CONNECTING SUSTAINABLE CITIES FOR THE FUTURE

CIVE 230 Engineering and Sustainable Development

Spring 2021

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David Denison

UNIVERSITY OF WATERLOO | Department of Civil and Environmental Engineering



Vancouver Convention Centre/Vancouver Economic

FOREWORD BY DR. IBRAHIM



Learning about sustainability beyond the classroom and the screens, we looked to the world for inspiration.

The class of CIVE230: Engineering and Sustainable Development have been at it again, online in the remote learning environment in the Spring 2021 term. This is the second COVID-19 edition of the course! Learning about sustainability requires systems-thinking and a curiosity to explore. Teaching sustainability is a rewarding experience when there are learning opportunities created for students so that they may learn from course content, but more importantly to learn from the world around us, and from each other.

The course introduces the concept of sustainability and how it applies to decision-making in engineering. It begins by defining sustainability, both practically and technically. The course deals with sustainability on two levels: first, the qualitative concepts and background information is covered; and next, specific, quantitative models which emphasize core engineering methods are presented and applied to sustainability problems. Quantitative methods and measures of effectiveness are derived and applied to components of sustainability: air quality, water quality, energy and solid waste. Attention is given to sustainable urban systems, as they apply to both developed and developing countries. Sustainability concepts covering the triple bottom line are also presented, and their applicability to sustainable cities are demonstrated. Students in the course were tasked with making a contribution to an e-book. They were creative and innovative in applying course concepts to cities of their choice and exploring sustainability challenges and innovations. Their sustainability project encouraged them to explore sustainable infrastructure, solutions and technologies in Canada and globally to generate an enriched learning experience and to tie ideas to the Sustainability Development Goals (SDG) and the Canadian Engineering Grand Challenges (CEGC).

The sustainability project had 3 parts. Firstly, students selected an environmental problem based on the weekly topic of focus that is observed in a Canadian city, not limited to major Canadian cities, but rather also including towns and communities across Canada from coast to coast to coast. Secondly, they selected a technological or infrastructure solution/ innovation, or policy, or sustainability strategy to address the problem identified earlier and its application in a city around the world. Again, not limited to large capital cities in the world, but also including towns and communities around the globe. Thirdly, they identified a Canadian Engineering Grand Challenge (CEGC) that this problem relates to in the Canadian city selected, and reflected on the important addressing this challenge; and identify which SDG(s) this solution helps address; and reflected on the city-to-city learning that is possible by imaging what one city can learn from the other. I am proud of their contributions. I am proud of the teaching team who ensured this course was smooth sailing, and the class reps who helped throughout, and the online learning assistants who put this e-book together with such skill. I single out David Denison with special thanks for his efforts in making this e-book a reality; he has certainly left his mark on this book. It has been a privilege to teach this course once again during these unique and challenging times, and the experience has been doubly rewarding.

This e-book serves as a contribution by the class for the class, and for the wider UW community. Please read through.
Sincerely,
Dr. Nadine Ibrahim, CIVE230 Course Instructor
Lecturer, Civil and Environmental Engineering and Turkstra Chair in Urban Engineering

FOREWORD BY THE TEACHING ASSISTANTS

Congratulations to all students on your successful completion of the course. This e-book will serve as a memory of our joint achievements and future lessons gained.

In this course, we learned how we could reduce the environmental impact of human activities by supporting creative solutions to global waste, climate change, pollution issues, and mitigating the pressure on natural resources. This course served as a link across subjects such as environmental science, conservation, and economics that are all interconnected.

It was great to meet so many curious and talented students in a course that is significant for our future. Your contributions have created this e-book which is a result of your impactful work. Thank you to everyone involved in the course. This e-book reflects the interest of the students. Each student was allowed to use his or her individual initiative to find the aspect of the research that they found most captivating.

We would like to appreciate the efforts in successfully handling this e-book. The time and effort that our students have put in is much appreciated. We are truly grateful and would like to express our sincere gratitude. We hope that you enjoy the book.

-CIVE 230 Teaching Assistants



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PhD. in Water Quality with Prof. Peter Huck and Prof. Sigrid Peldszus



Shreenita Chhetri
MASc. in Sustainable Pavement with Prof. Susan Tighe & Hassan Baaj.



Ezgi Demircan Ozelcaglayan
PhD. in Wastewater with Prof. Wayne Parker



Aida Mollaei
PhD. in Circular Economy in the built environment with Prof. Carl Haas and Prof.Chris Bachmann

FOREWORD BY THE CIVIL CLASS REPRESENTATIVES

We wanted to congratulate everyone on completing CIVE 230. Learning through the COVID-19 pandemic has been a challenge for everyone. From spending hours on end trying to connect to the Remote Desktop to learning about the wonders of the Mute Function on Teams, this term has been very different from the in-person experiences we so dearly miss. However, something that we can take from this term is understanding how connected we are to one another. Individual issues can instantly become global issues. Hence, it is important that we take steps to ensure the wellbeing of our fellow and future global citizens.

As tomorrow's engineers, we hold quite the responsibility. We must remember that our job is not only to design, but to connect the world. We must understand how the projects we undertake will impact local and global communities. It is our role not only to design for the future, but to maintain and evolve the present work of our predecessors. Climate change is inevitable, yet by adopting adaptive and mitigative strategies, we can ensure that we are building a greener tomorrow.

We wanted to take this opportunity to also thank Professor Nadine Ibrahim as well as the Teaching Team for their dedication towards this course, and for helping us expand our understanding of what it means to be engineers. Finally, the e-book showcases the work of our classmates. Each student had the opportunity to research the topic they found the most intriguing based on their assigned topic. As their representatives, we are beyond proud of what they have accomplished and hope you enjoy reading!

-CIVE ’24 Class Representatives



Adrian Sampson



Harshini Jeevaharan

FOREWORD BY THE ONLINE LEARNING ASSISTANTS

Congratulations to the class of CIVE 230 for completing another challenging online term. As a student, I understand how difficult online terms can be. This allows me to appreciate the hard work that the students put in this term even more. I was very pleased with the quality of the submissions as well as the variety of both topics and locations that the students covered. The topics covered by students in this e-book give me optimism for the uncertain future that we have ahead of us. They show us that even though some cities and communities have problems, other cities around the world have solutions to these problems. While it is easier said than done, these cities can adapt their solutions to help other cities with their problems. This will create a society of sustainable cities in the future. Which is why I chose to title this e-book “Connecting Sustainable Cities for the Future”.

I would like to thank Professor Nadine Ibrahim for everything she has done this term to make this e-book possible, as well as my fellow online learning assistants Vanessa, Jeffery and Colin and my senior online learning assistant Lee as their ideas and edits throughout the term were a big part in creating the final product.

It was a pleasure to be a part of creating this e-book. I hope that we were able to effectively capture the topics covered in CIVE 230 in an engaging manner.

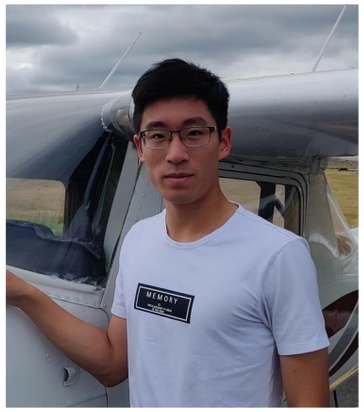
-David Denison, Online Learning Assistant



David Denison



Vanessa Hu



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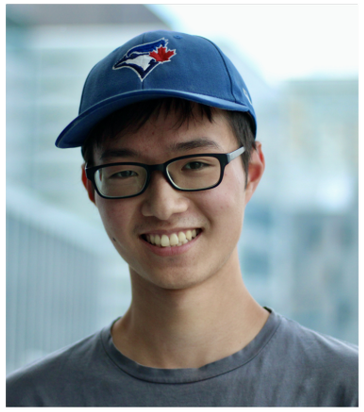

Colin Mende

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PROJECT INTRODUCTION

Connecting Sustainable Cities for the Future is a project created by students in the Engineering and Sustainable Development class (CIVE 230) taught by Dr. Nadine Ibrahim. The project consists of individual submissions from the students enrolled in CIVE 230 during the Spring 2021 term. The project builds on topics covered in the course and allows students to explore sustainable infrastructure, solutions and technologies. The project consists of three parts:



Part A. Canadian City Challenge

Students describe an environmental problem that impacts a specific Canadian city, town or community.



Part B. Global City Solution

Students describe a solution to the problem identified in Part A and how it applies to a global city, town or community.





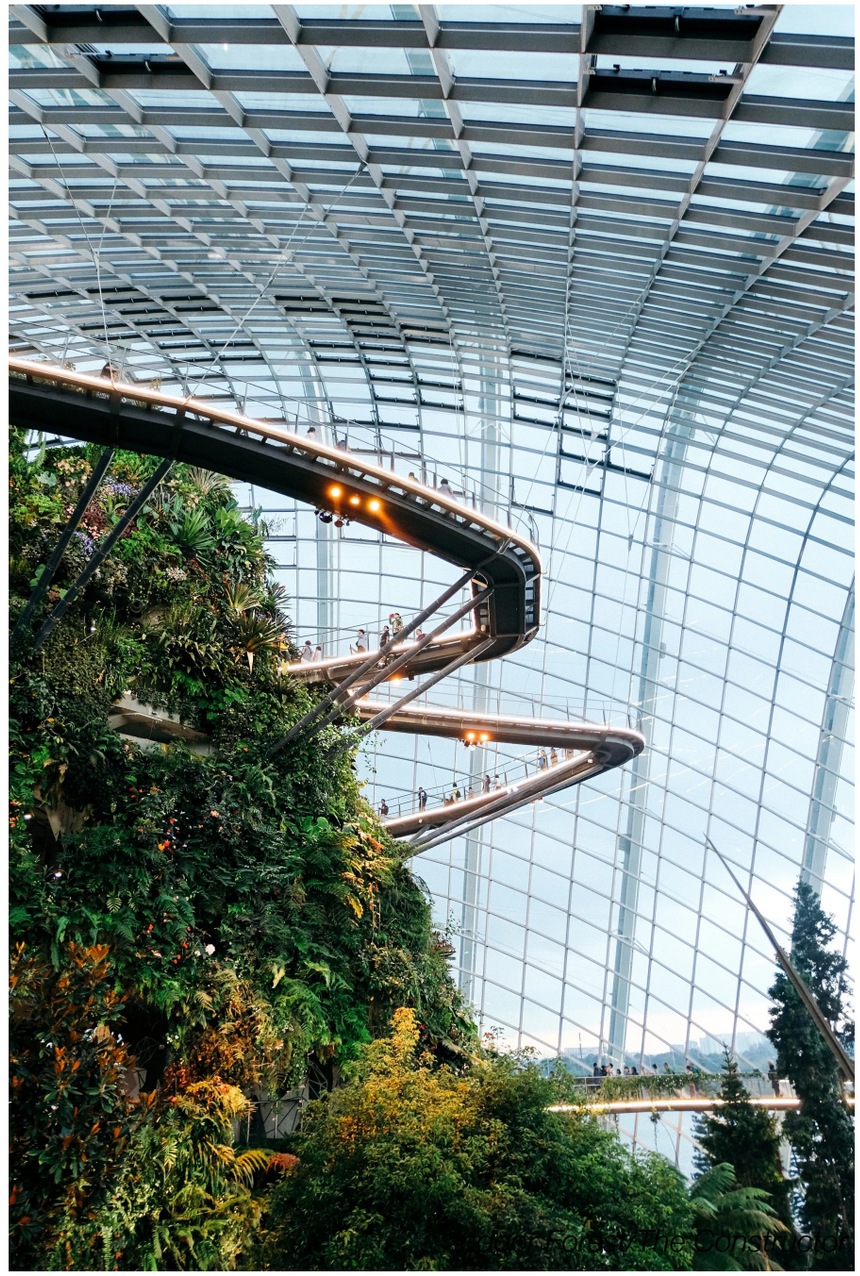


Part C. Connecting to CEGC and SDGs

The Canadian Engineering Grand Challenge (CEGC) that the environmental problem in Part A relates to is identified. The Sustainable Development Goals (SDGs) applicable to the solution are identified and reflected upon. What cities can learn from each other is addressed.

