January 2024

Climate Adaptation Plans in Ontario: Small and Medium Municipalities Preparedness for Extreme Weather

Zakary Blomme
blommez@uwindsor.ca

Climate Adaptation Plans in Ontario: Small and Medium Municipalities Preparedness for Extreme Weather

By

Zakary Blomme

An Internship Paper
Submitted to the Faculty of Graduate Studies
through the Department of Political Science
in Partial Fulfillment of the Requirements for
the Degree of Master of Arts
at the University of Windsor

Windsor, Ontario, Canada

2024

Climate Adaptation Plans in Ontario: Small and Medium Municipalities Preparedness for Extreme Weather

by

Zakary Blomme

APPROVED BY:

_____

G. Callaghan
Department of Political Science

_____

L. Miljan, Advisor
Department of Political Science

January 17, 2024

DECLARATION OF ORIGINALITY

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication.

I certify that, to the best of my knowledge, my thesis does not infringe upon anyone's copyright nor violate any proprietary rights and that any ideas, techniques, quotations, or any other material from the work of other people included in my thesis, published or otherwise, are fully acknowledged in accordance with the standard referencing practices. Furthermore, to the extent that I have included copyrighted material that surpasses the bounds of fair dealing within the meaning of the Canada Copyright Act, I certify that I have obtained a written permission from the copyright owner(s) to include such material(s) in my thesis and have included copies of such copyright clearances to my appendix.

I declare that this is a true copy of my thesis, including any final revisions, as approved by my thesis committee and the Graduate Studies office, and that this thesis has not been submitted for a higher degree to any other University or Institution.

ABSTRACT

Combatting climate change has largely been understood as a matter of federal and provincial jurisdiction and as a result has mostly been executed in a preventative lens. However, the effects of climate change are most significantly felt at the municipal level. As a result, I argue the onus for combatting climate change should switch to the municipalities in order to focus on climate mitigation and adaptation. In fact, many of the larger cities in Ontario such as the City of Windsor have acted on this and created Climate Adaptation Plans to aid in mitigation and adaptation efforts. The larger cities creation and Adoption of Climate Adaptation Plans has opened a policy window for small and medium sized (based on population) Ontario municipalities to do the same. This paper suggests through conducting cost-benefit analyses that small and medium sized municipalities should seize this opportunity and implement a Climate Adaptation Policy to mitigate the impact of extreme weather events caused by climate change.

Key Words: Climate Adaptation Plan, Small and Medium Municipalities, Extreme Weather Events, Climate Change, Cost-Benefit Analysis, Climate Adaptation, Climate Resilience, Climate Mitigation

TABLE OF CONTENTS

DECLARATION OF ORIGINALITY iii

ABSTRACT iv

LIST OF TABLES vi

LIST OF ABBREVIATIONS/SYMBOLS vii

Chapter I: 1

Chapter II: 4

Chapter III: 12

Chapter IV 23

Chapter V: 32

REFERENCES 42

VITA AUCTORIS 48

LIST OF TABLES

I. Table 4.1: Costs of Climate Action, 36 & 37
II. Table 4.2: Costs of Climate Adaptation Per Capita, 38
III. Table 4.3: Costs of Extreme Weather Events (Benefits), 39
IV. Table 4.3: Summary of Costs and Benefits for Wildfire, 40
V. Table 4.4: Summary of Costs and Benefits for Flood, 41

LIST OF ABBREVIATIONS/SYMBOLS

I. SMMs: Means Small and Medium Municipalities

II. CAP: Means Climate Adaptation Plans

III. EWE: Means Extreme Weather Events

Chapter I:

Introduction

Climate change policy in Canada has largely been conducted at the federal and provincial level with the federal government taking the lead on the issue. This has created a false impression and understanding that the issue of climate change is most effectively combatted under federal jurisdiction. In fact, climate change projects dealt with on the federal and provincial level have in large part failed to meet their targets and goals. For example, a recent audit of the federal governments Canadian Net-Zero Emissions Accountability Act conducted by the environment commissioner found that the plan is insufficient to meet the targeted emission reduction goals (Office of the Auditor General of Canada, 2023). Additionally, provincial attempts at dealing with climate change have seen similar levels of criticism. A 2019 report from the Ontario Auditor General found that the projected emissions reductions from the Ontario government's plan was not based on sound evidence and that as a result the plan will fall short of the emissions targets (Office of the Auditor General of Ontario, 2019). This shows that despite the federal and provincial government taking the initiative on climate policy it has been ineffective.

Furthermore, the bulk of climate change effects are expected to be felt at the municipal level through the impacts of extreme weather events. Therefore, I argue in order for meaningful change to occur municipalities must take the lead on climate policy through shifting the focus away from a preventative lens towards mitigation and adaptation. Many larger municipalities in Ontario have already begun this process

through the implementation of climate adaptation policies. However, the majority of small and medium municipalities (SMMs) in Ontario have yet to follow suit. As a result, through conducting a cost benefit analysis this paper suggests that SMMs should take initiative in climate policy and implement climate adaptation plans.

Over the course of this paper I will outline how climate change policy is most effectively served at the municipal level. The literature review will provide an understanding of institutionalism as the theoretical framework used throughout the paper. This section will outline the principles and main argument of the theory as well as the common research and methodological frameworks employed by institutionalist authors. The subsequent chapters through a cost benefit analyses will compare the expenses of implementing climate adaptation plans with the potential damages of extreme weather events. This is done through examining the crucial areas of infrastructure investment necessary for implementation as well examples of extreme weather events to showcase the potential associated risk of damages.

Throughout the paper and ensuing analysis, I argue for increased municipal involvement in climate policy. This is done through illustrating how climate policy can be cost effective when implemented at the municipal level. Chapter II will provide an introduction and rationale for the use of institutionalism as the theoretical lens for which the argument in this paper can be understood. Chapter III outlines the methodological framework that will be used to assess the effectiveness of climate adaptation plans for SMMs. This is done through conducting cost benefit analyses in order to determine whether climate adaptation plans result in cost savings. Chapter IV will provide the cost benefit analysis and present the findings. Finally, Chapter V concludes the paper through

summing up the findings of the paper and supporting the argument for increased municipal involvement in climate policy.

Chapter II:

Literature review

Institutionalism

The following chapter provides an introduction to the theory of institutionalism and presents the rationale for its use in this paper. Furthermore, this chapter outlines the relationship between institutionalism and climate policy. This is done through exploring the current research and methodologies conducted by institutionalist authors. Lastly, this chapter discusses the current gaps within the existing climate policy research and outlines how this paper will address these issues and attempt to fill the gaps.

Institutionalism is best understood as a theory used to organize a perspective rather than attempting to illustrate causation (Lowndes Marsh & Stoker, 2017). As a result, this paper uses institutionalism to provide the framework for organizing the argument and understanding the problem. The theory of institutionalism has many different branches or strands of research it can be applied to. For example, feminist institutionalism focuses on how gender norms function within an institution and how these institutions create and reinforce gender power dynamics (Lowndes, et al, 2017). This paper however, applies an alternative branch of institutionalism known as rational choice institutionalism. Rational choice institutionalists argue that political institutions are a system of rules and provocations which individuals use to leverage their abilities to solve collective action problems (Lowndes et al, 2017). Essentially, this means that institutions set out the rules to follow while the individuals or organizations attempt to bend these rules in order to gain an advantage in solving the issue at hand (Lowndes et al,

2017). Ultimately, this paper uses this framework to situate the argument for a shift of jurisdiction. For example, I argue that municipal staff and politicians (individuals) should utilize jurisdiction (rules) set out by the institutions to be more effective in combatting the collective action issue of climate change.

