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CLIMATE CHANGE ISSUES AND ADAPTATION STRATEGIES IN A MOUNTAINOUS REGION: CASE STUDY SWITZERLAND

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TABLE OF CONTENTS

CLIMATE CHANGE ISSUES AND ADAPTATION STRATEGIES IN A MOUNTAINOUS REGION: CASE STUDY SWITZERLAND[1]

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1. Introduction

An important part of Switzerland is characterized by the mountainous environment of the Alps. For people living in the Alps weather is always an important, even a vial topic of daily life. The same is true for climate and climate change (SAEFL, 2002).

Located in the Alps, Switzerland is a small ‘hazard prone’ country exposed to natural disasters, such as debris flows, earthquakes, floods, forest fires, hail storms, landslides, rockfalls, wind storms and snow and ice avalanches. Between 1972 and 1998, floods and landslides caused about 200 million CHF of direct financial damage per year (Röthlisberger, 1998). For snow avalanches, the financial damage covered by insurance was around 6 million CHF per year over the period 1972 to 1993. In February 1999, 1,200 destructive snow avalanches occurred, showing that snow avalanche damage can be very expensive (620 million CHF). The financial damage from the wind storm named ‘Lothar’ in December 1999 reached almost 1.8 billion CHF and the floods of May 1999 about 600 million CHF.

Switzerland lies not only in the middle of Europe but also, climatically speaking, in a transitional zone. Depending on seasonal and other meteorological factors, the country is subject to the climatic influence of the Atlantic Ocean to the west, or of the Eurasian continent to the east. In addition, the Alps form a boundary between the Mediterranean climate and that of the prevailing westerlies. In this transitional zone, even slight changes in wind circulation patterns can have a substantial impact on climatic conditions. Both existing observations and calculations based on models suggest that Switzerland and especially the Alps are particularly susceptible to the impact of climate change. Thus, temperatures in this country have risen by about 1.3 to 2.0 °C in the 20th century, compared with a global average of only 0.8 °C. The warming effect is particularly marked in the winter months. Switzerland has also experienced an above-average increase (16 percent) in rainfall in the 20th century compared with the global trend.

Extracted from findings of the Third Assessment Reports of IPCC the expected consequences for Switzerland have been summarized in a report of the Swiss “Advisory Body on Climate Change” (OcCC, 2002). In addition, a second report reviews the current status of knowledge on the relationship between extreme events in Switzerland and global climate change (OcCC, 2003).

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   The opinions expressed in this paper are those of the individual authors and do not necessarily reflect the views of their organisations or of the OECD.

