The UN's Sustainable Development Goal 6.6 in Switzerland: The melting glaciers in the "water tower of Europe"

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ABSTRACT

This dissertation focuses on the critical situation of "water-related ecosystems", notably glaciers, in the Swiss Alps during recent years. Its *in crescendo* melting due to climate change not only affects the photogenic landscape, and will likely affect the tourism industry, but worryingly threatens Central Europe's water supply, as the Alps are the cradle of rivers such as the Rhine, Rhone and Po, as well as of three quarters of the Danube's afluents.

By understanding the state of affairs, through an approach based on geological data concerning permafrost levels and ice retreat, and a historical analysis of Swiss climatic policies and conception of the Alps, this will allow the reader to comprehend this issue in the Swiss context. Furthermore, an analysis of the political and social climate of the Swiss Confederation will also contribute to an explanation as to why such a European powerhouse fails to pass legislation to tackle climate change.

Despite the monitoring of Swiss glaciers thanks to tools such as GLAMOS and the terms reached during the Paris Agreement, political action and citizen platforms are still attempting to tackle the issue by launching campaigns such as the *Initiative pour les glaciers*. Even with the extensive funds that the country has used to solve the situation, specific actions are just small victories in a tremendous war against climate change.

Keywords: climate change, glaciers, water, Switzerland, global warming.

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1. Introduction

Some years ago, skylines were considered as the silhouettes that marked the character and identity of certain towns or even countries. Nowadays, even though said outlines are not as trending as they once were, when we think about certain locations one of the first images that comes to our mind is its skyline. When we think of Barcelona we see the Sagrada Familia, Torre Glòries, etcetera. New York is recognisable by the Manhattan skyscrapers. However, also natural wonders can be part of a skyline, and when we think of a physical image of Switzerland it is inevitable to think about the Alps, covered in snow and ice, as the soul of the country. However, future generations will probably not see this when they think about Switzerland, as in some decades Alpine glaciers will just be a past memory, a legend, a myth.

Glaciers are the dying soul of many cultures. That's why some years ago the UN adopted the SDGs, in order to, among other objectives, save the natural wonders of our world. The Sustainable Development Goals, adopted by the UN in 2015, are a compilation of 17 objectives that should serve humanity and all the countries that agreed to them to protect our planet and respect human rights everywhere. Among those goals, there is the sixth one (Clear Water and Sanitation) and its sixth target (by 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes), which are to be analyzed in this dissertation in relation to the retreat of the Alpine glaciers in Switzerland.

The issue regarding the Swiss Alps and climate change is not new. Many scientists have discussed the extent of said environmental catastrophe and its scientific, social and economic reach. In addition to that, the situation has been lately worsened by 2022's summer, one of the hottest seasons measured in Central Europe since humankind started compilating temperatures and other climatic conditions. However, few have related the physical situation with the historical and ideological meaning that the Alps have had for the Swiss people and nation. Thus, the main objective of this dissertation is to merge the historical significance of the Swiss Alps with an analysis of how Switzerland is accomplishing SDG 6.6 and protecting its glaciers from climate change and global warming.

To begin with, by conducting a brief analysis of the glacier situation all around the world and in Central Europe, this dissertation will be able to discern the similarities and differences

between climate change effects in other mountain ranges compared to the Swiss Alps. To continue with, a detailed explanation of the country's situation will be drawn, including the important historical and ideological background (the old relationship between the Swiss and the nature of the Alps), the current situation in Switzerland[1] and the expectations of the impact of said natural catastrophe. To end with, a small evaluation and a series of recommendations will be explained in order to palliate the situation and its future effects, as it is neither the objective of this dissertation nor a possible outcome to provide a solution for an inevitable and colossal situation.

In order to analyze the different causes and consequences of this natural disaster, take into account the main actors and measures adopted by the Swiss government and investigate about the historical past of Switzerland and its relationship with the Alps, this dissertation will use a wide variety of references, from scientific articles to whole federal reports about the measures taken by the government. In addition to that, given that there have been some recent changes in the country's policy or new changes in legislation such as the CO2 Act, this dissertation has also used journalistic articles which, despite not being a scientific source of information, can provide rather new and complete information about recent votings and changes in the government's policies, such as the passing of the counter-proposal as an answer to the *Initiative pour les glaciers*. Moreover, even though this dissertation focuses on glacier retreat in Switzerland, it has been interesting and enriching to read about the situation in other regions of the world, such as the Peruvian Andes, in order to be able to understand if there are any differences regarding the retreat in itself or the policies passed by local governments.

Last but not least, the personal reasons behind the decision to choose said topic for my Final Dissertation are simple. During the last decades, news have been filled with apocalyptic premises about how the melting of the glaciers is accelerating itself and that, unless we unite efforts and considerably reduce greenhouse gas emissions, so many natural wonders will soon disappear. Thus, I wanted to investigate not only the situation in the Swiss Alps and if there are some measures able to delay the melting of the glaciers, but also to comprehend the socio-economic consequences of said catastrophe and the historical background behind Switzerland's relationship with glaciers.

[1] Regarding the main indicators of glacier retreat, the actors involved in the country's policies (such as the federal, cantonal and local governments, technology private institutions and NGOs) and the measures adopted to tackle the issue (such as the failed CO2 Act and the recently passed counter-proposal).

2. Literature Review

Climate change is not a new phenomenon and the available literature around said topic is abundant in many languages, focusing on different regions of the world. For instance, bearing in mind that this dissertation targets glacier retreat, a lot of the existing literature treats glaciers around the world, mostly in the poles, Scandinavia and the Andes. The Alps do not concentrate as much attention as other mountain ranges and glaciers, perhaps because of its relatively small size compared to others. Nevertheless, there's some literature regarding the scientific causes and consequences of glacier retreat in the Alps. However, the main issue is that most of these references about the scientific details of glacier retreat in the Swiss Alps are written in German: «A number of national reports on specific aspects have been produced, some of which are not peer-reviewed or only available in German» (Brönnimann *et al.*, 2014, p. 464).

On the one hand, compared to the other three official languages of the Helvetic Confederation, namely French, Italian and Romansh, German's importance within scientific research is unrivaled. In addition, most of the Swiss Alps are located in German speaking cantons, as are the most important institutions carrying out research about said phenomenon (such as the University of Zürich and the ETH Zürich). That's the main reason behind the over-representation of scientific research about glaciers written in German. On the other hand, it is true that less scientific aspects of the glacier situation, especially regarding the historical background or socio-economic consequences of the glacier issue, are more available in other languages (mainly English and French) as compared to the existing scientific literature.

Another relevant situation encountered is that in all the topics of this dissertation, the existing literature normally has some experts in common. Essentially, there are some researchers (from scientists and glaciologists to sociologists and economists) that have participated in several studies regarding their area of expertise. This is not a problem by itself, as there are some huge names among said experts such as Matthias Huss, an intellectual and glaciologist, and one of the founding fathers of the GLAMOS, a really useful Swiss glacier monitoring tool. Despite that, it can be argued that the excessive presence of a given expert in some studies can contribute to a lack of new ideas or points of view in said articles, as the main investigator will always, even unknowingly, alter the outcome or vision of the issues regarded in the study. For instance, it has happened that most of the research conducted by Huss, among many other

experts, almost always reaches the same conclusions and presents the same problems, not allowing there to be new and original production of knowledge and building up a homogeneous discourse.[2]

To end with, it is also difficult to discern from purely scientific and mathematical literature to more sociological or historical sources of information. This can be an issue as, although this dissertation briefly discusses the situation of glacier retreat, it mainly focuses on its economic and social consequences, as well as its historical background. Thus, titles may confuse the investigator and then be a whole article full of equations and mathematical considerations regarding the scientific aspects of glacier melting rather than being a redacted and reasoned analysis of more social events related to it.

3. Global situation regarding SDG 6

Climate change is a reality and, as the time passes, its effects and consequences are more and more visible to our society. However, certain changes are more obvious than others, especially when observing different regions of the world. Droughts are more common and drastic in the Southern Hemisphere, whereas extreme snow storms are becoming an everyday phenomenon in some parts of the Northern Hemisphere. Nevertheless, other changes have been partially ignored for decades, as they have been deemed as improbable or harmless in the short term (Willis *et al*., 2018).

