Mitigating the Heat Island Effect in Swiss Cities

By Stephanie Brownell, Carson Kershner, Jack McCarthy, Sophia Merolle

Advised by Curt Davis, Uma Kumar, and Leonard Polizzotto

Project Coordinator Nancy Burnham

Project Hosts: Erik Bühlmann, Johannes Schindler, Daniel Schweizer

Submitted October 10, 2023

Mitigating the Urban Heat Island Effect in Swiss Cities

Stephanie Brownell, Carson Kershner, Jack McCarthy, and Sophia Merolle

October 9, 2023

Advised by Dr. Leonard Polizzotto and Dr. Uma Kumar

Project Hosted by Grolimund + Partners AG, specifically;

Erik Bühlman, Johannes Schindler, and Daniel Schweizer

Abstract

The urban heat island effect (UHI) is a phenomenon in which urban areas exhibit higher temperatures than surrounding areas. The UHI effect can cause negative impacts ranging from poor health to infrastructure damage, making mitigating the urban heat island effect a significant concern for many cities. UHIs are also exacerbated by climate change, an increasing issue in recent decades. This project, hosted by Grolimund and Partner AG, explores the status of the UHI effect in Switzerland and its mitigation methods through interviews with experts in city governments. The data collected in these interviews was used to assess the status of the urban heat island effect and its mitigation methods throughout Switzerland. These results helped us to recommend the most effective steps to further mitigate Switzerland's urban heat island effect. In our findings, we determined which impacts of UHI are the most severe and which mitigation methods are the most implemented.

Executive Summary

Introduction:

The urban heat island effect (UHI) is a widely known phenomenon in which heat is trapped within cities, causing the overall temperature to increase. The surrounding pavement and concrete within dense urban areas exacerbate this phenomenon. This causes the heat to be absorbed and released, adversely affecting people's health and the environment. Different types of mitigation have been put in place to mitigate the UHI to adapt to the rising temperatures.

UHI has become an issue within Swiss cities as they are experiencing elevated temperatures that are five to seven degrees Celsius higher than those in rural areas. Due to this issue worsening within Switzerland, there is a need for innovations and actions to mitigate UHI. Grolimund + Partners AG (G+P), an environmental engineering company with multiple firms across Switzerland, has recognized the detrimental implications of this phenomenon. Their initiative aims to assess and disseminate information about the progress in mitigating Switzerland's urban heat island effect. They are fostering cooperation among cities and cantons to advance sustainable urban development.

Background:

The UHI effect contributes to pollution and harms surrounding ecosystems. UHI's can also increase health risks for respiratory disease and mental illnesses. Many cities worldwide must implement solutions to alleviate the urban heat island effect. Some of these steps - using high-albedo materials, greening, and vegetation - have already been successfully implemented. These methods aid in decreasing the surrounding temperature of urban areas, helping mitigate UHIs.

Methodology:

To better understand the current state of the UHI effect in Switzerland, we conducted interviews with representatives of various Swiss cities. The qualitative and quantitative data from each interview were then analyzed, which gave an overview of the status of the UHI effect and current mitigation methods that each city has implemented. Cities were grouped based on characteristics such as language and population size to find patterns and correlations between present mitigation methods or lack thereof. The results of these analyses are documented in this report.

Results and Discussion:

After interviewing nineteen different Swiss cities, we gained quantitative and qualitative data that allowed our group to assess the status of the UHI effect in Switzerland. Our results determined which impact of UHI is the most important to address in each city. The most important result was health impacts, as many cities were concerned with vulnerable groups such as the elderly and young. Our group was also able to determine which mitigation methods were frequently used. We were able to determine that many of the cities we interviewed had plans to increase the canopy coverage of their city to reduce the increasing temperatures. Lastly, we recommended unique mitigation methods already used in cities that may benefit other cities around Switzerland.

Conclusion / Recommendations:

This project aimed to identify the status of UHIs impact in Switzerland and promote open communication between cities to create a better understanding and share new possible solutions. Our findings concluded that cities must increase social awareness of the UHI among citizens. This sensitization of the public can increase the favorability of solutions and politicians who act in favor of mitigating the UHI. Many of the smaller cities that we interviewed found difficulties finding funding. We believe that rather than submitting requests to fund small individual strategies, cities should create a heat action plan to receive a larger budget encompassing multiple collaborative solutions. Lastly, we believe that it is essential that communication is opened between Swiss Cities to further the advancement of combatting the heat island effect. As newer and unique solutions can be implemented within other cities, that could benefit its citizens.

Contents

List of Figures

Authorship

Section	Authors	Editors
Abstract	Sophia Merolle	All
Executive Summary	Stephanie Brownell and Carson Kershner	All
1. Introduction	Sophia Merolle	All
2. Background	See below	See below
2.1 General Explanation of the Urban Heat Island Effect	Sophia Merolle	All
2.2 Stakeholders of the Urban Heat Island Effect	Carson Kershner	All
2.3 Introduction of Project Hosts	Jack McCarthy	All
2.4 Impacts of Urban Heat Island Effect	Carson Kershner	All
2.5 Proposed Solutions to Counter the Urban Heat Island Effect	Stephanie Brownell, Carson Kershner, and Sophia Merolle	All
2.6 Summary	Jack McCarthy	All
3. Methodology	See below	See below
3.1 Conduction of Interviews	Jack McCarthy and Sophia Merolle	All

3.2 Analyzing Interview Data	Jack McCarthy	All
3.3 Reporting	Stephanie Brownell and Sophia Merolle	All
4. Results	See below	See below
4.1 Characterization of Interviewees	Stephanie Brownell	All
4.2. Severity of the UHI Effect	Carson Kershner and Sophia Merolle	All
4.3 Current Status of Mitigation Methods	Stephanie Brownell, Carson Kershner, and Jack McCarthy	All
4.4 Future Solutions and Priorities	Carson Kershner	All
4.5 Hindrances and Difficulties	Stephanie Brownell	All
5. Conclusions and Recommandations	Stephanie Brownell, Carson Kershner, and Jack McCarthy	All
Acknowledgements	Carson Kershner	All

Disclaimer: This work is original to the project authors and study participants and was not generated or assisted using ChatGPT or any other AI tools.

Meet the Team

Hello, my name is Jack and I am from Easton, Massachusetts. I am a Junior at WPI pursuing my bachelor's in biomedical engineering. I am currently the Chaplain of the Zeta Mu chapter of Tau Kappa Epsilon. I have really enjoyed the time spent on this project especially getting to talk to representatives from all over Switzerland.

Hi, my name is Stephanie and I am from Glenville, New York. I major in Biology and Biotechnology on a pre-veterinary path with a minor in German. I have absolutely loved my time in Switzerland. The scenery was breathtaking, and we were able to travel to so many different places over the course of our IQP. Interviewing representatives all around Switzerland was an incredibly enriching and enjoyable experience, and I have grown so much as a student and person over the course of our term!

Hi, my name is Carson Kershner. I am from West Haven, CT. I am pursuing a degree in chemical engineering at WPI. At WPI I am the new member educator of the Alpha Tau Omega fraternity. I am also involved in club lacrosse, the Italian Student Association, WPI Green Team, and the American Institute of Chemical Engineers. In my free time I like to hike and go to the beach. My time in Switzerland has been a culturally fulfilling and enjoyable experience. I am grateful that WPI offers such an amazing experience!

Hello, my name is Sophia Merolle. I am a third-year student studying industrial engineering at WPI. I have loved getting to explore different cities across Switzerland during the process of conducting interviews. Getting to travel across the country has been such an enriching experience.

Acknowledgements

Our group is incredibly thankful for all those involved in the completion of this project. We extend our gratitude to all those who made this project possible and shaped our experience in Switzerland.

- Professor Uma Kumar and Leonard Polizzotto for the pivotal feedback and guidance during the project.
- Our project hosts at G+P, Erik Bühlman, Daniel Schweizer, and Johannes Schindler for their collaboration and providing us with the resources that made this project possible.
- Dr. Nancy Burnham for creating this project opportunity.
- The representatives from the Swiss cities of Bern, Winterthur, Lucerne, Thun, Lausanne, Freiburg, Chur, Kriens, Köniz, Basel, Biel, La Chaux-de-Fonds, Uster, Schaffhausen, Zürich, Lugano, Locarno, St. Gallen, Dübendorf. Thank you for your time and invaluable expertise on the heat island effect.

1. Introduction

The urban heat island effect is when heat accumulates in urban areas due to the structural composition of cities and human activities in those areas (Yang et al., 2016). The use of specific materials that absorb large amounts of heat, such as concrete and asphalt, also contributes to the urban heat island effect. These materials re-emit much of the heat they have absorbed, raising the temperature of the surrounding areas during the late afternoon and night (Stone & Rodgers, 2007). This phenomenon negatively impacts the environment and the health of residents in impacted areas (Yang et al., 2016). Due to the negative impacts of the urban heat island effect, methods to mitigate these effects have been implemented. However, it is an ongoing process that still requires research and development.

The urban heat island effect has impacted many Swiss cities. In fact, at night, Swiss cities can be five to seven degrees Celsius warmer than nearby rural areas (MeteoSwiss, n.d.). Unfortunately, the urban heat island effect does not only raise urban temperatures at night. When comparing the number of occurrences of several different climate scenarios, it was found that a difference in urban and rural temperature was present during the day as well (Burgstall et al., 2021). The intensity of the urban heat island effect in Swiss cities has created a need to mitigate the urban heat island effect in affected cities.

Our project host, Grolimund + Partners AG (G+P), is an engineering firm based in Bern, Switzerland. They focus on environmental sustainability across several fields, ranging from acoustics to building physics (Grolimund + Partner AG, n.d.-b). They have noticed the negative impact of the urban heat island effect on Swiss cities and hope to work with multiple partners and stakeholders in Switzerland to help mitigate it. Currently, cities work independently on implementing solutions to the heat island effect. Therefore, we aimed to assess and share the overall status of mitigating the heat island effect in Switzerland to inform cities nationwide of their respective advancements and setbacks. Our objectives to reach this goal were to:

1. Conduct interviews with Swiss cities to gain a better understanding of the urban heat-island effect in Switzerland;
2. Analyze information gained via interview to gain an overview of the progress of each canton in addressing the heat island effect;
3. Report the status of each canton's relationship with the heat island effect and their plans to mitigate it.

2. Background

This chapter discusses the phenomenon of the urban heat island effect. It will provide in-depth descriptions of the causes of the urban heat island effect, the impacts of the urban heat island effect, and previously implemented mitigation methods. We will also identify those affected by the urban heat island effect and introduce the project's project hosts.

2.1 General Explanation of the Urban Heat Island Effect

The urban heat island effect is present when cities exhibit higher temperatures than surrounding areas (Yang et al., 2016). The difference in temperature between cities and surrounding areas caused by the urban heat island effect can be very significant, as shown in Figure 1. Many factors contribute to increased temperatures in cities impacted by the urban heat island effect. One of these factors is building density. Using various spatial models, it was discovered that building density decreases ventilation, trapping heat in areas and raising temperatures significantly (Yin et al., 2018). The relationship between building density and the urban heat island effect explains the disparity between temperatures in rural and urban areas.

Furthermore, using specific materials that absorb large amounts of heat contributes to the urban heat island effect. The amount of light reflected by a material is known as the albedo. A higher albedo allows more energy to be emitted upwards (Liang & Wang, 2020). Increased human activity, such as vehicle usage, air-conditioning, and industrial processes in cities, also contribute to the urban heat island effect by releasing heat (United States Environmental Protection Agency, n.d.).