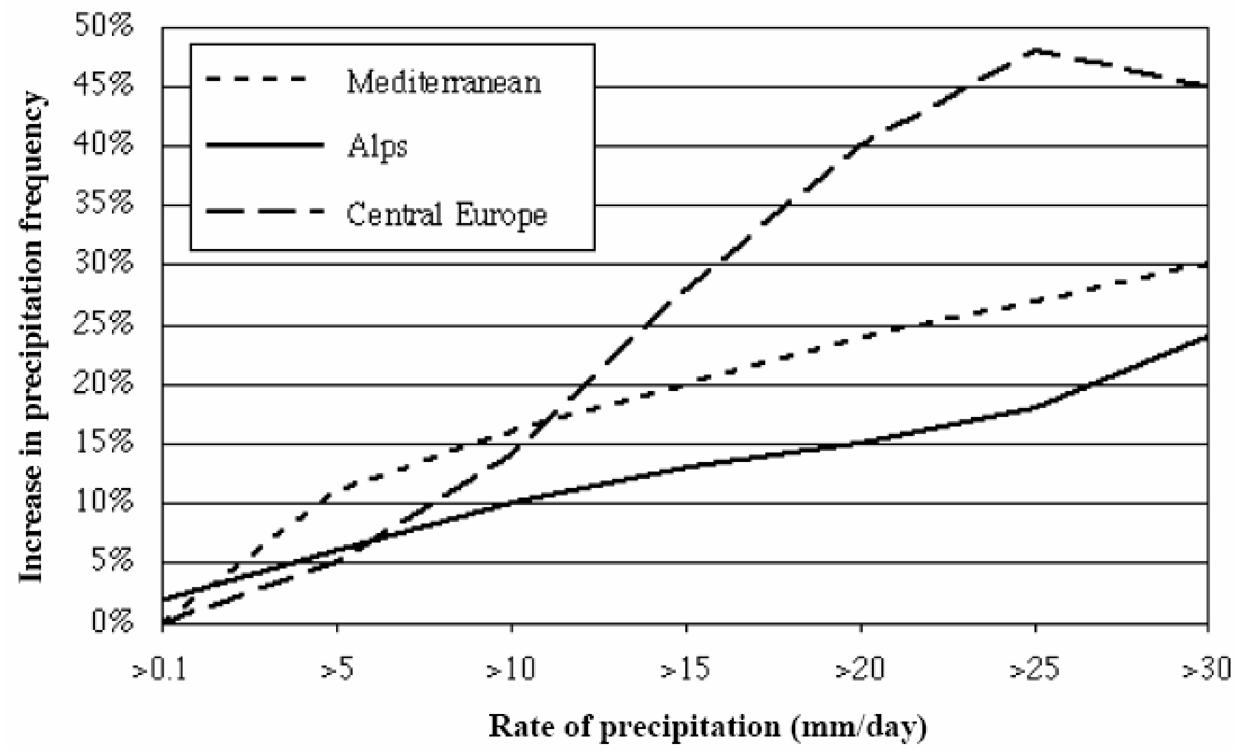
In this review consequences of climate change on some vital key issues in mountainous environment and related adaptation strategies are discussed.

2. Precipitation – the input into the hydrological cycle

In Switzerland, heavy precipitation may either be intensive and of short duration in connection with summer thunderstorms, or less intensive and of several days duration in connection with stationary weather systems. Extremely heavy precipitation can lead to floods, rivers overflowing their banks, debris flows and landslides. In the course of the 20th century, the frequency of intensive daily precipitation events has increased over wide areas of the Central Lowlands and at the northern fringe of the Alps (Frei and Schär, 2001). Most simulations based on climate models indicate a future increase in the average intensity of precipitation and the frequency of intensive daily precipitation. Assuming an acceleration of the hydrological cycle, intensive precipitation of long duration could become more frequent in the Alps.

Several global climate simulations for the second half of the 21st century were analyzed for characteristic indicators of heavy precipitation (Frei, 2003). The majority suggest a global increase in the average intensity of precipitation and the frequency of intensive daily precipitation values. This tendency is confirmed by the available regional model analyses for Europe, which show an increase in the maximum annual daily precipitation values of 10-25%. Increases by a factor of 2 and more have been identified in the frequency with which the current yearly and the current 50- yearly extreme precipitation values will be exceeded. An analysis of the results of 19 global climate models shows that the frequency of winters with extreme precipitation (current return period 40 years) could in fact be exceeded by factors of 3-5.

Figure 1. **Predicted increase in winter precipitation in three central European regions, given a 2ºC increase in atmospheric temperatures and a 15% increase in atmospheric moisture**



Source: after Frei et al., 1998

3. Floods and mudflows

Climate change can, however, influence the occurrence of floods through increases in temperature, changes in precipitation and changes in the catchment area. In summary, this means more rain in the winter, more intense rainfall, and an increase of the snow line by 200 to 300 meters. As a result of higher temperatures, precipitation tends to take the form of rainfall and the greater volumes run off immediately. Accordingly, hydrologic models for Switzerland indicate that in those areas of the Central Lowlands in which floods already occur in winter, an increase in the risk of floods is probable. For catchment areas in the high Alps, factors that increase or decrease runoff must be considered, so that changes in the risk of floods are very difficult to predict. Higher runoff peaks not only means higher risk for flooding, but also higher risks for debris flow, mudflows, bank erosion and deposition of debris in the floodplains.