The SDG around which this dissertation is centered, 6. Clear Water and Sanitation, and its sixth target (by 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes) have been overlooked, especially in Western countries (European Environment Agency and United Nations Environment Programme, 1997: p. 5). It's not surprising, afterall, as some Third World countries are suffering most of the extreme problems related to the loss of water-related ecosystems. For instance, states of the MENA region (Middle East and North Africa) are in a critical situation regarding water stress levels, according to the UN (United Nations, 2022) (see Figure 1).

[2] As seen in some sources by the mentioned researcher, Huss, the interpretations of the conclusions are exactly the same and do not provide additional points of view to the debate.

Globally, the scene is not better. The situation is improving but, at this pace, it would take a lot of effort and time to achieve the goals and, thus, according to the UN, saving up to 829,000 lives annually due to «diseases directly attributable to unsafe water, inadequate sanitation and poor hygiene practices» (United Nations, 2022). Nonetheless, let's not encompass such a colossal SDG, but direct the efforts of the analysis of the global situation towards the specific target of the dissertation, water-related ecosystems and, particularly, the situation regarding glaciers:

> The biosphere contains only 0.014% of Earth's water, distributed among lakes (0.008%), soils (0.005%), and the atmosphere, rivers, and biota (0.001 %). An additional 2.58% of Earth's water is fresh, occurring as ice (1.97%) or groundwater (0.61 %). The remainder of Earth's water is saline. Climate affects key fluxes (evaporation, water vapor transport, and precipitation) that determine the amount and distribution of freshwater. The availability of freshwater to both ecosystems and humans is therefore sensitive to changes in climate (Carpenter *et al.*, 1992, p. 119).

Water-related ecosystems have been suffering and disappearing for a long time all around the world. From lakes to marshes, drought and other extreme weather events have made an impact on them and reduced their numbers and, consequently, altered the natural balance of the area and decreased the availability of freshwater for human consumption and agricultural use. However, the distribution of said ecosystems will vary depending on climate conditions becoming more extreme. For example, arid regions will experience a drop of water supply below human demand, whereas others may become wetter and suffer frequent and savage floods (Carpenter *et al.*, 1992, p. 121).

Nevertheless, let's condense even more the analysis and focus on glaciers. These kinds of bodies of dense ice are crucial ecosystems in different parts of the world, usually within great mountain ranges, such as the Andes, the Himalayas or the Caucasus: «Glaciers affect strongly the hydrological regime of the catchment in which they are located, by storing water in winter in the form of solid precipitation and releasing it in summer through ablation» (Pellicciotti *et al.*, 2010, p. 1). Due to this, an important share of the water of our rivers comes from said glaciers, which have been shrinking for a long time. For instance, «throughout the Alps, glaciers have been retreating since 1850 with very significant loss since 1985 (Brugger *et al*., 2013)». The retreat of said glaciers endangers the water supply (Brönnimann *et al*., 2014, pp. 474-475) and, even though in the short run annual streamflow will increase (Schaefli *et al.*, 2019, p. 618), maximum runoff from glacier long-term storage will eventually be reached, contributing to the decrease of water flow in rivers around the world (Sommer *et al.*, 2020).

However, even though many mountainous countries around the world seem to be having problems with tackling the issue of glacier retreat, answers to the issue do not easily come by. In fact, although certain projects have been able to slow down snow and ice melting on a local scale, stopping ice melting would be highly improbable. This does not mean that glacier retreat can not be delayed. It is possible, but it would take an enormous amount of effort and cooperation between the countries in order to substantially reduce greenhouse gas emissions, especially CO2. Nevertheless, not only we are not able to delay this situation, but we're actually accelerating it in many parts of the world, such as Central Europe:

> Combination with the climate scenario applied for 2050 shows that the glacier surface area in the European Alps could be reduced with respect to conditions in 1971-1990 by further 75% (50% to 95%) as soon as by 2050. Slightly smaller losses can be assumed for the Swiss Alps, where the largest glaciers exist. A remarkable part – roughly one third – of this anticipated development has already taken place by now (in 2007) (Haeberli and Hohmann, 2008, p. 608).

Every year, summers are hotter and melt more and more accumulated ice that would take decades to recover. And, despite this dissertation focusing on Central Europe and, specifically, the Swiss Alps, many other regions of the world suffer the same evil (see Figure 2). Hundreds of glaciers in all continents are melting, and in some of them the rhythm of glacier retreat is even faster than in the Alps: «The glacier area changes are greatly governed by the glacier size, which means that small glaciers tend to suffer higher area reduction than large ones. These small glaciers are located in Central Europe and Tropical Andes, but the larger glaciers, such as those located in the polar region, tend to exhibit smaller rates of area reduction» (Li *et al.*, 2019, p. 207).

The panic and imminence of the disaster is such that misinterpretations of the situation can have very serious consequences in a country's economy, such as the following case:

> The fragility of this economic system confronted by sudden changes to the glacier environment can be illustrated by an event, which occurred in 2003 in the region of Huaraz (Kaser and Georges 2003). On 2 April 2003, NASA announced, on the basis of a picture taken by the ASTER satellite, the imminent fall of a large ice-cap into a lake above the town of Huaraz (100,0000 inhabitants), the heart of high mountain tourism in Peru. The anxiety provoked by this announcement ruined the tourist season, which was just beginning, causing damage estimated in millions of dollars (Chevalier *et al.*, 2011, p. 185).

All in all, water-related ecosystems have been in a critical situation for some decades (United Nations, 2022). Marshes, rivers, lakes, but especially glaciers, are directly suffering the consequences of climate change and global warming. And, although the UN and countries

affected by said issues have been agreeing to certain objectives and measures to try to solve the situation, these natural changes are caused by centuries of greenhouse gas emissions and mistreatment of the environment (Dodds *et al*., 2013). Consequently, it is nearly impossible to change the course of this disaster, no matter how much money the countries involved have. However, in the next section this dissertation will analyze the historical background, indicators, measures and actors involved in the fight against glacier retreat in one of the richest countries of the world, the Alpine Swiss Confederation.

4. Position of Switzerland regarding SDG 6

4.1. Historical background

First of all, in order to understand the position of the selected country, Switzerland, regarding climate change and glaciers, it is important to analyze the historical background of the relationship between the Alpine country and these ice giants. Said vinculation goes back centuries. There are even some intellectuals and historians that situate the Alps as one of the reasons the Swiss Confederation gained independence such a long time ago, in addition to the character of its nationhood:

> From an objective viewpoint, therefore, there can be no doubt that the Alps have been a significant feature of Swiss history ever since the Confederation took shape as a state- like entity in the late thirteenth and fourteenth centuries. On the ideological level, the 'nationalisation of nature' dominated until the latter half of the nineteenth century, when the 'naturalisation of the nation' came to prevail (Kaufmann and Zimmer, 1998, p. 489).

Thus, romanticism and its subsequent nascent idea of "nationalism" were the primary causes of the rising importance of alpine landscape at the heart of Swiss identity (Kaufmann and Zimmer, 1998).[3] In addition to that, the not so distant Little Ice Age (1550-1850), the last period of Neoglaciation, contributed to the strengthening of the Swiss mountainous character and the sublimation of snowy mountains according to romanticism (Brittain and Milner, 2001, p. 1573). As a consequence, European art and literature also became obsessed with the natural wonders of the Alps and its glaciers (Berthoud, 2007: 83). Travelers began swarming the mountain range and a new kind of tourism around the idealization of European nature arose:

[3] However, in the Swiss case nature and the Alps are not seen as an external reality. «Somehow it is a personified nature. Indeed, as a moral construct, nature means the Alps, with landscapes, animal life, people, activities and products» (Berthoud, 2007, p. 85).

> In the early 19th century, glaciers were "discovered" as beautiful landscape elements by early travelers and became a motif in proto-romantic and romantic paintings. In the late 19th century, the ice age theory, which revived age-old fears of an eternal winter, made glaciers a symbol of climate change. Glaciers and palm trees combined in one scenery were used in the early 20th century to illustrate ice ages and climate change, and in the late 20th century to illustrate global warming. The same motif was used in tourist advertisement since the late 19th century -and today- to illustrate the diversity of the Alpine landscape (Brönnimann *et al.*, 2014, p. 482).