Gardens by the bay/the Constructor

COURSE DESCRIPTION



This course introduces the concept of sustainability and how it applies to decision-making in Civil Engineering. The course begins by defining sustainability, both practically and technically, and describing the concepts of systems and systems interactions. Quantitative methods and measures of effectiveness are derived and applied to components of sustainability: air quality, water quality, energy and solid waste. Attention is given to sustainable urban systems and alternatives, as they apply to both developed and developing countries. Sustainability concepts covering the triple bottom line are presented, and their applicability to sustainability are described. The course deals with sustainability on two levels. First, the qualitative concepts and background information is presented. Next, specific, quantitative models which emphasize core engineering methods (such as probability and statistics, operations research, or simulation) are presented and applied to sustainability problems.

The following topics covered in the course are covered in the project: global atmospheric change including climate change, air pollution and models of air quality, water resources and water scarcity issues, water pollution and methods to improve water, energy - fossil fuels and renewables, solid waste management, sustainable buildings, sustainable transportation, sustainable energy and sustainable water use and urban forests.

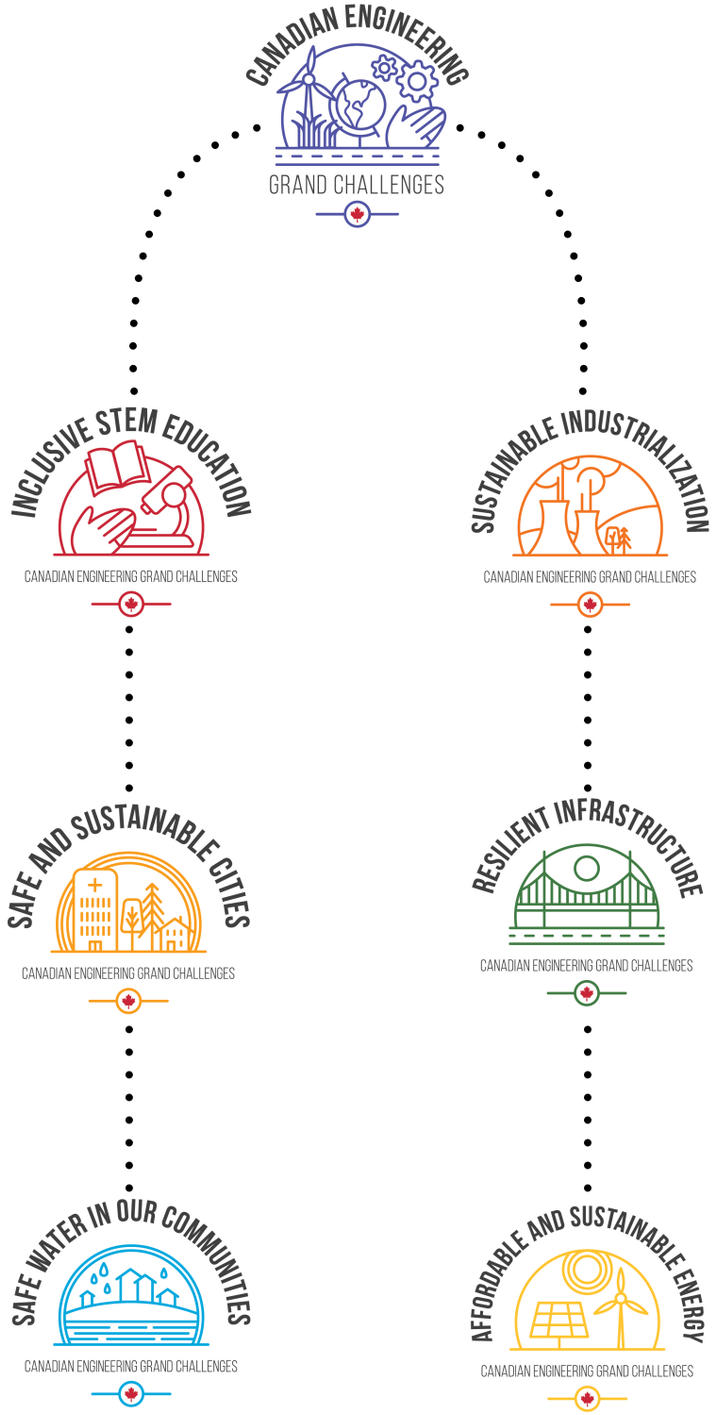
CANADIAN ENGINEERING GRAND CHALLENGE

What are the CEGCs?

Grand Challenges Canada aims to improve and save lives through the use of innovative technology.

Grand Challenges Canada has saved 3700 and improved 7.5 million lives. They have influenced 193 policies and have a 203% leverage rate from investors and partners. Additionally, Grand Challenges Canada supports over 1300 innovations globally, in 106 countries.

In the Connecting Sustainable Cities for the Future project, students identify a problem and which of the six Canadian Engineering Grand Challenges that it relates to. Be it inclusive stem education, sustainable industrialization, safe and sustainable cities, resilient infrastructure, safe water in our communities or affordable and sustainable energy.



SUSTAINABLE DEVELOPMENT GOALS

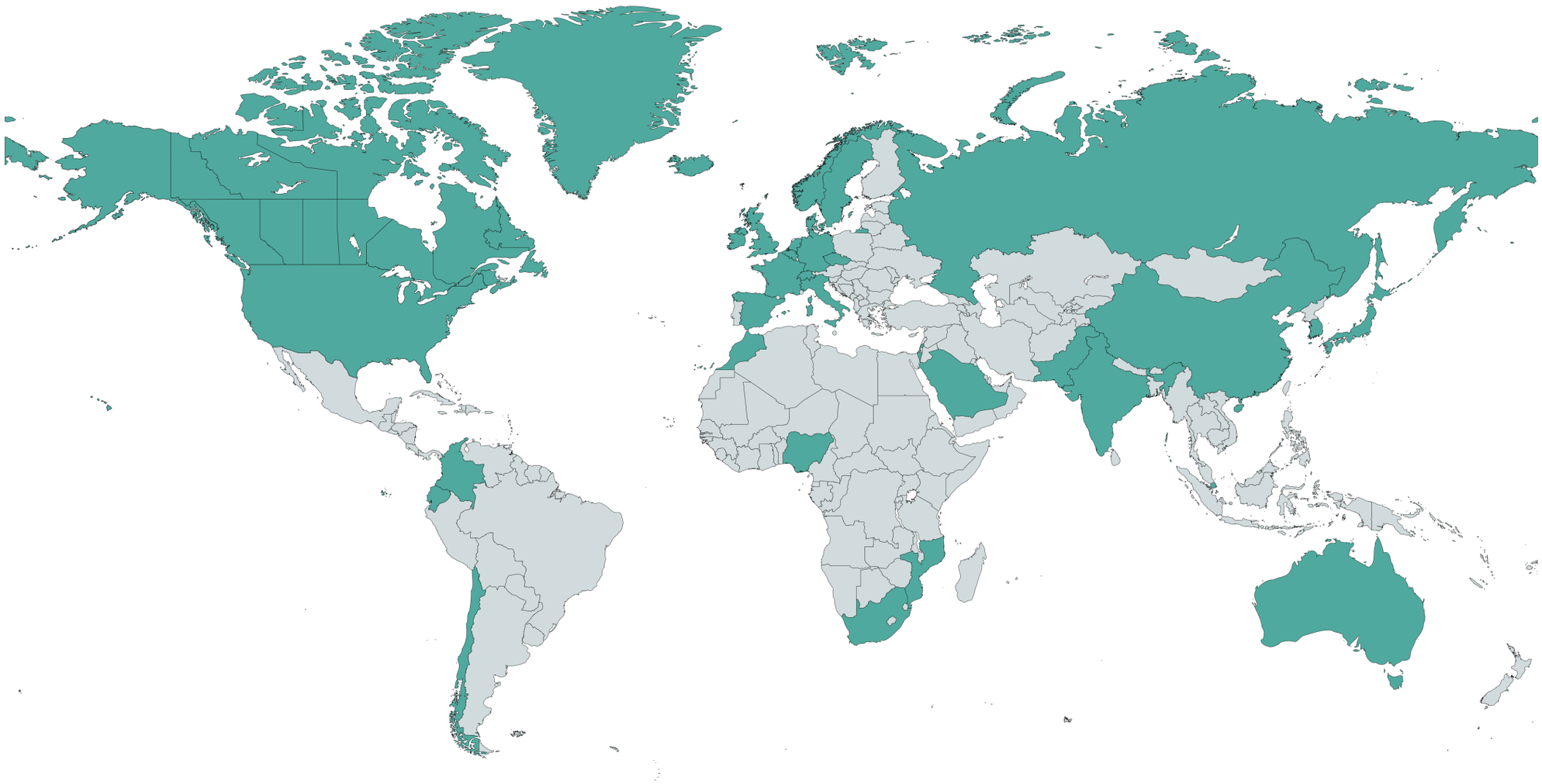
The 17 sustainable development goals are goals set by the United Nations in 2015 to achieve global sustainability by 2030.

In order to achieve global sustainability, all 17 goals have targets, events, publications and actions associated with them. There are a total of 169 targets, 3068 events, 1301 publications and 5432 actions associated with the 17 sustainable development goals.

In the context of Connecting Sustainable Cities for the Future, the SDGs that the global solution addresses are identified. Then the targets of the identified SDGs are reflected upon.



PROJECT MAP



The Connecting Sustainable Cities Project connects 34 countries with 12 Canadian provinces and territories

Additionally it addresses 16 SDGs and 5 CEGCs

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CHAPTER 1: GLOBAL ATMOSPHERIC CHANGE INCLUDING CLIMATE CHANGE



Smokestack/Future of Life Institute

CHAPTER INTRODUCTION

Global atmospheric change in modern history his linked to human activities resulting in releases of greenhouse gas emissions. Climate change is the most important environmental challenge of the 21st Century. This module introduces some climate change related definitions such as radiative forcing, carbon intensity and global warming potential and how they are used in calculating greenhouse gas emissions. The greenhouse gas concepts places global warming within the context of the global energy balance. Examples of climate change impacts are described, and strategies to control climate change is introduced by examples of mitigation and adaptation.

Learning Outcomes

By the end of this week, you will be able to:

- Differentiate between climate vs. weather
- Analyze climate change, Earth's controls and the greenhouse effect.
- Observe the impacts of climate change
- Calculate global temperature
- Determine global energy balance
- Understand radiative forcing
- Calculate carbon in the atmosphere
- Interpret global warming potential (GWP) values
- Use GWP and carbon intensity factors in greenhouse gas (GHG) emissions calculations
- Define mitigation and adaptation
- Recognize the work of the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports, and the Paris Agreement

SIGNIFICANT SNOWFALL

ST. JOHN'S, NL



Snowstorm in St. John's, Newfoundland

"To me, sustainability involves strengthening the needs of our society while compromising to maintain support in other aspects of our world such as the environment."

-Abigail Wong

RESILIENT INFRASTRUCTURE

CANADIAN ENGINEERING GRAND CHALLENGES

Precipitation events are becoming more frequent and extreme as a result of global temperature rise. When cities are unprepared, increased amounts of rain can lead to flooding from inadequate drainage systems being overburdened from runoff. Excess snow can also build up and damage infrastructure if effective mitigation processes are not in place. For cities in close proximity to the coast, the risk of flooding is especially heightened following extreme weather events. Existing systems that are not designed for extreme snow or rainfall will be placed under significant stress. Should these precipitation events have damaging impacts, infrastructure systems including transportation, electricity, communications, water, and buildings may require costly repairs. With these weather events becoming more extreme, cities across Canada are seeing an increase in the amount of rainfall and snow. One Canadian city that is being greatly impacted by climate change is St. John's, Newfoundland. St. John's is located in Eastern Canada, with about one-third of Newfoundland's population living near the city. On a yearly basis, St. John's sees an average of 1191 millimeters of rain and 322 centimeters of snow (City of St. Johns, 2021). This is significantly higher in comparison to other provinces in central Canada, where some cities only experience around 500 millimeters of rainfall annually. In January 2020 approximately 80 centimeters of snow had fallen over the course of one weekend, shutting down power and transportation in Newfoundland (The Guardian, 2020). As the global atmospheric temperature continues to rise, it is expected for cities around the world to see an increase in precipitation events. As for St. John's, Newfoundland, the city will continue experiencing more extreme snowstorms in the winter and more frequent rain events during the rest of the year.