For the context of this paper institutionalism is used to examine research on the institutional barriers to implementing climate change adaptation plans at the municipal or community level. This research can focus on but is not limited to the attitudes of government staff, councilors or community members, access to resources, the understanding of government staff, priority levels and more (Amundsen & Dannevig, 2021; Bausch & Koziol, 2020; Campbell-Gale, Fletcher & Reed, 2023; Choryński, Pińskwar, Graczyk, & Krzyżaniak, 2022; Fungfeld, Fila, & Dahlmann, 2023; Henstra, 2012; Klenk, Flueraru, & MacLellan, 2017; Mary-Ellen Tyler, 2023; Mehiriz & Gosselin, 2016; Oberlack, 2017; Siña, Wood, Saldarriaga, Lawler, Zun, Garcia, & Cárcamo, 2016). Authors who have researched the attitudes of government staff use institutionalism to understand and explain how positive or negative attitudes can either halt, prevent or accelerate the process of implementing climate action plans (Amundsen & Dannevig, 2021; Klenk et al, 2017). For example, research has found that government staff lack of willingness to adapt is a key barrier to implementing climate policy with some staff believing it is impossible to adapt to extreme weather events (Amundsen & Dannevig, 2021). Others have found institutionalism more effective in examining councilors and community members as a means to understand a municipalities climate preparedness (Campbell-Gale et al, 2023; Choryński et al, 2022; Mehiriz and Gosselin, 2016; Siña et al, 2016). For example, research examining five different municipalities local councilors

attitudes toward climate change adaptation in Peru found that climate change was of a low priority and is poorly understood among the councilors, resulting in limited climate adaptation policies (Siña et al, 2016).

Authors who employ the theme of institutionalism typically use similar methodological frameworks when conducting their research. This is done through using two distinct methodologies. The first methodological framework used is to conduct surveys and/or interviews (Amundsen & Dannevig, 2021; Bausch & Koziol, 2020; Campbell-Gale, et al, 2023; Mehiriz & Gosselin, 2016; Siña et al, 2016). Interviews and surveys are one of the main methodological tools used to answer questions of how barriers can impact the creation of climate policy in municipalities and communities (Amundsen & Dannevig, 2021; Bausch & Koziol, 2020; Campbell-Gale, et al, 2023; Mehiriz & Gosselin, 2016; Siña et al, 2016). As a result, surveys and interviews allow the author to hear directly from municipal staff members, councilors, or community members about which different institutional barriers are preventing or making the implementation of climate adaptation policies difficult. Furthermore, interviews and surveys allow the researcher to get an understanding of the subject's knowledge, understanding, willingness, or priority level of implementing climate adaptation policies.

The second methodological approach that is used when exploring the theme of institutionalism is to conduct case studies (Choryński, Pińskwar, Graczyk, & Krzyżaniak, 2022; Fungfeld, et al, 2023; Henstra, 2012; Klenk, Flueraru, & MacLellan, 2017; Mary-Ellen Tyler, 2023; Oberlack, 2017). Similar to interviews and surveys case studies are used to assess institutional barriers that prevent climate adaptation policy. Because authors are trying to find institutional barriers, case studies are used within the literature

when authors are working with a much larger scope. For example, case studies are typically used when the author is looking at institutional barriers on a national or international scale (Choryński et al, 2022; Fungfeld et al, 2023; Henstra, 2012; Klenk et al, 2017; Mary-Ellen Tyler, 2023; Oberlack, 2017). Typically, this is done through conducting multiple case studies over a large area or through conducting one large case study and generalizing it across that same area.

The current research on the theme of institutionalism all focuses on the different barriers to implementing climate policy. As a result, researchers tend to implement similar methodological frameworks. However, the methodological approach when using institutionalism will typically rely on the scale and the scope of the study. For example, research focusing on a smaller scope such as the barriers a singular city or town face when implementing climate adaptation policies will likely use surveys or interviews as a methodology (Amundsen & Dannevig, 2021; Bausch & Koziol, 2020; Campbell-Gale, et al, 2023; Mehiriz & Gosselin, 2016; Siña et al, 2016). Furthermore, researchers that are looking at how institutional barriers impact climate policies on a larger scale such as the barriers faced by multiple municipalities within one country or multiple countries across a continent are likely to use case studies as a methodology as this provides the authors the ability to generalize across a larger area (Choryński et al, 2022; Fungfeld et al, 2023; Henstra, 2012; Klenk et al, 2017; Mary-Ellen Tyler, 2023; Oberlack, 2017).

Policy Assessment

Authors who use institutionalism typically conduct policy assessments for their research. This research primarily focuses on evaluating existing climate policies and the

levels of risk faced due to climate change usually through extreme weather events (Bassett & Shandas, 2010; Bausch & Koziol, 2020; Boenkhe, Hoppe, Brezet & Blok, 2019; Donoghue & Katz-Rosene, 2023; Guayadeen & Henstra, 2023; Guayadeen, Thistlethwaite, & Henstra, 2019; Henstra, 2012; Henstra & Thistlethwaite, 2017; Jost, Dale, Newell, & Robinson, 2020; Mao & Thompson, 2004; Robertson, 2018; Liousbimsteva, 2022). In general authors who conduct assessment research agree on the dominant theoretical approaches however, there is some debate on the methodological framework when conducting the assessment. Similar to institutionalism authors who conduct assessments generally use one of two methodological frameworks. The two methodologies commonly used in assessments are case studies and data/content analysis.

Authors conducting case studies are typically looking to evaluate existing climate policies and evaluate the risk levels in their area of study (Boenkhe, et al, 2019; Donoghue & Katz-Rosene, 2023; Henstra & Thistlethwaite, 2017; Jost et al, 2020; Robertson, 2018). As a result, authors whose research question will require an assessment of a municipality, country or other unit of studies' existing climate policies are more likely to use case studies for the methodology. For example, in (Donoghue & Katz-Rosene, 2023) the authors used case studies of the fifteen largest cities in Ontario and evaluated their extreme weather preparedness through an assessment of their climate action plans. Furthermore, case studies provide authors the ability to apply specific frameworks or criteria into their methodologies, allowing them to assess the success of the existing climate policies (Boenkhe, et al, 2019; Donoghue & Katz-Rosene, 2023; Henstra & Thistlethwaite, 2017; Jost et al, 2020; Robertson, 2018).

The second methodology used for assessments are data/content analysis. Content and data analyses can be used for a variety of different research questions however are primarily used for assessing existing climate policies and/or the preparedness of the policies to the dangers of extreme weather events (Bassett & Shandas, 2010; Guayadeen & Henstra, 2023; Guayadeen, Thistlethwaite, & Henstra, 2019; Liousbimsteva, 2022). Therefore, both methodological frameworks of case studies and data/content analyses are used to answer similar research questions when conducting assessments. However, data and content analyses are typically used by researchers who are looking at larger data sets or units of study such as analyzing multiple policies across a larger area or events (Bassett & Shandas, 2010; Guayadeen & Henstra, 2023; Guayadeen, Thistlethwaite, & Henstra, 2019; Liousbimsteva, 2022). Alternatively, authors who employ case studies typically do so when conducting a smaller scope and unit of study and generally attempt to assess policy outcomes or objectives (Boenkhe, et al, 2019; Donoghue & Katz-Rosene, 2023; Henstra & Thistlethwaite, 2017; Jost et al, 2020; Robertson, 2018). In summation authors who use data and content analyses are attempting to analyze policies or risk levels across a large area and have many areas of study where case studies are used for smaller and more in-depth research.

Gaps:

This final section will explore how this paper will add value to the current state of literature. This value is added through exploring the current gaps within the research and attempting to address them. While municipalities' adaptation to extreme weather events is not a novel topic of research it has to this point mainly focused on large municipalities (Donoghue & Katz-Rosene, 2023; Gore, 2010; Henstra, 2012; Guayadeen,

Thistlethwaite, & Henstra, 2019; Henstra & Thistlethwaite, 2017; Jost et al, 2020; Mao & Thompson, 2004; Mehiriz & Gosselin, 2016; Siña et al, 2016). Furthermore, research that has focused on SMMs has been conducted largely in areas outside of Ontario (Amundsen & Dannevig, 2021; Bassett & Shandas, 2010; Bausch & Koziol, 2020; Boenkhe et al, 2019; Campbell-Gale et al, 2023; Choryński et al, 2022; Fungfeld et al, 2023; Liousbimsteva, 2022; Mary-Ellen Tyler, 2023; Mehiriz & Gosselin, 2016; Robertson, 2018). As a result, this ignores an important area for understanding municipal vulnerability and preparedness for extreme weather events as SMMs in Ontario are likely to be at risk and ill prepared.