Since then, winter tourism has become a powerhouse within the Swiss economy. Thousands of people travel to Switzerland every year to visit its natural wonders and enjoy a landscape that, even though exists in other neighboring countries, was made famous by the Swiss extraordinary glaciers. And, even though growing glaciers had always been a problem for the receding agricultural communities of the Alps (Brönnimann *et al.*, 2014, p. 482), this profitable resource rapidly became a product that had to be protected at all cost, starting a wave of climate monitoring:

> The first Swiss meteorological network was established in 1863 and gradually extended to include upper-air measurements (1942), phenology (1951), radiation (1991) and other observing systems. MeteoSwiss is responsible for climate monitoring in Switzerland. Monitoring of other climate variables such as greenhouse gas concentrations, glaciers, and runoff are carried out by other institutions. Switzerland contributes to global climate monitoring that started with the establishment of the Global Climate Observing System (GCOS) in 1992. MeteoSwiss hosts the national GCOS office, and acts as a competence centre for Alpine Meteorology and Climatology (Brönnimann *et al.*, 2014, p. 468).

However, it was not until the twentieth century that the Alps were seen as more than beautiful landscape with touristic potential, but considered as an endangered piece of the Swiss identity. «Since the 1970s and 1980s, environmental concerns have been put on the political agenda in Switzerland. Following debates on nuclear power, industrial waste, chemical hazards, and air pollution, climate change became a topic of interest in the 1990s» (Brönnimann *et al.*, 2014, p. 464). Then, in the 90s, the environmental concerns witnessed the addition of the vulnerability of the glaciers, with the launch of climate change research programs such as NRP31 "Climate Changes and Natural Hazards" (1992-1997) and CLEAR "Climate and Environment in the Alpine Region" (1997-2000) (Brönnimann *et al*., 2014, p. 463). And, even though the climate research programs came relatively late, earlier during the twentieth century there had been some local measures in order to reduce ice melt in certain parts of Switzerland,[4] showing that the preoccupation regarding climate change was not new.

[4] «Already in the hot summer of 1947 efforts to reduce glacier melt were employed with sawdust being placed on the roof of a touristic ice cave at Jungfraujoch, Switzerland, for reducing melt» (Huss *et al.*, 2021, p. 2).

However, more serious and generalized decisions were taken since the 1990s, as Switzerland witnessed the acceleration of glacier melt with preoccupation. In 1993, the Swiss Confederation ratified the UN Framework Convention on Climate Change and, since then, it has participated in many climate conventions, being one of the most recent ones the Paris Agreement, ratified in 2017 by the Alpine country (Andina and Jorio, 2021). In fact, Switzerland became a sort of leader of mountainous states that were worried about the effects of climate change on their landscapes:

> During the last 20 years, Switzerland played a key role in the process of the globalization of mountain issues. Setting aside a very radical conception of neutrality, Switzerland joined several international organizations and the Federal State had to identify priorities in its diplomacy [...]. Therefore, Switzerland was very active, before, during and after UNCED, in getting a specific mention of mountains included in Agenda 21. Many Swiss institutions and stakeholders were highly involved in the process (Debarbieux and Rudaz, 2008, p. 502).

All in all, how come that, even though being a country so worried about its natural wonders since the confederation's configuration centuries ago, the climatic situation in the Swiss Alps is worsening as time passes and legislation and referendums fail to be passed? That's why, in the next section of the dissertation, an analysis of the current situation will proceed, focusing on the main indicators of the Swiss situation, the actors and measures applied and the expectations for the near future.

4.2. Current situation

4.2.1. Main indicators/figures/data

Glacier retreat in Switzerland has been studied and controlled for many decades,[5] as the Swiss have a history of worrying about the Alps, with which they have a symbolic connection, as stated in the last part. Many programs and projects have focused their efforts towards monitoring snow variability and the trends, in order to survey the Alps health and ensure their near future:

> Swiss snow variability and trends have been analysed based on remote sensing data back to 1985, and based on station data back to the 1950s, to 1931 and to 1864. All studies found a decrease of the Alpine snowpack since the mid-1980s especially at low altitudes (<1300masl) which was shown

[5] In fact, «there are many measurement series of more than hundred years. The results are not only incorporated in current research (improvement of process understanding, calibration of glacier models), but also serve to estimate the direct and indirect effects of glacier changes on the environment» (GLAMOS).

> to be predominantly linked to an increase in local temperature. There is also a shortening of the snow season at all altitude levels. Scherreretal showed that for several snow parameters, the lowest values since the late 19th century were found in the late 1980s and 1990s. [...] Clear decreasing trends in snowfall days relative to precipitation days are found since the 1960s. [...] Negative trends are observed for extreme snow falls at low and high altitudes. Swiss glaciers have been receding since around 1980. In terms of mass, the current loss rate for a sample of eight Alpine glaciers is estimated as 2-3% per year (Brönnimann et al., 2014, p. 469).

All the main indicators and data share the same results, as it is such a controlled environment and, in fact, as stated in the literature review, many scientific articles share the same experts leading their projects. However, there is one specific tool that shines among the other ones because of its importance, reliability and interest. It's called GLAMOS (Glacier Monitoring Switzerland) and is headed by Matthias Huss, Andreas Bauder and Andreas Linsbauer. It measures 176 glaciers of the 1400 existent in Switzerland (an area of around 961 km2 back in 2016). More exactly:

> Glacier Monitoring in Switzerland systematically documents and monitors long-term glacier changes in the Swiss Alps. GLAMOS is operated jointly by the ETH Zurich and the Universities of Fribourg and Zurich and is in close contact with the Cryospheric Commission. The work is secured by financial support from the Federal Office for the Environment FOEN, MeteoSwiss within the framework of GCOS Switzerland, the Swiss Academy of Sciences, and is largely supported by the Federal Office of Topography swisstopo (GLAMOS).

Regarding other measurements indirectly related to glaciers, it is interesting to highlight the efforts put into understanding up to which point there is hydropower dependance in the Swiss Confederation. Despite being clean energy and an example to follow for many other countries, in case glacier retreat affected streamflow levels in the future, Switzerland will have to find an alternative source of energy. That's why measuring the amount of hydropower within Swiss electricity production (around 55% as of 2015) is of great importance. After all, «Alpine hydropower production (HP) is benefitting from glacier water resources that have been accumulated decades and centuries ago, and that cannot be replenished in the near future» (Schaefli *et al*., 2019, p. 629).

4.2.2. Main actors

In a country like the Swiss Confederation, with such a strong relationship between the government and civil society, it is understandable that there exist a multiplicity of actors involved in the fight against global warming, climate change and its effects, such as glacier retreat in the Alps. At the national, regional and local levels, the different administrations try

to collaborate in order to organize a united answer to the crisis. Both the Federal Government and the Canton governments include in their policies several environmental strategies. For instance, one of the most powerful Cantons of Switzerland (Zurich) included energy policies in its constitution during the year 2021:

> In November of last year [2021], the Zurich electorate gave a resounding yes to the revised energy law. It primarily concerns heat treatment in existing buildings. In particular, the replacement of a heating system by a system for fossil fuels will in future only be permitted in exceptional cases. With around 120,000 oil or gas heating systems in the Canton of Zurich, this is a powerful lever for reducing greenhouse gas emissions (Hofer, 2022).

With actions like that, civil society and public institutions help reduce private consumption of fossil fuels, which in its turn contributes to the achievement of the Paris Agreement and other climate conventions. Furthermore, it benefits the quality of life of the Zürich citizens and will be another grain of sand towards the reduction of greenhouse gas emissions and the softening of its consequences, such as glacier retreat.

Despite that, the actors that are involved in this fight are not only public, but there also exist private institutions and NGOs that are interested in said combat. To begin with, several institutions have been contributing to the technological research of ways to delay climate change or to reduce fossil fuel emissions and consumption. For instance, Zürich's Federal Institute of Technology has undergone 34 spin-offs to combat climate change, of the 250 done since 2010 (Andina and Jorio, 2021). Besides, not only Switzerland benefits from said spin-offs, but other countries house companies and projects of ETH Zürich to fight off climate change: «Two spin-offs in the field of climate technology have been able to expand: in Germany, Synhelion has built a test facility for the industrial production of solar fuels. In Iceland, Climeworks has built the largest facility to date for atmospheric CO_2 capture» (ETH Zurich, 2022).

In addition to the famous ETH Zürich, there are many other research groups carrying out investigations around climate change effects in Switzerland and ways to counter them:

> Swiss climate research is mainly carried out through research initiatives at the level of individual research groups. In addition, Switzerland had several large research programmes in the area of climate research. [...] The largest programme was the Swiss National Centre of Excellence in Research on Climate (NCCR Climate), a collaborative 12-year long (2001–2013) multi-institutional interdisciplinary programme addressing "Climate Variability, Predictability and Climate Risks". [...] In addition to climate-centered programmes, other national research programmes (such as NRP61

> "Sustainable Water Management") also have strong climate aspects (Brönnimann *et al.*, 2014, pp. 465-466).