Today it seems very difficult to quantify the possible change in probability and occurrence of floods. The already existing uncertainty for the design of flood protection measures increases. Together with already existing need for action this growing uncertainty urges policy to an adaptation policy which ended 1991 in a new Swiss policy for an integrated flood management:

Adaptation strategy: The new Swiss policy for an integrated flood management

Up-to-date flood protection is not limited to complete and maintain existing river training works. On the contrary, major efforts have to be made to include flood protection aspects in the planning and coordination of all land-use activities. This includes the legitimate demands of all concerned partners and of activities such as water quality control, fishery, forestry, agriculture, protection of landscapes, water supply, and hydropower generation.

Flood protection today is facing numerous demands that reflect conflicts of interest. In order to devise good solutions, flood protection must accomplish a number of requirements:

- Living space and the economic environment must be adequately protected.
- Further economic damage must be limited by means of a comprehensive prevention strategy.
- Handling of uncertainties needs to be improved and included in flood protection concepts.
- Rivers and streams have to be regarded and respected as an essential link element in nature and the landscape.

The new federal law and the federal ordinance on flood control clearly emphasize these requirements. Only a minimum of flood protection activities is allowed along rivers and streams. Flood prevention has a high priority. Despite preventive measures, functional emergency planning and emergency organization are indispensable. On this basis a number of flood protection principles can be formulated (see below). Sustainable flood protection can only be achieved if these principles are put into practice. Impacts on nature and landscape must not endanger living conditions for future generations.

Figure 2. **Processes from meteorological event to the damage, influenced by different measures on each level.**

The cornerstones of the strategy are:

- **Analysis and documentation of the existing danger –** Risk maps serve as a basis for prevention measures.

- **Safeguard of the required space for flowing water** – Sufficient space for extreme quantities of runoff water simultaneously guarantees space for the ecological function of watercourses**.**

- **Integral action planning** – It is imperative that the principles of sustainability be taken into account for planning and organisational measures as well as for technical safety constructions (fig. 2).

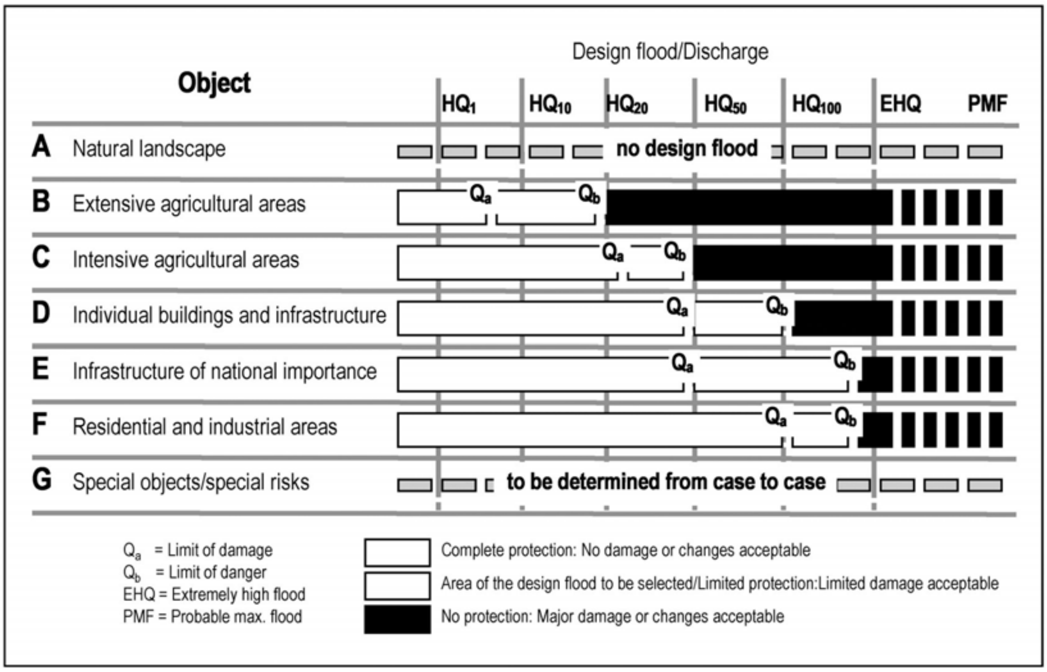
- **Minimisation of damage** – Maintenance of watercourses (= maintaining the existing safety conditions) as well as measures for spatial planning (= preventing a rise in the potential for damage by keeping space free or restricting the use of space) are of paramount importance.