Urban heat islands can damage the local community's environment, altering the local area's air quality, ecology, and vegetation (explained further in section 2.4). By focusing on

the qualities of a city that contribute to increased temperatures, the urban heat island effect can be successfully mitigated, improving the previously afflicted aspects of the area.

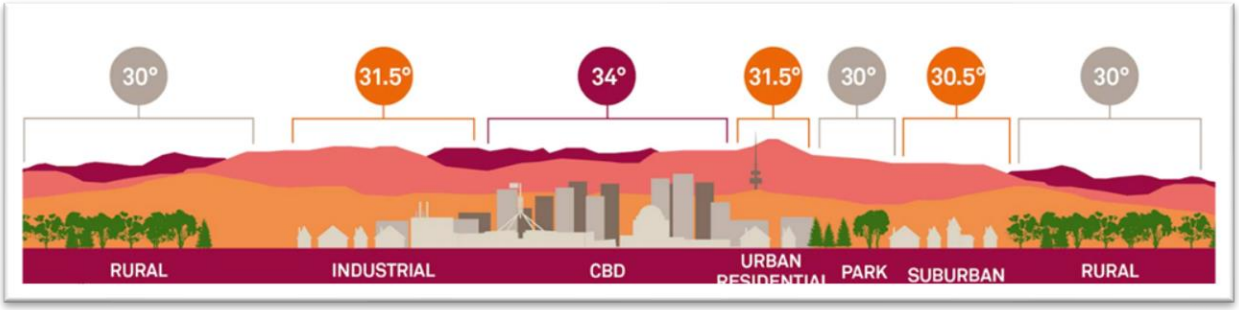

Figure 1- *Urban Heat Island Effect Across Different Land Use and Vegetation*.
Note. From ACT State of the Environment (p. 109), by the Office of the Commissioner for Sustainability and the Environment, 2019 (https://envcomm.act.gov.au/wp-content/uploads/2020/07/SOEfull.pdf). CC BY 3.0 AU.

2.2 Stakeholders of the Urban Heat Island Effect

To better understand the scope and significance of this project, it is crucial to understand the stakeholders involved. A stakeholder is an individual or a group that impacts and is impacted by an issue (André, 2012). Within this project, multiple stakeholders have different levels of influence over making changes to mitigate the urban heat island effect. This project's stakeholders include city residents, city planners, policymakers, people in the construction industry, and others who may not be as easily identified. Each of which can be seen in Figure 2.

The residents of affected urban areas experience the impacts of the heat island effect daily. These citizens would directly benefit from efforts to mitigate the heat-island effect since they currently experience adverse health effects (Piracha et al., 2022). The citizens within these regions have some influence over mitigating these issues. Using their public voice, they can lobby for policies that mitigate the urban heat island effect to be put into place. However, ultimately, it is up to policymakers to make decisions regarding laws and researchers and engineering firms to propose and implement solutions.

City planners are essential in this issue as they must decide where proposed solutions can best be implemented (Beaumont, 2022). City planners can also work with engineers to design urban areas that reduce heat retention within cities, including innovations such as cool pavements and green roofs (Wang, 2016). However, for these innovations to be implemented, they require the approval of city officials.

Some of the most influential stakeholders are the policymakers, who decide whether these mitigation methods may be implemented. The policymakers within the cities will be the

deciding factor in whether these mitigation methods will be put into place. These policymakers will be motivated to create ways to mitigate the heat island effect based on the input of the citizens (Keune, 2012). These policies can consist of building codes that force property owners to implement more eco-friendly materials and designs.

There is a growing demand by cities to create urban green spaces to confront the effects of climate change. As the need for more green buildings continues, construction companies must adapt to more eco-friendly designs. Construction companies stake a claim in this issue as many recognize the benefits of using environmentally friendly materials. However, using greener materials may be an abrupt transition for construction companies as current companies are far from where they should be in their use of green materials (Giesekam, 2018).

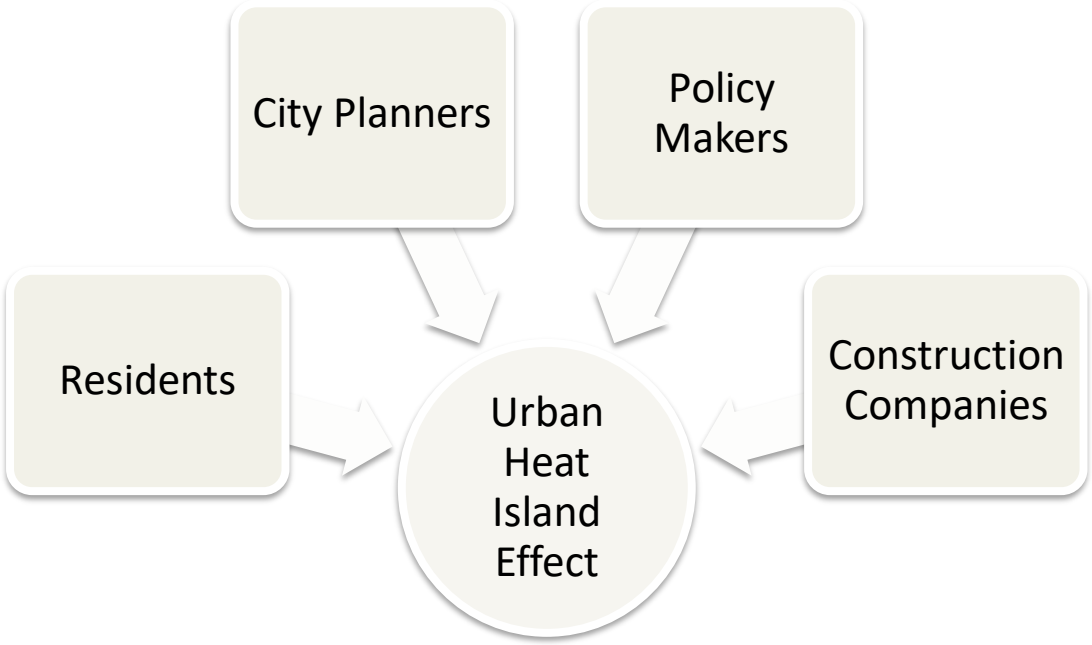

Figure 2 - List of Stakeholders

2.3 Introduction of Project Hosts

Grolimund + Partner AG is a specialized engineering firm focused on environmental sustainability. They have over thirty years of experience and five locations across Switzerland, with their headquarters in Bern. The company states that its main specializations are as follows: outdoor noise reduction strategies, road surface acoustics, building physics, software, and

research development (Grolimund + Partner AG, n.d.-b). In collaboration with its clients, G+P works to provide services and solutions to benefit the environment. The company emphasizes applying differing employee backgrounds to expand their expert knowledge. G+P also utilizes its vast international network of partners and universities to assist in solving various engineering issues.

G+P has recently begun its new pilot project, employing application-oriented research and analysis of cool pavements to combat the urban heat island effect. Together, we aim to promote communication of solutions between cities through a comprehensive report on the status quo of dealing with UHIs in Switzerland.

2.4 Impacts of Urban Heat Island Effect

The effects of climate change can be felt around the world. Cities across the globe are experiencing the urban heat island effect because of climate change (McCarthy et al., 2010). The drastic increase in temperature is causing issues for human health and local ecosystems (Dermody, 2007). These are all effects that make mitigating the heat island effect necessary worldwide.

The most significant concern for the heat island effect is its impact on human health. The temperature increase within urban areas causes air pollution due to photochemical smog formation. Photochemical smog forms when a mixture of harmful pollutants reacts with sunlight, thus creating a brown haze over cities (EPA, 2004). The high amounts of CO2 in urban areas and higher temperatures due to the heat island effect increase the rate of smog creation within cities (Aidaoui, 2015). The addition of smog within the atmosphere creates poor air quality within cities; this comes with an increased respiratory illness risk (Piracha et al., 2022). Studies have also found a connection between air pollutants, a decline in mental health, and significantly increased rates of anxiety and depression due to neuroinflammatory responses (Piracha et al., 2022). Living in these conditions over the years can lead to long-term health problems, and if nothing is done to mitigate these issues, it could lead to devastating consequences.

In recent years, cities worldwide have experienced a decreasing water supply (Sisto et al., 2016). This shortage of resources is due to their susceptibility to the urban heat island effect, which can increase the temperature of these areas (Tedesco, 2013). This causes an increase in evaporation rates of the water supply and decreases soil moisture (Dermody,2007). When the

moisture in the soil is reduced, it can cause issues with plant growth and production (Dermody, 2007).

The urban heat island effect can also have devastating impacts on local ecosystems. It causes the most harm by altering the migration patterns of animals by changing their habitats and ability to access resources (Moore, 2011). As the heat island effect worsens within these urban areas, it forces the animals within the ecosystem to either adapt to the increase in temperature or perish (Tedesco, 2013). If no progress is made to control the heat island effect, the ecosystems within these areas will be irreparable.

2.5 Proposed Solutions to Counter the Urban Heat Island Effect

Scientists and government officials worldwide are currently acknowledging the adverse effects of the urban heat island effect (Li et al., 2014). Due to the worsening nature of the UHI effect cities have invested money and researched different ways to mitigate its impacts. This results in multiple potential solutions being proposed and implemented in different cities worldwide. These solutions may be direct or indirect in their approach to limiting UHI's effects. As some methods directly mitigate or adapt to the effects of the heat island effect. While others generate awareness of the issue.

2.5.1 Direct Mitigation Methods

Natural Wind Corridors

A notable cause of a UHI is the inability of areas to have continuous airflow. This limits the ability to cycle out hot, polluted air with cool, fresh air. However, at the beginning of urban planning, a city can reserve a passage or street to allow for natural wind to flow freely (Bing 1 et al. 2). This is known as a natural wind corridor and helps to promote air exchange in dense urban areas thus mitigating the UHI effect.

Albedo Improvement

A study performed in Toronto, Canada, in 2016 by Wang et al. simulated what effect cool pavements and other approaches to mitigating the urban heat island effect would have on the city's average temperature using simulation software. It was found that an increase of 0.4 in the albedo of pavement would help to improve the physiologically equivalent temperature

(PET) by between five and seven degrees Celsius. The PET accounts for skin temperature, core temperature, and the sweat rate of the human body to create an index for comfort from the air temperature in the surrounding environment.

This study concluded that cool pavements would successfully mitigate the urban heat island effect during the daytime. A higher reflectivity of pavement would also result in better visibility during rain at night, potentially increasing the safety of the sidewalks in urban areas. Unfortunately, replacing regular asphalt pavement with concrete or other higher albedo materials would be expensive, depending on the city and how much replacement would be necessary. However, this has the potential to eventually recover the expenses due to the total amount of energy saved. Our group could use the information from this study to encourage and inform our project hosts about cool pavements as a successful technical solution. Depending on the city, the benefits of cool pavements may outweigh the costs and provide a reasonably simple solution for such a prevalent issue in urban areas. The determining factor would be the overall cost of cool pavements and receiving government approval.

Sponge City

Across Europe, there is a popular method known as Sponge City. This method aims for civil infrastructure to retain the runoff from stormwater (Zeiser, 2023). Sponge cities utilize permeable surfaces such as unsealed roads and urban green spaces to absorb water runoff. A system that retains the water within the soil is essential as it lessens the water demand created due to UHI.

