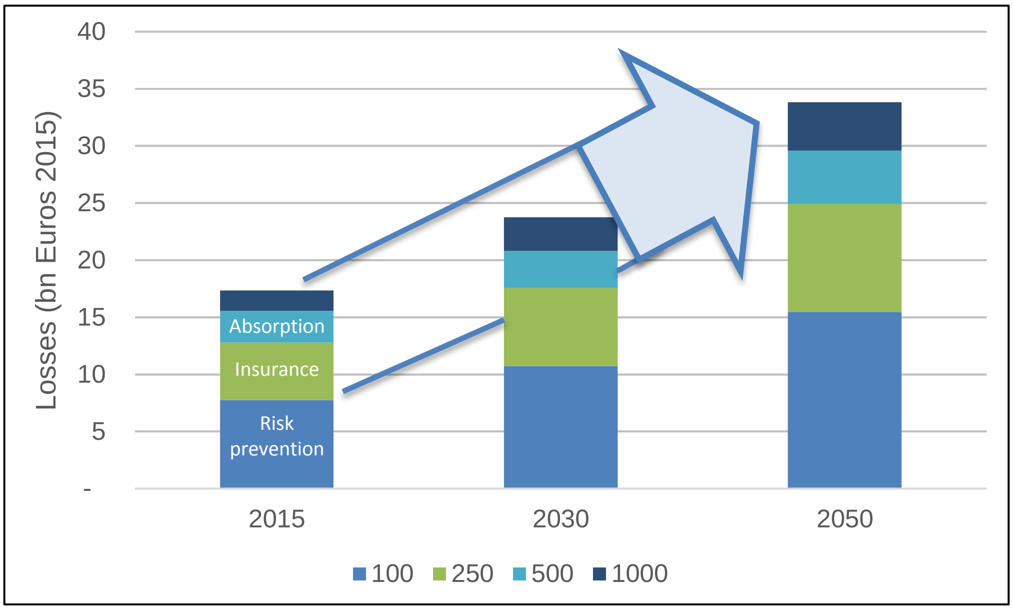


**Figure 18: Risk layering approach to deal with probabilistic projections of flood losses (with flood protection measures) for different return periods in Austria calculated with a copula approach (in billion 2012 EUR)**

While the Austrian disaster fund has been an effective and well-functioning tool for risk reduction at lower layers of risk, we still suggest some improvements to the current set-up of the fund. First, building-back-better damaged assets, which would serve the purpose of increasing resilience against future natural hazards, is not foreseen under the current form of Austria's disaster fund. Providing financial assistance beyond the asset's pre-catastrophe present value for rebuilding assets in a more catastrophe-proof fashion, would increase the effectiveness of preventive measures under the disaster fund as early adaptation measures dealing with existing and exacerbating climate variability and extremes. Second, while the preventive measures financed by the Austrian disaster fund today are almost exclusively building measures, a more comprehensive approach to financing ex-ante risk reduction should also incorporate tackling the underlying drivers of risk, e.g. by preventing the placement of capital (e.g. buildings) in flood-risk prone areas. The implementation of a national flood risk management plan, as required by the EU floods directive 2007/60/EC (European Parliament and Council, 2007) is currently being established in Austria accompanied by a comprehensive stakeholder process. The draft version (BMLFUW, 2015) proposes 22 measures along the full flood risk management cycle and has thus the potential to allow the broadening of the Austrian DRM praxis, moving beyond the pure focus on building measures as ex-ante risk management and the remedying of damages as post-disaster relief measure, towards a more integrative approach to DRM. Third, in its current form, the Austrian disaster fund does not finance preventive measures in the private domain. Private households are only eligible to relief (up to a certain percentage of the asset's pre-catastrophe present value) after a catastrophic event has occurred. Financing private preventive measures would change the incentive structure in the Austrian risk management practice further from a rather re-active to a pro-active approach and could prove highly cost effective in reducing climate-related risks.

Medium layers of risk (Figure 18), with a lower probability of occurrence but in case of emergence related to severely higher (economic) impacts, may require alternative risk financing and risk transfer mechanisms, such as insurances, if risk reduction possibilities are limited. High layers of risk, with climate related risks characterized by high return periods, meaning that these risks are rare but catastrophic, require instead public post disaster assistance to absorb the manifested risks– in the case of Austria today financed by the Austrian disaster fund. However, given the potential for severe fiscal stress imposed by climate related risks in the future – already indicated by three recent flood events in Austria – new and additional financing mechanisms may be needed. Internationally coordinated aid schemes, such as the European solidarity fund, or international risk pools are potentially highly cost efficient and effective risk management instruments to deal with these high layers of risk.