- **Emergency planning** – Good preparation (forecasting, alerting and mobile measures ...) can minimise the ever present residual risks. In addition, insurances can help make damages bearable.

- **Flood protection as a federal task –** Interdisciplinary cooperation among experts from all areas and inclusion at a sufficiently early stage of the political authorities as well as the concerned population are a condition precedent for sustainable protection policies.

Guidelines of the Federal Office for Water and Geology (FOWG, 2001) help the responsible authorities to implement the new strategy.

Figure 3. **Differential safety concept, as it was developed following the 1987 flood disasters. According to safety objectives a variable design flood can be applied for flood control works.**



4. Glaciers, ice and permafrost

Snow and ice in the Alps are particularly sensitive to climate change. Since 1850, the glaciated area of the European Alps has decreased by about 40 per cent, and about 50 per cent of glacier volume has been lost (Haeberli and Hoelzle 1995). Mass balance measurements and the first results from the new Swiss Glacier Inventory indicate a marked acceleration of this trend since the mid-1980s. The rising temperatures are also poorly tolerated by the frozen soil layers – known as permafrost – found at high elevations. Over the past 100 years, the lower boundary of permafrost regions has risen by 150–250 metres. Pronounced secular warming (1 to 2°C) is being observed in 100 m deep boreholes installed for the ongoing EU project on Permafrost and Climate in Europe (PACE). Such changes have been shown to lead to slope instability in both consolidated and unconsolidated material (Haeberli et al. 1997).

In alpine mountain regions, the snowpack is close to its melting point, so it is very sensitive to changes in temperature. As warming progresses in the future, current regions of snow precipitation increasingly will experience precipitation in the form of rain. For every 1°C increase in temperature, the snowline rises by about 150 m; as a result, less snow will accumulate at low elevations than today, although there could be greater snow accumulation above the freezing level because of increased precipitation in some regions (IPCC, 2001). A warmer climate will lead to the upward shift of mountain glaciers, which will undergo further reductions. It is likely that in the 21st century, 30–50% of alpine glaciers will disappear (Haeberli, 1995). Permafrost also could be significantly perturbed by warming. The melting of glaciers and thawing of permafrost increase the risk of landslides on previously stable slopes and rocks. In newly ice-free areas, mud and debris flows may also be triggered, threatening the valleys below.

5. Mass movements: landslides, blockfalls and rock avalanches

Where a large input of water persists over longer periods, it can lead to mass movement. Unstable slopes represent approximately 7% of the land area in Switzerland. (Raetzo and Lateltin, 2003). In western Switzerland, the increase in precipitation has led to more frequent movements in many landslide areas since the early 1970s. In recent times, heavier winter precipitation in combination with large volumes of snow water have also provoked more frequent landslides. Receding glaciers, thawing of permafrost in the ground, increasing winter precipitation and the rising snow line could cause a general increase in slope instability.

The frequency of mass movements is influenced by changes in the temperature, the hydrological cycle, the glaciers and permafrost. The rise in winter and spring temperatures changes, the form that precipitation takes, the amount of snow cover and the ground temperatures. Climate change gradually alters the stability of large landslide masses. Extreme events such as heavy precipitation and thunderstorms can, however, trigger smaller landslides and earth flows.

The acceleration of the hydrological cycle has a negative influence on slope stability. Owing to the increase in winter precipitation, landslide activity could increase in future. Higher temperatures will result in more rain and less snow. Through the increased quantities of water in supply in the winter months, slope stability will decrease.