The NCCR Climate provided new techniques and technologies to fight against climate change and its effects on the Swiss environment and landscape. For instance, some important products of the NCCR are «a new assessment of crop suitability under changing climate conditions in Switzerland, assessment of future drought risks and irrigation requirements, and research on the optimal design for new tools to protect agriculture against climate risks» (SNF). And where does the money to fund organizations such as the Swiss National Science Foundation (the institution behind de NCCR Climate) come from?

> The main extramural funding sources (i.e.aside direct University or ETH funding) for fundamental and applied research are the Swiss National Science Foundation (SNSF), oriented research initiated by Federal Agencies and Offices (Environment, Energy, Public Health, Agriculture, among others) and the Private Sector. [...] EU research programmes (FPs, ERC, COST, among others) have been particularly important for Swiss climate research. Since the start of FP3 in the early 1990s, Switzerland has participated in dozens of climate-related projects. ETH Zurich hosts the Swiss Climate-KIC offices. Climate-KIC is one of three Knowledge and Innovation Communities (KICs) created in 2010 by the European Institute of Innovation and Technology (EIT) and addresses climate change mitigation and adaptation (Brönnimann *et al.*, 2014, p. 466).

Having reached this point, let's focus on the last but definitely not least kind of actors involved in the fight against climate change in Switzerland, NGOs. These non-governmental organizations are a product of civil society and its effort to push for certain measures that political parties do not consider as important as others. In this context, the Swiss Association for Climate Protection is probably one of the most powerful NGOs of the Swiss Confederation, with civil support in all the cantons, no matter the language (Valentin, 2022). This association has been organizing initiatives for some years, with one in particular shining because of its relationship with the issue of this dissertation, the *Initiative pour les glaciers*.

This initiative is the primary project of the NGO and has had some impact on the political landscape of Switzerland, by pressing the federal government into putting forward the counter-proposal. The main objective of the initiative since it was created in 2019 was to reduce greenhouse gas emissions to net zero by 2050, respecting the Paris Agreement of 2015. In 2019, about 100.000 signatures were collected and the initiative was presented to the Federal Chancellery. Then, despite the agreement in terms of long-term objectives, the government refused some measures which were deemed "radical". Thus, the counter-proposal was brought up and examined by the parliamentary federal commission named Environment, Spatial

Planning and Energy Committee (ESPEC). On September 30, 2022, the proposal was approved and the initiative favored it because of its faster applicability. «Le contre-projet fixe un but pour 2050 et des objectifs intermédiaires avec des valeurs indicatives de réduction des émissions dans différents secteurs. Le projet prévoit deux milliards de francs sur 10 ans pour aider les propriétaires à changer de chauffage et abandonner les installations fossiles» (Emery, 2022).

Nevertheless, before passing to the next section about the adopted measures, there's another kind of actors that are usually not taken into account or at least not exactly regarded as actors. However, given that Switzerland is currently a direct democracy that passes laws and legislation by consulting its citizens through referendums, it's obvious that said citizens should be considered as actors within the climate change debate in Switzerland, as their vote can directly affect the passing of a law such as the CO2 Act, which will be mentioned in the next segment of the dissertation.

> The public is generally sensitive to whether or not they will be personally impacted by a certain policy. In direct democratic processes, citizens can directly influence policy outcomes by voting against such policies, therefore asking to consider the specific context of popular votes if interested in the reaction of citizens towards the policies implementing. Similar to elite actors, the individual attitudes of citizens influence their voting behavior. For example, if a citizen values environmental protection and public goods, they are more likely to vote for conservation-minded policies (Kammermann and Dermont, 2018, p. 50).

Thus, the role of citizens in the fight against climate change should not be ignored, especially in a country with direct democratic processes such as Switzerland. The issue with this situation is that the presence of a political party which wants to gain voters by opposing climate change policies can strongly affect the reach of the political measures passed by the ruling government and delay the actions of a state to mitigate the effects of global warming, as it has already happened in the Swiss Confederation, as will be seen in the next section.

4.2.3. Adopted measures

> *Recognizing* that climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response, with a view to accelerating the reduction of global greenhouse gas emissions (Conference of the Parties, 2015, p. 1).

This sentence belongs to the introduction of the draft decision of the Paris Agreement, an international treaty adopted in 2015 by 55 parties of the UNFCCC (United Nations Framework Convention on Climate Change). As of February 2023, this accord had been signed by 195 members of the aforementioned organization, including the Swiss Confederation, which signed it (22 April 2016), approved it (6 October 2017) and entered into force (5 November 2017). According to it, there are certain measures that all countries that approved it should carry out in order to achieve a reduction of global warming, limiting its increase to 1.5 °C. In this section of the Final Project, the objective is to analyze the situation of said efforts towards global warming and greenhouse gas emissions reduction by Switzerland, with special attention to the Federal Act on the Reduction of CO2 emissions, rejected in a referendum held on June 13, 2021 (Gesley, 2021).

To summarize everything, the measures adopted by the Federal Government of the Swiss Confederation to fight against climate change can be divided into three fronts: the Federal Act on the Reduction of CO2 emissions, the counter-proposal motivated by the *Initiative pour les glaciers*, and other alternative climate policies inside and outside the country.[6] However, first of all, it is necessary to understand the position that Switzerland occupies right now in relation to the Climate Change Performance Index (CCPI), an independent monitoring tool whose yearly results are published by the NewClimate Institute and the Climate Action Network. Its main objective is to track efforts made by 60+ countries to fight off climate change and «it aims to enhance transparency in international climate politics and enables comparison of climate protection efforts and progress made by individual countries» (Burck and Ulich). Thus, according to the CCPI on its 2023 results, Switzerland fell from the 14th place to the 22nd, «meaning it is no longer among the CCPI high performers and now ranks medium overall» (Heiligtag, 2023). Among the reasons behind said downfall there is the aforementioned failed attempt of the CO2 Act amendment[7] and the inability to speed up implementation all around the country.

Having mentioned it several times, let's begin with the first front of the fight against climate change in Switzerland, the CO2 Federal Act. This act was the main tool to reach the 2030

[6] Such as specific measures meant to help with the impact of glacier retreat on winter tourism, like the use of geotextile blankets to decrease between 50% and 70% the melt rate in certain ski resorts (Huss *et al.*, 2021, p. 7).
[7] Despite just having been publicly rejected by one political party, the populist SVP, in order to «gain voters among the distributional losers of energy transition» (Lüth and Schaffer, 2022, p. 184).

climate target in Switzerland established by the Paris Agreement. However, as it has been said previously, «on 13 June 2021, the revision of the third CO2 Act[8] was rejected in the referendum by the Swiss population» (Swiss Confederation, 2022). This law, informally referred to as "polluter pays" (Andina and Jorio, 2021), wanted to raise greenhouse gas emissions target reduction to a minimum of 50% by 2030 and net zero by 2050 (CO2 Act, 2022). Additionally, it proposed a series of levies on several commodities, such as:

> The CO2 levy adopted in 2008 on thermal fuels, such as heating oil and natural gas and coal, would have been raised to 210 Swiss francs (CHF) (about US$229) per metric ton from the current CHF 120 (about US$131). In addition, a new air ticket levy of CHF 30 (about US$33) for short and medium-haul flights and CHF 120 for long-haul flights would have been instituted. The amendment foresaw another new levy on private and business jets ranging from CHF 500 to CHF 3000 (about US$545–$3,272) (Gesley, 2021).

In addition to said measures, another important part of the Act was the establishment of a climate fund made up of one-third of the CO2 levy and one half of the air ticket levy. Thanks to the money of said fund, the government would have been able to «invest in building charging stations for electric cars and buses and making energy-efficient renovations to buildings; to support innovative Swiss firms that develop climate-friendly technologies; and to build protection structures in alpine regions» (Gesley, 2021).

However, said taxes, comprehensively, raised the unpopularity of the amendment among the citizens of Switzerland. In fact, the opposition argued that the amendment would be far too expensive and useless, as Switzerland emits a mere 0.1% of worldwide greenhouse gas emissions and «Swiss people have reduced their CO2 output by 24% per capita in the last 10 years, making this amendment unnecessary and expensive» (Gesley, 2021). And, to top it all, they argued that said amendment would especially affect low and middle income citizens from rural areas, precisely where most of the support against the act came from during the referendum of 2021.