The second gap can be found through exploring the type of research that is being conducted. As mentioned earlier in the section much of the research using institutionalism has been conducted focusing on assessing existing policies in order to evaluate climate preparedness (Bassett & Shandas, 2010; Bausch & Koziol, 2020; Boenkhe, et al, 2019; Donoghue & Katz-Rosene, 2023; Guayadeen & Henstra, 2023; Guayadeen et al, 2019; Henstra, 2012; Henstra & Thistlethwaite, 2017; Jost et al, 2020; Mao & Thompson, 2004; Robertson, 2018; Liousbimsteva, 2022). This in turn ignores municipalities who have yet to implement climate adaptation plans or policies. As a result, municipalities without implemented climate adaptation plans are ignored in the existing research. Furthermore, this creates a gap in the literature through not providing policy proposals for municipalities who have yet to implement climate adaptation policies.

This paper will address these gaps by conducting a policy proposal for small and medium municipalities in Ontario to implement climate adaptation plans. Furthermore,

the implementation of climate adaptation/action plans by larger municipalities has created a policy window for SMMs to overcome the institutional barriers preventing the implementation of climate adaptation plans. Recently Guayadeen & Henstra (2023) conducted a climate policy assessment of rural Ontario municipalities. This would suggest that SMMs in Ontario have already begun to implement climate adaption plans. However, the research found that rural climate change planning is in its infancy and has had an emphasis on mitigation as opposed to adaptation (Guyadeen & Henstra, 2023). As a result, this paper looks to build on this research through proposing further climate policy which focuses on Ontario SMMs developing and implementing climate adaptation plans for extreme weather events.

Chapter III:

Methods

Framework

The two main extreme weather events that pose a threat to SMMs in Ontario are wildfires and flooding. However, the threat of wildfires and flooding are not spread equally throughout the province. Northern municipalities, due to their geographical location, are at a much greater risk for catastrophic fires. Alternatively, SMMs in southern Ontario are at a heavy risk for extreme flooding but not for catastrophic fire. This makes it very unlikely, that a municipality were to be hit by both extreme flooding and catastrophic wildfire. As a result, this paper will propose a climate adaptation plan to be implemented by SMMs and compare the costs against the damages of the two extreme weather events through conducting two separate cost benefit analyses. The first cost benefit analysis will be aimed at Northern Ontario SMMs and will focus on catastrophic fires. The second will target Southern Ontario municipalities and focus on combatting extreme flooding. Through comparing the costs of implementation with the potential savings accrued from the mitigation of extreme weather events both analyses will look to assess the viability of enacting climate action plans into SMMs. The costs are calculated from the investment required into updating municipal infrastructure. While the potential benefits come in the form of mitigation and prevention of future damages from extreme weather events caused by climate change. As a result, I argue that the potential costs of not implementing a climate action plan (i.e. benefits) will likely outweigh the initial costs of development and implementation.

In order for the cost benefit analysis to produce accurate results the monetary amounts attributed must be reliable. As a result, the framework for analysis has been chosen as follows: Each cost benefit analysis will compare the costs of updating and creating infrastructure with the potential damages of extreme weather events. This will be done through proposing one climate adaptation plan for both municipalities as infrastructure investment will be necessary for both municipalities. The total cost of infrastructure updates is then compared separately with the expenses of the associated extreme weather event in order to determine whether the implementation of a climate adaptation plan would result in cost savings.

As mentioned, determining appropriate prices is vital to the success of this analysis. Therefore, the method for data collection will use established prices. The Federation of Canadian Municipalities (an advocacy group which represents over 2000 Canadian Municipalities) in conjunction with the Insurance Bureau of Canada (a lobby group for Canadian insurance companies) has conducted a report on implementing climate action plans for municipalities, including for extreme weather events. Additionally, this report includes examples of previous extreme weather events and the total cost of damages. Consequently, this paper will use this report to provide relevant fiscal amounts for both the costs of implementation of climate adaptation plans and for providing the costs of damages from extreme weather events. In addition to this report price projections have also been collected from an existing climate adaptation plan from The City of Windsor. Using an established climate adaptation plan and the report will help ensure that the analysis uses trustworthy and established monetary projections for the costs of implementation and damages from extreme weather events.

Climate adaptation investment can be very specific and complicated. This paper aims to provide a baseline price projection for Ontario SMMs to implement climate adaptation plans. This will help municipalities strategically allocate funds to implement climate adaptation plans so that they may be more resilient to the likely increase in extreme weather events. Therefore, I have outlined the areas required for municipal investment in order to achieve climate resiliency for both extreme weather events. To achieve climate resiliency from catastrophic fire and flooding municipalities will need to invest in the following infrastructure areas: buildings/developments and energy infrastructure, communication systems, transportation systems, green infrastructure, waste management systems, and water systems. The next section of this chapter will further outline the need for these areas of investment through exploring their overall importance to a climate adaptation plan. Lastly, this paper will consider the benefits of climate adaptation plans through exploring the costs endured following municipalities/counties exposure to extreme weather events. The costs of these extreme weather events will be determined through a provided example of each extreme weather event. The 2016 Fort McMurray fire will be used to outline the potential damages of catastrophic fires while, the 2016/2017 Essex County flooding will provid the costs for extreme floods.

Building & Development Infrastructure

Destruction of buildings and development is probably the most well-known damage that occurs during extreme weather events. Notably, this paper includes energy infrastructure in the definition and pricing of building and development infrastructure. Currently there are two aspects of making climate resilient building and development

infrastructure. The first aspect is to develop and implement bylaws and policies to ensure all future and current developments are climate resilient. The second aspect of adapting buildings to extreme weather events is retrofitting old and current buildings to meet current standards. While new buildings can be designed and constructed with protections against extreme weather events older buildings will likely be vulnerable to extreme weather. As a result, older infrastructure and developments will need investment to become climate resilient.

Communication Systems

Providing effective communication during extreme weather events is an essential function for the municipality as it helps keep residents safe through communicating any emergency response plans or procedures and also disseminates valuable information to the public. Additionally, updates to communication infrastructures to make it climate resilient is crucial to ensuring the dissemination of information during extreme weather events. Therefore, it is important for municipalities to implement communication plans and procedures, as well as update communication infrastructure for extreme weather events. Furthermore, risk communications in the days before and during extreme weather events can be crucial to protecting the health and safety of residents. In fact, recent research suggests that risk communication efforts during extreme weather events are much more effective than broad climate change risk communications and suggests these strategies should be applied to broader climate change discourse (MacIntyre, Khanna, Darychukk, Copes, & Schwartz, 2019). This would suggest that not only are

communication systems during extreme weather events vital to the safety of the public but are also effective at disseminating important messages and information.

Transportation Systems

When discussing the potential impact of extreme weather events on transportation services and systems the obvious impact is that of the physical damage that can be caused to transportation services such as roads, bridges, train tracks, trains, and buses. However, additional costs are experienced for the municipality when these services are unavailable. This can be seen through the economic losses that occur such as loss of staff and citizens access to jobs, access to services, or a lack of access to stores and other economic drivers. As a result, it is vital that transportation systems are resilient and prepared for the impacts of extreme weather events. A recent study looking at making climate resilient transportation systems found operational preparations for climate change and constructing climate resilient transportation infrastructure were the most beneficial in creating climate resilient transportation systems (Deveci, Gokasar, Mishra, Rani, & Ye, 2023). However, the policy implication of this study largely concerns cities with large and complex transportation systems (Deveci et al, 2023). Despite this there is some relevance to Ontario based SMMs as many municipalities share transportation systems in their counties or regions as part of a larger network of transportation.