Urban Green Spaces

Another possible solution to the urban heat island effect implemented elsewhere is "greening." Adding green spaces or "greening" can be defined as adding various types of trees and vegetation to a given area (Wang et al., 2016). Green spaces have been successfully used in many cities to lower urban temperatures. In an analysis of temperatures in Fuzhou, China, researchers found that the parks in urban areas significantly decreased the temperatures in surrounding areas. (Yao et al., 2022). Increasing urban green spaces and vegetation is a reasonably realistic solution to mitigate the urban heat island effect.

Vegetation can cool the air and surrounding area in several ways, making it an efficient and advantageous method. Trees can help to block sunlight and create shade, thereby reducing the surface temperature of the area below them. The albedo of greenery is also essential for urban heat island effect mitigation. They have a higher albedo than the surrounding pavement, enabling them to reflect more ultraviolet light, which also cools the temperature (Barradas et al., 2022). Vegetation also transpires at different rates, which is a biological process of plants where moisture is drawn up from the roots and into pores in the leaves, eventually leaving the plant as vapor into the surrounding air (Wang et al., 2016). Transpiration can significantly help in lowering air temperature.

Green Roofs

A study was conducted in 2014 by Li et al. during a heat wave in the Baltimore-Washington metropolitan region of the United States. This study used a climate model to predict the air temperature above different roof materials and deduce the effectiveness of green and cool roofing as urban heat island mitigation strategies. Green roofs were found to decrease the circumambient air significantly, but a large portion of the city would have to use these roofs to make a notable difference. For example, approximately thirty percent of roofs in the studied area would have to use green roofs to decrease the average temperature by one degree Celsius.

This study concluded that changing the surface of roofs in cities would successfully help to mitigate the urban heat island effect. Green roofs were proven more effective due to the dual action of transpiration and reflectivity; however, cool roofs were cheaper to install with less maintenance necessary, making them a more viable and feasible option for urban heat island mitigation. Green roofs would require constant care and surveillance of moisture levels to reach the full potential of decreasing the surrounding air temperature. Based on this study, we would likely consider exploring this option due to its practicality and financial feasibility.

Urban Blue Spaces

Blue spaces consist of both artificial and naturally occurring bodies of water. They can be categorized as static or dynamic bodies. Static bodies of water consist of lakes and ponds, while dynamic bodies are streams or rivers. They help combat the UHI effect through atmospheric advection and evaporative cooling (Ampatzidis and Kershaw, 2020). Atmospheric advection

occurs when the wind created by a flowing river carries warm air to spaces previously occupied by cooler air, thus decreasing the temperature of the warm air. Evaporative cooling happens when the heat from air passing over a lake turns the water into vapor. Both processes have proven to effectively mitigate the UHI while improving nearby residents' mental and general health.

2.5.2 Indirect Mitigation Methods

Heat Strategy

A heat strategy or climate action plan is a plan approved by a city, outlining all mitigation efforts and a timeline by which specific methods should be implemented. According to the World Health Organization's 2008 guidelines, a heat health action plan should include services to help vulnerable populations during extreme heat and long-term urban planning to reduce heat. A heat strategy provides the organization needed to implement direct mitigation methods city-wide.

Hot Spot Identification

Like heat strategies, hot spot identification is often necessary before implementing any direct methods. Albuquerque, New Mexico, has a heat report that includes heat maps that show the temperatures of different areas of the city at different points in the day (CAPA Strategies, 2021). Hot spot identification is simply the act of identifying the areas within a city that are most affected by the UHI effect. This allows cities to implement direct mitigation methods in the areas that need them the most.

Infrastructure Regulations

Infrastructure regulations help ensure that a city progresses toward its goal of mitigating the UHI effect. The city of Ontario uses such regulations to require the use of cool roofs. These regulations specifically include the minimum solar reflectance, thermal emittance, and solar index for buildings. These requirements vary from non-residential and residential buildings and vary by the roof's slope. (Cool roof requirements for nonresidential, high-rise residential, hotel/motel buildings for climate zone 10,). Such regulations are highly beneficial to cities

reaching their goals in mitigating the UHI effect, as implementing direct mitigation methods can be very costly, and private entities may otherwise be unwilling to participate in mitigation efforts.

Subsidies and Incentives

In New York, there is a program in which projects involving the implementation or maintenance of green spaces can apply for a grant to finance the project (Department of Environmental Conservation, 2023). The implementation of direct mitigation methods is often costly. As a result, there is a need to encourage people to contribute to mitigating the UHI effect. Subsidies and incentives can be used to encourage people to construct new buildings in a way that does not further contribute to the UHI effect or to implement direct mitigation methods on private property.

2.6 Summary

The urban heat island effect can be defined as the higher average temperatures in cities due to less green space, more significant pollution, and greater effects of climate change. The urban heat island effect contributes to pollution and harms cities' residents. Furthermore, the urban heat island effect can also increase the risk of respiratory disease and cause harm to other aspects of residents' health, such as mental health and work performance. In many cities worldwide, steps to alleviate the urban heat island effect, such as using high-albedo materials, greening, and vegetation, have already been successfully implemented. As for Swiss cities, our group, in partnership with our project hosts, hopes to begin a significant movement to make urban environments more sustainable.

3. Methodology

Cities throughout Switzerland are not consistent in dealing with the urban heat island (UHI) effect. There is a need to assess what each city is doing and to share the assessment results to learn from one another and potentially take additional steps to mitigate the UHI effect. Our objectives to reach this goal were to:

1. Conduct interviews with Swiss cities to gain a better understanding of the urban heat-island effect in Switzerland;
2. Analyze information gained via interview to gain an overview of the progress of each canton in addressing the heat island effect;
3. Report the status of each canton's relationship with the heat island effect and their plans to mitigate it.

3.1 Interview Process

Throughout the course of the project, we conducted nineteen interviews across Switzerland. These interviews provided insight into the status of the UHI in Swiss cities from experts across various fields. A map of the cities interviewed can be found in Figure 3.

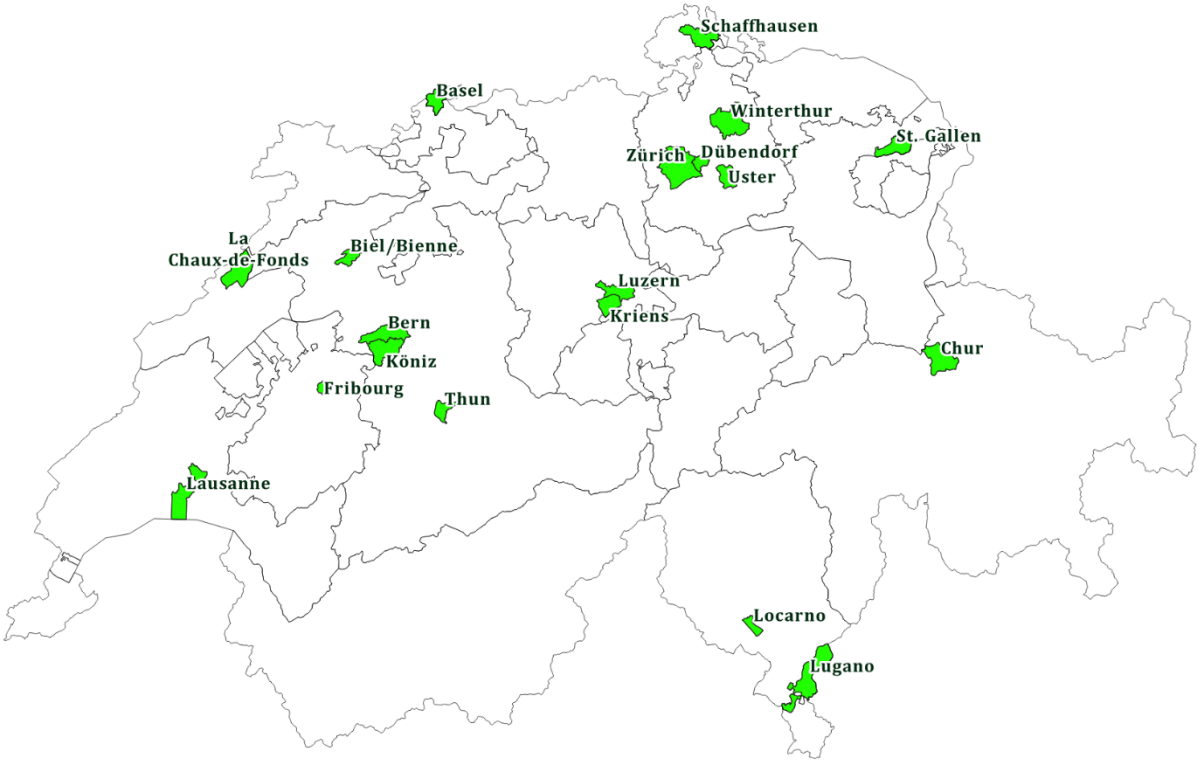

Figure 3 - Map of Swiss Cities that Participated in the Interview Process.

3.1.1 Interviewee Selection

When planning the interviews, we aimed to conduct several interviews throughout Switzerland to understand UHI's status throughout the country. First, cities with large populations were identified. Then, potential interviewees working within the administration of these cities were identified. These potential interviewees have many different administrative roles, but most interviewees worked in city planning or environmental departments. Our project hosts at G+P contacted prospective interviewees over the summer to schedule interviews before we arrived in Switzerland. We then scheduled interviews with any contacts who responded that they could participate in our interviews.

3.1.2 Question Design

The interview questions were designed to provide a comprehensive understanding of the status of the UHI effect in Swiss cities. To ensure that the interview asked questions about all aspects of the UHI in Swiss cities, we created three categories that encompassed all relevant aspects of the UHI. The categories are as follows: questions meant to determine the severity of the UHI in each city, questions regarding implementing mitigation methods, and questions regarding obstacles each city faces. In addition to these three main categories, two personal questions were designed to gain an understanding of the interviewees' personal experiences and opinions regarding UHI. We were able to design these questions using the BAFU tool in Appendix F. The interview questions can be seen in Appendix A.

3.1.3 Onsite & Email Interviews

After contacting prospective interviewees, some responded that they wished to participate in the interviews but could not take part in in-person interviews due to language barriers or limited time. We then designed a form containing the consent script, the interview questions, and space for responses. This form was then translated into German, French, and Italian and sent to interviewees who could not participate in in-person interviews.

3.2 Analyzing Interview Data

Our next step was to analyze the data we received from the answers given during the interview. We generated a transcript for each interview from the audio recordings. We then documented the transcripts and started our analysis by examining the questions involving quantitative data and numerical information gathered from the interviews. These questions can be found along with the rest of the interview questions in Appendix A. The answers provided us with an array of numerical values, which gave us insight into the measures taken to mitigate the UHI effect by each canton. This information later helped us assess the country's overall commitment to prioritizing this issue, what solutions have been implemented to mitigate this effect, and what restrictions impede adding these methods for each canton.

From the rubric we created to record answers given during the interview, we organized our findings into three categories based on UHI impact, current steps to mitigate, and plans. The first category was assessing the general opinion towards the UHI impact. Questions 2 through 4 were the main sources of data since they were opinionated questions about how the interviewee views the severity of the UHI effect in their area and precisely where they see its impacts the most. The second category was designed to determine what has already been implemented or what is currently being implemented to mitigate the UHI effect. Questions 5-7 were the focus of this category. From these questions, we got information on what each city was doing and what they hoped would be done regarding urban, political, and social planning. It also gave us insight into whether they have expertise on the UHI effect in their administration. The last category was the city's challenges in implementing these mitigation methods. Questions 8 and 9 helped provide this information. From these two, we got the interviewees' opinions on the most impactful challenges and what they believe should change to overcome these setbacks.