As indicated by Figure 18, we suggest that the choice of instruments taken under a risk layering perspective should be iteratively updated, taking into consideration new scientific and empirical evidence. A multi-stakeholder driven evaluation of the current CRM practice in combination with monitoring the climate signal, natural hazards, loss databases, and the instruments in place, may lead to the conclusion that an adaptation of existing instruments, as well as the introduction of new instruments, over time is required. Moreover, model based analysis of future climate risks might indicate a shift in the different risk layers over time, thus fostering the ex-ante adaptation of the current CRM practice to likely future climate risk scenarios.

### 6.1. Strategies at the provincial level – Upper Austria and Styria

Both provinces, namely Upper Austria (2013) and Styria (2015) have developed their own Adaptation Strategies, based on the Austrian Adaptation Strategy and Action Plan from 2012. The adaptation measures are taken into consideration and elements of relevance for the provinces are reflected upon and modified to the provincial level. Thus a first feeling of climate adaptation related costs is of interest to the provinces and can be seen as a starting point for a closer linkage between risk prevention and climate change adaptation on the provincial level, aiming at a more resilient province, safeguarding its citizens and assets, based on climate risk management approaches.

## 7. Conclusions: Synthesis and linking up to the international context

Coming back to the key questions initiating our comprehensive assessment of a potential confluence of DRM and CCA within an operationalized CRM approach, we established a nuanced picture with reference to the Austrian case. In terms of a joint perspective on CCA and DRM, based on multiple lines of evidence – expert interviews and workshops focusing on the Austrian DRM practice in the context of CCA, empirical budget analyses, and risk-based modeling of past, current and medium-term economic impacts of flood risks– we find that climate change is today not being explicitly taken into account in the Austrian DRM practice. Across the institutions involved, climate change considerations do not play a major role, and are not considered via specific instruments, such as mark-ups in hydrological assessments.

On the other hand, we find that there is good understanding that DRM and CCA need to be assessed concurrently, and that the importance and notion of updating practice with scientific evidence is a consideration that has been taken forward. The empirical budget analyses has shown that recent extreme events have already put Austria's major risk financing instrument – the disaster fund – under severe pressure and made budget diversions necessary, creating awareness for potential contributions by climate change to overall risk. Under future climate and socioeconomic developments climate related risks are expected to increase substantially, leading to even stronger fiscal implications in the future. Also, fiscal risk planning is seeing increasing emphasis in Austria in the wake of the budget crisis and high expenditures for climate change mitigation, but also due to increasing requests to the disaster fund (our CATSIM analysis discussed with Austrian Ministries shows how to practically incorporate climate risks into fiscal risk planning and projects considerable increases) for ex-post payments to remedy damages, and a need for fostering preventive measures not only in the public but also in the private domain.

These multiple lines of evidence for the fiscal impacts of natural hazards in Austria inform our second research question regarding the potential of CRM. We find that – for our point in case Austria - the iterative CRM conceptualization serves as a useful framework to address the existing adaptation deficit and the uncertainties associated with future climate change impacts, losses and damages in policy and practice. The Austrian DRM and CCA practice can be interpreted as being situated in the first phase of an iterative CRM strategy, dealing with existing weather extremes and climate variabilities. To cope with the potentially severe monetary and fiscal stress imposed by future climate risks we propose to continue this iterative and integrative CRM approach as an actionable way forward for Austria and other contexts.

A mix of policy measures, carefully selected under a risk layering lens, will be needed to fully implement the CRM conceptualization in Austria: risk reduction measures for low layers of risk, potentially financed by a reformed disaster fund, risk financing, e.g. via insurances, for medium layers of risk, and national and internationally coordinated disaster relief in combination with alternative risk transfer mechanisms for high risk layers. Proactively engaging with all three layers of risk and fostering explicit budgeting for contingent disaster risk liabilities will be needed to reduce climate stress on public budgets and to ensure fiscal stability in the future.

Our findings and conclusions are of relevance beyond the case of Austria: Many countries and communities are feeling the impact of changes in extreme events and are looking for robust strategies to reduce and manage the risks. Regions are developing improved approaches for absorbing the increasing burdens, such as in the EU through reforming the European Solidarity Fund or setting up regional risk pools for buffering against the financial risks from extremes, such as in the Caribbean or Africa. Finally, the international community is committed to jointly tackle disaster risk based on the principle of moral responsibility via the Sendai mandate as well as through the Warsaw Loss & Damage mechanism, which is based on recognized liabilities. Fundamental to all these approaches is a broad-based and actionable perspective on CRM, which, as we demonstrate and believe, will see further impetus over the years to come.