Nevertheless, the CO2 tax is the only way to reach the objectives set by the Kyoto Protocol, ratified by Switzerland in June 2003, according to which the Swiss Confederation committed to a considerable greenhouse gas reduction (the same as the European Union). The difference

[8] Given that the first CO2 Act had already been proposed by Switzerland in 1995, having been «accepted by Parliament and introduced in 2000, revised four years later and finally implemented in 2008» (Ingold and Fischer, 2014, p. 90). To counter it, the Swiss Petrol Union, supported by center-right parties, «launched the "climate penny" project to avoid the introduction of a tax on motor fuels» (Ingold and Pflieger, 2016, p. 22).

is that «Switzerland is already quite efficient in its use of fossil energy and that it will be difficult and thus relatively costly to further lower CO2 emissions» (Thalmann and Baranzini, 2007, p. 3). After the failure of the CO2 Act, the «Parliament approved an extension of the CO2 reduction target and crucial mitigation measures. This amendment to the CO2 Act ensures that Switzerland will continue to reduce its emissions by 1.5 per cent annually until 2024 compared to 1990 levels through mitigation measures taken mainly domestically» (Swiss Confederation, 2022).

Changing the topic, another important and even more recent policy of the Swiss government regarding climate change is the passing of the counter-proposal. This law came into existence as an answer to the popular Glacier Initiative submitted by the Swiss Climate Protection Association in 2019, which «requires that from 2050 Switzerland should not emit more greenhouse gasses than can be permanently stored in safe greenhouse gas sinks» (Swiss Confederation, 2022). As the main objective of the initiative was supported by the Swiss Parliament, despite having some radical details not so popular among the administration, the Federal Council passed an indirect counter-proposal, a framework law. The advantage of such an amendment is that it «aims to anchor concrete climate objectives in Swiss law as quickly as possible and thus to advance Swiss climate policy in the long term» (Swiss Confederation, 2022). Since then, the Glacier Initiative backed down and announced that they would support the counter-proposal.

Other than government policies, there have been more local measures taken to palliate the effects of glacier retreat. For instance, some scientific researchers launched studies to cover specific glacier sites in geotextile blankets in order to minimize the melting of the ice and to save ski slopes and ice caves (like the case of Rhonegletscher), helping to preserve winter tourism (Huss *et al*, 2021, p. 10). Since 2005, the effectiveness of geotextile coverage has been evaluated and it is calculated that, recently (during 2018 and 2019), up to 300,000 m3 of ice were saved. Despite the good results, the studies agree on the fact that a large scale application of geotextiles would not be reasonable, neither ecologically nor economically (Huss *et al*., 2021, p. 11).[9] Furthermore, the vision of the covered glaciers would most probably affect the appeal of the Swiss landscape and its touristic revenue. In addition to that, other scientific and

[9] «For achieving a maximum effect – here defined as covering 1000 glaciers by 76% of their surface – Switzerland would need to commit about 1.4 billion CHF each year» (Huss *et al.*, 2021, p. 9).

technological measures have been tried, although neither of them has been so successful as the geotextile coverage:

> Several alternative approaches to reduce glacier melt have been discussed, sometimes being prominently exposed by the media: These include, for example, the blocking of katabatic winds or painting of the glacier surroundings in white. The effectiveness of such exploratory techniques is unproven, and their efficiency is very likely lower than the one of geotextiles as they only have some effect on less important components of the ice surface energy balance. Moreover, also their applicability at large scales is more than questionable (Huss *et al.*, 2021, p. 10).

To end with, Switzerland's actions to counter climate change have not only been applied within the borders of the Alpine country, but also outside. In fact, there were some polemic decisions made by the Federal Government, which was criticized for not reducing its emissions enough and compensating it by paying poorer countries so they reduce their emissions and Switzerland gets credit for it.

> Here is an example of how it would work: Switzerland is paying to install efficient lighting and cleaner stoves in up to five million households in Ghana; these installations would help households move away from burning wood for cooking and rein in greenhouse gas emissions.
>
> Then Switzerland, not Ghana, will get to count those emissions reductions as progress toward its climate goals (Tabuchi, 2022).

This worries some NGOs and ecologist groups, as if other countries did the same as Switzerland in order to not have to apply radical restrictions on greenhouse gas emissions, this could delay the application of policies against climate change (Tabuchi, 2022). Not a good prospect for the future, to be sure, but one of the aspects that can condition the expectations for the next decade of Switzerland's fight against glacier retreat.

4.3. Expectations for the next 5 to 10 years

As witnessed in the last section, although the Swiss Confederation is trying to pass legislation on climate change and greenhouse gas emissions, its direct democracy and privileged society are putting themselves in the middle of the struggle to reach the objectives agreed upon in Kyoto (1997) and Paris (2015). Thus, and added to the worsening of CO2 emissions all around the world and the scorching hot summers reaching higher latitudes each year, the expectations regarding the glacier situation at the heart of Europe are not positive. Although the Swiss Confederation «has a high per capita income and is economically stable», its economy depends on sectors that are directly related to landscape and glacier activity, such as «tourism, energy

(hydropower as well as river-cooled nuclear power), insurance, and agriculture» (Brönnimann *et al.*, 2014, p. 464).

Even though sectors such as the energetic one will witness a short-term increase of their productivity (Burkhardt *et al.*, 2020, p. 21), due to an immediate increase in streamflow (Brönnimann *et al.*, 2014, p. 474), in the long-term «once the loss of mass has reduced the glacier area sufficiently, streamflow will decrease» (Pellicciotti *et al.*, 2010, p. 1). More apocalyptic views suggest drying rivers and a complete change of ecosystem in the long-run:

> Consequently, in some years, the Rhone may dry up partially or completely towards the end of the summer and into the early fall. The future characteristics of runoff shown in this figure are more typical of rivers that are currently found in the Mediterranean parts of the Alps, as in the French Provence region and in parts of the Italian-facing slopes of the Alpine arc, for example (Beniston, 2012, p. 295).

This means that the main source of energy of Switzerland will be severely affected by the radical decrease of water in Swiss rivers,[10] not only drastically changing the landscape of the area but also condemning the Alpine country to look for other sources of energy instead of relying on its trusted green energy, hydroelectric power.[11] In addition to the impact on the obtention of hydroelectric power, some projections also include navigation and agricultural affectations as a result of glacier retreat and the melting of the ice coverage of said Alpine giants, among many other plausible outcomes with different severity rates (see Figure 3):

> Alimentés essentiellement par l'eau des glaciers, les bassins d'accumulation profitent actuellement du recul des glaciers et de la fonte accrue de ces derniers. À long terme cependant, ils disposeront d'une quantité d'eau moindre pour la production d'électricité. La navigation est également menacée, car de bas niveaux d'eau peuvent se traduire par des restrictions et des interruptions d'exploitation (Burkhardt *et al.*, 2020, p. 39).

Besides the economic and energetic consequences of said natural disaster, there will be physical evidence of said events, affecting the attractiveness and touristic value of the landscape (Haeberli and Hohmann, 2008, p. 609). «Large areas are projected to be deglaciated by the end of this 21st century based on the A1B scenario translating to a volume loss of 85-95%.

[10] The consequences would not only mean a decrease in the streamflow levels of the rivers, but «any substantial changes in the mountain snow-pack would have a significant impact on the flow of many major river basins, not only because of changes in the amount and timing of runoff, but also because of the potential for enhanced flooding, erosion, and associated natural hazards» (Beniston, 2012, p. 294).

[11] As a consequence, in the electoral context, «more ambitious climate action is likely to cause more distributional conflict within nation-states, we assume that polarization over energy and the environment will probably increase» (Lüth and Schaffer, 2022, p. 184).