Just as we did to understand the problem, we conducted a literature review to understand possible strategies to mitigate the UHI effect. Our team compiled data from case studies and research articles in this literature review. This literature review differed from 3.1 as the research focused on strategies already implemented within Swiss Cities.

3.3 Reporting

Our third objective is to report the status of each city's relationship with the UHI effect and their plans to mitigate it. We used Microsoft Excel to display the relationship of the quantitative data we gathered via the interview rankings. This gave our group insight into the differences of each canton in addressing the UHI effect. We also used qualitative data from interviews that described specific issues caused by the UHI effect to understand further the intensity of the UHI effect in each canton. The qualitative data also provided us with first-hand opinions and predictions from experts who live and work in the canton daily.

Once we determined the severity of the UHI effect, we determined how effectively each canton was mitigating the UHI effect. This was done by assessing the analyses performed in section 3.2 and finding trends across different interviews. This accounts for the severity of the urban heat island effect and the progress of mitigation methods, allowing us to determine the status of each city's relationship with the UHI effect. Reporting the status of each canton's relationship with the UHI effect and their plans to mitigate it helps to make ideal additional solutions easily identifiable, assisting in further research into the mitigation methods with the most potential to mitigate the UHI effect and for widespread use. After assessing the needs of the city and the most severe obstacles, we suggested future steps to mitigate the urban heat island effect.

Once we assessed the severity of the UHI and each canton's efforts to mitigate it, we grouped interviews by region, geography, and cultural groups. We looked for similar responses across each group to see if certain groups either suffered from the same problems or implemented similar solutions. If a group had overwhelmingly similar responses to a specific question, we compared it to other groups' answers. This allowed us to determine if regional, geographical, or cultural background impacted each canton's relationship with the UHI effect.

4. Results and Discussion

Over seven weeks, our group interviewed experts on the urban heat island (UHI) effect within nineteen Swiss cities. Our goal of these interviews was to attain a firm understanding of the UHI effect within Switzerland and to formulate a report that would convey our findings. Questions asked during the interviews were structured to receive information on the following categories:

- the impact of the UHI on the city
- the solutions in place to mitigate the issue
- the hurdles each city faces concerning implementing solutions

This organization enabled the cross-analysis of specific data points and assisted in identifying issues on a national scale.

4.1 Characterization of Interviewees

Most interviewees were experienced urban planners with a background in either civil and environmental engineering or sustainability. Many also worked with the urban planning department's climate adaptation and mitigation division if they were employed in a larger city. They all held current positions within the city administration. Larger cities were targeted for interviews due to the likelihood of more intense UHI effects. While approximately thirty cities were asked to participate, fifteen of these were in-person, and four were sent in via email. Some cities declined due to scheduling conflicts or the lack of availability of an appropriate representative. This sample of cities does not represent a mean opinion of Switzerland but instead features cities that can and do act against UHI. Some responses were sent via email due to time constraints or language barriers. The results in this section are based on the opinions of individual representatives of the following cities:

- Basel
- Bern
- Biel
- Biel
- Chur
- Dübendorf
- Freiburg
- Kriens
- La Chaux-de-Fonds
- Lausanne
- Locarno
- Lucerne
- Lugano
- Schaffhausen
- St. Gallen
- Thun
- Uster
- Winterthur
- Zürich

4.2 Severity of the UHI

4.2.1 Current Severity and Development

Questions two and three primarily aimed to better understand the severity of the UHI in Swiss Cities. Question two aimed to get the interviewee's opinion on how the heat island effect affected their daily lives. Many participants noted that they experienced a decrease in sleep quality. These sleepless nights result from an issue known as "tropical nights", in which the elevated heat throughout the day lingers into the evening. People enduring these tropical nights experience temperatures higher than 20 degrees Celsius. As the effects of climate change increase, issues such as "tropical nights" will only worsen (Dosio & Fischer, 2018). Some participants also noted that they had to take different routes when exercising or commuting.

Interview question three asked the interviewee to rate the severity of the heat island effect in their city on a scale of one to ten over three periods: five years ago, in recent months, and five years. The average of the responses shown in Figure 4 shows that the experts we interviewed believe that the severity of the UHI effect will worsen over time. Cities must act soon in order to decrease the rate at which the effects of the UHI increase.

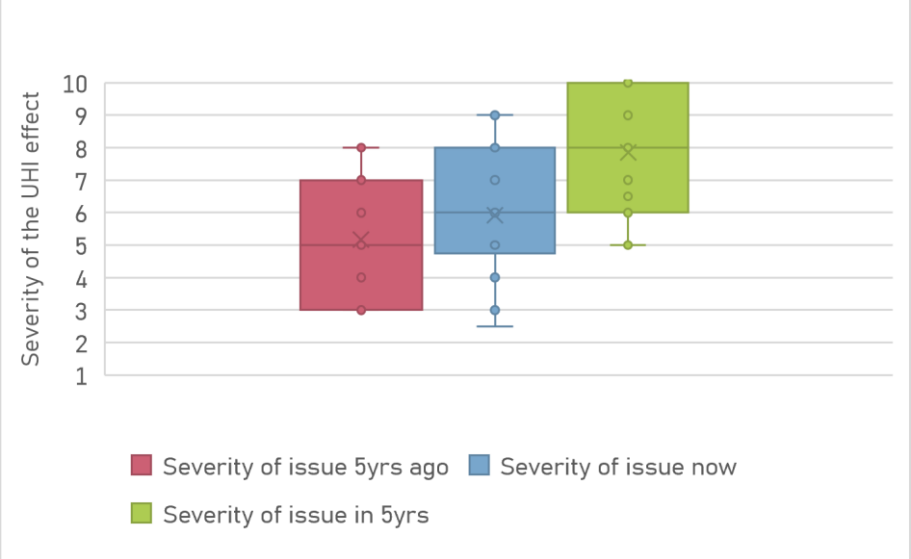

Figure 4 - The Severity of the Heat Island Effect Over Time.

When comparing data with city characteristics, it was found that there was a correlation between responses to question 3 and population size.

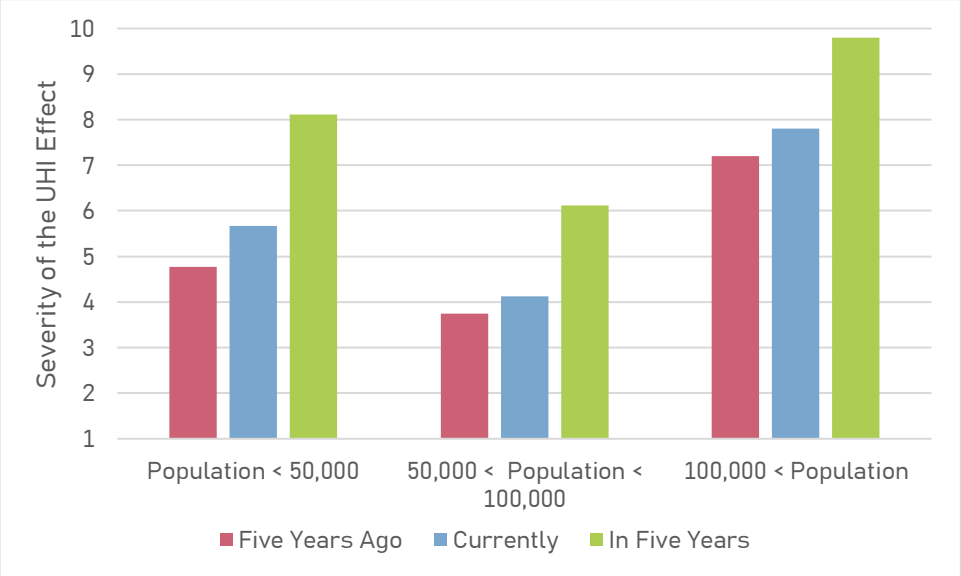

Figure 5 - Representative Opinion of the Severity of the Heat Island Effect Over Time by Population Size.

Figure 5 shows that the belief that the urban heat island effect has worsened in the last five years and will continue to worsen in the next five years is the same regardless of the size of each city's population. However, larger cities ranked the severity of the UHI effect significantly higher five years ago, currently, and five years in the future than cities with medium or small-sized populations. This difference is likely due to larger cities being more urbanized and populated. Surprisingly, smaller cities tended to rank the UHI effect as more severe than medium-sized cities. While the population size for this study is small, this pattern may result from decreased financial funds and a lack of solutions.

4.2.2 Issues Caused by the Heat Island Effect

Question four listed various harmful effects of the UHI effect, and the interviewees were asked to rank them from most harmful (1) to least harmful (10) in the city they were representing. The answers were based on the interviewees' opinions since cities have not yet conducted in-depth analyses of the effects of the UHI. The averages of these rankings from each city representative can be seen below in Figure 6. Results show that, on average, UHIs have the most

significant negative impact on health, while economic productivity loss is the least affected area. In the following section these impacts are explained in detail.

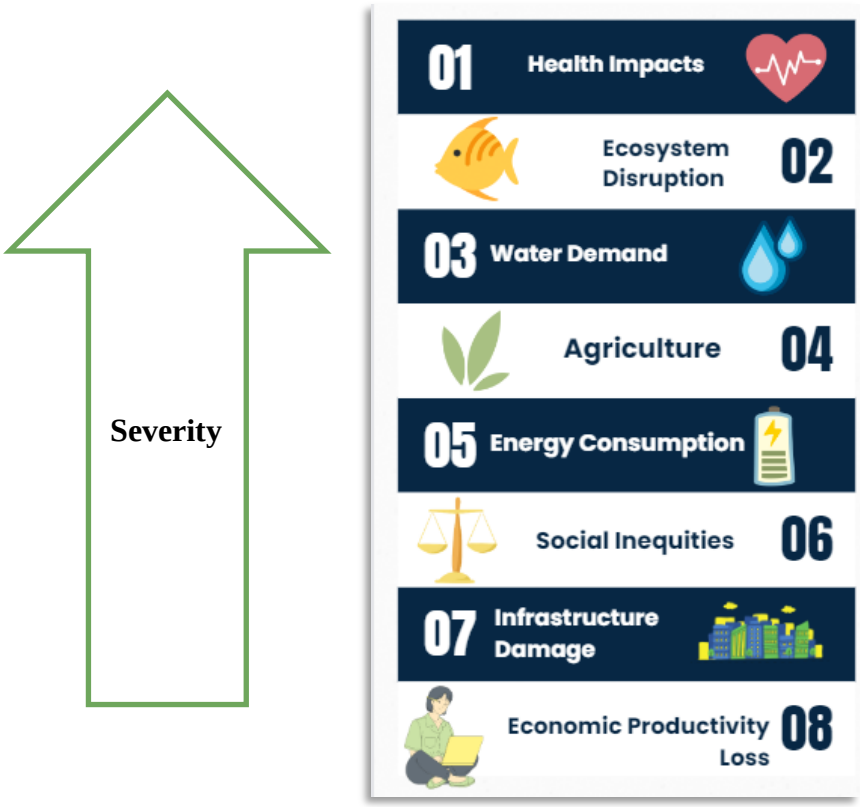

Figure 6 - The Most Devastating Impacts of the Heat Island Effect (1 = Most Severe, 8 = Least Severe)

Health Impacts

Based on the opinions of the experts questioned in our interview, it was found that the most devastating effect of UHI is its impact on human health. These health impacts can include dehydration, dizziness, and fatigue. For vulnerable groups such as the elderly and children, the increased heat can even be fatal. Interviewees expressed concerns about these health complications and sleep quality during heat waves.