Green Infrastructure

The concept of green infrastructure in this paper refers to the use of natural processes or systems to help minimize the impact of extreme weather events. For

example, green infrastructure such as parks, trees, and wetlands has been a proven method to help limit the impacts of flooding caused by extreme weather events through reducing the burden on storm water management systems (Li, Uyttenhove, & Eetvelde, 2020). Green infrastructure acts as a sponge soaking up much of the excess water that comes with storms, flooding, and heavy rainfall. This can help alleviate pressures and prevent overwhelming of storm water management systems. In turn, this helps prevent or limit the effects of flooding during extreme weather events. Crucially, an additional benefit of green infrastructure is that in the events of extreme weather green infrastructure aids in the maintenance of water quality. A recent study modelled three distinct rainfall scenarios to assess the impact of green infrastructure on water quality, finding that green infrastructure has a positive influence on limiting pollutants in storm water runoff (Yu & Li, 2023). As a result, green infrastructure not only limits the damages of flooding through reducing the burden on storm management systems but also helps maintain water quality in the event of extreme weather events. This shows the overall value of green infrastructure when developing and implementing a climate adaptation plan.

Waste Management Systems

Waste management systems refer to any infrastructure which is used to deal with waste within a municipality. Of particular interest for the purpose of this paper are sewer and stormwater sewer systems involved in overall waste management. Sewer and stormwater sewer systems play a vital role in both ensuring water quality and managing the impact of flooding (Li et al 2020; Yu & Li, 2023). Climate change and the increase of

extreme weather events is expected to significantly increase the burden on stormwater and sewer systems and thus modernization of these systems will be a critical aspect of adapting to the impacts of extreme weather events (Helmreich, 2021). The goal of modernization is to increase capacity of these systems to help limit the potential for heavy rainfall, storms, and other weather events to overrun the systems. Furthermore, wildfires have the potential to cause significant issues for storm water systems as residues such as ash and black carbon build up and prevent storm water systems from treating and filtering runoff (Raoelison, Das, Guyett, Merrifield, Visweeswaran, Indiresan, Yan, Pierce, Moharty, 2023). However, recent research has shown that updating of stormwater systems, specifically through implementing biofilters can limit this effect and can help stormwater systems in wildfire prone areas remain functional (Raoelison et al, 2023). This shows that updating water management systems used in conjunction with the implementation of green infrastructure are key aspects of adapting to the increases in extreme weather events.

Water Systems

For this paper water systems include infrastructure such as pipes, water mains, or any structures or buildings owned and operated by the municipality. Providing access to high quality water is an essential function of a municipality and is paramount to ensuring the health and safety of their residents. Therefore, it is important that proper steps to prevent or limit as any potential threats to the maintenance and delivery of high-quality water to residents should be taken. Climate change and extreme weather events are a significant threat to these systems. As previously mentioned, flooding and other extreme

weather events pose a significant risk to the maintenance of water quality due to the increased risk of overwhelming of stormwater and sewer systems (Li et al, 2020). Furthermore, extreme weather events such as droughts, extreme heart, wildfire, or precipitation can increase microbiological risks and negatively impact general quality of drinking water (Xiao, Yu, & Fu, 2023; Raoelison, 2023). In addition to the water quality risks, water system infrastructures such as pipes, maintenance systems, and structures are at risk for potential damage caused by extreme weather events. Due to the increased risk factors brought on by extreme weather events investment to create more climate resilient water systems is crucial in maintaining the health and safety of residents. Recent scholarship has suggested that despite the challenges of adapting drinking water systems to environmental changes and extreme weather, frameworks for implementing climate resilient water systems have been effective (Kloosterman, van der hoek, & Herder, 2021).

Limitations

It is important to consider the limitations which impact this research paper. The first limitation for this paper is that climate adaptation plans are likely to be unique to each municipality (Robertson, 2018). Therefore, the potential costs and benefits are likely to be unique to each municipality as well. This is because every municipality will have its own individual set of risk factors to extreme weather events and level of necessary investment into infrastructure. However, a possible explanation for this limitation can be found in the goal of this paper. This paper aims to provide a generalized cost benefit analysis on climate adaptation plans for SMMs which can then be adapted by individual municipalities and applied to fit their own unique risk factors. Additionally, this paper

attempts to account for this limitation through conducting two separate cost benefit analyses based on the extreme weather events. Conducting two separate analyses manages the impact of this limitation through only applying the damages from extreme weather events that the individual municipality is at risk for.

The second possible limitation also has to do with the scope of the study. This study focuses on small and medium municipalities in Ontario which is defined for this paper as municipalities with populations under 100,000 residents. This encompasses an extremely wide range of municipalities and risk factors. For example, a municipality with 90,000 residents is likely to have significantly different climate adaptation issues than that of a municipality with under 10,000. Therefore, it is likely different sized municipalities will face different risks and are likely to be at different points in their climate preparedness. Furthermore, this could result in issues with determining risk factors and costs for implementing a climate adaptation policy. However, this paper accounts for this in its methodological framework. The use of an existing climate adaptation plan from a larger municipality and a verified report should provide accurate baseline expected costs and benefits. Furthermore, SMMs in Ontario are likely to take the lead from larger municipalities. The goal is to provide a baseline cost benefit analysis which individual municipalities can adapt to fit their unique needs.

The last limitation for this research has to do with the methodology. Due to the nature of extreme weather events there can be difficulties in the quantification of cost/benefit assessment. This means that it can be difficult to assign accurate prices or figures to the potential cost or benefit. Potential damages caused by extreme weather events can alter due to a multitude of reasons such as severity. To perform an effective

cost-benefit analysis having accurate prices is crucial to the success of the proposal. As a result, in order to mitigate the impact of this limitation this research will use established data, prices, and figures from a qualified and reliable source in the Federation of Canadian Municipalities and from an established climate adaptation plan. However, there is still a risk of inaccurate pricing and figures as each municipality has individual needs and thus prices are likely to fluctuate. Furthermore, climate adaptation plans are not a prominent feature in SMMs. Thus, SMMs are expected to have different climate adaptation needs and therefore cost projections. However, as mentioned costs are expected to be unique to each individual municipality. Therefore, using projections from an existing established climate adaptation plan provides the strongest reference to provide baseline projections for SMMs.

There is a potential for the analysis to not show cost savings. Possible information which may lead to costs outweighing the benefits for the implementation of climate adaptation plans in SMM in Ontario is outlined here. There is the potential for small and medium municipalities to have relatively low risk to damages caused by extreme weather events where the cost of developing and implementing a climate adaptation policy would outweigh the potential benefits however this is predicted to be unlikely. The second piece of information which could result in the analysis not showing cost savings is initial costs for implementation being too high for small and medium municipalities. For example, while the overall potential benefits may outweigh the costs, the initial costs for development and implementation of a climate adaptation policy may be so high that SMM may be unwilling or unable to incur the financial burden required to implement a climate adaptation policy. This is mainly expected to be a potential issue for the much

smaller municipalities such as those under 10,000 residents. This is for two reasons the first is that they are anticipated to be much further behind in their climate adaptation and thus the costs may be higher. The second is that they will have access to less resources and smaller budgets and thus the initial costs may be too high.

Chapter IV

Results

Climate Adaptation Plan

As mentioned SMMs in Ontario are faced with different challenges when adapting to the effects of extreme weather events. Because of this the following chapter is split into two sections. The first section will provide the climate adaptation plan proposal. This will outline the proposed infrastructure updates required to create a climate resilient municipality and the associated costs projections of these updates. The second section of this chapter will conduct two separate cost benefit analysis. The first cost benefit analysis will compare the cost of implementing the proposed climate adaptation plan with the potential damages of catastrophic wildfire and assess whether the plan results in cost savings. The second cost benefit analysis will then compare the cost of the proposed plan with the potential damages of catastrophic flooding and similarly assess whether the plan results in a net benefit for municipalities at risk of flooding.

