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Regional climate change and adaptation

The Alps facing the challenge of changing water resources

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European Environment Agency

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Vulnerability of the Alps to climate change

Spanning the centre of continental Europe, the Alps play a crucial role in accumulating and supplying water to the continent. Recognised as the '**water towers of Europe**', the mountains host most of the headwaters of the rivers Danube, Rhine, Po and Rhone; as such, they deliver vital ecosystem services both within and beyond the region, underpinning social and economic wellbeing in vast lowland areas.

Troublingly, the alpine climate has changed significantly during the past century, **with temperatures increasing more than twice the global average**. This makes alpine mountains especially vulnerable to changes in the hydrological cycle and decreases in snow and glacier cover, which are already occurring. Global climate change threatens to continue altering the alpine hydrological system drastically. Projected changes in precipitation, snow-cover patterns and glacier storage will further alter run-off regimes, leading to more droughts in summer, floods and landslides in winter and higher inter-annual variability.

Projected water shortages and more frequent extreme events, combined with increasing water demand (for irrigating agriculture or tourist influxes, for example), are likely to have severe adverse effects on ecosystem services, such as the provision of drinking water. Furthermore 60 % of mountain plant species may face extinction by 2100 if unable to adapt by moving northward or uphill. Economic sectors, including households, agriculture, energy production, forestry, tourism, and river navigation, are already now vulnerable to water shortages.

Climate change may worsen current water resource issues and lead to increased risk of conflicts between users in the alpine region (particularly the south) but also outside the Alps where droughts are also expected to become more frequent. Observed and projected reductions in permafrost are also expected to increase natural hazards and damage to high altitude infrastructure.

The global climate is forecast to keep changing unless global greenhouse gas emissions are reduced substantially to keep global temperature increases below 2 °C (above pre-industrial levels), which is the EU target. This target is guiding the negotiations on a global post-2012 climate agreement to be discussed at the UNFCCC climate change conference in Copenhagen (December 2009). However, even a global increase of 2 °C will still result in major impacts to which the world and Europe (primarily mountain regions, coastal areas, river floods-prone areas, the Mediterranean and the Arctic) will need to adapt.

The heatwave of summer 2003 demonstrated the potentially severe impacts of higher temperatures and drought on human wellbeing, ecosystems and water-reliant economic sectors (such as power generation). Such extreme events have raised the national and community awareness of the **need to develop adaptation strategies**. Some initial adaptation measures are already in place, partly as a response to extreme events. These initial measures can provide governments and citizens elsewhere guidance on which approaches are likely to be successful and which less so, and also provide a preview of the challenges ahead.

The EU Adaptation White Paper together with the National Adaptation Strategies and the Action Plan on Climate Change of the Alpine Convention provide key steps towards European frameworks for adaptation measures and policies to increase resilience to climate change impacts. The knowledge base, governance structures and implemented actions are important issues to consider for developing effective adaptation measures. Hence, drawing on the most recent knowledge of climate change impacts in the Alps and experiences across the region, this report analyses the risks that climate change presents to the region's water supply and quality, identifying needs, constraints, opportunities, policy levers and options for adaptation. **It extracts policy guidance on adaptation practice and aims to assist regional and local stakeholders in developing robust adaptation strategies. The focus of the report is on water resources and related adaptation**, rather than water-related extreme events like floods, avalanches, landslides or mudflows, which are already well covered by existing studies of climate change impacts in the Alps.

Photo: © European Environment Agency

Regional case studies

The case studies and literature review contained in this report provide valuable insights into the forces that promote or obstruct adaptation and the measures that have proven successful. The key findings are presented below.

Success factors

Political support is a key catalyst for initiating, driving and coordinating adaptation to climate change, providing a strategic framework for effective action. Policies have generally been responses to extreme events or natural hazards that motivate demand for action by public authorities.