Additionally, multi-day snow cover is projected to become a rare phenomenon in the Swiss plateau, whereas snow depth and duration will be significantly reduced at higher altitudes» (Brönnimann *et al.*, 2014, p. 474). According to other projections, said reduction of glacier surface could happen way before the end of this century, but rather by 2050, reaching between a 50% and a 95% melt, although perhaps the Swiss Alps could last a little longer compared to the mountain ranges of neighboring countries, as their glaciers are considerably larger (Haeberli and Hohmann, 2008, p. 608). Nevertheless, the differences regarding future projections are caused by the constant worsening of the global warming situation all around the world.[12]

Alas, the lack of snow and the loss of ice will affect the economic Swiss powerhouse in other ways, such as a strong hit to winter tourism:

> Projected reduced snow cover directly impacts the snow-dependent winter tourism which could substantially decrease the number of snow-reliable areas under high emission scenarios. Some of this reduction could be compensated by expanded application of artificial snowmaking, which would, however, require substantial investments and entail costs and non-negligible environmental impacts. Müller identifies not only the lack of snow, but also the lack of a "winter atmosphere", the scarcity of water (for artificial snowmaking), and the possible increase of natural hazards, and adaptation costs (e.g., costs of changing the offer towards less snow-dependent activities) as important factors (Brönnimann *et al.*, 2014, p. 475).

In conclusion, the future expectations regarding glacier retreat in the Swiss Alps are negative. However, it is safe to assume that during the following 5 to 10 years, Swiss citizens will not be witnesses to the worst consequences of climate change and global warming. On the contrary, the effects of glacier melting on streamflow levels and hydroelectric potential will be positive, as the melting ice accumulated during centuries will feed and perhaps even overflow rivers in the short-term. Winter tourism will perhaps be the industry that is harmed the soonest, given that the warming of Swiss climate, especially during summer, will cause a reduction of the snow and ice that made Switzerland's Alps famous and attractive to the eyes of many travelers and locals. Nevertheless, in the long run, the situation will most certainly worsen and the effects of global warming will dry Switzerland's clean energy sources.

[12] In fact, according to many measurements, 2022's summer was the warmest season ever recorded in many European countries: «Switzerland's meteorological service has confirmed the alpine nation's annual average temperature of 7.4°C was "by far the highest value since measurements began in 1864"» (Frost, 2023).

5. Evaluation and recommendations

As we have seen in the previous section, the situation in Switzerland is not better than in other parts of the world. The fight against climate change, global warming and its consequences, such as glacier retreat, is finding many obstacles in its road towards reaching the objectives ratified in Kyoto and Paris. Due to specific conditions such as the scientific apocalyptic display of the situation combined with the voters' doubts about how certain policies will affect their everyday life can impact how said crusade to protect the Alps is perceived and, consequently, influence the outcome of the referendums designed to pass certain acts and laws that will help the Swiss Confederation to reduce greenhouse gas emissions and protect its glaciers.

Overall, Switzerland was already quite involved in the fight against climate change when the great climate agreements were signed and ratified, as the Alpine country had a tradition of worrying about its landscape and monitoring the glaciers that made the state famous, boosting winter tourism and benefitting its economy. However, during recent years the Swiss Confederation seems to have lost its way and began to consider the Alps as a given thing, not as the natural wonders that are about to disappear, partially losing its connection with the landscape. The country is struggling to pass laws to protect natural resources against global warming, while part of the population (especially in rural areas) wonders about how taxes of the CO2 Act will affect their everyday lives whereas another part of the population (especially in urban areas and the German cantons of the country) pushes for more ecological and climatic measures through NGOs and various organizations. Universities and scientific institutions also press the Federal government to take action and promote projects to palliate the melting of glaciers, such as geotextile coverage of the ice in specific locations. And, all the while, petrol lobbies and center-right parties try to convince the Swiss people to distrust ecological policies and support alternative measures such as the "climate penny", all this in order to regain votes and take profit of the critical situation of hydropower energy to push for a re-use of fossil fuels in Switzerland.

Consequently, there are several recommendations that would help Switzerland to regain control of the situation and better protect its environment. Said recommendations could be divided into two categories: the ones that focus on the scientific and technological aspects of the issue's

solutions and the ones that refer to more social and political approaches that would help with public opinion and passing laws that would alleviate the situation.

Let's begin with the scientific recommendations:

- Switzerland should continue supporting monitoring and research programs that control glacier retreat and variations in snow and ice coverage, as it has done during more than a century in some mountain ranges. This activity is beneficial for a constant management of the Swiss environment and landscape, which will facilitate the implementation of the necessary measures in advance.

- Related to the last recommendation, the Federal Council should encourage both public and private funding of the aforementioned programs, as tools of monitoring such as the GLAMOS are not cheap and easily maintained. Besides, an increase in the funds of research programs would not only allow the maintenance of the existing ones but also an expansion of the areas investigated. As stated earlier in the dissertation, GLAMOS only covers 176 of the more than 1400 existing glaciers in Switzerland. Thus, in order to better understand and manage glacier retreat, a more detailed and larger monitoring would be necessary.

- Global warming will not be stopped, at least in the short-term. Its effects will impact all the world, including Switzerland. Thus, besides an adequate monitoring of glaciers, studies about water management and alternative sources of electricity will be necessary for the future of the Alpine country. In order to better adapt to the consequences of climate change, it is important to predict them and prepare ways to counter them.

- Up to this date, international cooperation has been used by Switzerland to hide some of its failures in implementing ecological and climatic policies in its soil. However, the actions carried out by the Swiss Confederation, no matter their real intentions, should be an example for many other Western countries to follow. Contributing with funds and experts to helping poorer and less developed countries with their fight against climate change is an important action if we want to overcome its effects together, by reaching objectives such as greenhouse gas emissions reduction.

- Although it is not a direct responsibility of the scientific community in Switzerland, most problems in passing legislation to tackle climate change come from the lack of comprehension of a section of Swiss society about the impact that certain policies will have on their everyday lives. Furthermore, it seems there are still people unaware of the real future consequences of climate change. A good strategy would be to adequately explain the advantages and disadvantages of climatic policies and the impact of climate change in Switzerland through educational campaigns coming from the institutions and universities that carry out so many studies about it. Without falling into desperation and with a clear explanation of the situation, perhaps the electoral situation will change and legislation will begin to pass.

Let's continue with the social and political recommendations:

- Research about the obstacles in the way to tackling climate change should not limit itself within the limits of the scientific and technological realms, but also investigate the social and political spheres. For instance, like the studies of Kammerman and Dermont, it would be interesting to study the recent failures in passing amendments such as the CO2 Act, locating the mistakes committed, identifying the sections of population that voted against it[13] and trying to find a way to convince those citizens that the benefits of these laws for Switzerland's environment compensate for the individual cost of the taxes within the amendments.

- The main opposition of the Federal government's CO2 Act was coming from one specific political party, the populist SVP. Thus, given that it exists almost an absolute consensus within the Swiss Parliament regarding the need for such legislation on greenhouse gas emissions, it would be a good decision to try to form some sort of political alliance with said party, no matter the ideological differences, in order to facilitate the acceptance of climate policies among the Swiss people and, thus, making it easier for the next legislation (such as the recently ratified indirect counter-proposal) to be accepted by the majority of the electorate when it is submitted to a referendum.

[13] Which, according to several studies, mostly corresponds with people with lower educational background and mainly from the French-speaking part of the country (Kammermann and Dermont, 2018, p. 53).

- Another important obstacle towards passing climatic legislation are the economic lobbies integrated by certain elites and the main fossil fuel defenders, such as the Swiss Petrol Union. Said organizations still have power within Swiss society, despite clean energies such as hydroelectricity having an important role within the economy of the country. Consequently, it would be wise to shift the country's economy and energy sources, slowly but surely, towards cleaner alternatives which are more respectful with the environment. In addition to helping fight climate change, that would undermine the power of the fossil fuel lobbies and flatten the path towards fighting climate change.

- Last but not least, NGOs and ecologist groups should be granted more credibility and their demands answered faster. In the case of the Glacier Initiative, promoted by the Swiss Association for Climate Protection, it took from 2019 to 2022 for their project of law to reach the Parliament and be discussed, just for it to be deemed as too radical and, consequently, the government offered the alternative of the indirect counter-proposal. It is good that popular initiatives reach the political arena, but it should not take the administration that long to process that kind of projects, as the counter-proposal will not be voted on until April 18, 2023.

6. Conclusion

As stated in the introduction, the Swiss landscape would not be the same its their major attraction, the Alps. The ice giants have been part of the soul of the Swiss Confederation since its creation and, although the Little Ice Age is already a distant memory and, since then, glaciers have been retreating (especially since the end of the twentieth century), this does not mean that the Swiss government and its people have to surrender themselves to the inevitable and worry more about individual problems than such a collective issue. Climate change and global warming can not be stopped. That's a fact. However, their effects can be reduced and slowed down if the countries reach the objectives ratified in the Kyoto Protocol (1997) and the Paris Agreement (2015) without making up excuses and focusing on convincing the political parties, citizens and economic lobbies that a united front and a small collective sacrifice is the best solution.