REDUCING RAIN RUNOFF WITH GREEN ROOFS

COPENHAGEN, DENMARK



Green Roofs in Copenhagen, Denmark

What can St. John's Learn from Copenhagen?

With growing urban spaces, the number of grasslands or forested areas are decreasing. Implementing green roofs is one way of integrating vegetation and gardens into local infrastructure where it would not traditionally have the space for it. While St. John's might not benefit from green roofs year long the same way Copenhagen can, due to its changing seasons, the city can find similar solutions to mitigate climate related damages inflicted on infrastructure. As for Copenhagen, although green roofs are aiding with increased precipitation, the city is facing a handful of other climate change challenges, such as increasing temperatures and rising sea levels. Both St. John's, Newfoundland and Copenhagen, Denmark can learn from each other and help withstand the impacts of climate change.

To address the growing problem of frequent and extreme precipitation events, cities around the world are adopting the use of green roofs. These are systems that include planting vegetation on rooftops, allowing for waterproofing and insulation. Green roofs aid in mitigating flood potential, as well as producing other benefits such as reducing greenhouse gas emissions and lowering temperatures from the urban heat island effect. For water events in particular, the average roof retains approximately 26 to 100 percent of rainfall (SFGate, 2020). Most roofs tend to collect over 50 percent of rainfall per weather event, greatly reducing the amount of runoff and preventing occurrences of flooding. Stormwater retention from green roofs is especially beneficial in cities that do not have the infrastructure to adapt or mitigate the risks of extreme precipitation. A city that has implemented green roofs is Copenhagen, Denmark. Copenhagen encounters 728 millimeters in annual rainfall with a significant amount of rainy days throughout the year (Climate Data, n.d.). The city is expected to see water levels increase by 33-61 centimeters within the next decade (European Commission, 2021). Denmark is starting to see an increase of green roofs across the country in order to combat the increase in precipitation. In addition to this, Copenhagen has enforcement in place regarding green roofs. The website Inhabitat stated, "Copenhagen has become the first Scandinavian city to adopt a policy that requires green roofs for all new buildings with roof slopes of less than 30 degrees" (2010). Green roofs in Copenhagen collect approximately 80 percent of rainfall, which significantly reduces the risk of flooding and stress on the city's infrastructure. In the future as green roofs become more frequent, the impacts of climate change will be mitigated.

INDUSTRIAL SECTOR OF CANADA BRACES FOR CLIMATE CHANGE

HAMILTON, ON



Greenhouse Gases from Hamilton Industrial District

“For me, sustainability is the potential for things to be preserved or repeated, thus if something is sustainable it has a repeatable and reliable blueprint or it can be reused. For example, I consider using wooden products sustainable because it can be recycled after usage, and the recycled wood can be turned into other wooden products. This shows that the wooden product can be reused and the process for recycling the wooden product is repeatable and repeatable.”

-Bill Deng

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

Hamilton, Ontario is one of the biggest cities in Canada with a total population of 747,545 as of 2016 (Government of Canada, 2016). Hamilton has the highest greenhouse gas emission in the Greater Toronto area with 15 tonnes/capita carbon emission, which easily eclipses the next closest region, Region of Peel with only 8 tonnes/capita carbon emission. The amount of greenhouse gases produced from Hamilton are predominantly industrial/energy and transportation related, since they account for around 90 percent of all greenhouse emissions within the city in 2017 (Lu, 2017.).

In 2013, the city of Hamilton announced a series of objectives set for 2020, 2030 and 2050 to reduce the emission of greenhouse gas by 20 percent, 50 percent, and 80 percent respectively; this plan uses the year 2005 as the reference (Hamilton, 2021). And by 2050, Hamilton plans to ensure that the amount of greenhouse gas emitted will be less than or equal to the amount leaving the atmosphere. In 2019, it was reported that the original plan from 2013 is currently matching all expectations since greenhouse gas emission has been reduced by 42 percent compared to 2005. (Hamilton, 2021). Despite this, the industrial sector reduced emission by around 34 percent from 2006, which still makes the emission reduction less than the 42 percent average reduction, even when the missing years are accommodated (Rankin, 2019). Furthermore, the transportation sector has seen a slight increase in greenhouse gas emission (Rankin, 2019). Thus, it would be extremely difficult to have a desired greenhouse gas emitted to greenhouse gas released ratio by 2050, when potentially two of the biggest sources of carbon emission categories: industrial and transportation are decreasing at a slower rate than the others.

CLIMATE CHANGE PLAN PAVES FUTURE

STOCKHOLM, SWEDEN



Biomass Power Plant Opened in 2016 Stockholm, Sweden

What can Hamilton Learn from Stockholm?

In order to reduce greenhouse emissions to meet city goals, Hamilton can convert natural gas powered industrial plants to biomass and other renewable energy sources similar to the measures that Stockholm has already taken; Hamilton can also attempt to develop its public transit; for example: expanding its subway systems similar to Stockholm, to dissuade people from using vehicles, thus lowering the emission of greenhouse gases.

Stockholm, Sweden is currently one of the most climate-friendly cities in the world with only around 2.3 (tonnes/capita) of carbon dioxide emission predicted for 2020 (C40 Knowledge, 2016). Stockholm's continued sustainability success can be credited to The Climate Action Plan, which has already implemented measures that decreased carbon dioxide emission and aims to further eliminate non-sustainable and greenhouse gas producing energy generating methods by 2040 (Stockholms Stad, 2020).

Through the contribution of the Climate Action Plan, Stockholm plans to become free of fossil fuel by 2030 (stockholms Stad, 2020), and reduce greenhouse gas emission by 100 percent by 2040 (CNCA, n.d.). Starting from 1990, Stockholm Sweden has effectively lowered carbon emission from 5.4 (tonnes/capita) to around 3 (tonnes/capita) in 2015 (Lönngren & Musabasic, n.d.). This can be credited to policies in the plan such as replacing non-sustainable power plants with sustainable energy sources such as: biomass, hydro, nuclear, and wind, and reducing non renewable, fossil fuel power plants which are still providing around 30 percent of households with energy as of 2015. This alone is equivalent to 2.7 (tonnes/capita) (CNCA, n.d.). Furthermore, Stockholm has continued to cut into the fossil fuel percentage past 2015, through emphasizing and building sustainable biomass power plants, and as of 2019, these power plants supply energy to around 190,000 homes in Stockholm, which is roughly 32 percent of total households in Stockholm which has around 600,000 homes (Lang, 2019). Moreover, Stockholm is also planning to expand its sustainable subway from 25.5 km in 2021 to 40.8 km in 2030 (Zasiadko, 2020), which provides an alternative to driving, thus reducing carbon dioxide emissions in the transportation sector.

SEA LEVELS AT CANADA'S COASTS ARE RISING...



LIVERPOOL, NS



High Sea Levels at Peggy's Cove in Nova Scotia

"I believe the role an engineer should have in sustainable development is that of providing a foundation to which we base our decisions on. Engineers are those who will make technological and research based advancements that will help educate and persuade our decisions to making a more sustainable future."

-Jad Salama

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

As the title states, the sea levels in Canada's coastal cities are rising. With global temperatures rising, the glaciers around the world begin to melt. This increase in volume brings the water level up, thus flooding coastal cities. The other reason the sea levels rise is due to the water expanding with an increase in temperature. Though such a small temperature increase of the ocean does not seem detrimental, is will expand the already large volume of the ocean by a large margin, therefore allowing the sea levels to rise even further. Currently, in the coasts of Nova Scotia, the sea levels are predicted to rise an average of seventy-four centimeters in the next eighty years (Donovan & Weikle, 2020). This almost one-meter sea elevation change would greatly impact the coastal cities in Nova Scotia such as Lunenburg, or Liverpool. There would likely be major floods destroying infrastructure in the city as well as major damages to water management systems due to the overwhelming volume of water the systems would have to endure. Liverpool, a small town with an approximate population of twenty-seven-hundred people (Peterson, 2012), is currently experiencing the side effects of rising sea levels as many of the coastal buildings fill with water with even roads along the shore disappearing during major storms. If the sea level were to rise a whole meter, large amounts of these cities would disappear, and many communities would have to relocate as their whole neighborhood becomes submerged under the ocean.

ARE DIKES THE TEMPORARY SOLUTION TO RISING SEA LEVELS?

RIBE, DENMARK



Northern Sea Dikes Protecting the Coastal City

What can Liverpool learn from Ribe?

The combat of rising sea levels also relates to goal 13, the combat of climate change and its impacts. If Canadian coastal cities were to construct dikes, they would first have to extend the land into the sea as many homes and buildings are built directly next to the water.

The problem of rising sea levels affects almost every coastal city around the world. This is a problem that will not be resolved without resolving the larger issue of climate change. Though in the short-term scheme of things, Engineers are finding solutions to combat the side effects of climate change until a solution for the root problem is found. Denmark's city Ribe has been always had issues with flooding due to rising sea levels as they located on marshes and are close to the north pole where many ice caps are melting. To minimize the effects on the city, the city and its neighboring cities have constructed a dike along the coast to counter the rising sea level and floods. A dike is an embankment wall or ditch used to retain or prevent flooding. The dikes walls allow the water level to increase in elevation without entering the city whereas the dike ditches are used to capture water, thus bring the water level down. Dikes of this size are meant to withstand highly unlikely storms and therefor protect the cities and towns for most of the time. The Ribe dikes are built at the coasts of many Denmark cities, including Ribe, a small town at the coast of Denmark with a population of about nine thousand people (Population 1. January by Urban and Rural Areas, Population, Area and Population Density and Time, 2021). These dikes being reinforced will further increase the safety that the citizens of the town feel.

STRUGGLE WITH EXTREME WEATHER:

ST. JOHN'S, NL



A residential neighbourhood in St. John's Newfoundland after Hurricane Isaac

St. John's is the capital of Newfoundland and Labrador in Atlantic Canada and is the easternmost city in the North American continent (St. John's, Newfoundland and Labrador, 2021). According to the 2016 Canadian census St. John's is the 20th largest metropolitan city in Canada with a population close to 110,000 (St. John's, Newfoundland and Labrador, 2021). Two projections for the climatical impact in St. John's are that the average daily temperatures will be rising by 4.8°C by the year 2080 with sea levels increasing by 75 to 100 centimetres by the year 2100 (Mercer, 2020). These climatical changes can have a catastrophic impact on wildlife threatening approximately 40 bird species and endangering the caribou to access food (Winter Sea Ice). The deadliest impact Climate Change has had on St. John's is the increase in frequency of powerful storms such as hurricanes hitting the city (Mercer, 2020). According to scientists, precipitation is forecasted to increase by 7% by 2050 and 9% by 2080's with winter being milder and with less snowfall (Mercer, 2020). 24-hour storms taking place on average once every century is set to becoming a quarterly annual occurrence by the year 2050 (Mercer, 2020). Last year, Environment Canada meteorologist Bob Robichaud predicted between 19 to 25 storms from an average of 12 every season (What are El Nino and La Nina, 2020). The potential increase is due to La Nina meaning "cold event" which leads to warmer waters in the Atlantic Ocean due to the trade winds being stronger than usual (US Department of Commerce, 2009). In 2010 Hurricane Igor, a Category 4 Hurricane destroyed the city with damages over $200.5 million and researchers predict more severe storms to pass the city in the future years (Hurricane Igor, 2021).