Once initiated, adaptation measures rely on a broad variety of factors for their success, relating primarily to institutional and governance structures, as well as organisational settings:

- measures are generally more accepted and successful when they **promote** (or at least do not conflict with) **other goals**, including economic gains. Effective adaptation processes therefore depend a great deal on the people involved and their motivations, as well as organisational factors such as stakeholder participation processes or cooperative structures *(this applies to all case studies to a varying extent)*;

- a **sound legal framework** is a crucial complement to political support. It can provide a clear mandate for establishing cooperation at the water basin, cross-sectoral or inter-regional scale, facilitating sharing of water resources and coordination of water and land users *(see, for example, the case studies on 'River Lavant' and 'Vienna's water mountain' in Austria, the South Tyrol in Italy, Savoy in France and 'River Soča' in Slovenia/Italy)*;

- **technological measures** (e.g. improved irrigation techniques, new reservoirs, rainwater harvesting, wastewater and greywater re-use) play a major part in adaptation measures *(see, for example, the case studies on Valais in Switzerland, the South Tyrol in Italy and Savoy in France)*;

- an increasing number of initiatives consider complementary 'soft' actions on the **demand management side,** such as behavioural adaptation and ensuring full participation and empowerment of stakeholders. By complementing more widespread supply-side technological measures, this strongly supports the resilience and adaptive capacity of the Alps, which is high compared to other mountain areas in Europe due primarily to higher economic resources and a more advanced knowledge base *(see, for example, the case studies on Savoy in France, 'Vienna's water mountain' in Austria and 'River Soča' in Slovenia/Italy)*;

- introducing **market-based economic incentives** (in particular water pricing) and financial support (for example subsidies) is also helpful in encouraging proactive and innovative adaptation measures, ensuring private sector participation and enhancing the success rate of measures taken *(see, for example, the case studies on 'River Lavant' and 'Vienna's water mountain' in Austria, Valais in Switzerland and the South Tyrol in Italy)*;

- **raising stakeholder awareness** about the need for anticipatory adaptation actions is vital, especially in sectors with long lead times (i.e. where long-term investments are needed) such as forestry and power generation. Long term adaptation planning occurs mainly in those sectors, while others plan and act on the basis of shorter timeframes *(see, for example, the case studies on 'River Lavant' and 'Vienna's water mountain' in Austria, Valais in Switzerland and 'River Soča' in Slovenia/Italy)*;

- other **social factors,** in particular local practices and social networks, are also key. For example accepted long-standing adaptation strategies such as complex, traditional irrigation systems, unwritten rules, the effective distribution of responsibilities and existing communication networks, which do not need to be formally institutionalised, decrease conflicts between

Box ES.1 The six regional case studies

The present report contains six case studies that illustrate regional adaptation to key water resource issues resulting from climate change and other causes such as increased water use. In addition to detailed literature analysis for each region, the case studies included interviews with stakeholders who were directly involved in adaptation activities or had knowledge about them. The case studies addressed the Lavant valley and Vienna in Austria, the Valais in Switzerland, South Tyrol in Italy, the Savoy region in France and River Soča in Slovenia and Italy. The key characteristics and issues for each case study are listed below.

River Lavant valley (Austria)
The region has a low level of precipitation and a limited number of springs that can be used for water supply. It has already been affected by water shortages during hot summers. Due to projected climate change impacts, it can be expected that the water resource issues will increase and that further adaptation activities will be essential.

The Valais (Switzerland)
An inner-alpine arid valley, the Valais has always needed to adapt to temporary low water availability. Traditionally, water needed in summer is taken from groundwater or glacial melt run-off, water in winter is taken from reservoirs. Water-related conflicts of interest have been rare. In the future climate change will increase water resource issues because there will be less glacial melt water to compensate for summer drought, with effects on groundwater capacity.

South Tyrol (Italy)
South Tyrol is characterised by dry inner-alpine valleys, where water has been a rare resource for centuries. To address this problem, the South Tyrol has a long history of adapting to water scarcity with a traditional and complex system of irrigation channels, water rights and local water managers. In the last decade, mainly due to a series of dry years combined with increasing demand for water for irrigated agriculture, tourism and households, water scarcity has become a challenge in particular seasons (early spring, high summer) in parts of South Tyrol. While the total amount of water available within the region is sufficient, water scarcity arises from an uneven temporal and spatial distribution of demand and supply.