Ecosystem Disruption

A common concern for UHI is its impact on the ecosystems within Swiss Cities. The experts we interviewed expressed concern over how the rising temperatures affect the local

environment's biodiversity. Fish in the lakes and rivers near the cities are dying as the average temperature of the water increases (Moore, 2011). Trees that were historically native to the areas cannot withstand higher temperatures. Likewise, pests commonly found in southern countries due to being unable to survive in colder temperatures are now found in Switzerland. These insects are invasive to the trees in Switzerland and can contribute to the withering of weakened trees (Wermelinger, 2020).

Water Demand

Heightened temperatures within cities caused by the UHI lead to an increase in water demand (Dermody, 2007). This increase is especially prevalent in cities with less access to water. As temperatures rise, there is an increased need for water for irrigation. This issue is exacerbated by less water runoff, causing cities to divulge limited water resources such as surface water (Dermody, 2007). Interviewees from cities with less access to natural water sources stated limitations on water usage for watering gardens and water fountains.

Agriculture

As mentioned in the previous parts, the city's agriculture can feel the effects of UHI. Interviewees expressed that dry periods substantially affect the city's agriculture output annually. Increasing temperatures decrease soil moisture, causing the plants to require more water (Dermody, 2007). This issue directly correlates with water demand, which explains their similarity in ratings.

Energy Consumption

The use of air conditioning is not very common within Switzerland, which is why this issue is less of a priority. However, most interviewees anticipate energy consumption due to the usage of AC will become a more significant issue. This increase in the use of AC units is due to uncomfortable workspaces and hotter temperatures in the nighttime, causing poor sleep quality (Randazzo, 2020).

Social Inequities

An overlooked aspect of climate change is how marginalized groups experience effects differently. The changing climate negatively affects people in lower-income groups (Smiley, 2022). Individuals in lower-income groups are less likely to have air conditioning in their homes and workspaces (Smiley, 2022).

Infrastructure Damage

The representatives we interviewed saw that damage to civil infrastructure was less of a priority. However, there is some preparation put in place to prepare for the changes in climate. Alpine cities always have disaster risk management at the center of city planning due to increased rainfall. However, some concern was voiced over damage to civil infrastructure, such as roads and railways, from heat expansion and flooding.

Economic Productivity Lost

Economic productivity loss was not seen as a significant symptom of UHI as it is not as drastic as the higher-ranked impacts. However, there is still anecdotal evidence that this is important when addressing UHI. During the interviews, people noted that summer heat waves made offices unbearably hot, which impeded workflow. It is primarily an issue for those who work outdoors and are at risk of heat stroke.

4.3 Current Status of Mitigation Methods

4.3.1 Measures Used to Mitigate the Urban Heat Island Effect

Question five asked each city which mitigation methods they had implemented. By compiling each cities responses, we were able to determine which methods were most widely implemented, which can be seen in Figure 7.

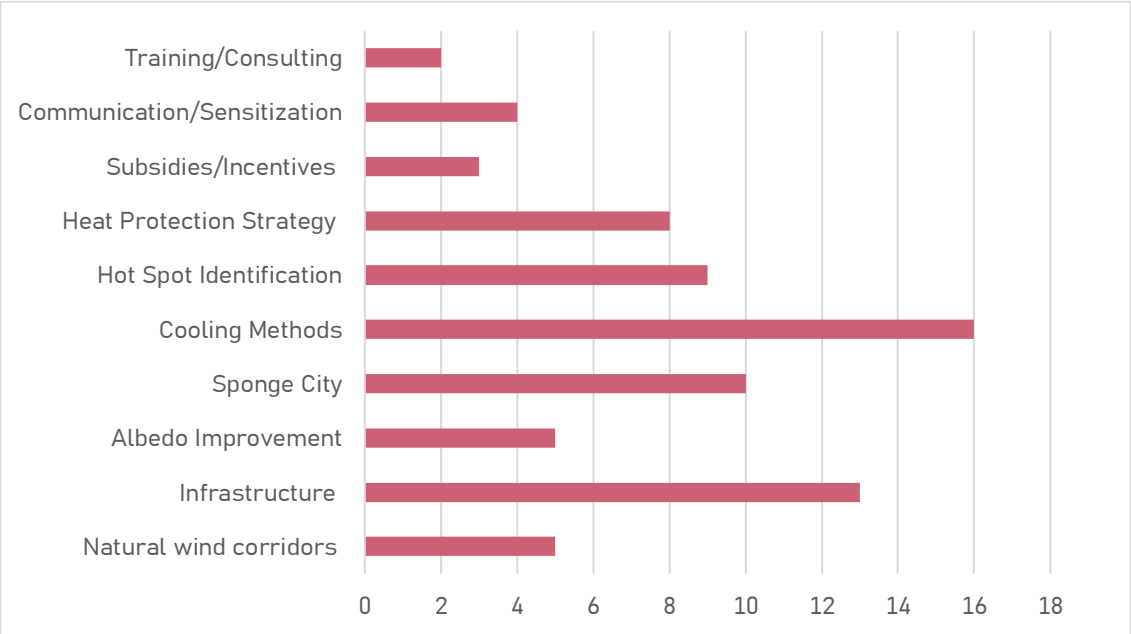

Figure 7 - Number of Cities that Have Implemented Each Mitigation Method.

Cooling methods were the most implemented method across the cities that we interviewed, while training concepts and consulting services were the least commonly implemented methods. It is important to note that this question does not account for the frequency of these measures in each city. As a result, this question has been used to indicate the interest in different methods, not to determine the number of times they have been implemented. These results were also categorized with comparison to population size and language. Both of which yielded prevalent patterns.

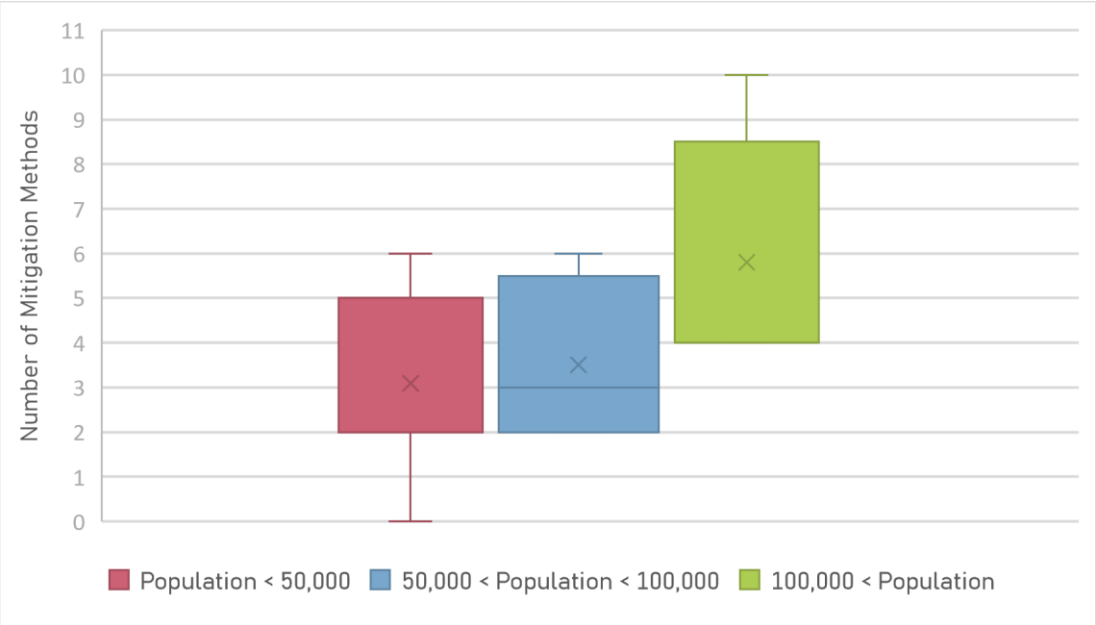

Figure 8 - Number of Different Mitigation Methods Implemented Based on Population Size.

Figure 8 shows that larger cities have implemented significantly more types of mitigation methods than medium or small cities. Similarly, cities with a medium sized population also tend to have implemented more types of mitigation methods than small cities. This is most likely because cities with a large population or more likely to have more resources available to implement these methods than cities with medium or small sized populations.

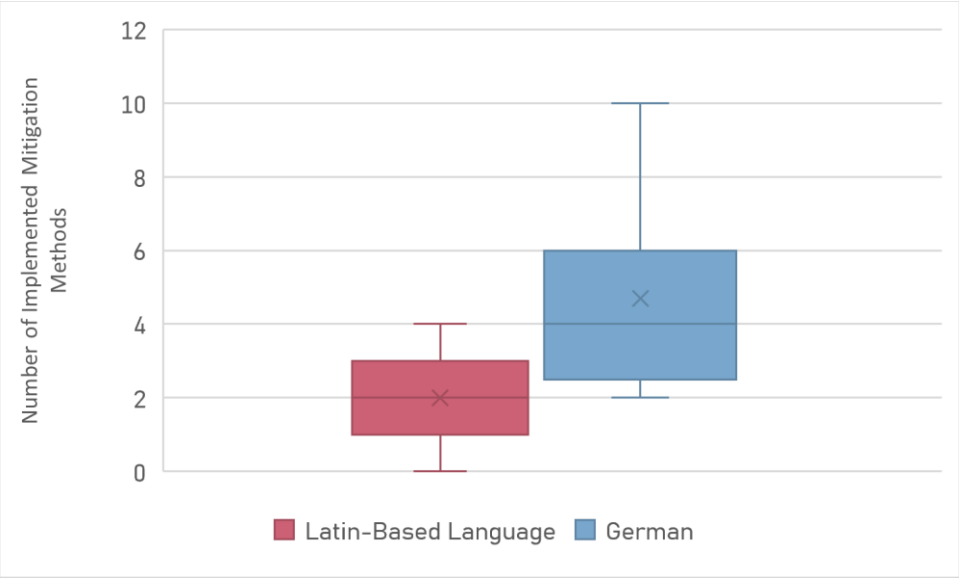

Figure 9 - Number of Different Mitigation Methods Implemented Based on Spoken Language.

Figure 9 shows that when grouped by language, a stark difference emerges. German speaking cities tend to have implemented significantly more mitigation methods than cities that speak a Latin-based language. It is unclear if this is due to differences in cultural attitudes between German speaking cities and French and Italian speaking cities. Furthermore, the results in this question may be impacted by the city sample, as a limited number of cities that primarily speak a Latin-based language were interviewed, especially since Geneva, a very large city, was not interviewed.

4.3.2 Administrative Measures

Question six asked about the status of city departments focused on mitigating UHI in their cities. Most interviewees indicated that there was sufficient expertise regarding the urban heat island effect in their city's administration. However, some interviewees expressed that there was not currently sufficient expertise in their city's administration, but they are making progress in reaching an acceptable level of expertise within the city administration. The results of this question six can be seen in Figure 10. Only two interviewees expressed that there was not sufficient expertise and that there has been no progress in this regard.

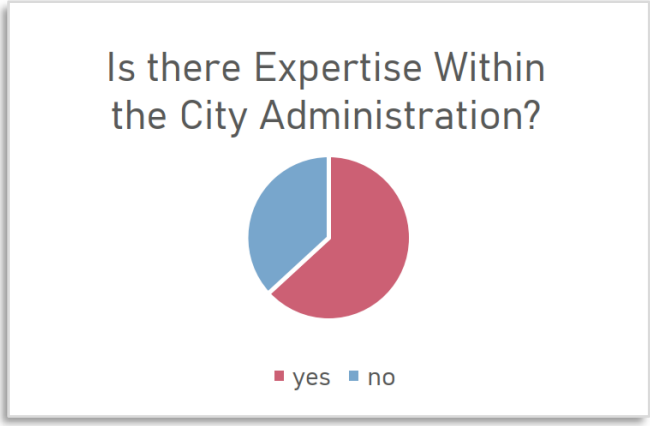

Figure 10 - Do cities have expertise on the Heat Island Effect?