"For me, sustainability means to use natural resources in a sparse manner and at the rate that nature can reproduce the same amount itself without depleting any resources. Sustainability means being green and eco-friendly by perhaps avoiding the use of fossil fuels by walking, using public transportation or purchasing electric vehicles."

-Simran Nag

RESILIENT INFRASTRUCTURE

CANADIAN ENGINEERING GRAND CHALLENGES

HOUSTON'S FIGHT FOR SURVIVAL WITH SEA WALLS:

HOUSTON, UNITED STATES



Houston, Texas Flood Gates

What can St. John's learn from Houston?

Cities such as Iowa are having scientists forecast the amounts of rainfall annually through historical and projected data and conduct an analysis on transportation infrastructure that will be at risk in the future. In Mississauga, Ontario the Credit Valley Conservation Authority designed their watershed to retain rain especially during heavy rainfalls and threats to flood (Venema, 2017). With this new technology, annual runoff was reduced by approximately 80% (Venema, 2017). Netherlands is reshaping their landscape to expand area of the rivers since they are 30% below sea-level and therefore 30% more susceptible to flooding (Venema, 2017). Through these examples' cities can learn new technologies and techniques to adapt to the effects of Climate Change (Venema, 2017).

Houston, Texas is often being threatened with destructive hurricanes between the spring and fall months of the year. One of the most recent and catastrophic storms was Hurricane Harvey bringing down 43 inches of rain in the city. Scientists suggest that due to climate change, hurricanes are only going to intensify the damage and increase in frequency each year. Due to this coastal cities such as Houston, Texas have to face the inevitable and adapt to the severe weather conditions in the future. Clear Lake City located approximately 20 miles from downtown Houston have reconstructed their golf course into five detention pools which will be able to store approximately a billion gallons of stormwater (Garfield, 2017).

This will enable to save approximately 2,000 homes in an event of a hurricane and prevent water pipes from not being overwhelmed with the water pressures and buildup (Garfield, 2017). In order to protect endangered wildlife especially the native birds, butterflies, and flora, approximately 5,000 trees were replanted (Garfield, 2017). According to researchers, wetlands are areas which behave as sponges to help absorb excess water on the ground and would be benefitable to prevent against flooding (Garfield, 2017). In addition to this, to help protect downtown Houston, a five-mile ring of parkland will be designed to help absorb the stormwater (Garfield, 2017). In the future to prevent and adapt to the severe hurricanes from causing catastrophic damages The Army Corps of Engineers adopted the plan known as the Coastal Texas Protection and Restoration Feasibility Study (Cusick, 2020). The plan incorporates a network of sea walls, surge gates, vertical lift gates and a ring barrier around the Galveston Island along with a beach and dune restoration stretching 70 miles of the coastal line (Cusick, 2020).

THE MELTING OF ICE: WARNING FOR THE REST OF THE WORLD

RESOLUTE BAY, NU



A Brighter, Warmer Arctic

"When I think of the word sustainability, I think of environmental sustainability. So to me personally, this sustainability means that I should strive to live in a manner that ensures that the world I leave behind for my children is a world that is still abundant with natural resources."

-Joy Jiayi Lin

RESILIENT INFRASTRUCTURE

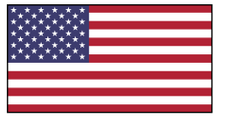
CANADIAN ENGINEERING GRAND CHALLENGES

Resolute Bay, a northern community located in Nunavut, Canada, boasts of its abundant wildlife and winter activities. Like many cities around the world, Resolute Bay is facing the impacts of climate change. The city suffers from the melting of the arctic ice and the warming of permafrost which has significantly impacted traditional activities and the overall community.

Resolute Bay's economy and culture are largely centered around hunting and fishing, but global warming has shortened the window for both activities because the ice takes longer to freeze. This results in lack of game that affects food security and income. For instance, the poor ice conditions resulted in the narwhal harvest being only 18% of the previous 4 years (Ford, 2007). Caribou numbers have also significantly declined because of the increased frequency of winter freeze-thaw cycles, resulting in a lack of accessibility of forage beneath the winter snowpack (Gunn, 1993). The unusually hard icy snowpack during early winter has created unfavorable foraging conditions, leading to a 97% decrease in caribou from 1994 to 1995 (Ford, 2007). Additionally, it is predicted that sea ice thickness will continue to decrease by an average of 50cm by the year 2100 which will posed safety hazards for hunters who have always travelled on ice.

The increase in temperature also contributes to the warming of permafrost, imposing risks to infrastructures like roads and buildings. This is because the increase in temperature reduces the ground surface, thereby making infrastructures unstable, and causing erosion and landslides. The melting permafrost have also introduced mercury levels into the lakes within the community, which in return contaminates humans through the consumption of food. The realities of global warming at Resolute Bay should serve as a stark reminder that the world must come together to revert the cycle before it's too late.

THE FUTURE IS ELECTRIC



NEW YORK CITY, UNITED STATES



The Eco-friendly way of getting around

What can Resolute Bay learn from New York City?

Resolute Bay can learn the importance of documentation and setting deadlines from NYC. NYC has specified deadlines for major milestones in their sustainability plan and closely monitors its gas emission numbers on the NY State Energy Research & Development website. The advantage of doing both can help guide the city and keep itself accountable to their goals. One thing NYC can learn from Resolute Bay is to involve its people more throughout the sustainability planning process. The smaller city often listened to what its people have to say and regularly incorporated their feedback. This ultimately enhances collaboration and teamwork within the community which is proven to be more effective when achieving goals.

Gas fueled vehicles have always been a major concern for many people due to the mass emission of greenhouse gases that contribute to global warming. One global city, New York City, is known for being the definition of city life – of excitement, endless possibilities, and all the nuances of a bustling metropolis. 18 million people call this city home, and according to 2016 statistics, each person's carbon footprint from their daily commute averaged to around 8 metric tons per person a year. Currently, Transportation by car accounts for 60% of the transportation pollution in New York. In 2020, 37.5 million gallons of fuels were burned via busses. Acknowledging the devastating effects that diesel fuel vehicles have on the world, the city launched the campaign "Destination: Zero Carbon" in which the city strives to convert the entire transportation system to run on electricity by the year 2035. This requires technological innovation within the manufacturing industry to create more sustainable means of transportation via electricity. New York is on its way to implementing this solution by investing billions of dollars in technology development and has already converted 45% of its diesel buses to electric. Additional innovations include the development of energy storage, vehicle to grid technology, and smart charging, which subsequently makes electric vehicles more appealing and accessible for people. In 2021, the NYC Transit announces that if technology continues to advance at the same rate, it can "meet its goal of a full electric fleet well before 2040" (Guse, 2021). Additionally, the city launched a Drive Clean Rebate Program that resulted in 25,000 new purchases of electric vehicles in just one month. Through various financial incentives and tax credits like this, more people are encouraged to adopt a newer means of transportation.

RISING TEMPERATURES

CAMBRIDGE BAY, NU



Effects of Global Atmospheric Change in Cambridge Bay, Arctic Region (in Canada)/ Prokosch

“Sustainability to me, means to maintain a balance between the resources we consume and contribute for future generations. In other words, ensuring that along with our current needs being met, it is also important to ensure that the needs of future generations are also met."

-Bhoomika Sood

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

The concern for the effects of the changes in the atmosphere are ever growing. The most challenging environmental concern is in regards to climate change. Some drawbacks of climate change in the Arctic region lead to the thawing of permafrost. When permafrost thaws, the ice inside the permafrost melts, leaving behind water and soil and as a result can have dramatic impacts on earth and living beings. Thawing permafrost can destroy houses, roads and other infrastructure, and also release greenhouse gases like carbon dioxide and methane to the atmosphere (Doyle, 2021).

Along with climate change, another major concern is the increasing concentrations of carbon dioxide in the atmosphere due to global warming. High concentrations of carbon dioxide in the atmosphere can harm human health. Some causes of global warming include combustion of fossil fuels which can lead to increases in air pollutants, acid deposition, and exposure to ultraviolet (UV) radiation (Piver, 1991).

Cambridge Bay is a hamlet situated in Victoria Island in the Nunavut region of Canada. It has a population of 1,766 and is the largest settlement on Victoria Island. In the Arctic Ocean’s Northwest Passage, also considered the Canadian Internal Waters, Cambridge Bay is the largest stop for passenger and research vessels that are travelling through (Huebert).

The Cambridge Bay area used to be a traditional hunting and fishing location. Some archaeological sites can still be found. The barren-ground caribou, muskox, arctic char, lake trout and ringed seal are the primary prey, and remain important food sources to this day(Ovayok Territorial Park). Tourist cruises are the most commonly seen passenger ships in the Northwest Passage nowadays. For other modes of transportation, there is an annual sealift owned by Arctic Co-operatives Limited that allows people to travel (Northern Transportation Company, 2013). Cambridge Bay usually records temperatures ranging from 10 °C as the highest to constant periods of below freezing temperatures for most part of

PLAN TO FIGHT CLIMATE CHANGE & GLOBAL WARMING

TOKYO, JAPAN



Tokyo, Japan shutting down use of coal-fired power plants to reduce harmful gas emissions./Ibrahim

What can Cambridge Bay learn from Tokyo?

Cambridge Bay and Tokyo both are experiencing the impact of atmospheric change and climate change, but have slightly different approaches to fight against it. Cambridge Bay focuses more on the impact it has on infrastructure, transportation along with human well being, whereas, Tokyo focuses more on air pollution, reducing the emissions of greenhouse gases, and saving energy. Based on Cambridge Bay's location, as it is part of an arctic climate, some strategies that are applied in Tokyo might not be relevant due to the different environments, although it can learn from Tokyo's strategic plan in regards to saving energy. Tokyo, on the other hand should give more importance to planning out infrastructure as climate can have a lasting impact on infrastructure. Both cities can learn a few strategies that are relevant and will help combat the negative impact of climate change.

In order for Tokyo to address the problem of climate change and global warming, it has to implement the following measures: firstly, set ambitious GHG reduction targets such as 40-50% reduction by 2030 and net-zero emissions by 2050, secondly, radically reform current coal-fired power policy, including stopping construction of new coal-fired power plants, and discontinue providing financial assistance for the construction of coal-fired power plants abroad, and thirdly, to introduce full-fledged carbon pricing. Tokyo needs to set these goals in order to transition into a zero-carbon society. Another solution that will address the problem of global atmospheric change is implementing changes to Tokyo's current Energy Basic Plan. According to the current Fifth Strategic Energy Plan, power sources in 2030 will be 26% coal-fired power, 22-24% renewable energy, and 20-22% nuclear power. Coal-fired and nuclear power plants have large numbers and renewable energy is too small. In the sixth revision, these figures must be drastically changed to increase renewable energy and reduce dependence on coal and nuclear (Matsushita, 2020).

Another strategy implemented by the government in Tokyo is the Joint Credit Mechanism (JCM). The JCM strategy will work on promoting the use of low-carbon technologies, products, systems, services and infrastructure to help reduce greenhouse gas emissions in a quantitative manner (Mizuno, 2013).

Tokyo is the capital city of Japan and also the political and economic center of the country. It has a population of over fourteen million residents. Tokyo generally experiences hot, humid summers and cool winters. Tokyo falls in the urban landscape and accounts for a major part of Japan's industrial sector. Tokyo is an example of an 'urban heat island', which essentially means that due to the release of greenhouse gases, air temperature has increased resulting in global warming. In order to counter this issue, Tokyo has implemented an 'emissions cap system' to reduce the greenhouse gases being released into the atmosphere. Another measure that was taken was to build roadside trees and plan to

ATMOSPHERIC CHANGE

TORONTO, ON



Gas Emissions at a complex in Toronto, Canada.

“Sustainability means to meet the societal needs of today, while preserving the environment for future generations.”