Savoy (France)
Savoy has a complex topography with many high altitude mountain chains and a wide range of climatic zones, from sub-Mediterranean and oceanic to dry inner-alpine valleys. The available water resources are very variable and, depending on their surface and groundwater storage capacity, are sensitive to climate change and human impacts. Local water supply from springs used to be sufficient for local populations but this supply is now increasingly limited due to expanding communities and the temporary influx of tourists. Thus, water demand problems are exacerbated by a combination of supply limitations and climate change.

Vienna's water mountains (Austria)
The karstic mountains (Mt Hochschwab, Mt Rax, Mt Schneeberg and Mt Schneealpe) play a vital role in supplying water to approximately 2 million people, including the city of Vienna. The main water resource issues in the region arise from the specific geological features (e.g. the short time span between infiltration and discharge of water after an event), from climate change (e.g. rising temperature) and from land use activities (e.g. farming, forestry), which substantially influence water quality. Adaptation activities have been initiated in response to past environmental and socio-economic impacts rather than climate change scenarios. Adaptation to current water problems has been successfully managed so far by the competent authority within the City of Vienna.

River Soča (Slovenia and Italy)
The Soča provides a good example of transboundary river management. The Slovenian part of the Soča river basin is not only one of the wettest parts of Slovenia but also of Europe as a whole. The main focus in this region is on heavy precipitation episodes, related flash floods, debris flow and landslides. Drought is unknown in the Upper Soča valley but in the southern part of the basin drought sometimes occurs due to less precipitation and higher water consumption. Due to projected hotter summers and higher evapotranspiration water supply in the southern part of the basin is expected to decrease while water demand will increase. The Italian representatives to the bilateral Slovenian-Italian Commission in the field of Water Management have already requested more water, especially during periods of drought.

stakeholders and facilitate adequate adaptation responses *(see, for example, the case studies on Valais in Switzerland and 'Vienna's water mountain' in Austria).*

Barriers to adaptation

The case studies and literature review also revealed various barriers to adaptation *(these apply to all case studies to a varying extent)*:

- **limited scientific knowledge and uncertainty** about future climate change's local impacts on water availability, quality and demand is clearly a key barrier to political commitment to anticipatory and forward-looking adaptation measures. This is partly due to huge uncertainties in downscaling climate models and scenarios;

- the **lack of long-term planning strategies, coordination and use of management tools** that consider climate change at regional, river basins and cross-sectoral levels hinders sustainable development of water resources and is a key barrier to effective adaptation. Water supply networks connecting communities or regions can generally cope better with local water shortages and help avoiding uncoordinated actions and individualistic or inefficient solutions;

- **climate change is seldom considered explicitly** in water supply or demand management plans, meaning that water-related adaptation measures responding specifically to current and future climate change impacts are still largely absent. This is partly due to the weak knowledge base on climate change impacts at the local and regional levels. The Water Framework Directive and the River Basin Management Plans (first plans due in 2010) should certainly help integrate and streamline climate change adaptation into sectoral policies.

Potential policy options

The regional case studies and broader empirical research contained in this report generate a variety of insights into developing effective policies for adapting to climate change and water resource issues.

Regional and local adaptation strategies are needed

Stakeholders need to work across municipalities, massifs or river basins/valleys to address climate change impacts and adaptation issues effectively. Regional and local adaptation strategies should as much as possible take into account the characteristics of the local situation (e.g. type and timing of water issues; economic circumstances; ecosystem-related services; drivers of adaptation; and success factors and barriers).

The cross-sectoral nature of water resources and their transboundary interdependence also calls for **multi-level governance and integrated approaches**, which can help coordinate multiple stakeholders from different sectors, regions and policy levels (local, regional, national, EU).

A regional approach to adaptation can significantly help decrease vulnerability, reinforcing local adaptive capacity by delivering adequate institutional and governance structures and combining economic resources. It is appropriate for addressing many climate change-related water resource issues, such as the growing need for inter-communal water transfers or coordination platforms between upstream and downstream localities.

Regional adaptation strategies must guarantee coordinated and efficient exchange of information between different levels of policy-making and stakeholders so that climate change is adequately reflected in policies ('climate proofing'). Some management tools exist that consider climate change (e.g. analytical frameworks, downscaled scenarios, cost-benefit analyses, good practice examples) but are largely unknown among local and regional stakeholders, underlining the high need for dissemination and outreach.