Costs Green Infrastructure

The benefits of green infrastructure are typically discussed in reference to limiting the impacts of flooding and storms. Nevertheless, green infrastructure also plays an important role in mitigating the effects of catastrophic fire. For example, debris and pollutants from wildfires can have a very damaging impact on water quality (Raoelison et al, 2023). However, green infrastructure has shown to successfully limit pollutants in run off to help aid in the treatment and maintenance of water quality (Yu & Li, 2023). Green infrastructure in turn plays a valuable role in both wildfire and flooding resiliency. The

implementation of green infrastructure project is projected to cost approximately $4.5 million (City of Windsor, 2020). As seen in table 4.1 this includes projects such as the development of an air quality index, research and implementation of French drains, dry wells and other methods of flood maintenance, a forest management plan, improving climate resiliency of trees in parks and forests, and incorporating native and drought tolerant plants (City of Windsor, 2020).

Costs of Building/Developments

The most obvious threat to municipal infrastructure when discussing extreme weather events is the destruction of buildings and homes. Therefore, it is recommended that all structures in at risk areas have climate adaptation and resiliency measures put in place. However, the cost of municipal investment into climate resilient buildings and developments can be difficult to arrive at. This is because the level of investment largely depends on the age and number of buildings owned and operated by the municipality. The costs of implementing climate resilient standards into new developments is expected to be much cheaper than retrofitting old buildings to meet current climate resiliency standards. Due to this the cost of implementation will be rather unique to each municipality. However, a baseline estimate can be established through examining existing climate adaptation plans. As seen in table 4.1 investment into climate resilient buildings and developments is expected to cost $8.9 million (City of Windsor, 2020). Municipal investment into projects such as improving building and maintenance standards to protect damage from increased cooling demands, improving design standards, enhancing inspection of municipal owned facilities, and implementing a

community energy plan are some of the projects contributing to the cost. A more in-depth list of building and development costs can be found in table 4.1.

Costs of Communication Strategy

A detailed communication strategy is vital for any climate adaptation plan seeking to combat extreme weather events. As mentioned earlier communication systems is a rather broad term and encompasses both communication plans and infrastructure. However, except for in unique circumstances most communication infrastructure tends to be owned and operated by third party or private companies and not by the municipality (Middleton, 2008). This means that most of the cost and adaptation measures undertaken by SMMs is likely to be the development and implementation of communication plans and procedures. Therefore, it is beneficial to use established communication strategies when projecting the costs for SMMs. Established climate adaptation plans project municipal investment to cost approximately $2.1 million including programs such as implementing/updating heat alert and response plans, developing a media notification system, and developing emergency response and evacuation procedures for extreme weather events such as wildfires (City of Windsor, 2020).

Costs of Waste Management Systems

In the context of extreme weather events waste management systems are typically understood when discussing the threat of flooding. However, wildfires due to the buildup of ash and black carbon have the potential to clog and cause stormwater systems to become overrun as well as harming water quality (Raoellison, 2023). As mentioned earlier, sewer and stormwater systems play a vital role in both ensuring water quality and

preventing stormwater systems from being overrun (Lie et al, 2020; Yu & Li, 2023). As a result, upgrading and improving stormwater infrastructure is vital to creating a municipality which is resilient to both flooding and wildfires. A plethora of different options exist when looking to update waste management systems (Helmreich, 2021). This can make calculating the cost of updating stormwater and sewer systems quite difficult. To account for this, the cost is based on figures presented in a report by the federation of Canadian Municipalities in conjunction with the Insurance Bureau of Canada. The report finds that in response to extreme weather events the County of Essex (an area primarily consisting of SMMs) invested $120.3 million into updating and improving its stormwater and sewer systems (Federation of Canadian Municipalities & Insurance Bureau of Canada, 2020). It is important to note that this is not the cost of the damage from the extreme weather events but rather investments made to help mitigate future damages from extreme weather. The breakdown of projected costs included a $90 million commitment to replace sewers, upgrade pumping stations and sewers, and rebuilding roads as well as a $30.3 million investment to cover road ditches, and improve sewer and pump capacity (Federation of Canadian Municipalities & Insurance Bureau of Canada, 2020). While, this is a significant investment the cost is likely to be spread over a large period of time and is much less than the damages incurred from the initial extreme weather event which can be seen later in the chapter. Despite this investment being in response to flooding similar investment will be necessary to implement infrastructure that is resilient to both flooding and wildfires.

Costs of Transportation Systems

Determining the cost of implementing climate resilient transportation largely depends on the size of the transportation system, the level of public transit, and the current climate preparedness of the systems for the impact of extreme weather events. Furthermore, there are multiple courses of action a municipality may take in order to limit the impact of extreme weather events. For example, the cost of determining alternate ways of travel is likely much cheaper than a complete overhaul of transportation infrastructure to be more climate resilient (Deveci et al, 2023). However, a mix of both options is likely the route municipalities will take in order to adapt to extreme weather events. The total projected costs associated with creating climate resilient transit systems is $4.3 million (City of Windsor, 2020). This includes costs relating to protecting and improving vulnerable roads to flooding, improving and developing extreme weather contingency plans for transit systems, and identifying alternative routes for extreme weather.

Cost of Water Systems

As mentioned earlier implementing resilient water systems plays a vital role in the overall climate adaptation plan because of its role in ensuring water quality which is under threat from both flooding and wildfires. However, many SMMs and even larger municipalities share water treatment facilities, structures, and other infrastructure. This means that costs are likely to be spread out across municipalities. Due to this the best course of action for projecting costs of implementing climate adaptation measures is to use a municipality with an established plan as a reference. As can be seen in table 4.1 projects such as monitoring the buildup of blue-green algae, supporting the completion of floodplain mapping of watersheds, and the protections of water pump stations from

extreme weather such as flooding and fires are all included in the cost of climate adaptation (City of Windsor, 2020). These projects in addition to others shown in more depth in table 4.1 are projected to cost $3.1 million (City of Windsor, 2020). Furthermore, much of the costs of improving water systems and protecting water quality are shared with updating stormwater systems. This means that many of the risk factors for decreased water quality caused by flooding and fire events can be mitigated with an updated waste management system (Li et al, 2020).

Total Cost of Implementation

The final cost of implementation when adding together the costs of all infrastructure updates necessary is $143.2 million for one municipality. This number is significant and is expected to fluctuate depending on the individual needs and size of a municipality This can be seen through examining table 4.2 which outlines the costs of adaptation on a per capita basis. Municipalities with a population size of 10,000 – 20,000 residents can expect the cost of implementation range from $14,320 – $7,160 per person. Adaptation for municipalities within the population range 20,000 – 50,000 will cost approximately $7,160 – $2,864 per resident. Lastly, SMMs with a population range of 50,000 – 100,000 residents can expect costs to fall in the range of $2,684 – $1,432 per person. This shows how the size of the municipality can greatly impact the cost of implementing climate adaptation plans. These numbers should provide a strong baseline for Ontario SMMs to use when making decisions to start the climate adaptation plan process. The next part of this section will outline the potential damages of each extreme weather event and compare it to the total cost of implementation in order to determine if the plans will show cost savings.

Catastrophic Fires

Wildfires pose a significant threat to many northern Ontario SMMs. Because of this the 2016 Fort McMurray fire was chosen to provide an example for the projected potential damages of wildfires. Despite Fort McMurray not being an Ontario municipality, it provides valuable insight for some northern municipalities as it shares similar risk factors. For example, the City of Timmins shares similar geographical and population similarities with Fort McMurray. As a result, the potential damages of wildfires for Ontario SMMs can be seen through examining the Fort McMurray event. As can be seen in table 4.3 in 2016 the town of Fort McMurray was hit with a wildfire which would displace approximately 88,000 residents, damage or destroy 1,900 residential structures, 23 commercial and industrial buildings, and destroy over 18,000 vehicles (Federation of Canadian Municipalities & Insurance Bureau of Canada, 2020). The estimated costs of damages totaled $5.4 billion with the government costs amounting to $1.2 billion (Federation of Canadian Municipalities & Insurance Bureau of Canada, 2020).