When asked if the city administration had any training programs that were designed to increase expertise of the UHI, most interviewees responded that they did not have any formal training programs. However, many interviewees expressed that they frequently conduct meetings across different departments within the administration. The results of this question can be

seen in Figure 11. Additionally, several cities had different events that were designed to create awareness of climate change among the general public.

Figure 11 - Do Cities have Training Programs for Mitigating the Heat Island Effect?

Most interviewees indicated they had a climate strategy or another strategy that included plans for mitigating the UHI. Most of the interviewees whose city did not have a climate strategy already in effect indicated that they had a climate strategy in progress but that the climate strategy still needed approval. Only two cities did not have a climate strategy that included efforts to mitigate the urban heat island effect. Most cities with a climate strategy have started to implement the mitigation methods outlined in the climate strategy. However, some cities with climate strategies had not yet implemented the mitigation methods in their climate strategies.

Under half of the interviewees said they had sufficient financial resources to implement their climate strategy. Two cities indicated a basic budget covering salaries and other administrative expenses but had to apply for financing for specific projects outlined in the climate strategy. The cities that indicated they did not have any available financial resources also indicated that they had not yet implemented the mitigation methods outlined in their climate strategy. These responses may be related as the lack of financial resources may have made it impossible to implement mitigation methods. On the contrary, some of these cities may not have a budget for mitigation methods simply because they are not yet ready to implement them.

4.3.3 Unconventional Solutions

The following cities currently have solutions implemented that cannot be included within the categories above:

- **Lausanne –** Offers a service where elderly or individuals that are vulnerable to the heat can be checked on daily during heat wave if requested. This is done by civil servants such as firemen and police officers.
- **Zürich –** Created a walking tour around the city of many of the hot spot locations. People can feel the differences in temperature while walking, thereby giving them a direct experience with UHIs and become more aware of the issue.
- **Dübendorf –** Holds an annual competition where citizens are given a budget and can come up with their own solutions to mitigate climate change. The winning idea is then implemented by the city without needing a vote. This encourages social engagement while implementing methods that are already approved of by the citizens.
- **Chur –** Plans to be climate neutral by 2040 thanks to its collaboration with IBC Energy Wasser Chur. Together they plan to promote renewable energy sources and decreased energy consumption. Namely, they plan to implement a CO_2-free grid-connected heating and cooling supply that will cover 60% of the city's heating needs by 2040. (Maissen, 2023)
- **Basel –** There is a regulation in place where one must pay the city a fine when building a new property above a certain height. This fine will go towards creating new green spaces in other areas of the city.
- **St. Gallen –** Similarly to Chur, St. Gallen has ambitious plans to be climate neutral by 2050. They currently have around 150 plans working in tandem to reach these goals. Notable goals include the exclusive use of renewable energies and all modes of transport being 100% electric.

4.4 Future Solutions and Priorities

Question seven asked interviewees to rank potential mitigation methods by their priority in solving the UHI in their city. The results across the interviews in which this question was asked can be found in Figure 12. Please note that a lower ranking indicated a high priority. For

example, if a city were to rank a mitigation method as one for priority, they consider that method to have the highest priority out of all potential methods.

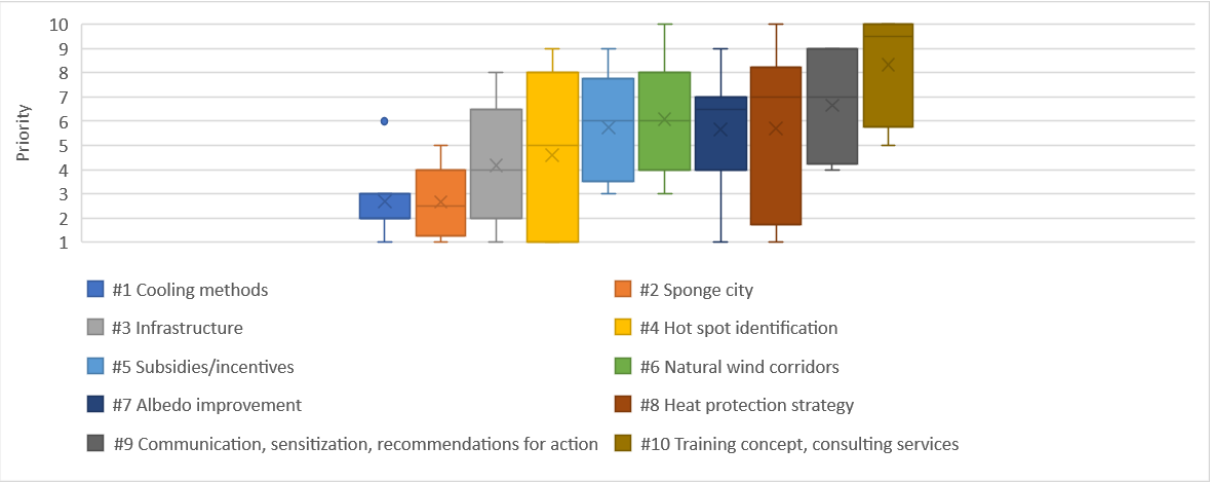

Figure 12 - Prioritization of Solutions to Implement in the Future

Based on the opinion of the experts our group interviewed, cooling methods are the most crucial mitigation method to implement. Cooling methods such as increasing tree coverage are currently the most cost-effective means of heat mitigation. One report found that increasing tree cover in European cities to 30 percent could have reduced premature deaths from urban heat islands by 40 percent (Iungman, 2023). These promising results most likely explain why the Swiss cities with a climate plan, aim to have 30 percent of tree cover within their city. Another popular solution is the concept of “sponge city”, a type of agricultural planning that intends to use unsealed roads and agriculture to absorb runoff water (Iungman, 2023). Thus, creating a natural irrigation system and mitigating the chances of flooding (Iungman, 2023).

4.5 Hindrances and Difficulties

4.5.1 Ranking Difficulties

Question eight asked the interviewees to rank the following difficulties: political will, financial means, technological readiness, and social acceptance, from most obstructive (1) to least obstructive (5) in implementing further mitigation methods. They were also given a fifth category to place any other hindrances that were not included in the list. If interviewees did not provide a ranking for the category "Other", it was given a ranking of five to reflect its relative low importance to the interviewee. The results of this question are shown in Figure 13 below. The average of all responses was taken to find that financial means caused the most difficulty when implementing new methods to mitigate the UHI. In contrast, technological readiness caused the least difficulty.

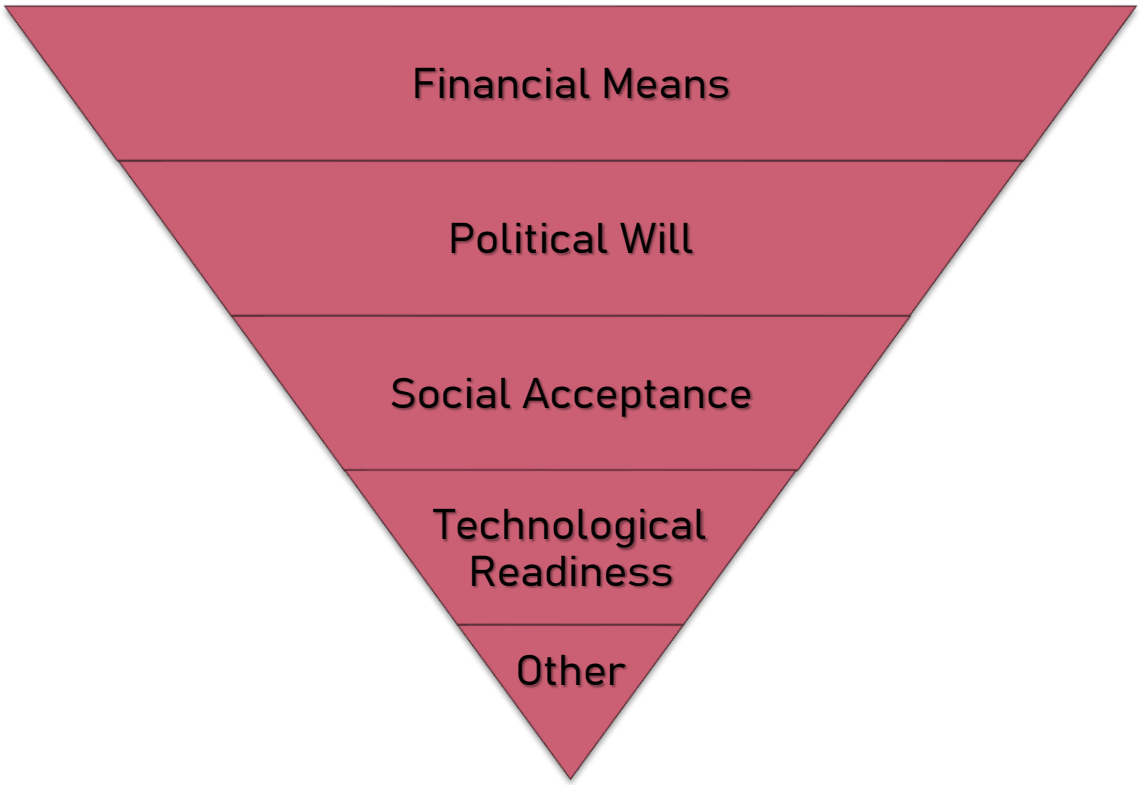

Figure 13 - Ranking of Obstacles to Mitigating UHI Effect from 1 (Most Hindering) to 5 (Least Hindering).

Financial Means

Many interviewees expressed that there was a lack of funding given to mitigation methods of UHI's, as well as lack of budgeting for more climate researchers to conduct more studies on finding the best methods in their city. If a greater budget was allowed for climate research and engineering, many cities may be able to contribute more to mitigating the UHI. While this is the largest concern for cities on average, a trend was found that larger cities found financial means to be less of a problem. Larger cities typically have more funding for urban projects, while smaller cities must prioritize other issues with lesser finances.

Political Will

Political will was the second largest concern on average among all surveyed cities. Many interviewees expressed a strong correlation between political will and financial means, being hindrances to implementing methods. They suggested that when political opinions differ among citizens and those who hold office, it can be difficult to make suggestions or pass new regulations. Many also described the process of creating new laws and regulations as incredibly long and tedious, impeding the implementation of new methods even further.

Social Acceptance

On average, social acceptance was not viewed as a significant obstacle to implementing new mitigation methods. Most representatives expressed that citizens in cities that suffer from the UHI are concerned with the issue and would like to see changes made. However, private property ownership can pose an issue when creating new regulations. While many support the general idea of cooling the city, persuading landowners to alter their properties can be difficult.

Technological Readiness

Technological readiness was the least concerning difficulty among the choices given. Most interviewees believe that the current status of technology is more than advanced enough to aid in mitigating the UHI. They believed that the other obstacles described should be

prioritized over further technological advancements, as plenty of effective methods can be implemented now.