Although Switzerland, since a long time ago, excels at monitoring and controlling the glaciers, snow cover and streamflow levels, the Alpine country has failed to pass legislation in order to protect its environment, reduce greenhouse gas emissions and prepare for the consequences of glacier retreat. The country does have universities and researchers that have and can continue to investigate specific solutions to certain issues related to the melting of glaciers. It has social backing from ecological parties and popular initiatives, such as the Glacier Initiative, that suggest measures and ways of tackling climate change and its effects. It has the funds to apply said measures and to look for alternative clean energy sources, despite being able to rely on hydroelectric power in the short-term (before streamflow levels eventually decrease and partially impact the capacity of the Swiss rivers and the amount of electricity that can be generated from them). It has a better situation than many other countries around the world, which have been, are and will continue to suffer more drastic effects of climate change through severe droughts and floods. Switzerland has time to prepare itself, to devise strategies to overcome water shortages during specific seasons or the impact of deglaciated mountains on winter tourism. Countries in the MENA region or South-East Asia are not that lucky. However, as seen in this dissertation, Switzerland surprisingly fails at solving its present problems and preparing for the future ones, despite being in a position that many other regions of the world envy.

Direct democratic processes can harm the passing of laws if some political parties take advantage of the uncertainty of the effects of climatic policies on the low and middle class Swiss citizens. Thus, one of the missions of the Federal government and the political parties ruling the Swiss Confederation is to present more clearly and simply how the amendments such as the CO2 Act will affect the everyday lives of the Swiss. Convincing the electorate is the only way to pass laws and measures that will improve the situation, thanks to the investigation of universities and institutions such as ETH Zürich or the Bern University. Take advantage of the monitoring tools such as GLAMOS and listen to the large list of glaciologists and various experts that have been trying solutions for decades, such as Matthias Huss and the project of geotextile coverage of specific areas of glaciers. In fact, Switzerland should continue to encourage and fund research groups and programmes such as the Swiss National Center of Excellence in Research on Climate (NCCR Climate) and return to its rightful place among the high performers of the Climate Change Performance Index (CCPI).

Additionally, some late attempts to try to reach the objectives of the fight against climate change not through national measures but through international cooperation should not be the main strategy of any country. It is positive that such an economic powerhouse as Switzerland collaborates with countries that do not have enough funds and experts in order to advance towards cleaner energy sources and a reduction of their greenhouse gas emissions, but not at the cost of not acting within Swiss borders. It is true that Switzerland is by no means among the giants of pollution, such as the United States, China, India and even some European countries. However, that's not an excuse to overlook the duty that Switzerland accepted when it ratified the Paris Agreement. Actions must be taken in order to further reduce greenhouse gas emissions in Swiss territory, by reducing them to 50% by 2030 and, eventually, as stated by the recent indirect counter-proposal, reaching net zero emissions by 2050. This should be the minimum effort of all the countries in the world. If we do not reach net zero emissions by 2050, the situation will worsen steadily and the effects of climate change will be far worse than glacier retreat.

Taking into account the more recent expectations for Switzerland, the Alpine country will most probably be facing some increase in streamflow levels of the rivers born in the Alps' glaciers. This will in its turn benefit hydroelectric power plants, which account for half of the energy production of the country. However, the short-term excessive increase in streamflow levels combined with the long-term decrease of said levels will most likely negatively affect agriculture and cause a drastic change in the ecosystem of the region, transforming it into a more Mediterranean climate. Besides, as mentioned previously, in the future the glacier retreat will not only affect the animals and vegetation of the surrounding areas, but also provide a different and non-attractive vision of the Alps, without all the ice and snow, which will strongly affect winter tourism and the economic revenue that Switzerland makes from it.

In conclusion, Switzerland's strategy to fight against climate change, global warming and glacier retreat is going worse than one would expect, despite having great potential, extensive funds and a huge quantity of researchers, experts and institutions to investigate the causes, consequences and strategies of said threats to the environment. In fact, the issue is so enormous that avoiding it from happening would be impossible. Scientific and technological measures can help palliate its effects at the local scale, and social and political strategies should contribute to a wider acceptance of ecological amendments among the Swiss electorate. These are the

steps that the Swiss Confederation should take in order to be a great example to other countries regarding climate change management.

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8. Annexes

Figure 1

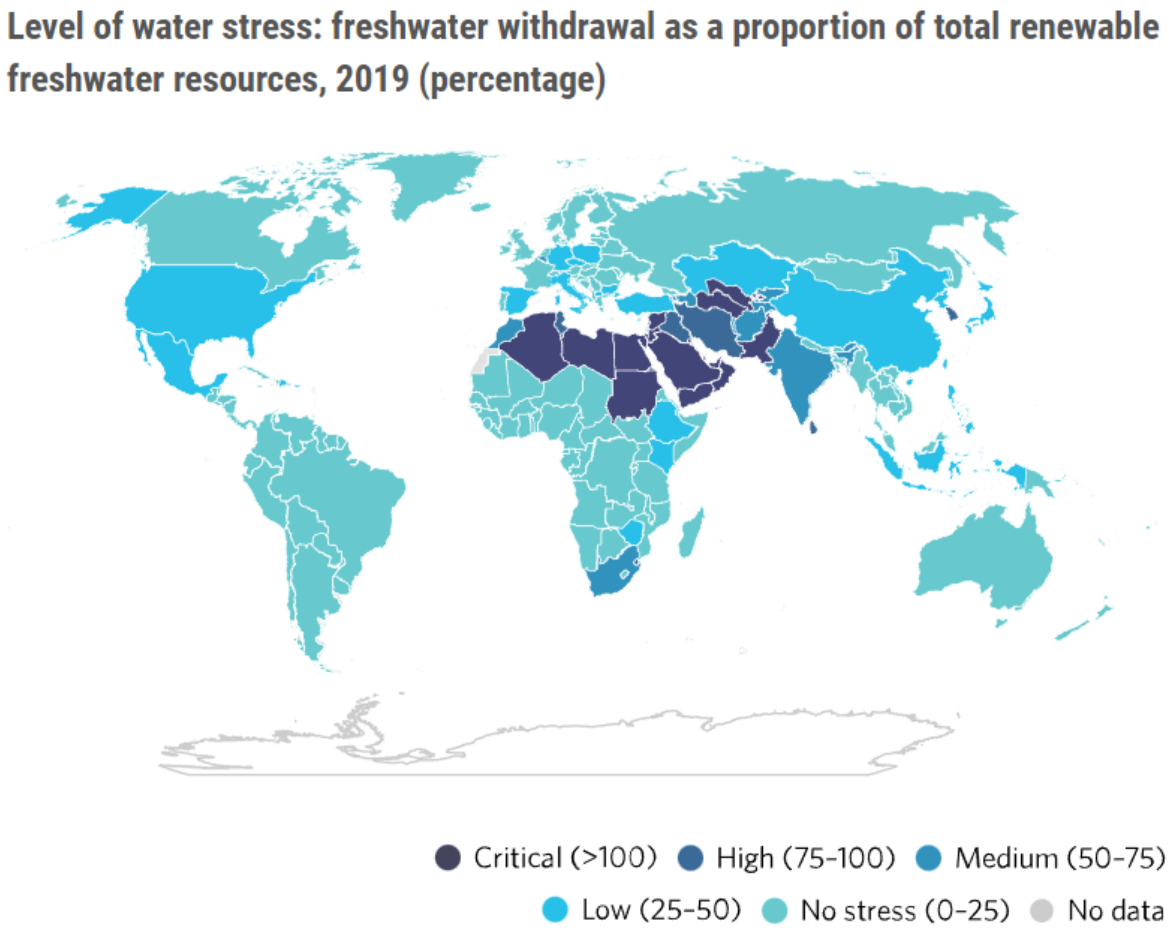

Table showing freshwater availability worldwide (English) (United Nations, 2022).

Figure 2

Table 1
Retreating rate of glacier areas for each RGI region (References are shown in Table S1).