Wildfires and weather conducive to wildfires are beginning and will continue to increase in frequency (Gaur, Benichou, Armstrong & Hill, 2021). This is an issue which has been further highlighted by the recent 2023 fire season. Although the Fort McMurray event was one of the more devastating examples, it serves as an example of the potential impact of climate change. We can use the event to make estimates for potential damages to other municipalities. Similarly, to how was done above with the cost of adaptation it may be helpful to understand the potential cost of wildfire's through analyzing it on a per person scale based on municipal population. From using the $1.2 billion cost of the Fort

McMurray fire we can estimate that this would cost municipalities with a population range of 10,000 - 20,000 residents approximately S120,000 – $60,000 per person. While, SMMs with 20,000 - 50,000 residents can expect costs of $60,000 – $24,000 per resident. Finally, SMMs with 50,000 – 100,000 residents can expect costs ranging from $24,000 – $12,000 per resident. This shows the potential for wildfires to cause significant damages and costs for SMMs.

The total cost of implementing a climate adaptation plan is $143.2 million. The potential damages (benefits) to be sustained from the extreme weather event of a wildfire is $1.2 billion. As can be seen in table 4.4 this shows a cost savings of $1.06 billion. This means that overall the benefits of implementing a climate adaptation plan to make SMMs climate resilient to wildfires far outweigh the costs of implementation showing a net benefit of $1.06 billion. Furthermore, the costs of implementing a climate adaptation plan can be amortized over multiple years. This means that the initial cost of 143.2 million although significant especially for SMMs can be spread out across multiple years. This can be used to help lessen the burden of the extremely high initial cost while still maintaining the benefit of mitigating extreme weather events. For example, the $143.2 million initial cost of climate adaptation amortized over 5-10 years would cost the municipality in the range $28.6 million – $14.3 million per year. While this is still significant investment it would substantially lower the burden of upfront cost while keeping the benefit of mitigating the one-time catastrophic event.

It is important to note that the implementation of climate resilient infrastructure and a climate adaptation plan in general will not make municipalities completely resistant to the damages of extreme weather events like wildfires. As a result, damages are still

likely to occur in the event of wildfires. However, recent research has shown that the savings from climate adaptation plans outweigh the costs on a ratio of 6:1(Martinez-Diaz, 2018). This means that not only are the potential damages of extreme weather events higher than the costs of climate adaptation plans but the savings accrued from climate adaptation plans outweigh the costs of implementation as well.

Catastrophic Flooding

Most Ontario SMMs but especially those in southern Ontario are at risk of extreme levels of flooding whether it is from heavy rainfall or storm. Essex County is an area comprised of SMMs and in 2016 and 2017 experienced two extreme flooding events. After extreme rainfall hit the region in 2016, the county's ill prepared stormwater systems capacity was overrun causing inundated roads, fields and further flooding of dirty sewer water (Federation of Canadian Municipalities & Insurance Bureau of Canada, 2020). The flood would result in insurance costs over $153 million and estimates place the government costs to be approximately 3 or 4 dollars for every one dollar spent by insurance (Federation of Canadian Municipalities & Insurance Bureau of Canada, 2020). These costs would be further compounded when one year later in 2017 the region would be hit with similar levels of flooding resulting in damages totaling approximately 165 million dollars (Federation of Canadian Municipalities & Insurance Bureau of Canada, 2020). Adding the two events together the costs total $318 million in insurance payments with the government costs expected to be 3-4 times that amount (Federation of Canadian Municipalities & Insurance Bureau of Canada, 2020). This would bring estimated government costs on the low end to $954 million. However, because the total government

costs are unknown to avoid inflating numbers this paper will use the total insurance costs as reference for municipal costs in this paper.

After conducting the second cost benefit analysis it becomes clear that the implementation of a climate adaptation plan once again shows cost savings. With the cost of climate adaptation plans totaling $143.2 million and the cost of the potential damages from catastrophic flooding amounting to $318 million table 4.5 shows a net benefit of $174.8 million. This means that in both cases of catastrophic flooding and wildfire the potential damages of extreme weather significantly outweigh the initial costs of implementation. Therefore, it is recommended that SMMs show a stronger initiative in climate change policy through taking the opportunity to implement climate adaptation plans. Ontario SMMs will have to make significant initial investment into infrastructure order to create a climate resilient municipality. However, this analysis shows that in both extreme weather event scenarios the costs are markedly less than potential damages posed by extreme weather events. Additionally, costs are able to be amortized over multiple years which may help limit the burden of initial investment while still enjoying the benefit of reduced costs from catastrophic extreme weather events.

Incentive

After conducting the cost benefit analyses it becomes clear that the implementation of climate adaptation plans can be a cost-effective method of climate policy. This furthers the argument that SMMs should take a more active role in climate policy as municipalities have the potential to implement efficient and effective climate policy. However, there is still a significant barrier for implementing climate adaptation

plans at the municipal level. Emergency funding for catastrophic events is largely provided by the federal and provincial governments yet the cost of adaptation would need to be borne by the municipalities. This means that despite the catastrophic risks of not implementing climate adaptation plans there is currently little to no incentive for implementation if municipalities have to bear the costs. Thus, due to the fact that emergency funding is provided by the federal and provincial governments SMMs in particular have no real incentive to bear the extremely high costs of adaptation even with the risk of catastrophic damage.

Chapter V:

Conclusion

The federal and Ontario provincial government have largely failed in their attempts to implement effective climate change policy. Additionally, the impacts of climate change will be mainly felt at the municipal level through extreme weather events. As a result, the responsibility of enacting climate change policy should fall to municipalities in the form of climate adaptation plans to mitigate the impact of extreme weather events such as catastrophic fires and flooding. The results of this paper clearly show that the implementation of a climate adaptation plan for both catastrophic fire and flooding results in cost savings for Ontario SMMs. Thus, SMMs should take advantage of this opportunity to develop and implement climate adaptation plans in order to combat the impact of extreme weather events. While, the initial costs of climate adaptation are high many opportunities for assistance have been made available to municipalities from both government and non-profit organizations. This should aid in lowering costs for implementation and alleviate some of the burden of high initial costs. The high initial costs of implementation may be especially difficult for SMMs causing hesitancy in adaptation and these opportunities should help ease this issue. However, even without this funding the cost benefit analyses in this paper suggest that Ontario SMMs would significantly benefit from developing climate adaptation plans. Therefore, I argue that climate change policy is best served at the municipal level as it is both effective and results in cost savings. Lastly, there is a noticeable lack of research surrounding SMMs in Ontario and their climate preparedness. Although, a plethora of existing research regarding large municipalities in Ontario and their responsibilities and efforts

surrounding climate adaptation exists this research has yet to extend towards SMMs in the same region. As a result, this paper calls for further research in Ontario SMMs climate preparedness. This will help researchers understand and assess Ontario SMMs level of climate resiliency, better understand the needs of SMMs, and provide more accurate analysis in the future.