-Kirellos Khalil

AFFORDABLE AND SUSTAINABLE ENERGY

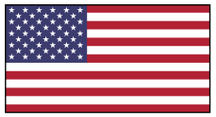
CANADIAN ENGINEERING GRAND CHALLENGES

Toronto’s atmospheric air quality has been on a decline as pollutants make their way into the atmosphere. Toronto is a major metropolis area and serves as the capital of Ontario. The greater Toronto and Hamilton area account for 44 per cent of Ontario’s global greenhouse gas emissions. In 2018, Toronto released 16.2 mega tonnes (MT) eC02 of greenhouse gases into the atmosphere. Examining the data further, we can attribute 55 % of the greenhouse gas emissions to heating and running buildings – both commercial and residential. Most of these buildings are powered using natural gas. Breaking down the data further, another 36 percent of the greenhouse gas emissions comes from transportation, with 80% of the transportation being personal vehicles. The remaining 9 percent are a result of our waste – originating from landfills in the city and the surrounding areas. The human cost of living with these pollutants day in and day out is 1,300 premature deaths and 3,550 hospitalizations, per year.

It is important to note that a slight increase in our energy consumption results in an unproportionate increase in the greenhouse gas emissions. A study published by The Atmospheric Fund finds that a 4.8 per cent increase in our electricity consumption resulted with a 57% increase in electricity related emissions. As the city of Toronto continues to support its growing population and infrastructure it is important to look to transition to more ecologically friendly power sources, to preserve the atmosphere for future generations.

Greenhouse gases have catastrophic global effects. Greenhouse gases acts as a catalyst for climate change; by trapping heat they accelerate global warming. Global warming has catastrophic effects like extreme weather, increased wildfires, and stronger more frequent natural disasters.

RENEWING THE ENVIRONMENT WITH RENEWABLE ENERGY



BURLINGTON, UNITED STATES



7 AFFORDABLE AND CLEAN ENERGY

Winooski One Hydro Plant in Burlington, Vermont.

What can Toronto learn from Burlington?

Toronto can learn from Burlington and commit to a 100% renewable energy future.

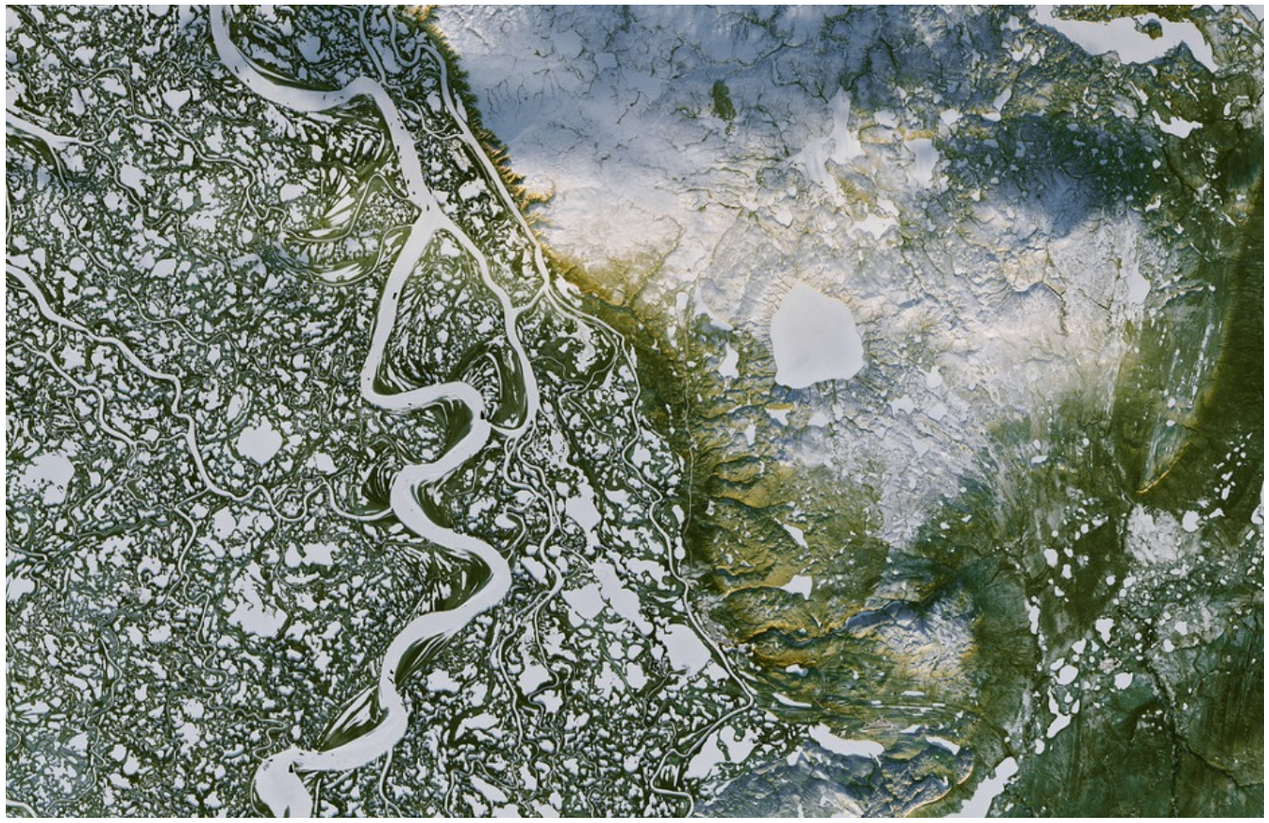
Despite the popularity of fossil fuels worldwide, some cities have been able to make the switch to 100% renewable energy. Burlington, a small city of some 42 000 people located in Vermont, USA has steadily incorporated renewable energy into their power grid. This started back in 1978 when the town replaced an aging coal mine with a 50-megawatt biomass generating station. A coal station produces 888 tonnes of CO2 emissions per GWh compared to a biomass generating station which produces 45 tonnes of CO2 emissions per GWh. A biomass generating station combusts biological material (e.g., wood) to heat steam which is them pushed through a turbine to create electricity. A key part of the process is replacing the biological material used through the planting of new trees, a practice which Burlington follows.

Burlington also has a series of cell arrays across the city, they use solar energy in their high school, airports, and the Burlington Electric department. Solar panels work by utilizing a photovoltaic array

to harness photons and excite atoms. This results in a flow of electrons, generating an electric current.
Burlington also has a 10-megawatt wind farm. Solar energy and wind energy produce 85 tonnes of CO2 emissions/GWh and 26 tonnes of CO2 emissions respectively. For reference, Toronto's primary source of electricity, natural gas, produces 499 tonnes of CO2 emissions/GWh. Burlington is coupling their renewable energy with infrastructure to support electric transport through charging stations; an option Toronto can utilize considering that 80 % of transport related pollution comes from personal vehicles. In 2014, Burlington made the switch to 100 per cent renewable power with the acquisition of the 7.4-megawatt Winooski One Hydro Plant.

A SONG OF FIRE AND ICE: YELLOWKNIFE'S PERMAFROST PROBLEM

YELLOWKNIFE, NT



Mackenzie River's permafrost is melting. This river feeds into Yellowknife's Great Slave Lake

"Sustainability means consistent cyclical patterns that we (as a society, engineer, group, individual) can predict and use to create designs that benefit a stakeholder. This means thinking on long term designs that will require little investment or predictable investments in the long run."

-Eli Lee

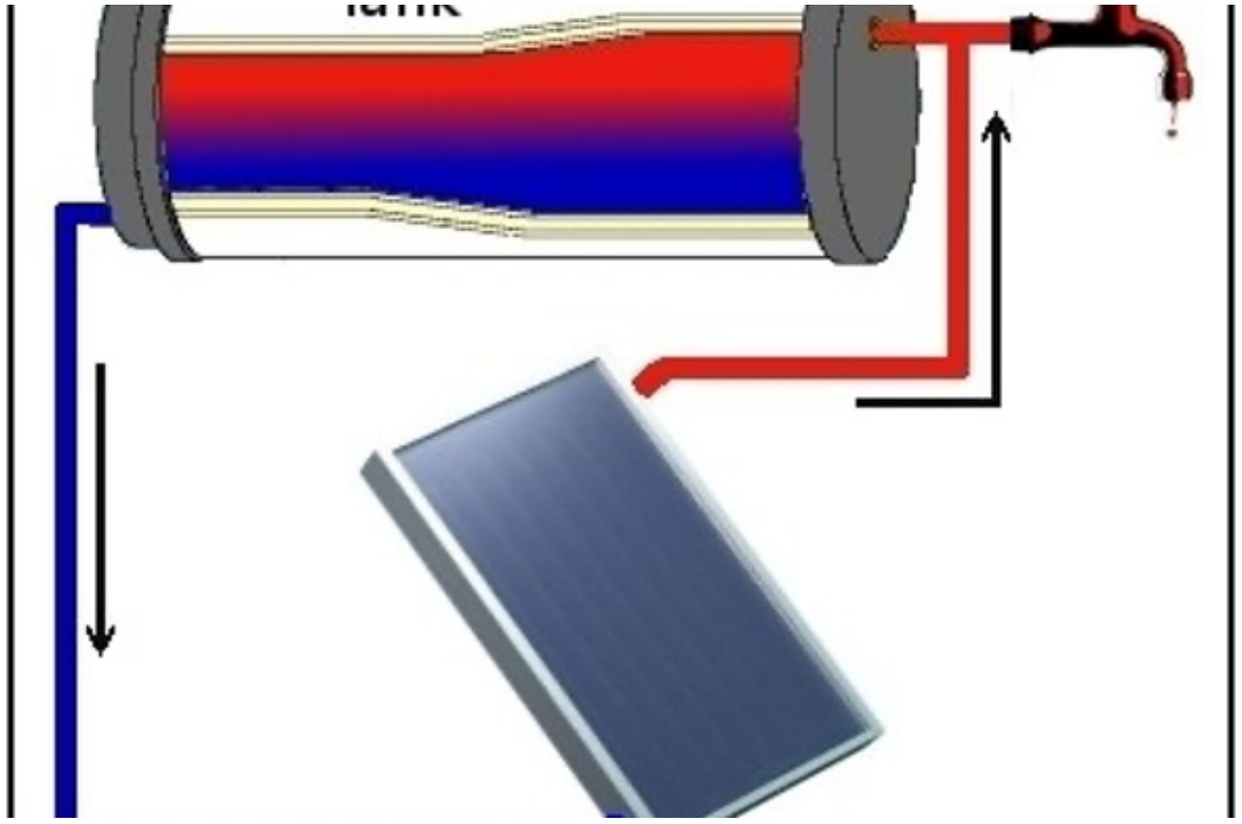
RESILIENT INFRASTRUCTURE

CANADIAN ENGINEERING GRAND CHALLENGES

For decades, the accumulation of greenhouse gases in the Earth's atmosphere has led to climate change leading to rising average global temperatures. One of the most sensitive regions to increasing temperatures has been in located in Canada's Northern territory city of Yellow Knife. As Yellow Knife is in a discontinuous permafrost zone, experts have begun to ponder the possibility of the melting of these permafrost zones around these areas. This is harmful to the environment because Permafrost has many trapped greenhouse gases in the soil. If these areas melt, then millions of tons of permafrost will be released into the atmosphere that will only accelerate climate. Not only are there damages to the environment but there are also damages to the economy as well. In fact, problems arising from permafrost has already cost the Northwest Territories a hefty 51 million dollars. Arctic region's maintenance and creation of infrastructure already faces major challenges due the nature of the climate; however, as permafrost becomes frost and might possibly become none, roads, pipelines, and buildings are suffering from these effects of uneven soil and unpredictability of the thawing discontinuous permafrost zone. Indeed, it can be concluded that melting of permafrost is not only costly to the environment, but also costly to the economy of the Arctic as well. With necessities such as groceries and fuel already being high in Northern Canadian communities, Permafrost melts could heavily shift northern communities from an unforgiving climate to an unlivable one.

DANCING WITH SPRING: THE THERMOSIPHONS

FAIRBANKS, UNITED STATES



Design of Thermosiphon used in Arctic Climates

What can Yellowknife learn from Fairbanks?