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## Appendix

### Open ended interview questions for the federal level interviews

| |
|---|
| **Questions regarding the status quo of the Austrian DRM practice** |
| Where are the financial resources for the Austrian DRM practice coming from? |
| How is your agency's activities connected to the Austrian disaster fund? |
| Which DRM measures have already been implemented due to previous climate related extreme events and how much did they cost? |
| How effective, in terms of increasing resilience against extreme events, have these measures been? |
| How did previous extreme events in Austria change disaster risk management practices? |
| How did previous extreme events in Austria change public budgeting practices? |
| Is climate change explicitly considered in the risk management practice and public budgeting procedures? |
| How are international budgeting requirements regarding expenditures for climate change adaptation influencing the Austrian case? |
| How do you judge the cooperation of the Austrian DRM community and the CCA community? |
| **Questions regarding the medium term future of the Austrian DRM practice** |
| Are there already any enhancements to existing financing and promoting instruments in the Austrian DRM practice planned due to climate change? |
| Is there an influence of the climate change signal on the expansion of risk provisioning in the Austrian DRM practice, involving adequate (financial) risk transfer mechanisms? |
| What would be needed from the field of climate science to inform the Austrian DRM practice regarding climate change adaptation? |
| How do you evaluate the perceptions of Austrian policy makers regarding long-term climate change adaptation measures? |
| How do you evaluate the perceptions of Austrian policy makers regarding the responsibility for the implementation of adaptation measures? |

**Open ended Interview questions for the provincial level interviews (Styria and Upper Austria)**

| |
|---|
| **Ereignisse, Maßnahmen und Kosten in der jüngeren Vergangenheit** |
| Welche klimabedingten (Extrem-)Ereignisse (z.B. Hitzewellen, Stürme, Starkniederschläge, Hochwasserereignisse und Überschwemmungen, Trockenheit, Dürre,) wurden in ihrem Bundesland seit etwa 2000 beobachtet. (Ereignis: Jahr, Jahreszeit) |
| Welche Reparaturmaßnahmen für Schäden (Auswirkungen der Ereignisse) an öffentlichem Gut waren in Ihrem Bundesland (/Ihrem Ressort) notwendig? Wenn ja - nach welchen Ereignissen, wie hoch waren die Kosten, wer ist dafür aufgekommen? (Ereignis: Jahr, Maßnahme: Jahr, Kosten, Finanzierung (OH, AOH)?) |
| Welche Risikominderungs-Maßnahmen bzw. Anpassungs-Maßnahmen sind in ihrem Bundesland (/in ihrem Ressort) wegen vergangener Ereignisse umgesetzt worden. Wenn ja wann (nach welchen Ereignissen?) und wie hoch waren die Kosten? (Ereignis: Jahr, Maßnahme: Jahr, Kosten, Finanzierung (OH, AOH)?) |
| Sind die Kosten für Reparatur von Schäden durch Katastrophenereignisse bzw. für Anpassungsmaßnahmen in den Budgets von uns richtig identifiziert worden (OH, AOH)? Wenn nein – korrigieren und Gründe nennen! |
| Wie stellt sich der Aufteilungsschlüssel (Bund-Land-Gemeinde) für die Finanzierung von Maßnahmen (Reparatur & Prävention) dar? |
| Hat ihr Bundesland Mittel aus dem Katastrophenfond erhalten? Wenn ja für welche Ereignisse, für welche Maßnahmen und wieviel? (Ereignis: Jahr, Maßnahme, Höhe) |
| Wie effektiv sind bereits implementierte Maßnahmen; d.h. haben bereits umgesetzte Maßnahmen zu einer höheren Widerstandsfähigkeit gegenüber Extremereignissen geführt? Wenn ja in welcher Form? |
| **Erwartungen hinsichtlich Ereignissen, Maßnahmen und Kosten in der Zukunft** |
| Rechnen Sie in Anbetracht von zu erwartenden Änderungen des Klimas mit Veränderungen von künftigen (Extrem-)Ereignissen in ihrem Bundesland? – Wenn ja, welche Veränderung? |
| Haben vergangene Extremereignisse und Naturkatastrophen ihre Budget(planungs)-praxis verändert? Wenn ja , wie (OH, AOH)? |
| Glauben Sie, dass künftige Extremereignisse (Veränderung von z.B. häufiger und stärkere Ausprägung) mehr Auswirkung auf ihre (zukünftige) Budgetplanung haben? (Wenn ja, welche?) |
| Rechnen Sie mit einer Erweiterung von Finanzierungsinstrumenten im Bereich des öffentlichen Katastrophenmanagements in Anbetracht der zu erwartenden Änderungen des Klimas? |
| Welchen Einfluss haben Extremereignisse auf die Verstärkung der Risikovorsorge und Risikotransfermechanismen? |
| Wie hoch ist das Bewusstsein in der Verwaltung / im Landtag über die Notwendigkeit langfristiger, Klimawandel-bedingter Anpassungsmaßnahmen im öffentlichen Bereich und über die Zuständigkeit für deren Umsetzung? |
| Wie hoch ist das Bewusstsein in der Bevölkerung über die Notwendigkeit langfristiger, Klimawandel-bedingter Anpassungsmaßnahmen im privaten Bereich? |