Tables

Table 4.1: Costs of Climate Adaptation

Infrastructure	Associated Cost
Green Infrastructure: Total 4.5 million CAD	Develop Air Quality Health Index Plan - $100,000 Tree Pruning Program - 500,000 Research and implement green infrastructure such as french drains, dry wells etc.. - 100,000 Protect and enhance management of natural areas to increase climate resilience - 500,000 Investigate potential for natural areas to enhance flood attenuation - 500,000 Enhance linkages of and between natural heritages - 1.0 Million Implement invasive species program - 500,000 Complete urban forest management plan - 500,000 Improve climate resilience of trees in parks and forests - 100,000 Improve community benefit and knowledge of natural areas - 100,000 Incorporate native and drought tolerant plants - 100,000 Decrease public and private contributions to Air quality through promoting and implementing the benefits of green infrastructure - 500,00
Waste Management Systems: Total 120.3 million CAD	Sewer Replacement, upgrades to pumping station and sewers, and rebuilding roads - 90 million Cover road ditches and increase sewer and pump capacity - 30.3 million
Transportation Systems: 4.3 million CAD	Enhance community safety during icy conditions - 1.0 Million Protect and improve roads from overland flooding - 1.0 Million Improve communications from transit to the public - 100,000 Develop extreme weather contingency plans for transit systems - 500,000 Developing and implementing Transportation Master Plans - 100,000 Review and improve policies and procedures to prepare for overland flooding - 500,000 Review, develop, and implement design standards and maintenance practices for road construction and maintenance - 1.0 million Enhance the inspections of roads to assess infrastructure deficiency - 100,000
Water Systems: Total 3.1 Million CAD	Enhance Surveillance of Blue-Green Algae - 100,000 Implement recommendations of studies and protect Water Pump Stations - 1.0 Million Enhance protection of Pollution control plants - 500,000 Complete flood mapping study and implement findings - 1.0 Million Improve Stormwater Design Standards - 500,000
Building & Developments: Total 8.9 million CAD	Continue to protect Indoor Air Quality - 100,000 Enhance the basement flooding subsidy Program - 1.0 Million Promote and Protect Public and Private building standards and maintenance programs to protect from increased cooling demands: 100,000 Incorporate Climate change considerations into infrastructure design development and maintenance - 500,000 Review design and maintenance standards to ensure they meet climate projections - 1.0 Million Explore options for increased Electrical power from Municipal generators to supplement Ontario grid when needed - 100,000 Improve design standards for Recreational Facilities to ensure they are climate resilient - 1.0 Million

	Identify strategies to minimize cancellations of recreation activities at facilities - 1.0 Million Enhance Inspections of special event facilities - 100,000 Replace docks with more climate resilient docks - 1.0 million Enhance the use of low impact developments in both public and private areas - 1.0 Million Consider thermal comfort and Heat levels in Development designs - 1.0 Million Implement community Energy Plan-1.0 Million
Communication Systems: Total 2.1 million CAD	Increase community Knowledge on Climate Change - 100,000 Update community development and health emergency response plan - 100,000 Develop an Extreme emergency response plan for extreme weather events - 100,000 Enhance public education in order to increase resident preparedness for Extreme Weather - 100,000 Develop or Review and update Heat response and alert plan - 100,000 Increase education on how to reduce risk of basement flooding -100,000 Develop a media notification system for extreme weather events - 100,000 Increase Community knowledge on the benefits of natural areas and private trees - 100,000 Improve communication of Transit systems to the public - 100,000 Develop Communications campaign on lot resiliency for residences - 100,000 Enhance communication and knowledge on the impacts of extreme heat on human health - 100,000 Improve collaboration and data sharing with other municipalities within the region to improve climate adaptation and preparedness - 1.0 Million

Table 4.2 Cost Range of Adaptation Per Capita

Population Size	Costs of Climate Adaptation Per Person (Total Cost of 143.2 Million)
10,000 - 20,000	$14,320 - $7,160
20,000 - 50,000	$7,160 - $2,864
50,000 - 100,000	$2,864 - $1,432

Table 4.3: Costs of Extreme Weather Events (Benefits)

Extreme Weather Event	Associated Cost/Benefit
Catastrophic Fire	Fort McMurray Fire, 2016 - The Fire in Fort Mcmurray displaced 88,000 residents, damaged/destroyed 1935 residential structures, 23 commercial and industrial buildings, and destroyed 18,600 vehicles. Estimated total costs were 5.4 billion with the estimated government costs to be approximately 1.2 billion with an additional 368 million in Wildfire fighting costs
Catastrophic Flooding	Essex County Flood, 2016& 2017- Stormawater infrastructure could not handle extreme rainfall causing inundated roads, fields, and dirty sewer water flooding. This resulted in over 6,000 insurance claims with insurance costs of over 153 Million dollars. This is a fraction of total costs as it is estimated Government cost is 3-4$ for every 1$ of insurance costs.A Year later in 2017 a similar rainfall and flooding hit the same region with Insurance payouts of that event totalling 165 million. Two events totalling 318 million in Insurance payouts with the Government cost expected to be 3-4x that amount.

Table 4.4: Summary of Costs and Benefits for Wildfire

Infrastructure Investment	Associated Cost
Buildings/Development Energy Infrastructure	8.9 million
Communication Systems	2.1 million
Transportation Systems	4.3 million
Waste Management	120.3 million
Water systems	3.1 million
green infrastructure	4.5 million
Total investment	143.2 million
Extreme Weather Event	**Associated Cost**
Fort McMurray Fire	1,200 million
Net Benefit	**1061.3 million**

Table 4.5: Summary of Costs and Benefits for Flooding

Infrastructure Investment	Associated Cost
Green Infrastructure	4.5 million
Waste Management	120.3 million
Water Systems	3.1 million
Communication Systems	2.1 million
Building/development and energy	8.9 million
Transportation	4.3 million
Total investment	143.2 million
Extreme Weather Event	**Associated Cost**
Essex County Flooding	318 million
Net Benefit	**174.8 million**

REFERENCES

Amundsen, H., & Dannevig, H. (2021). Looking back and looking forward—adapting to extreme weather events in municipalities in western Norway. *Regional Environmental Change*, *21*(4). https://doi.org/10.1007/s10113-021-01834-7

Bassett, E., & Shandas, V. (2010). Innovation and Climate Action Planning. *Journal of the American Planning Association*, *76*(4), 435–. https://doi.org/10.1080/01944363.2010.509703

Bausch, T., & Koziol, K. (2020). New policy approaches for increasing response to climate change in small rural municipalities. *Sustainability (Basel, Switzerland)*, *12*(6), 1894–. https://doi.org/10.3390/su12051894

Boehnke, R. F., Hoppe, T., Brezet, H., & Blok, K. (2019). Good practices in local climate mitigation action by small and medium-sized cities; exploring meaning, implementation and linkage to actual lowering of carbon emissions in thirteen municipalities in The Netherlands. *Journal of Cleaner Production*, *207*, 630–644. https://doi.org/10.1016/j.jclepro.2018.09.264

Campbell-Gale, H. K., Fletcher, A. J., & Reed, M. G. (2023). "A heart attack away from boarding up Main Street": How neoliberalization of farming shapes adaptive capacity to climate change in rural and small-town Saskatchewan, Canada. *Journal of Rural Studies*, *97*, 365–374. https://doi.org/10.1016/j.jrurstud.2022.12.031

Choryński, A., Pińskwar, I., Graczyk, D., & Krzyżaniak, M. (2022). The Emergence of Different Local Resilience Arrangements Regarding Extreme Weather Events in Small Municipalities—A Case Study from the Wielkopolska Region, Poland. *Sustainability (Basel, Switzerland)*, *14*(4), 2052–. https://doi.org/10.3390/su14042052

City of Windsor. (2020). Degrees of Change: Climate Change Adaptation Plan. *City of Windsor*. https://www.citywindsor.ca/residents/environment/Documents/Climate%20Change%20Adaptation%20Plan%20-%20FINAL.pdf

Deveci, M., Gokasar, I., Mishra, A. R., Rani, P., & Ye, Z. (2023). Evaluation of climate change-resilient transportation alternatives using fuzzy Hamacher aggregation operators based group decision-making model. *Engineering Applications of Artificial Intelligence*, *119*, 105824–. https://doi.org/10.1016/j.engappai.2023.105824

Donoghue, S., & Katz-Rosene, R. (2023). Evaluating the comprehensiveness of municipal climate change adaptation plans in Ontario, Canada. *Regional Environmental Change*, *23*(1), 44–. https://doi.org/10.1007/s10113-023-02036-z

Federation of Canadian Municipalities., & Insurance Bureau of Canada. (2020). Investing in Canada's Future: The Cost of Climate Adaptation at the Local Level. *Federation of Canadian Municipalities.* https://data.fcm.ca/documents/reports/investing-in-canadas-future-the-cost-of-climate-adaptation.pdf?_gl=1*1tdxt5b*_ga*ODgxODUzODk2LjE2OTg3NzMwOTU.*_ga_B4BFFLM1JF*MTY5ODk1MzQ4My4yLjEuMTY5ODk1MzU0OC41NS4wLjA.