The social development goals that are most relevant to thermosiphons are Infrastructure, climate change, cities, and sustainable production. Thermosiphons are key components of Fairbanks' infrastructure and will positively impact cities and create more sustainable production of security. This is a direct response to the scientifically proven effects of climate change. Yellow knife can reflect on Fairbanks' practices by not only improving on existing infrastructure such as in pipelines that run across the north, but also implanting these designs in the everyday services in communities. This includes things such as using thermosiphons in utility infrastructure, foundations, and roads. Although the use of this technology in public works is at an infancy, the simplicity of the innovation creates a low barrier for entry in the form of low start up costs and low maintenance costs. Thermosiphons are a simplistic way for Arctic Cities to become more resilient.



Being right by the Arctic Circle, the Alaskan city of Fairbanks has had to implement innovative solutions to combat the effects of climate change. Indeed, rather than complex systems with expensive budgets, this simple solution seems to embody the elegance that may be needed to improve infrastructure resiliency in times of global warming. Fairbanks, like other Arctic cities seems to be suffering from permafrost melting and consequently, costly repair and maintenance of existing and future infrastructure. However, Fairbanks' infrastructure has seemed a major technology that will drastically decrease climate change impact. This one technology is called the Thermosiphon. Traditionally, Thermosiphons have been used in costly but profitable oil pipelines in Arctic infrastructure to minimize long term costs such as repairs. Engineers in the University of Alaska Fairbanks Campus have begun to implement these designs into not just pipelines, but also potentially to utility poles and foundations for structures. Thermosiphons work by having large containers of gas that is non powered and buried into the ground. When temperatures warm, this closed container of gas carries heat from the ground and dissipates heat into the air. Conversely, during winters, these containers of gas will liquify and keep the cold in the ground as well. Thermosiphons help stabilize permafrost temperatures. Indeed, rather than expensive alternatives such as deeper foundations, thermosiphons could be implemented in at-risk Arctic Regions to improve climate change resistance. In an area as unforgiving as the Arctic, life has always found a way to survive and using thermosiphons, life will continue to do so.

GONE WITH THE FLOOD: IMPENDING DOOM FROM FLOODING.

RICHMOND, BC



Fraser River (n.a.,2014)

“In my opinion, sustainability can be thought of as the ability to manage different actions and their consequences. This includes how frequently the action is performed and how much/ what damages are caused. To be sustainable is to prevent irremediable damage to our surroundings and environment.”

-Stanley Lee

RESILIENT INFRASTRUCTURE

CANADIAN ENGINEERING GRAND CHALLENGES

Climate change has become a growing issue throughout the years with no signs of stopping. As the average global temperature reaches record highs, more extreme weather conditions and natural disasters have begun to emerge. Flooding and sea-level rise, for example, are direct consequences of climate change. The increase in average global temperature has caused icecaps and glaciers to melt, thus raising the sea level. It is estimated that the global sea level rises approximately three millimeters per year. (Tabari H, 2020) In turn, flooding has become more common throughout the years. This proves to be a serious issue for coastal cities as they are at the greatest risk for floods.

Richmond is located along the west coast of Canada and has a population of over 200,000 (Zeidler, 2020). The city has a very low elevation is surrounded by the Fraser River (Zeidler, 2020). By 2050, it is estimated that local sea levels will increase by 50 cm and the greater Richmond area will receive 10 percent wetter climates (City of Richmond, 2018). As sea levels and precipitation increase, the tendency for floods will follow suit (City of Richmond, 2018). The rivers surrounding Richmond also act as a potential source of flooding as climate change will cause river levels to increase (Zeidler, 2020). Metro Vancouver (2016) believes that Richmond is at the largest risk for flooding and that the City’s infrastructure is insufficient to deal with increased flooding from climate change. Since a large portion of the city's elevation is close to sea level, flooding can be caused under windy conditions or high precipitation (Metro Vancouver, 2016). This is further enhanced by climate change and these phenomena will occur more often and at a higher severity (Metro Vancouver, 2016).

ROTTERDAM HOLDS THE DOOR: SOLUTION TO FLOODING

ROTTERDAM, THE NETHERLANDS



Maeslantkering (Simonfi, 2010)

What can Richmond learn from Rotterdam?

Although a controllable storm barrier may not as effective for preventing floods in Richmond, many aspects of Rotterdam's solution can still be applied. A key takeaway is to design a solution that is sustainable according to the triple bottom line. The Maeslantkering barrier protects the city from floods without impairing the local lifestyle, environment, and economy. Richmond would benefit greatly if they were to follow the same principles.

Within the Netherlands, many coastal cities are at risk of flooding. A major city with the area would be Rotterdam. A large river and multiple smaller rivers run throughout the city, making it especially prone to flooding during high tide (Teichner, 2017). The city is a major economic and logistics center and has a population of over 600,000 (Council of Europe, 2016). Much like Richmond, rising sea levels pose a threat to an already flood-susceptible city. The city's economic standing makes the areas especially valuable and would cause severe damage to the supply chain in the Netherlands if damaged (Teichner, 2017).

Fortunately, a solution has already been successfully implemented to help control flooding from climate change and rising sea levels. Between 1991 and 1997, the Maeslantkering Storm Surge Barrier was specifically constructed to protect Rotterdam and neighboring cities from flooding (Teichner, 2017). The barrier is part of the Delta Works project, a series of sea barriers across the Netherlands, and can support over 350 Mega Newtons of force (Gelder, P. et al, 2012). The Maeslantkering barrier allows for control over how much water passes through by opening and closing itself when necessary (Gelder, P. et al,2012). Similarly, this allows ships and wildlife to pass through without obstruction (Teichner, 2017).

With the growing risk of floods from rising sea levels, the Dutch government intends to use the barrier more frequently. According to Zhong, H. et al. (2012), the Maeslantkering barrier can prevent floods at elevated sea levels. The barrier is capable of withstanding elevated water levels of up to 4 meters and can partially redirect the water away from the city. Zhong, H. et al. estimate that the barrier can extend the return period of floods from 141 years to 16,420 years in 2050 and 19 years to 3849 years in 2100.

MISSISSAUGA'S EMISSIONS



MISSISSAUGA, ON



Carbon Emissions through Transportation/Haljackey

To me, sustainability means whether something can be maintained or not. This includes the environment, society, and future generations. For example, deforestation is not sustainable due to the pollution generated and the mass destruction of ecosystems.

-Chanhyeok Lee

AFFORDABLE AND SUSTAINABLE ENERGY
CANADIAN ENGINEERING GRAND CHALLENGES

Climate change is a term used to describe complex shifts in weather conditions caused by greenhouse gas emissions. Climate change not only encompasses global warming, but also extreme weather events, disrupting food supply, disrupting wildlife populations, and the rising of sea levels (Nunez, 2019). Greenhouse gases absorb solar energy and keep heat trapped in the atmosphere rather than letting it escape into space, creating a "Greenhouse Effect". These gases also contribute to respiratory problems from smog and air pollution. Human activity is the main cause of climate change, driven primarily by the combustion of fossil fuels. Burning fossil fuels produces carbon dioxide, the primary greenhouse gas (Government of Canada, 2019). Carbon dioxide alone is responsible for about 75 percent of emissions. The most prominent source of global CO2 emissions is the production of electricity and heat (EPA, 2021). Mississauga, a city in Southern Ontario, is home to over 700,000 people. Mississauga contains Canada's largest airport, Pearson International Airport, which also connects to seven major highways. Being Toronto's closest suburb, Mississauga attracts many immigrants and home buyers each year (Britannica, 2012). However, due to atmospheric changes, Mississauga has experienced more intense heat waves, rain, flooding, and winter storms within the last 5 years. Mississauga's estimated annual CO2 emissions is 5.1 million metric tons, with buildings contributing 3 million metric tons and transportation contributing 2.1 million. Only 31% of the city's energy comes from renewable sources, the rest coming from the combustion of fossil fuels (Rajvanshi, 2019). "Virtually every sector of the global economy, from manufacturing to agriculture to transportation to power production, contributes greenhouse gases to the atmosphere, so all of them must evolve away from fossil fuels if we are to avoid the worst effects of climate change" (Nunez, 2019). Mississauga has begun implementing their plans to mitigate the effects of climate change, which revolve around reducing emissions and adapting to the changes (Rajvanshi, 2019).

EMISSION-LESS TRANSPORTATION

ALBANY, NEW YORK



Electric Vehicle Charging Station/Ken Fields

What can Mississauga learn from Albany?

Electric vehicles offer the opportunity to use renewable energy for transportation instead of fossil fuels and the charging stations facilitate easy access to clean energy technology. Therefore, the implementation of EVs will make crucial contributions to reaching these targets. Every city can learn from another city in many ways. Comparing climate change prevention acts and learning how the other has reduced CO2 emissions can encourage clean energy adaptation city-to-city. For example, when a city implements EVs, the need for charging stations in that city and the neighboring cities increases. As charging stations become more readily available, purchasing an EV will become a more reliable investment. When one city reaches their goal for reducing emissions, this sets a great example for other cities to learn from.

7 AFFORDABLE AND CLEAN ENERGY

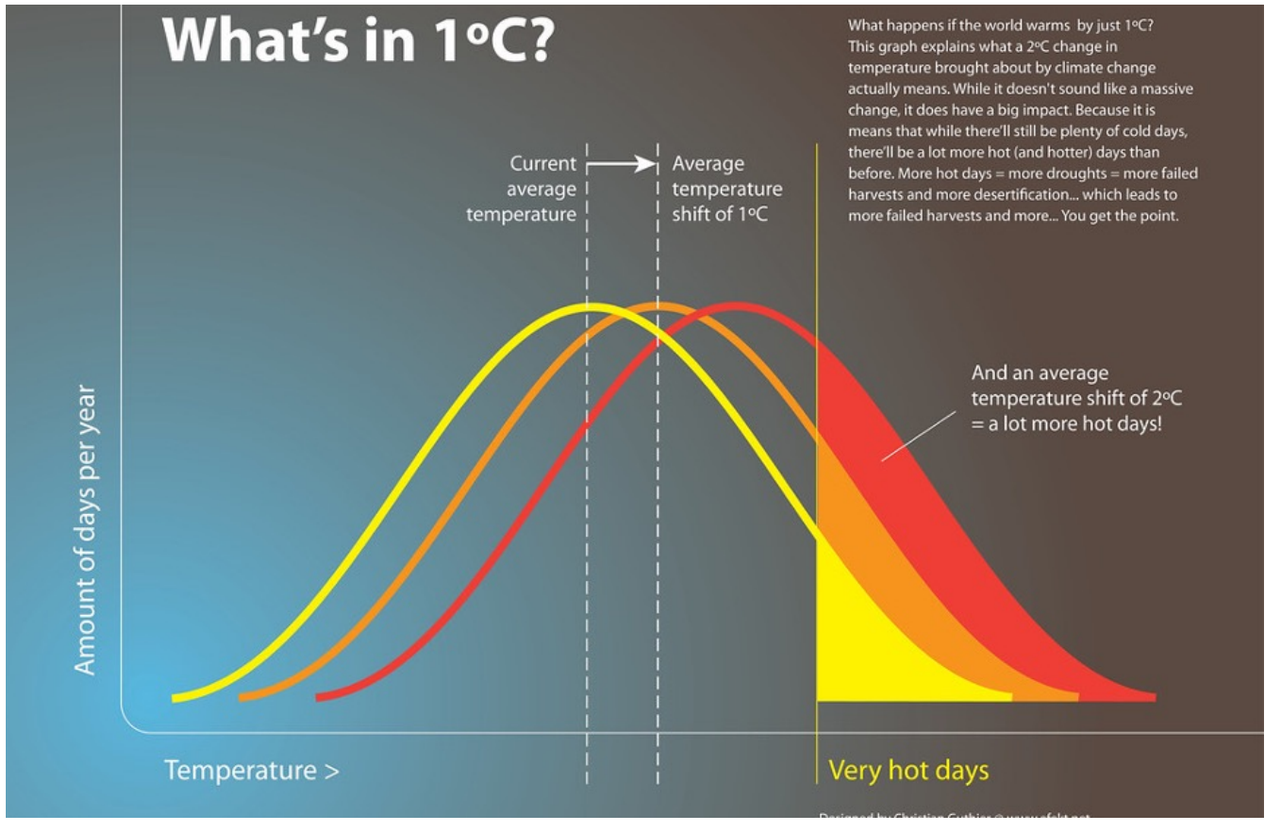
12 RESPONSIBLE CONSUMPTION AND PRODUCTION