Adaptation strategy: Strategy for protection against natural hazards

A global approach to coping with natural hazards must be taken, and climate change aspects have to be included. A concerted effort by all players enables efficient reductions in future disasters. The reduction of destruction caused by natural disasters requires an integral prevention strategy. Natural hazards, socio-economic conditions and cultural values have to be given equal consideration. The implementation of the measures requires co-operation with the population directly affected. It is not possible to achieve 100 per cent safety. The existing land use defines the safety objectives necessary. In the long term, the acceptance of certain risk has to be discussed openly. The step from the battle against nature to a distinct management of risks ('risk culture') proclaimed since 1997 by the national platform for natural hazards (PLANAT) is being prepared in Switzerland. It also enables changing hazard conditions due to global warming and changing demands and possibilities of society to be considered adequately and quickly.

Strong efforts are made to apply the same strategy and similar approaches for dealing with all kind of natural hazards. The legal and technical framework for the management of natural risks has undergone considerable changes during recent years. Since 1987, when major flooding affected many valleys, the strategy has shifted from fighting against the natural disaster towards the management of risk.

The main emphasis is now to an increasing extent placed on preventive measures. Therefore, hazard and risk assessment, the definition of protection targets, the integral planning of measures (mapping, technical measures and warning systems) and the limitation of the residual risk are of central importance.

The cantons are required to establish registers of events and hazards maps at a scale of 1:5,000 (local large-scale map) depicting endangered areas (Tab. 1). They also have to take hazards into account for the purposes of land-use planning. For the elaboration of registers of events and hazards maps, the federal government provides subsides to the cantonal authorities of up to 70 per cent of the costs, as well as helping with new guidelines to elaborate these hazard maps. The federal government assists the cantons in the protection of built-up areas and transport infrastructure, providing early warning systems and the associated monitoring points and information systems.

Table 1. **The degree of hazard depends on the probability and the magnitude or intensity of an event. High intensity and high probability results in a "red zone degree".**

Hazard maps:	Degree of hazard
red zone:	high risk for constructions and people inside houses → no new constructions allowed
blue zone:	medium risk → constructions allowed with restrictions
yellow zone:	low risk → information for the ground-owners
yellow/white zone:	residual risk → pay attention in case of special objects, planning of emergencies

6. Tourism

For many alpine areas in Switzerland winter tourism is the most important source of income, and snow-reliability is one of the key elements of the tourist offers. In 1998, tourism contributed 20.7 billion CHF in income for Switzerland (about 5.4 per cent of GNP) and accounted for 11.6 per cent of export income, making tourism the third most important export sector in Switzerland. Activities related to tourism provide 9 per cent of all jobs (300,000 jobs) and a much higher fraction in mountain regions.

Important factors for the success of tourism have been the snow cover, good weather conditions, the length of season and the scenic value of glacial landscapes. But the crucial factor for the long-term survival of mountain cableway companies is the frequency and regularity of winters with good snow conditions (Bürki et al, 2003). Today, 85% of Switzerland's 230 ski resorts can be considered to be snow-reliable. If the line of snow reliability were to rise to 1'500 m as a result of climate change (year 2030 – 2050), the number of snow-reliable ski resorts would drop to 63%. Large parts of medium range altitude ski resorts will be particularly jeopardized by global warming. The ski regions of Valais and the Grisons will experience virtually no major problems, since the mean altitude of the cableway terminals in these regions is higher than 2500 m above sea level. Climate change will lead to a new pattern of favored and disadvantaged ski tourism regions.

The only areas with good prospects will be those with transport facilities that provide access to altitudes higher than 2000 m. The regions at higher altitudes may experience greater demand, prompting a further expansion in quantitative terms. The pressure on ecologically sensitive high-mountain regions will increase.

Meier (1998) calculated the potential annual costs of climate change in Switzerland at CHF 2.3 to 3.2 billion by the year 2050, CHF 1.8 to 2.3 billion would be accounted for by tourism. Even if there are many reservations that can be voiced regarding this calculation, it nevertheless shows that tourism is the economic sector that would be most affected by climate change in Switzerland.