Decisions on current and future climate change adaptation actions at regional and local levels must be taken in conditions of uncertainty. Adaptive management, especially close monitoring, is therefore needed to facilitate regular review of policy objectives and the inclusion of new scientific information that might reduce uncertainty once it becomes available. Climate change adaptation in this respect is not different from any other environmental issue where perfect information and complete scientific knowledge is lacking. The precautionary principle is an appropriate response to knowledge deficits. According to the precautionary principle, the absence of full scientific certainty should not be used as a reason to postpone measures where there is a risk of serious or irreversible harm to public health or the environment. Decision-makers can also take advantage of 'no-regret' measures, i.e. those that

would be justified under all plausible climate futures.

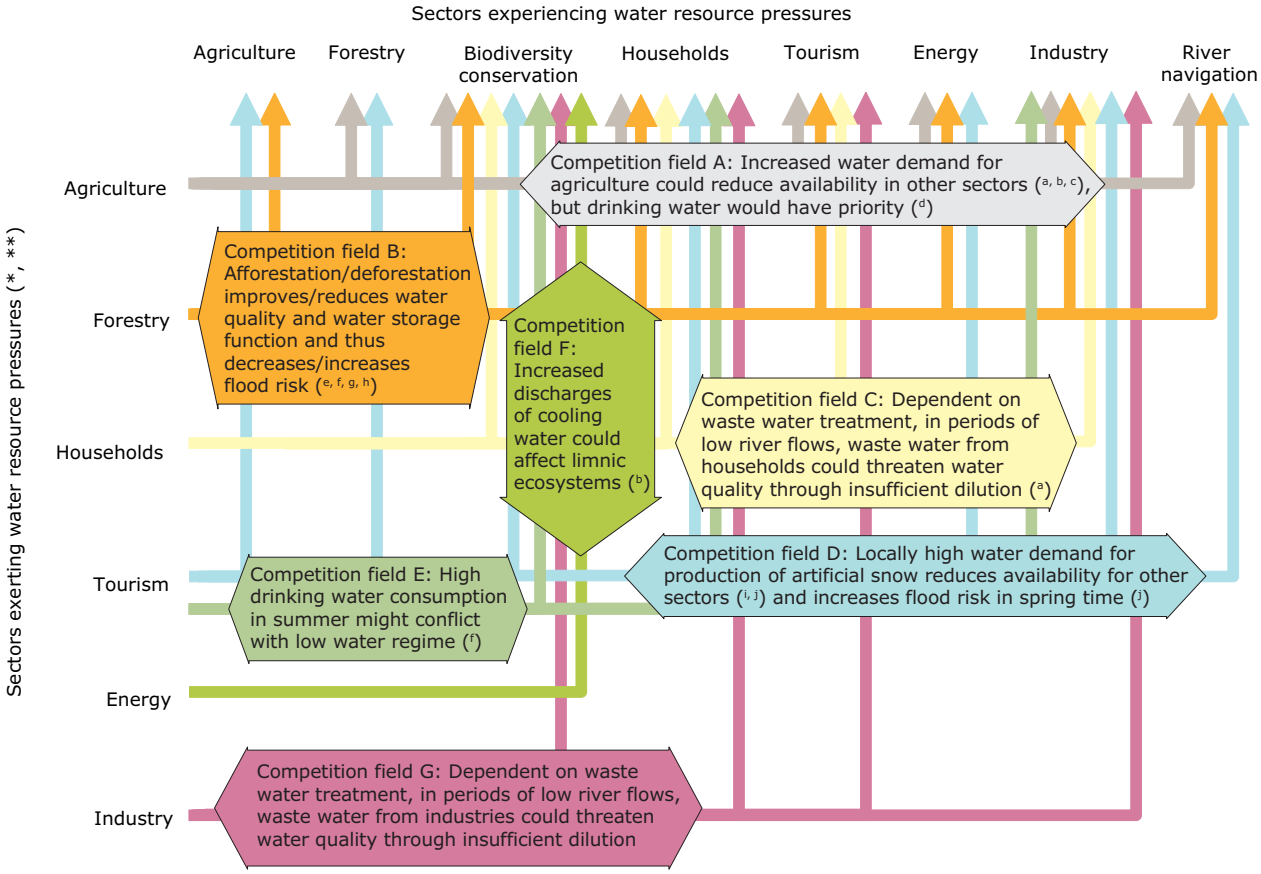
The possibility of non-linear, abrupt or step changes that can alter the state of the environment once a threshold has been reached must also be taken into account in order to **build resilience to cope with the unexpected**.