The implementation of electric cars has been a surging trend in the 21st century, especially around the topic of climate change. Electric vehicles play a key role in our efforts to mitigate climate change by reducing carbon dioxide emissions. Electric vehicles (EVs) generate energy from a battery instead of burning fossil fuels. The energy generated spins an electric motor instead of having an internal combustion engine (United States Environmental Protection Agency, 2021). According to Samaras and Meisterling (2008), when 1 litre of gasoline is burned, about 2.3 kilograms of CO2 is released. Electric vehicles, however, are virtually emission-less due to the absence of an internal combustion engine. The implementation of EVs would result in less demand and consumption of petroleum-based fuels meaning less greenhouse gas emissions into the atmosphere. As more and more EVs are utilized, the main source of energy to power vehicles could shift from the combustion of fossil fuels to drawing energy from a grid, where the energy production is easier and cheaper to control. (Babaee et al., 2014). In addition to the internal combustion of gasoline inside a vehicle, the process of extracting, transporting, refining, and distributing these oils also emits greenhouse gases. Albany in New York state is one of many cities that has implemented strategies to reduce gasoline-powered vehicles and is moving toward fully electric and hybrid vehicles instead. With a population of almost 100,000 people and a detailed response plan for climate change, Albany has planned to reduce their CO2 emissions to 40% of 1990 emission levels by 2030 and 85% by 2050. The New York State Department of Transportation (DOT) has already reduced more than 7 million gasoline-powered vehicle trips across the state, accounting for more than 300 million miles of travel from 2010 to 2018. This act alone avoided nearly 125,000 metric tons of carbon dioxide being released into the air (New York State, n.d.). Government official, Andrew Cuomo stated he was confident Albany, New York would have 10,000 charging stations for EVs by the end of 2021, a steady increase from 3,000 chargers by the end of 2018, allowing for more reliability and accessibility of EVs (New York State, n.d).

FLOODING AND WARMER TEMPERATURES



GEORGIAN BAY, ON



What's in 1 Degree/Christian Guither

"Sustainability to me means advancing as a society without compromising the future. Whether large or small scale, sustainability practices are important and effect global climate change. Without considering sustainability in future projects, we will feel the effects and repercussions of the actions down the line."

-Michael Provenzano

RESILIENT INFRASTRUCTURE
CANADIAN ENGINEERING GRAND CHALLENGES

The Township of Georgian Bay Ontario is a small town located in northern Ontario, on the northeastern arm of Lake Huron (The Editors of Encyclopaedia Britannica, 2020). The Township of Georgian Bay is grouped with that of Midland, Penetanguishene, Tiny, Tay, Severn, and Oro-Medonte and has a population of 85,000, with that increasing to 200,000 with seasonal residents. The total GHG emissions for all seven municipalities was 643,883 tonnes of CO2 equivalent (tCO2e) in 2015. About only 1% of the total GHG emission are from municipal operations with the remainder being generated by the community. The region accounts for around 3990 tonnes of CO2 equivalent (tCO2e) of the 643,883. Most of the GHG emissions from solid waste are from the impact of methane released through landfill and was calculated to be 475kg of waste per capita (Sustainable Severn Sound (SSS) and the Sustainability Committee, 2018).

Since the Township of Georgian Bay is located on a large body of water (Lake Huron), environmental challenges that are caused by climate change are present. The seven municipalities will have to deal with more precipitation and hotter temperatures which will lead to lower Georgian bay water levels because of the increased evaporation and transpiration of water (Sustainable Severn Sound (SSS) and the Sustainability Committee, 2018). There will be more heatwaves which could put residents at risk because higher temperatures could result in a decrease in air quality and could increase the intensity of algal blooms (Sustainable Severn Sound (SSS) and the Sustainability Committee, 2018). One of the main issues that could present itself is with the frequency of rainfall, storm water networks will be overtaken, and flooding could occur and cause damage to local communities. Furthermore, winter storms will be more unpredictable with chances of ice and hailstorms happening more frequently and causing damage.

BLUE AREAS FOR COOL AREAS

TORONTO, CANADA



Don Valley River from DVP by Karen Maraj is licenced under CC BY-NC-ND 2.0

What can Georgian Bay learn from Toronto?

The Township of Georgian Bay can learn from Toronto's flood protection project because Georgian Bay has access to a larger body of water at its disposal which could be used for flood protection in a similar way to that of the Port Lands.

To adapt to warmer weather and increase chance of flooding due to more precipitation, regions and countries must turn to more eco-friendly, nature-based solutions to help adapt to changing climate. 'Blue Areas' are a common practice that has started to be applied to large cities. They use the close proximity of a river and lake to have a cooling effect and provide relief against heatwaves in cities. Blue and green areas in cities could also capture and store some of the excess water during heavy downpours and floods, thereby helping to reduce damage (European Environment Agency , 2018).

A 'blue area' has been implemented in Toronto Canada during the Portland Flood Protections Project. Not only does this project provide a blue area through some parts of the city, but also provides flood protection. "The project will create a new mouth for the Don River in the middle of the Port Lands between the Ship Channel and the Keating Channel, as well as the foundations of a new urban island neighbourhood called Villiers Island, and more waterfront access for everyone. It will also create new natural habitats and re- establish wetlands in the area, which provide social and environmental benefits and naturally moderate the effects of flooding and erosion (Backgrounder: Port Lands Flood Protection)."

LAKE HURON IS ON THE RISE NEAR THE TOWN OF GODERICH

GODERICH, ON



Erosion of Bluffs in Goderich Due to Rising Lake Levels

"Sustainability, to me, means creating advancements and progress humanity while also maintaining and conserving our environment."

-Zachariah Chamas

RESILIENT INFRASTRUCTURE

CANADIAN ENGINEERING GRAND CHALLENGES

Goderich, Ontario is a small town located along the coast of Lake Huron. It is known as "the prettiest town in Canada" and as of 2016, it has a population of 7,628. Making Goderich the largest town in the county of Huron. Goderich is also the home of the largest salt mine in the world which mines salt directly underneath Lake Huron.

In recent times, there has been a noticeable rise in the lake levels over the past few years. More specifically, from 2019 to 2020 the recorded lake levels have been 0.6 – 0.9 metres above the average lake levels for period 1918-2019 (The Coastal Centre, 2021). In July 2020, the lake had reached its highest recorded water level for the month of July. The recorded water level was 177.45 metres or 582.18 feet. The previous record high for the month of July for Lake Huron had been in 1986 at 177.50 metres (Goderich Signal Star, 2020). As a result of the rise in water levels there has been erosion issues all around the coast of Lake Huron in Huron County, specifically the coast in proximity to Goderich.

There are many causes to rises in lake levels. The major natural factors include precipitation, evaporation, and importantly ice cover. These factors can influence the lake levels by metres. There are also minor human-caused factors that influence changes in centimetres such as dredging, Water withdrawals, water diversion, and dams (The Coastal Centre, 2021). The factor that is the most interesting and relevant relative to climate change is ice cover.

The trend of ice coverage over a 47-year timespan shows that the amount of ice cover in the great lakes have been decreasing for the past 5 decades. The long-term changes in ice cover can be attributed to climate change. (National Oceanic and Atmospheric Administration, 2020).

Overall, the lake levels are on the rise in Goderich, and this could be devastating to not only the beach area but also the Port of Goderich located right next to the beach. The Port of Goderich also houses the previously mentioned salt mine which is Goderich's main source of jobs and controls a large portion of the town's economy. With all this said rise in lake levels could be cataclysmic for the town's survival.

THE PORT OF ROTTERDAM'S IMPRESSIVE FLOOD DEFENCE SYSTEM



ROTTERDAM, THE NETHERLANDS



The Maeslatkering Along the Nieuwe Waterweg

What can Goderich learn from Rotterdam?

Goderich and Rotterdam share similarities in the sense that they both are coastal cities, their ports are a large necessity to their economy, and they both deal with rising water levels that is a product of the climate crisis. Rotterdam has one of the most advanced flood protection innovations around the globe currently and the Maeslatkering is a marvel of sustainable infrastructure. Goderich could learn from the Dutch, as a storm surge barrier would be great protection for Goderich's own port.

Rotterdam is the second largest city and municipality in The Netherlands, with an urban population of 1.2 million, it houses the Port of Rotterdam which is the largest seaport in Europe and is on the coast of the North Sea. This makes Rotterdam a coastal city, which thus means the elevation of this city is at sea level. Due to its elevation, the city is prone to flooding from rising sea levels. To combat this problem, the city implemented the "Rotterdam Climate Change Adaption Strategy," that aimed at defending from flood, storm water surge, and sea-level rise (C40 Cities, 2016). One innovation that they implemented was the construction of The Maeslatkering.

The Maeslatkering, located in South Holland, The Netherlands, is a movable storm surge barrier that lies near the mouth of the Nieuwe Waterweg (English: New Waterway). This storm surge barrier is comprised of two swinging barrier gates that are both 210 metres long and 22 metres high. Each barrier is located on a side of the Nieuwe Waterweg and is open normally. The structure starts to close when a storm surge of about 3 metres above regular sea level is forecast (Patowary, 2014).

The Maeslatkering is a part of the previously mentioned "Rotterdam Climate Change Adaption Strategy" which comprised of several permanent sand dunes along the coast and dikes along the rivers. The reason that Rotterdam is so successful is that the city itself is not unfamiliar with flooding and change in sea level as it is an old city dating back to 1340. The city also identifies climate change adaption as a priority as it is a driving force towards rising sea levels and flooding in the region (C40 Cities, 2016).

PERMAFROST DEGRADATION

ROSS RIVER, YT



Damage to Concrete Piers at Yukon Community College Campus

"Sustainability is the practice of developing methods by which environmental resources, economic and social stability can be preserved and continue to support the population without the compromise of one another."

-Hamad-Ur-Rehman Qazi

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Permafrost is defined as the ground layer of material that remains frozen for at least 2 consecutive years. In many arctic regions, structures rely on the underlying permafrost conditions for stability. With temperatures on a steady rise due to ongoing climate change, Canadian communities in the artic zone are experiencing permafrost thawing. The process of permafrost formation can take long periods of time while exposed to cold temperatures, likewise, the degradation of permafrost happens over long periods of time. The thawing action of the permafrost layer has resulted in foundation settlement and ground shifting, posing a significant risk to the structural integrity of the surrounding infrastructure. The community of Ross River, in the territory of Yukon, has been subject to permafrost degradation and is experiencing challenging problems with its existing infrastructure. Ross River is a remote community situated at the junction of both the Pelly and Ross River; it has a minimal population of approximately 293 people as per the 2016 Census. The community has a relatively warm permafrost zone typically greater than –2°C, this makes it extremely vulnerable to increasing temperatures. The average air temperature in Ross River has increased by 4.8°C in the past 30 years, currently the average air temperature is approximated as -2 C (Holubec, 2008). The relatively warm permafrost zone, along with increasing temperatures has posed significant challenges to infrastructure in the community. Schools and community centres that play an integral role in the prosperity of the community are being assessed for rehabilitation due to foundation damages as a result of thawing permafrost and ground settlement. Settlement in the underlying ground causes an uneven distribution of load not accounted for during the design phase. The images below show structural damages in the Yukon College Community Campus. Figure A.1 shows significant cracks in the concrete foundation piers of the campus (Holubec, 2008).