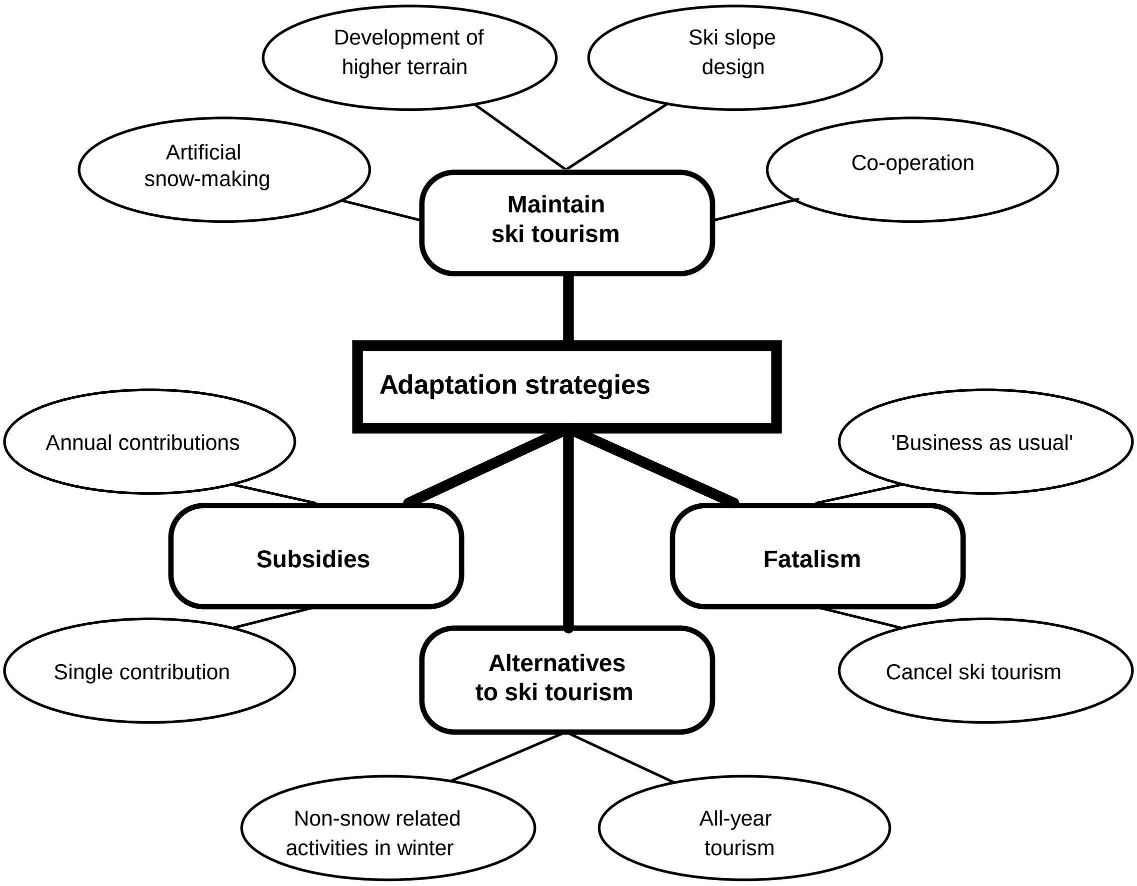
Adaptation strategy: Strategy for winter tourism

Climate change represents a new challenge for tourism, and particularly for winter tourism in mountain areas. It is not, however, the case that tourism's initial position will undergo a sudden, radical change.

Since climate change is a relatively long-term development in comparison to other trends in tourism, tourism managers and tourists will have every opportunity to adjust to the different constraints and adopt the corresponding strategies and measures (fig. 4). The tourism representatives will not just sit back idly in the face of climate change. They are reacting to the deteriorating snow conditions and the changes in demand. One of the most familiar technical measures in the struggle against snow-deficient winters is the construction of high cost artificial snowmaking facilities. Another mean is extending existing ski runs and opening new ones in high-alpine regions (at above 3000 m).

One of the most important questions will be, how young people would start skiing/snowboarding, if there is only little snow in the big towns and if the little and cheap ski lifts for families at small distances to these towns will be dismantled due to climate change. Although indoor skiing is a growing industry in European towns, it is uncertain that indoor ski domes can replace the role of little ski resorts for beginners in the foothills.