All sectors need to be considered in adaptation strategies

Water resources are an inherently cross-disciplinary issue, affecting almost all socio-economic sectors. Figure ES.1 illustrates the most important current and expected **cross-sectoral water competition** in the Alps. It differentiates sectors exerting pressures on water resources (with respect to both water quantity and quality) from those experiencing pressures. The main sectors exerting pressure are agriculture, households, tourism and energy production, while the main socio-economic and environmental sectors affected by water resource competition are agriculture, biodiversity conservation, households and energy production.

Integrated management approaches, such as Integrated Water Resource Management, should be used when developing and implementing adaptation measures. They are usually well equipped to take into account the variety of drivers, success factors and barriers to successful adaptation. Integrated approaches require that various elements (e.g. an enabling environment, definition of institutional roles and functions, and the use of management instruments) be integrated consistently

Figure ES.1 Fields of potential cross-sectoral water competition relevant for adaptation



* River navigation is not considered as a sector exerting water resource pressures as it uses but does not consume water.

** Biodiversity conservation is not considered as a sector imposing water resource pressures as it does not actively change water use pattern but rather can be considered as a sector exposed to water competition.

Source: ([a]) OcCC/ProClim, 2007; ([b]) BUWAL and BWG, 2004; ([c]) Oleson *et al.*, 2005; ([d]) Wilibanks *et al.*, 2007; ([e]) IPCC, 2008; ([f]) Leipprand *et al.*, 2007; ([g]) Anderson *et al.*, 2008; ([h]) Giller and O'Holloran, 2004; ([i]) OECD, 2007; ([j]) Teich *et al.*, 2007; ([k]) de Jong, 2008.

and coherently in water resource management. An in-depth assessment of cross-sectoral competition is important to define effective, proportionate and transparent adaptation strategies and options at the regional scale. All strategies should preferably use an ecosystem goods and services framework.

The European Union should provide the overall policy frameworks

The European dimensions of climate change impacts and water resource issues in the Alps are diverse. EU initiatives should provide stakeholders the framework and policy instruments to consider climate change impacts effectively and develop adaptation strategies at national and sub-national levels that address local needs. This will help integrating ('mainstreaming') climate change into policies and streamlining and coordinating adaptation actions across Europe.

Impacts of climate change vary by region, with mountain areas (together with coastal areas and flood plains) particularly vulnerable. This is why most adaptation measures will be carried out nationally, regionally or locally. The European Union should support these efforts through an integrated and coordinated approach, particularly in connection with cross-border and regional solidarity issues, as well as EU policy areas (e.g. common policies, such as agriculture, water, biodiversity, fisheries and energy, and the single market). Climate change adaptation will need to be embedded in all EU policies.

Existing European legislation, particularly the **Water Framework Directive** (WFD), is a good basis for cross-border water coordination and adaptive management. It paves the way towards further integrating climate change adaptation into European policies and implementing adaptation measures, also at a river basin scale where uncoordinated actions should be avoided. Within this context River Basin Management Plans (RBMPs), a key instrument of the WFD (first RBMPs are due in 2010 and the second in 2015), must be coordinated with other sectoral policies (e.g. the Common Agricultural Policy) and secure broad public participation. Economic incentives and demand-side management options also have to be considered further. Guidance on how to include climate change into the RBMPs is being developed (due to be made available in second half of 2009). The Water Framework Directive is complemented by the Floods Directive and the policy on water scarcity and droughts, which provide a more specific framework for adapting to the key water-related impacts of climate change (e.g. droughts management plans, water scarcity and droughts information system).