First-order region	Research region	Period	Rate (% per year)	Area after 2000 (km^2)	Area in 1980 (km^2)	Regional (% per ye
Alaska	Chugach Mountains	1952–2007	−0.42	990	1102	−0.24
	Harding Icefield, Grewingk–Yalik Glacier Complex, and surrounding glaciers	1986–2000	−0.16	2327	2401	
Western Canada and U.S.	Western Canada	1985–2005	−0.55	26,728	30,403	−0.53
	Yukon	1959–2007	−0.46	9077	10,204	
	North Cascades	1958–2006	−0.34	23	25	
	Wind River Range	1966–2006	−1.1	29	37	
Arctic Canada North	Queen Elizabeth Islands	1960–2000	−0.066	104,180	105,555	−0.066
Arctic Canada South	Barnes Ice Cap	1958–2000	−0.048	5875	5931	−0.080
	Penny Ice Cap	1959–2000	−0.046	6479	6538	
	Terra Nivea	1958–2000	−0.33	169	180	
	Grinnel Ice Cap	1958–2000	−0.26	120	126	
	Baffin Island	1975–2000	−0.16	1914	1975	
	Bylot Island	1959–2001	−0.12	4633	4750	
Greenland	Central East Greenland	2000–2005	−0.019	29,842	29,984	−0.019
Iceland	Most Iceland Glaciers	1990s–2000s	−0.3	11,079	11,910	−0.3
Svalbard	Svalbard	1980–2010	−0.23	33,775	36,105	−0.23
Scandinavia	Norway	1966–2013	−0.29	2668	2923	−0.29
Russian Arctic	Nan					−0.23*
North Asia	Ural	1956–2000	−0.51	7	8	−0.48
	Kodar Mountains	1995–2010	−2.68	7	13	
	Altai in Russia	1952–2004	−0.39	923	1010	
	Altai in China	1960–2009	−0.75	179	218	
Central Europe	Alps	1985–2005	−1.2	2034	2644	−1.2
Caucasus and Middle East	Main Caucasus ridge and Mt. Elbrus	1994–2005	−0.43	388	430	
	Georgian Caucasus Mountains	1960–2014	−0.7	356	441	−0.58
	Turkey Glacier	1970–2013	−1.3	11	16	
Central Asia	Tienshan	1961–2012	−0.35	13,190	14,667	
	Inner Tibet	1970s–2008	−0.27	8036	8644	
	Pamir	1964–2001	−0.21	1920	2005	−0.28
	Qilian Mountains	1956–2003	−0.46	311	344	
	West Kunlun	1970s–2001	−0.01	2712	2718	
	Gongga Mountains	1966–2009	−0.26	229	246	
South Asia West	Mapam Yumco Basin	1974–2003	−0.23	100	105	−0.39
	Himachal Pradesh	1962–2001	−0.54	1628	1813	

	Ten basins mean	1962–2002	−0.38	5329		5775	
	Kang Yatze	1991–2010	−0.09	83		85	
	Gharwal Himalaya	1968–2006	−0.12	600		619	
	Naimona'Nyi Region	1976–2003	−0.31	79		85	
South Asia East	Koshi Basin Nepal	1976–2000	−0.15	1079		1111	−0.40
	Mt. Qomolangma National Nature Preserve	1976–2006	−0.50	2710		3062	
	Planimetric and volumetric glacier	1962–2005	−0.12	87		90	
	Boshula Mountain Range	1975–2001	−0.28	155		164	
	Southeastern Tibet	1980–2001	−0.9	175		208	
	Tisa	1997–2004	−0.36	392		426	
	Mt. Everest	1962–2011	−0.27	352		381	
Low Latitudes	Tropical Andes	1980–2005	−1.6	1920		2688	−1.6
Southern Andes	Subtropical Andes of Chile	1955–2007	−0.56	8	9		−0.18
	Central Chilean and Argentinean Andes	1955–2013	−0.51	94	110		
	Monte San Lorenzo Region	1985–2008	−0.81	195	239		
	Patagonian Region	1986–2011	−0.17	22,718	23,915		
New Zealand	Southern Alps	1978–2002	−0.69	428		493	−0.69

Table 1 (*continued*)

First-order region	Research region	Period	Rate (% per year)	Area after 2000 (km^2)	Area in 1980 (km^2)	Regional average (% per year)
Antarctica and Subantarctic	Heard Island	1947–2004	−0.54	4	5	−0.11
	Kerguelen Island	1963–2002	−0.55	552	619	
	Kin George Island	2000–2008	−0.20	1230	1299	
	Antarctic Peninsula	2000–2010	−0.098	43,890	45,180	

Table showing retreating rate of glacier areas for each RGI region (English) (Li *et al.*, 2019: 206-207).

Figure 3

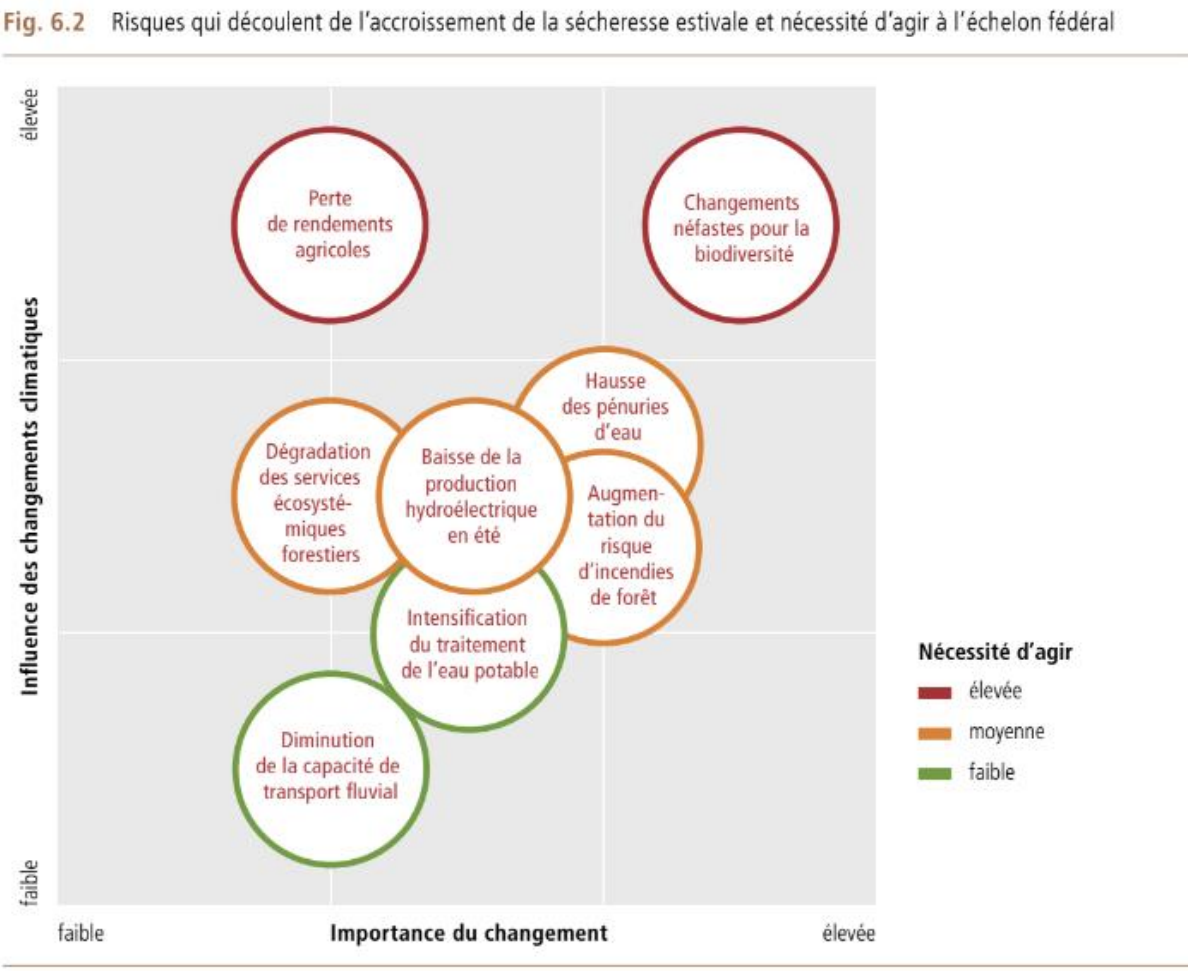

Table showing the risks of summer droughts according to their severity (French) (Burkhardt *et al.*, 2020: 38).