Fünfgeld, H., Fila, D., & Dahlmann, H. (2023). Upscaling climate change adaptation in small- and medium-sized municipalities: current barriers and future potentials. *Current Opinion in Environmental Sustainability*, *61*, 101263–. https://doi.org/10.1016/j.cosust.2023.101263

Gaur, A., Bénichou, N., Armstrong, M., & Hill, F. (2021). Potential future changes in wildfire weather and behavior around 11 Canadian cities. *Urban Climate*, *35*, 100735-. https://doi.org/10.1016/j.uclim.2020.100735

Gore, C. D. (2010). The Limits and Opportunities of Networks: Municipalities and Canadian Climate Change Policy. *The Review of Policy Research*, *27*(1), 27–46. https://doi.org/10.1111/j.1541-1338.2009.00425.x

Guyadeen, D., & Henstra, D. (2023). Evaluating rural municipal climate change plans in ontario, Canada. *Journal of Rural Studies*, *97*, 123–139. https://doi.org/10.1016/j.jrurstud.2022.12.008

Guyadeen, D., Thistlethwaite, J., & Henstra, D. (2019). Evaluating the quality of municipal climate change plans in Canada. *Climatic Change*, *152*(1), 121–143. https://doi.org/10.1007/s10584-018-2312-1

Helmreich, B. (2021). Rainwater management in urban areas. *Water (Basel)*, *13*(8), 1096–. https://doi.org/10.3390/w13081096

Henstra, D. (2012). Toward the Climate-Resilient City: Extreme Weather and Urban Climate Adaptation Policies in Two Canadian Provinces. *Journal of Comparative Policy Analysis*, *14*(2), 175–194. https://doi.org/10.1080/13876988.2012.665215

Henstra, D., & Thistlethwaite, J. (2017). *Climate Change, Floods, and Municipal Risk Sharing in Canada*. Institute on Municipal Finance.

Jost, F., Dale, A., Newell, R., & Robinson, J. (2020). Evaluating development path changes using a novel climate action assessment framework in three municipalities in British Columbia, Canada. *Environmental Science & Policy*, *114*, 410–421. https://doi.org/10.1016/j.envsci.2020.09.007

Keating, B., & Keating, M. O. (2013). *Basic cost benefit analysis for assessing local public projects* (First edition.). Business Expert Press.

Klenk, N., Flueraru, D., & MacLellan, J. I. (2017). Experimentalist Regional Governance for Climate Change Adaptation: A Canadian Case Study. In *Climate Change Adaptation in North America* (pp. 51–66). Springer International Publishing. https://doi.org/10.1007/978-3-319-53742-9_4

Kloosterman, R. A., van der Hoek, J. P., & Herder, P. (2021). Resilient Drinking Water Resources. *Water Resources Management*, *35*(1), 337–351. https://doi.org/10.1007/s11269-020-02736-9

Li, L., Uyttenhove, P., & Van Eetvelde, V. (2020). Planning green infrastructure to mitigate urban surface water flooding risk – A methodology to identify priority areas applied in the city of Ghent. *Landscape and Urban Planning*, *194*, 103703–. https://doi.org/10.1016/j.landurbplan.2019.103703

Lioubimtseva, E. (2022). The role of inclusion in climate vulnerability assessment and equitable adaptation goals in small American municipalities. *Discover Sustainability*, *3*(1), 1–16. https://doi.org/10.1007/s43621-022-00071-0

Lowndes, V., Marsh, D., & Stoker, G. (2017). *Theory and Methods in Political Science*, 39-54. https://doi.org/10.1057/978-1-137-60353-1_1

MacIntyre, E., Khanna, S., Darychuk, A., Copes, R., & Schwartz, B. (2019). Evidence synthesis - Evaluating risk communication during extreme weather and climate change: a scoping review. *Chronic Diseases in Canada*, *39*(4), 142–156. https://doi.org/10.24095/hpcdp.39.4.06

Mao, Y., & Thompson, W. (2004). A MULTI-CENTRE APPROACH TO INVESTIGATING THE HEALTH IMPACTS OF EXTREME HEAT AND COLD EVENTS DUE TO CLIMATE CHANGE AND CLIMATE VARIATION IN CANADA. *Epidemiology (Cambridge, Mass.)*, *15*(4), S102–. https://doi.org/10.1097/00001648-200407000-00257

Martinez-Diaz, L. (2018). Investing in resilience today to prepare for tomorrow's climate change. *Bulletin of the Atomic Scientists*, *74*(2), 66–72. https://doi.org/10.1080/00963402.2018.1436805

Mary-Ellen Tyler. (2023). Climate Risk Assessment and Adaptation Considerations for Municipal Governance. *The School of Public Policy Publications (Online)*, *16*(1).

Mehiriz, K., & Gosselin, P. (2016). Municipalities 'preparedness for weather hazards and response to weather warnings. *PloS One*, *11*(9), e0163390–e0163390. https://doi.org/10.1371/journal.pone.0163390

Middleton, C. (2008). Building Wi-Fi Networks for Communities: Three Canadian Cases. *Canadian Journal of Communication*, *33*(3), 419–442. https://doi.org/10.22230/cjc.2008v33n3a2110

Oberlack, C. (2017). Diagnosing institutional barriers and opportunities for adaptation to climate change. *Mitigation and Adaptation Strategies for Global Change*, *22*(5), 805–838. https://doi.org/10.1007/s11027-015-9699-z

Office of the Auditor General of Canada. (2023). 2023 Report 6 of the Commissioner of the Environment and Sustainable Development- Canadian Net-Zero Emissions and Accountability Act - 2030 Emissions Reduction Plan. https://www.oag-bvg.gc.ca/internet/docs/parl_cesd_202311_06_e.pdf

Office of the Auditor General of Ontario. (2019). 2019 Annual Report. https://www.auditor.on.ca/en/content/annualreports/arreports/en19/v2_300en19.pdf

Raoelison, O. D., Das, T., Guyett, K., Merrifield, R., Visweswaran, A., Indiresan, S., Yang, K. L., Pierce, G., & Mohanty, S. (2023). Resilience of stormwater biofilters following the deposition of wildfire residues: Implication on downstream water quality management in wildfire-prone regions. *Journal of Hazardous Materials*, *465*, 132989–132989. https://doi.org/10.1016/j.jhazmat.2023.132989

Robertson, N. S. (2018). Neighbourhood Resilience to Extreme Weather Events: An Assessment Methodology for Canadian Cities. ProQuest Dissertations Publishing.

Siña, M., Wood, R. C., Saldarriaga, E., Lawler, J., Zunt, J., Garcia, P., & Cárcamo, C. (2016). Understanding perceptions of climate change, priorities, and decision-making among municipalities in Lima, Peru to better inform adaptation and mitigation planning. *PloS One*, *11*(1), e0147201–e0147201. https://doi.org/10.1371/journal.pone.0147201

Van Aalst, M. K. (2006). The impacts of climate change on the risk of natural disasters. Disasters, 30(1), 5–18. https://doi.org/10.1111/j.1467-9523.2006.00303.x

Xiao, X., Fu, J., & Yu, X. (2023). Impacts of Extreme Weather on Microbiological Risks of Drinking Water in Coastal Cities: A Review. *Current Pollution Reports*, *9*(2), 259–271. https://doi.org/10.1007/s40726-023-00255-w

Yu, Q., & Li, N. (2023). Assessment of Green Infrastructures Performance for Water Quality Management. In *Environmental Science and Engineering* (pp. 61–68). https://doi.org/10.1007/978-3-031-31289-2_5

VITA AUCTORIS

NAME:	Zakary Blomme
PLACE OF BIRTH:	Toronto, ON
YEAR OF BIRTH:	1998
EDUCATION:	St Paul Secondary School, Windsor, ON, 2015
	University of Laurier, BA., Windsor, ON, 2021
	University of Windsor, MA., Windsor, ON, 2023 (Ongoing)