The EU Adaptation White Paper, published by the European Commission on 1 April 2009, is a key step towards a framework for adaptation measures and policies to strengthen EU resilience to climate change impacts. It stresses the need to develop the knowledge base further and to integrate adaptation into EU policies. The White Paper also prominently recognizes that the impacts of climate change will have varying regional implications, which means that most adaptation measures will need to address local needs.

The EU framework for action presented in the White Paper sets out a two-phase strategy that complements actions taken by Member States through an integrated and coordinated approach. The first phase (until 2012) will be dedicated to preparing a comprehensive EU adaptation strategy from 2013 onwards. The first phase will focus primarily on improving the knowledge base on climate change, possible adaptation measures and means of embedding adaptation in EU policies. An EU Clearinghouse on climate change impacts, vulnerability and adaptation is proposed in the White Paper to be put in place by 2011.

The EU is well placed to facilitate the implementation of the first phase of the framework for action through a series of actions, including:

- supporting **monitoring and data collection networks** to expand the knowledge base and widen the scope for in-depth analysis of long data series. For example, qualitative and quantitative data are still very much needed on water balances, abstraction and its impact on ecosystems, or optimal ecological flow. These data would provide more accurate information, which would enhance transparency for water users and better inform policy-makers;

- developing analytical tools and assessments that report on the adaptive capacity and **vulnerability of natural and human systems**. This will serve the purpose of developing and implementing ecosystem-based adaptation options;

- developing **information platforms** on climate change impacts, risks and adaptation options at the local and regional levels to facilitate information sharing among stakeholders and the dissemination of management tools

that consider climate change. Creating such web tools (the proposed EU Clearinghouse) would complement resources available at the national and European levels and help regions, communities and all stakeholders make informed decisions;

- facilitating **exchange of good practices** between Member States to further support capacity-building of regional and local authorities, and encourage those that have not yet prepared national and/or regional adaptation strategies to do so. For instance, so far there has been limited transboundary cooperation in managing water shortages along river basins originating in or fed by the Alpine region;

- fostering **stakeholder participation** in research projects to bridge the gap between scientists, policy-makers and all other relevant parties. Engaging stakeholders more could streamline the flow and sharing of information, and avoid duplication of work and undue delays in taking decisions. This could improve understanding of local knowledge and practices and public awareness, which are essential for successfully implementing adaptation measures, avoiding maladaptation or unsustainable solutions (e.g. artificial snow making).

Under the framework of the **Alpine Convention**, the Alpine Conference adopted an Action Plan on Climate Change in March 2009, aimed at making the Alps an exemplary region in preventing and adapting to climate change. The Action Plan calls for better sharing of information on climate change in the Alps, including good practices in mitigating and adapting to climate change, and on water management to help decision-makers and other stakeholders develop adaptation strategies.

For this purpose a platform on 'Water management in the Alps' will be established. Its mandate is to undertake a survey of water management plans, give guidance on sustainable and balanced use of hydropower and assess the needs for adaptation to climate change. In addition, the *Second Report on the State of the Alps* with focus on water and water management issues, published in 2009, dedicates a specific chapter to climate change and water management.

Adaptation experiences are not easily transferrable to other mountain regions

Local and regional situations differ considerably both within the Alps and by comparison with other European mountain regions. That means significant variance in demography, climate and environmental impacts, economic structures, cultures and values, land uses (urban, agriculture, pasture), and patterns of public and private partnerships. These local conditions make it challenging to transfer lessons learned from the regional case studies and other information sources to other areas within the Alps or to other European mountain regions as a whole.

Nonetheless, many lessons learnt from adaptation in the Alps are of a **generic nature** and practical experience in the Alps provides guidance for designing regional strategies to adapt to climate change impacts and water resource issues. As noted above, key elements of successful strategies include tailoring measures to specific regional climate conditions, affected sectors and political and socio-economic contexts; ensuring dialogue between stakeholders through cooperative structures and knowledge transfers; and monitoring progress to support regular reviews of policy objectives and the inclusion of new scientific information when becoming available. These elements would help deliver water resource management that takes climate change into account more systematically and follows a proactive, precautionary and cross-sectoral approach.

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