Other

Two representatives mentioned other concerns not listed in question eight, bringing up other significant hindrances to implementing UHI mitigation methods. The first mentioned that there was simply not enough space to satisfy the needs of the citizens and the environment. This challenge was ranked first in the order of obstacles. An example would be that there is not enough room on the streets for cars, bikes, pedestrians, and cooling methods such as planting new trees. The second interviewee suggested that city climates are undergoing such frequent changes that it is challenging to keep up with effective methods to cool the cities. However, this was placed last in terms of damage.

4.5.2 Suggested Solutions to Difficulties

Question nine asked the representatives to provide possible solutions that can be implemented on a cantonal or national level to address the obstacles given in question eight. This was a free-response question with no suggested answers or choices. Almost every interviewee said that political changes need to be made. Most described a need for politicians to prioritize the climate crisis and that laws and regulations must be implemented to see proper and timely change. Additionally, increased communication between cities on the implementation of successful solutions and how they overcome common obstacles is something that interviewees believed to be beneficial. Specifically, funds should be put toward research, materials, future plans, and subsidies.

5. Conclusion / Recommendations

Combating the UHI is becoming an ever-growing responsibility of cities worldwide. This issue is especially prevalent in Switzerland, as cities are trying to find means to lessen its negative impact on the citizens within the city and the surrounding environment. However, with hindrances such as lack of financial means and political will, these methods can take time and effort to implement. Currently, most cities need more financial support from the cantonal and national governments. They can successfully gather the resources needed to implement meaningful solutions with such funding. While this issue is common, cities with multistep heat strategies to deal with the UHI have encountered fewer issues with acquiring financial support. Rather than submitting requests to fund small individual strategies, they can receive a larger budget encompassing multiple collaborative solutions.

Due to the democratic and federal system of Swiss governments, mitigation measures often need to go through a long process before being put into action. To accelerate this process, cities need to increase social awareness of the UHI among citizens. This sensitization of the public can increase the favorability of solutions and politicians who act in favor of mitigating the UHI.

Lastly, a prominent issue is that cities in Switzerland do not commonly communicate with each other about UHIs and how to deal with this problem. If cities were to create an exchange platform where they can talk about their experiences and successful implementation of solutions, it would create a cohesive understanding of how to tackle UHIs across Switzerland.

This project aimed to identify the status of UHI's impact in Switzerland and open communication between cities to create a better understanding and share new possible solutions. The representatives we interviewed envisioned the future of their city to be much greener and more sustainable. They hoped to see more regulations put into place to create a cooler and more comfortable city, making it more enjoyable.

Appendices

Appendix A: Interview Guide for Swiss City Representatives

1. What is your professional background and current city administration role?

2. How has the urban heat island effect impacted your life **personally**?

3. How harmful was the heat issue in **your** city …
   (Please provide a rating [1-10], 1 meaning not harmful at all, 10 meaning extremely harmful.
   After each rating, please briefly describe why you gave it that number)

   a. … five years ago (2018),

      Rating:
      Description:

   b. … in recent months,

      Rating:
      Description:

   c. … will it be in five years (2028)?

      Rating:
      Description:

4. Please **rank [1-9]** the following nine problems according to their prevalence in your city and briefly describe **how** and **where** they affect it?
   (How to rank: 1 being the most important problem and 9 being the least important problem.
   a – i à possible ranks: 1, 2, 3, 4, 5, 6, 7, 8, 9
   Please fill in each box and do not repeat ranks/numbers.)

   a. **Health impacts** (stress, sleep quality, unproductive, vulnerable people)

   Rank:
   How/where:

   b. **Economic productivity loss**

   Rank:
   How/where:

   c. **Energy consumption** (cooling)

   Rank:
   How/where:

   d. **Water demand**

   Rank:
   How/where:

   e. **Agriculture – drought**

   Rank:
   How/where:

   f. **Ecosystem disruption**

   Rank:
   How/where:

   g. **Infrastructure damage**

   Rank:
   How/where:

   h. **Social inequities/injustice** (rich/poor)

   Rank:
   How/where:

   i. **Other problems?** (please specify)

   Rank:
   How/where:

5. Are there any **existing** solutions in your city addressing the problems discussed in the previous question? If so, what are these solutions?
(For examples of specific solutions, see question 7)

6. Certain structural adjustments are also required within the administration to implement concrete solutions to reduce the heat problem. (Please answer the following sub-questions)

   a. Is the expertise regarding the urban heat island issue already embedded within the city administration?

   b. Are there training and development programs within the organization for this purpose?

   c. Is there a heat strategy? If not, is this still planned?

   d. Has the strategy already been implemented organizationally? (Personnel structures / processes). If not, is this still planned? If so, what are the methods that have been implemented?

   e. Have financial resources been made available to counter the heat island problem? If so, for which measures?

7. What other solutions should be tackled in your city, in what order / with what priority? Please rank [1-11] the following eleven solutions.
(How to rank: 1 being the solution with the highest priority and 11 being the solution with the least priority.
a – k à possible ranks: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Please fill in each box and do not repeat ranks/numbers.)

   a. **Utilize natural wind corridors** (urban planning solution)

      Rank:
      Description:

   b. **Infrastructure (building regulations)** (urban planning solution)

      Rank:
      Description:

   c. **Albedo improvement of infrastructure (roads and public spaces)** (urban planning solution)

Rank:
Description:

d. **Sponge city (= Schwammstadt)** (urban planning solution)

Rank:
Description:

e. **Cooling methods (green spaces, blue spaces)** (urban planning solution)

Rank:
Description:

f. **Hot spot identification** (political solution)

Rank:
Description:

g. **Heat protection strategy** (political solution)

Rank:
Description:

h. **Subsidies/incentives** (political solution)

Rank:
Description:

i. **Communication, sensitization, recommendations for action** (social training solution)

Rank:
Description:

j. **Training concept, consulting services** (social training solution)

Rank:
Description:

k. **Other solutions?** (please specify)

Rank:
Description:

8. Please rank [1-5] the following five difficulties/impediments for implementing specific solutions in your city.
   (How to rank: 1 being the greatest difficulty and 5 being the least difficulty.
   Please fill in each box and do not repeat ranks/numbers.
   a – e à possible ranks: 1, 2, 3, 4, 5
   After each ranking, please briefly describe why you gave it that number)

   a. **Political will** (lobbying of specific organizations/parties, legal hurdles)

Rank: Description:

   b. **Financial means**

Rank: Description:

   c. **Technological readiness**

Rank: Description:

   d. **Social acceptance** (lack of understanding, resistance to change)

Rank: Description:

   e. **Other difficulties?** (please specify)

Rank: Description:

9. What should be implemented/improved at the cantonal or national level to address the difficulties/impediments in the previous question?

▪ … ▪ … ▪ …

10. How do you hope your city will adapt to the climate by 2035?
    (Please provide your personal view/vision)

Appendix B: Consent Script for Interviews with City Representatives

As a group of students from Worcester Polytechnic Institute (WPI) in Massachusetts, United States, we would like to invite you to participate in an interview for our research to learn more about the urban heat island effect and its mitigation methods. The purpose of our research is to learn about methods to mitigate the heat island effect. The kind of information that we aim to get from the interview is qualitative data. We anticipate that the interview should take about 45 minutes.

This is a collaborative project between the Grolimund + Partners AG (G+P) and WPI, and your participation is greatly appreciated. Information from our project will be published in a publicly available academic document at the end of our term and we can share a copy of our results if you are interested. No names or identifying information will appear in any of the project reports or publications unless you give us consent to do so.

Your participation in this interview is completely voluntary and you may withdraw at any time. This also means that you can skip any questions that you want. Do you have any questions for us about this interview?

For more information about this research and the rights of research participants, you may contact us by email gr-gr-swissheat@wpi.edu or the Institutional Review Board (IRB) Manager (Ruth McKeogh, Tel. 508-831-6699, Email: irb@wpi.edu) or Human Protection Administrator (Gabriel Johnson, Tel. 508-831-4989, Email: gjohnson@wpi.edu). Thank you very much!

Appendix C: References

Aidaoui, L. Triantafyllou, A. G., Azzi, A., Garas, S. K., & Matthaios, V. N. (2015). Elevated stacks' pollutants' dispersion and its contributions to photochemical smog formation in a heavily industrialized area. *Air Quality, Atmosphere and Health*, *8*(2), 213–227. https://doi.org/10.1007/s11869-014-0300-9

Ampatzidis, P., and T. Kershaw. "A Review of the Impact of Blue Space on the Urban Micro-climate." *Science of The Total Environment*, vol. 730, Aug. 2020, p. 139068. *ScienceDirect*, https://doi.org/10.1016/j.scitotenv.2020.139068.

André, K., Simonsson, L., Swartling, Å. G., & Linnér, B. (2012). Method Development for Identifying and Analyzing Stakeholders in Climate Change Adaptation Processes. *Journal of Environmental Policy & Planning*, *14*(3), 243–261. https://doi.org/10.1080/1523908X.2012.702562

Barradas, V. L., Miranda, J. A., Esperón-Rodríguez, M., & Ballinas, M. (2022). (Re)designing urban parks to maximize urban heat island mitigation by natural means. *Forests*, *13*(7), 1143. https://doi.org/10.3390/f13071143

Berg, B. L., & Lune, H. (2011). *Qualitative research methods for the social sciences* (8th ed.). Pearson Education. Retrieved April 21, 2023, from http://law.gtu.ge/wp-content/uploads/2017/02/Berg-B.-Lune-H.-2012.-Qualitative-Research-Methods-for-the-Social-Sciences.pdf

Bing 1, Dang, et al. Cooling the City with "Natural Wind": Construction Strategy of Urban Ventilation Corridors in China. Feb. 2021. ProQuest, https://doi.org/10.1088/1755-1315/657/1/012009.

Burgstall, A., Kotlarski, S., Casanueva, A., Hertig, Elke., Fischer, E., Knutti, R. (2021)., Urban multi-model climate projections of intense heat in Switzerland. *Climate Services*, 22(2021), 1-13. https://www.sciencedirect.com/science/article/pii/S2405880721000169?via%3Dihub

CAPA Heat Watch Program. "Albuquerque New Mexico heat report." CAPA Strategies, 2021. https://www.cabq.gov/sustainability/documents/heat-watch-albuquerque_report_111921.pdf

"Cool roof requirements for nonresidential, high-rise residential, hotel/motel buildings for climate zone 10." City of Ontario, 2017. https://www.cabq.gov/sustainability/documents/heat-watch-albuquerque_report_111921.pdf

Climate Change and Health WHO Team. "Heat-health action plans: guidance." *World Health Organization,* edited by Franziska Matthies, Graham Biokler, Neus Cardeñosa Marin, Simon Hales, World Health Organization, 2008, p. 8. https://iris.who.int/bitstream/handle/10665/107888/9789289071918-eng.pdf?sequence=1

Debbage, N. & Shepherd, J. M. (2015). The urban heat island effect and city contiguity. *Computers, Environment and Urban Systems, 54*, 181–194. https://doi.org/10.1016/j.compenvurbsys.2015.08.002

Department of Environmental Conservation. "Urban and Community Forestry Grants." New York State, 2023. https://www.dec.ny.gov/lands/5285.html.