Figure 3. **Adaptation strategies**



Source: Bürki et al., 2003.

7. Hydropower

The reports of the Intergovernmental Panel on Climate Change (IPCC, 2001) note that climate change would impact energy supply and demand. Hydropower generation is the energy source that is most likely to be impacted because it is sensitive to the amount, timing, and geographical pattern of precipitation as well as temperature (rain or snow, timing of melting of snow and ice). Where reduced streamflows occur, they are expected to negatively impact hydropower production; greater streamflows, if they are timed correctly, might help hydroelectric production. In some regions, change of streamflow timing from spring to winter may increase hydropotential more in the winter than it reduces it in the spring and summer. Hydroelectric projects generally are designed for a specific river flow regime, including a margin of safety. Projected climate changes are expected to change flow regimes. What is known suggests more intense rainfall events, greater probability of drought in summer(less hydroelectric production), and less precipitation falling as snow (less water available during warm months). Reduced flows in rivers and higher temperatures reduce the capabilities of thermal electric generation.

In Switzerland annual hydropower production in lowland rivers may almost not be affected. In general, a shift from summer to winter season is probable, due to an increase of winter precipitation and the increase of winter temperature. Compared to the natural variability of the water resources this additional variation will be relatively small.

Most power production is generated in the alpine power plants with water stored in large reservoirs. As many of the reservoirs have a drainage area well above winter snowline and rainfall amount will – in most regions – even be slightly larger, hydro power production will not change remarkably. Schaefli et al. (2004) found for an inner alpine reservoir that due to lower rainfall and higher evaporation the hydropower production could strongly decrease.

The fact that glacier will clearly diminish in the coming time period will enhance discharge into the reservoirs during this time. In future, glacier mass balance will be stabilized again, and no influence has to be expected from the fast, that glacier volume is much smaller than nowadays.

Glacier retreat and permafrost degradation could considerably influence sediment yield into the reservoirs. This has to be taken into account for the management of the reservoirs, e.g. for rinsing of the sediments out of the reservoirs.

Adaptation strategy: hydropower

Even if there is some concern by the hydropower industry about climate change, there is still no visible strategy in sight. Energy manager think that fluctuations in the energy market and the coming changes in the energy market in Europe (opening of the electricity market) will influence the management of hydropower production in a much larger degree than the relatively slow changes in climate.

8. Mainstreaming climate change issues in Switzerland – a long lasting story in Switzerland

In Switzerland climate change is an important issue for a long time, in public policy and for a much longer time in research. In this context, ProClim – “the Swiss forum for climate and global change issues” - was founded already in 1987, even before the First IPCC Assessment Report was published in 1990. ProClim seeks to facilitate both integrated research activities and the necessary linkages among scientists, policy-makers and the public at home and abroad.

ProClim organizes four times a year meetings with a “Parliamentary group for Climate Change” in order to bring the key people in the two chambers of Swiss parliament together with leading scientist and to inform about background news from climate policy.

The first comprehensive research project was the so called National Research Programme NRP 31 on “Climate Changes and Natural Disasters” which started already 1991 and ended successfully 1998 with many exciting scientific results.

The actual Swiss research program is the NCCR Climate (National Centre of Competence in Research) which is a Swiss Research Network with the aim to acquire better understanding of climate system processes, variability and predictability, and the complex inter-relationships of climate, economic and societal driving factors. It started in 2001 for duration of 12 years.

On the governmental level, the “Advisory Body on Climate Change” (OcCC) was appointed in 1996 by the Federal Department of Home Affairs and the Federal Department of the Environment, Transport, Energy and Communication (ETEC). Its role is to formulate recommendations on questions regarding climate and global change for politicians and the federal administration.

The national platform for natural hazards PLANAT was created in 1997 by the Swiss Federal Council and made responsible for coordinating concepts in the field of prevention against natural hazards. The main objective of the extra-parliamentary commission is a paradigm change from pure protection against hazards to the management of risk. PLANAT consists of twenty specialists coming from all regions of Switzerland. The Confederation, the cantons, research, professional associations, the economy and insurances are all represented in PLANAT.

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