Dermody, O., Weltzin, J. F., Engel, E. C., Allen, P., & Norby, R. J. (2007). How do elevated [CO_2], warming, and reduced precipitation interact to affect soil moisture and LAI in an old field ecosystem. *Plant and Soil*, *301*(1-2), 255–266. https://doi.org/10.1007/s11104-007-9443-x

DukeEHDi. (2016, November 1). *What is a Code? Qualitative Research Methods* [Video]. https://www.youtube.com/watch?v=BAKRKZq_Ebo

EPA. (2004). Photochemical Smog. *EPA Information.* https://www.epa.sa.gov.au/files/8238_info_photosmog.pdf

Fetterman, D. (2008). Key Informants. In L. M, Given (Ed), *The SAGE Encyclopedia of Qualitative Research Methods.* (pp 478). SAGE Publications, Inc. https://doi.org/10.4135/9781412963909

Giesekam, J., Tingley, D. D., & Cotton, I. (2018). Aligning carbon targets for construction with (inter)national climate change mitigation commitments. *Energy and Buildings, 165*, 106–117. https://doi.org/10.1016/j.enbuild.2018.01.023

Gordon Library. (2023). *Writing a literature review*. Worcester Polytechnic Institute. https://libguides.wpi.edu/literaturereview

Grolimund + Partner AG (n.d. -a). *Logo*. Retrieved May 2, 2023 from https://www.gundp.ch/en/home

Grolimund + Partner AG (n.d.-b). *Areas of expertise.* Retrieved April 11, 2023, from https://www.gundp.ch/en/fachbereiche

Iungman, T., Cirach, M., Marando, F., Pereira Barboza, E., Khomenko, S., Masselot, P., Quijal-Zamorano, M., Mueller, N., Gasparrini, A., Urquiza, J., Heris, M., Thondoo, M., & Nieu-wenhuijsen, M. (2023). Cooling cities through urban green infrastructure: a health impact assessment of European cities. The Lancet (British Edition), 401(10376), 577–589. https://doi.org/10.1016/S0140-6736(22)02585-5

Jans, P. (n.d.). Energiekonzept 2050 - home | stadt.sg.ch. https://www.stadt.sg.ch/home/raum-umwelt/energie/energiekonzept-2050/_jcr_content/Par/stsg_downloadlist/Download-ListPar/stsg_download.ocFile/STSG_Energiekonzept_V1_web.pdf

Keune, H., Ludlow, D., van den Hazel, P., Randall, S., Bartonova, A. (2012). A healthy turn in urban climate change policies; European city workshop proposes health indicators as policy integrators. *Environmental Health*, *11*(1). https://doi.org/10.1186/1476-069X-11-S1-S14

Li, D., Bou-Zeid, E., & Oppenheimer, M. (2014). The effectiveness of cool and green roofs as urban heat island mitigation strategies. *Environmental Research Letters*, *9*(5). https://doi.org/10.1088/1748-9326/9/5/055002

Liang, S. & Wang, J. (2020). Broadband albedo. *In Advanced remote sensing terrestrial information extraction and applications*, *1*(2), 193–250. Elsevier. https://doi.org/10.1016/B978-0-12-815826-5.00006-4

Maissen, S. (2023, April 4). *Masterplan Energie und Klima Stadt Chur*. Masterplan Energie und Klima. Masterplan Energie und Klima Stadt Chur https://www.chur.ch/_docn/4649449/230816_Masterplan_Energie_und_Klima_print.pdf

McCarthy P., Best, M. J., & Betts, R. A. (2010). Climate change in cities due to global warming and urban effects. *Geophysical Research Letters*, *37*(9). https://doi.org/10.1029/2010GL042845

MeteoSwiss. (n.d.) (accessed October 9, 2023) *Urban heat*. https://www.meteoswiss.admin.ch/climate/the-climate-of-switzerland/urban-heat.html

Moore, T.T. (2011). Climate change and animal migration. *Environmental Law* (Portland), *41*, 393-405.http://ezproxy.wpi.edu/login?url=https://www.proquest.com/scholarly-journals/climate-change-animal-migration/docview/879479122/se-2

Nasr, A., Björnsson, I., Honfi, D., Larsson Ivanov, O., Johansson, J., & Kjellström, E. (2021). A review of the potential impacts of climate change on the safety and performance of bridges. Sustainable and Resilient Infrastructure, 6(3-4), 192–212. https://doi.org/10.1080/23789689.2019.1593003

Nikolopoulou, K. (2022, August 17). *What is snowball sampling? | definition & examples*. Scribbr. https://www.scribbr.com/methodology/snowball-sampling/

O'Mahony, T., (2021). Cost-Benefit Analysis and the environment: The time horizon is of the essence. *Environmental Impact Assessment Review, 89*(2021). 1 - 9. https://www.sciencedirect.com/science/article/pii/S0195925521000378

Piracha, A., & Chaudhary, M. T. (2022). Urban Air Pollution, Urban Heat Island and Human Health: A Review of the Literature. *Sustainability*, *14*(15), 9234. https://doi.org/10.3390/su14159234

Randazzo, T., De Cian, E., & Mistry, M. N. (2020). Air conditioning and electricity expenditure: The role of climate in temperate countries. Economic Modelling, 90, 273–287. https://doi.org/10.1016/j.econmod.2020.05.001

Rev. (2022, March 30). *How to analyze interview transcripts in qualitative research.* Rev. https://www.rev.com/blog/transcription-blog/analyze-interview-transcripts-in-qualitative-research

Schweizer, D., Bühlmann, E., & Schindler, J. (2022, January 1.-c). *Cool pavements – We do research with a practical purpose*. Grolimund + Partner AG. https://www.gundp.ch/en/blog/cool-pavements-we-do-research-with-a-practical-purpose

Scribbr. Retrieved April 13, 2023, from https://www.scribbr.com/methodology/qualitative-quantitative-research/

Sisto, N.,Ramírez, A., Aguilar-Barajas, I., & Magaña-Rueda, V. (2016). Climate threats, water supply vulnerability and the risk of a water crisis in the Monterrey Metropolitan

Area (Northeastern Mexico). *Physics and Chemistry of the Earth*. 91, 2–9. https://doi.org/10.1016/j.pce.2015.08.015

Smiley, K., Noy, I., Wehner, M. F., Frame, D., Sampson, C. C., & Wing, O. E. J. (2022). Social inequalities in climate change-attributed impacts of Hurricane Harvey. Nature Communications, 13(1), 3418–3418. https://doi.org/10.1038/s41467-022-31056-2

Stone, B.,Jr, & Rodgers, M. O. (2001). Urban form and thermal efficiency: How the design of cities influences the urban heat island effect. *American Planning Association. Journal of the American Planning Association, 67*(2), 186-198. doi:https://doi.org/10.1080/01944360108976228

Susca, T., Gaffin, S. R., & Dell'Osso, G.R. (2011). Environmental Pollution. *Positive effects of vegetation: Urban heat island and green roofs.*, *159*(8-9). 2119-2126. https://www.sciencedirect.com/science/article/pii/S0269749111001539

Tedesco, Oberdorff, T., Cornu, J.-F., Beauchard, O., Brosse, S., Dürr, H. H., Grenouillet, G., Leprieur, F., Tisseuil, C., Zaiss, R., & Hugueny, B. (2013). A scenario for impacts of water availability loss due to climate change on riverine fish extinction rates. *The Journal of Applied Ecology*, *50*(5), 1105–1115. https://doi.org/10.1111/1365-2664.12125

The Swiss Capital.jpg. (2023, February 25). *Wikimedia Commons*. Retrieved 22:06, May 2, 2023, from https://commons.wikimedia.org/w/index.phptitle=File:The_Swiss_Capital.jpg&oldid=73554722

United Nations. (n.d.). *Sustainable Development Goals.* https://www.undp.org/sustainable-development-goals

United States Environmental Protection Agency (n.d.) *Learn about heat islands*. EPA.gov.

Wang, Y., Berardi, U., & Akbari, H. (2016). Comparing the effects of urban heat island mitigation strategies for Toronto, Canada. *Energy and Buildings, 114*, 2–19. https://doi.org/10.1016/j.enbuild.2015.06.046

Weber, A. (n.d.). *Ideenwettbewerb Klima*. Dübendorf. https://www.duebendorf.ch/stadtentwicklung/47974

Wermelinger, B., Mathis, D. S., Knížek, M., & Forster, B. (2020). Tracking the spread of the northern bark beetle in Europe and first records from Switzerland and Liechtenstein. Alpine Entomology, 4, 179–184. https://doi.org/10.3897/alpento.4.53808

Yang, L., Qian, F., De-Xuan, & S., Zheng, K. (2016). Research on urban heat-island effect. *Procedia Engineering*, *169*, 11-18. https://www.sciencedirect.com/science/article/pii/S1877705816332039

Yao, X., Yu, K., Zeng, X., Lin, Y., Ye, B., Shen, X., Liu J., (2022). How can urban parks be planned to mitigate urban heat island effect in "Furnace cities"? An accumulation perspective. *Journal of Cleaner Production. 330*, 1-10. https://www.sciencedirect.com/science/article/pii/S0959652621040257#bib51

Yin, C., Yuan, M., Lu, Y., Huang, Y., Liu, Y., (2018). Effects of urban form on the urban heat island effect based on spatial regression model. *Science of The Total Environment*. *634*, 696-704. https://www.sciencedirect.com/science/article/pii/S0048969718311100

Zeiser, A., Rath, S., Grimm, K., Schmidt, S., Klammler, G., Zimmermann, D., Murer, E., Roth, T., Strauss, P., & Weninger, T. (2023). Überlegungen zur Dimensionierung und Ausführung des Systems Schwammstadt für Bäume. Österreichische Wasser- und Abfallwirtschaft, 75(7-8), 449–462. https://doi.org/10.1007/s00506-023-00962-0

Appendix D: Further Information

- **Zürich:** https://www.stadt-zuerich.ch/ted/de/index/gsz/planung-und-bau/fachplanung-hitzeminderung.html
- **Basel:** https://www.stadtklima.bs.ch/stadtklimaanalyse.html
- **Lausanne:** https://www.lausanne.ch/portrait/climat/plan-climat.html
- **Bern:** https://www.bern.ch/rahmenstrategie-nachhaltige-entwicklung
- **Winterthur:** https://stadt.winterthur.ch/themen/leben-in-winterthur/planen-und-bauen/strategische-entwicklung/rahmenplan-stadtklima
- **Luzern:** https://www.stadtluzern.ch/dienstleistungeninformation/25993#dienst_63151
- **St. Gallen:** https://www.stadt.sg.ch/home/raum-umwelt/umwelt-nachhaltigkeit/hitze.html
- **Lugano:** https://www.lugano.ch/temi-servizi/energia-ambiente/citta-verde/lugano-al-verde.html
- **Biel:** https://www.biel-bienne.ch/de/klimawandel.html/2744
- **Thun:** https://deinklima.ch/processes/klimaideethun
- **Köniz:** https://www.koeniz.ch/wohnen/umwelt/energie/klima-und-energiepolitik.page/309
- **Fribourg:** https://www.ville-fribourg.ch/de/hitzewelle
- **Chur:** https://www.chur.ch/_docn/4649449/230816_Masterplan_Energie_und_Klima_print.pdf
- **Schaffhausen:** https://www.stadt-schaffhausen.ch/News.316.0.html?&tx_ttnews%5Btt_news%5D=3004&cHash=6763285a08e9e8148e9f96dd922ab837
- **Uster:** https://www.uster.ch/_docn/2958172/Bericht_Massnahmenplan-Klima-Uster_20210126.pdf
- **Dübendorf:** https://www.duebendorf.ch/_docn/4379887/Aktenverzeichnis_Beilage3_Massnahmenplan_Klima_Bericht_20230.pdf
- **Kriens:** https://mitreden-kriens.ch/processes/Klima-und-Energiestrategie?locale=de

- **BAFU-Tool:** https://www.bafu.admin.ch/bafu/de/home/themen/klima/dossiers/klimarisiken-lokal-angehen.html