USING BISON TO SAVE SIBERIA'S PERMAFROST

SIBERIA, RUSSIA



Bison and Musk in Pleistocene Park

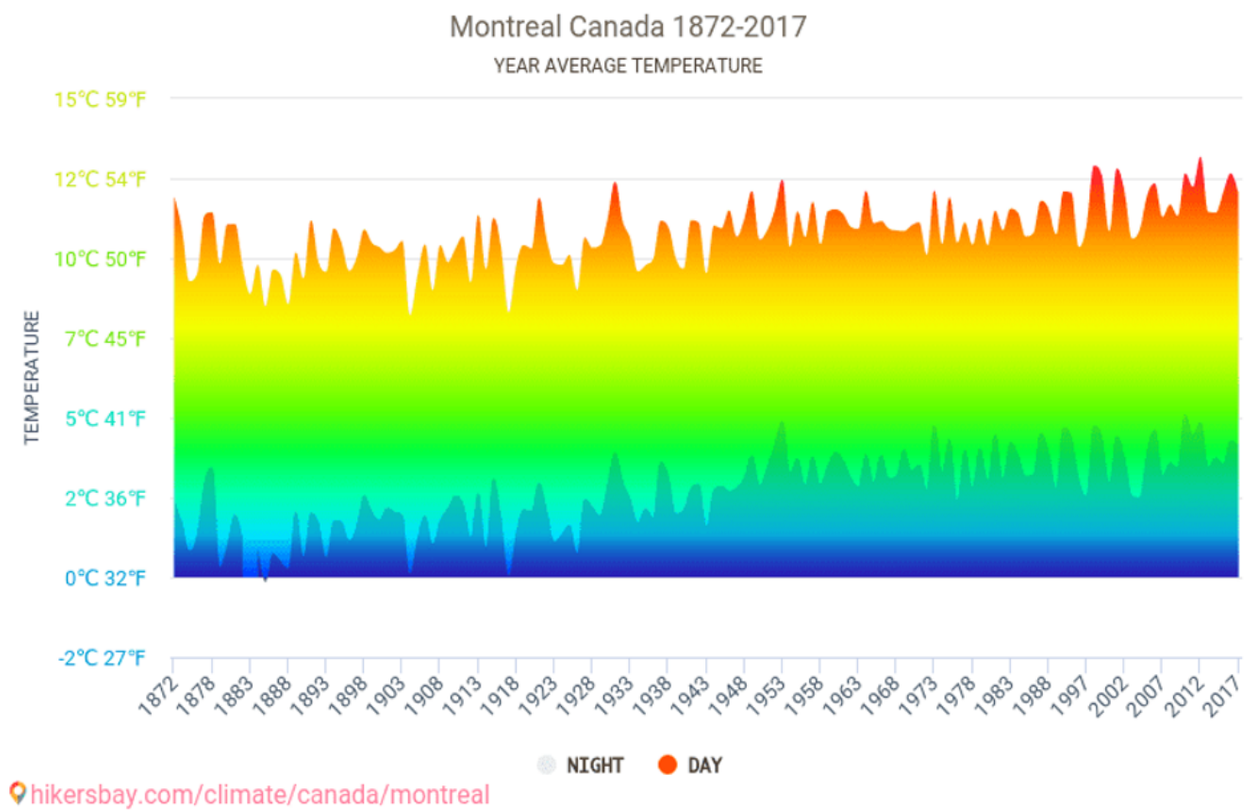
What can Ross River learn from Siberia?

The majority of global cities are not affected by permafrost degradation, hence there is not a great deal of well published studies that suggest solutions or mitigation techniques. For that reason, it is extremely important for the cities/communities that are affected by it to share their information collected through studies and experimental results with each other. Arctic communities globally should share their findings as this will lead to a wide variety of implementation and a larger sample size of results to determine the effectiveness of the solution. For instance, the experiments conducted in Siberia shall be implemented in Ross River to see if the solution is feasible in Canadian communities.

Researchers have approximated the annual cost of permafrost degradation to be several billion dollars, it is a problem that will continue to escalate given the climatic trends and the need for effective solutions is critical. Russian scientist Nikita Zimov has brought forth a solution to overcome the thawing of permafrost. He suggests that the re-creation of an Arctic tundra ecosystem as it was prior to human settlement is the solution to permafrost degradation. The solution involves re-introducing large mammals in regions with existing permafrost. These animals will support increased grass growth, causing a reduction in Co2 presence in the atmosphere by returning it to the soil. Furthermore, these animals with significant weight will trample down the snow, making it denser throughout the year and thus allowing for deeper freezing during winter seasons while keeping the permafrost frozen year-round. This solution is already being implemented in the Siberian region of arctic Russia. In 1996, Zimov embarked on this project and began his experiment in Pleistocene Park located in northeastern Siberia. The park has an area of 144 square kilometers and today it is home to over 100 large land mammals. The animals mostly consist of European/American bison, Kalmyk cows, musk, ox, sheep, yaks and horses. Figure B.1 shows animals living together in Pleistocene Park (Davydova, 2018). Preliminary studies on this experiment using computer models estimate that the predicted increase in permafrost temperature can be reduced by 44%, and 80% of the world's permafrost could remain frozen until 2100 (McCall, 2018). Although this solution has resulted in positive results generated through studies based on experimentation, the challenge is to up-scale this solution to the global arctic region, and how to incorporate this across different landscapes and arctic communities. Investigating how many animals are needed to cover a given area will be extremely beneficial for communities to understand how many animals they need to import in order to preserve their permafrost.

TEMPERATURE RISE ISSUE

MONTREAL, QC



Yearly Average Temperature in Montreal

Sustainability is an obligatory act that a person, country, and the whole world should be part of, in not abusing our needs in order to save it for the next generations and save the earth. It is also the saving and maintaining of the environment from its destruction.

-Ahmed Al-Saeed

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

Temperature rise is an evolving process that has been occurring for centuries, worsening year after year, due to the anthropogenic activities more energy is being consumed leading to the damage of the atmosphere. Consequences of damaging the atmosphere is temperature rise resulting in frequent wildfires, longer periods of drought, frequent extreme snow events, heat strokes, frequent hurricanes, tornadoes, flooding, diseases, and lastly, change of location of weather events. Major cities around Canada are deeply affected by the temperature rise and greenhouse gas emissions. Montreal is one of the cities facing the highest impacts, it is ranked as the 16th city in the world facing climate change impacts. Montreal's emission of greenhouse gases is currently 14.6 megatonnes of carbon dioxide equivalent. Due to these emissions, the city could face a 3.2 degrees Celsius rise by 2050. With a population of 4,247,000 people as of 2021, it is estimated that 1 in 3 people will be affected by those impacts and could see up to 20 days of heat waves that will threaten human health. In addition, in July 2018, Montreal experienced 70 heat-related deaths. Also, this temperature rise is causing sea ice to melt and warming of the St. Lawrence River and water bodies in Montreal. Melting of sea ice results in shifting of landscape and ground underneath which causes damages to communities and local infrastructure. Furthermore, warmer water holds less oxygen impacting on marine ecosystems. With temperature rise, it was discovered Ticks carrying Lyme disease are spreading quickly through Montreal. In 2017, 30 centimeter March snowstorm, spring flooding, and record-breaking heat wave put Montreal under pressure of needing to redesign the city's infrastructure to make it withstand climate change. Therefore, higher temperatures and heat waves can impact the local economy and residents' well-being.

THE PARIS AGREEMENT

MOROCCO



United Nations Climate Change Conference in Morocco 2016

What can Montreal learn from Morocco?

The Paris Agreement which has already been put in place and Canada is included in the treaty. In addition, an improvement in education, raising awareness and human and institutional capacity on climate change, adaptation, and early warning, this is extremely helpful because the higher increase in awareness, the more people will act in the reduction of temperature rise. The high impact of social media in this generation assists greatly in addressing the situation, more followers and media users will have the knowledge about global warming and its impacts, also, many steps will be provided for those who are trying to contribute to help change directions to a better path and future for the world and the countries heavily impacted by climate change. Therefore, city to city learning is highly encouraged in the help of temperature rise reduction.

Global warming is a gradual increase in the overall temperature of the earth's atmosphere attributed to the greenhouse effect. Many countries are trying to reduce global warming by making agreements with each other, but not many are successful with the process. As the world is becoming more innovative and economy is rising, temperature is increasing as well, this led to a sustainability strategy called The Paris Agreement to limit global warming. The Paris Agreement is a legally binding internationally treaty on climate change, the goal is to reduce global warming to around 1.5 degrees Celsius compared to preindustrial levels. 197 countries participating in this agreement. Other key aspects of the agreement include mitigation, aiming to reach global peaking of GHGs emissions, adaptation, finance, technology and capacity-building support, climate change education, and public awareness. One of the few countries meeting the Paris Agreement goals is Morocco. Although Morocco's emissions are expected to increase towards 2030, they will still be in place for their 1.5 degrees Celsius target. The country is meeting those expectations because it is prioritizing renewable energy. Morocco's government created the National Energy Strategy, which aims to have 42 percent of its power generated by renewable energy and increasing to 52 percent by 2030. This renewable energy comes from solar, wind and hydropower energy. It is one of the few developing countries to be able to curb it's emissions by 2030, Morocco is currently ranked fourth with the highest achievements in climate protection based on the Climate Change Performance Index 2021.

Smog Over City/CNN

CHAPTER 2: AIR POLLUTION AND MODELS OF AIR QUALITY



CHAPTER INTRODUCTION

Air pollution is responsible for human mortality and respiratory-related diseases in large numbers globally. Much of the work on air pollution focuses on a small set of substances known as criteria pollutants. Pollutants are predominantly anthropogenic and therefore controlling their emissions would be beneficial for human health and the environment, so an understanding of their sources and impacts is important. This module briefly touches upon the historical developments in air quality and presents some Air Quality Indices to enable an interpretation of the resulting numbers and their impacts, in addition to a quick glance at indoor air quality. Lastly, emission dispersion is described using models of air quality for point source pollution which is covered in detail, and line-source pollution; and the box model for area-source pollution presented only conceptually.

Learning Outcomes

By the end of this week, you will be able to:

- Identify the qualities of good air and polluted air
- Recall the composition of air
- Recognize the importance of air quality
- Define the types of air pollutants – primary and secondary pollutants
- Analyze the six criteria pollutants including their sources and impacts (CO, O3, NO2, SO2, PM10 and PM2.5, Pb) and Volatile Organic Compounds (VOCs)
- Describe historical developments in air quality
- Calculate the Air Quality Index
- Interpret AQI values in Canada, US, and globally
- Recognize indoor air quality (briefly)
- Describe emission dispersion
- Calculate emission dispersion using the Gaussian plume model for point source pollution
- Calculate emission dispersion using the line-source emission dispersion model
- Identify emission dispersion for area sources using the box model

HAMILTON STILL HAS MUCH TO DO TO IMPROVE ITS AIR QUALITY

HAMILTON, ON



Hamilton Harbour exhaust discharged directly into the air (Ziubinski, 2011)

"As a future engineer, sustainability is closely related to me. It not only affects our future life, but more importantly, it carries the living environment of future generations. In particular, the position of engineer plays a vital and indispensable role in sustainable development."

-Yu Fu

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

The city of Hamilton, one of the ten largest cities in Canada, has a population of only half a million and is located at the western end of Lake Ontario. This zone and its surrounding cities serve as the economic hub of Canada, covering almost the most important economic and trade activities and heavily industrialized production in Canada. Hamilton played a critical role in the industrial area, is encapsulated most of the city proper by four major expressways. Transportation corridors include highway and railroad traffic between the Greater Toronto Area and the United States of America; and shipping flows, which initiate and terminate at Hamilton Harbour (Adams et al., 2012). However, these factors also contribute to Hamilton's much higher air pollution levels.

As a city of high-density industrial development, Hamilton has deposited considerable air pollution which releases from 143 facilities spread throughout the city; and Emissions from vehicular traffic in the city (Adams et al., 2012). Steel production and vehicle emissions are major sources of nitrogen oxide, as shown in figure 1. In 2012, there were nearly twenty smog days in Hamilton compared to four in 2009, eight in 2010 and two in 2011 (Moir, 2013). This pollution has more serious influences on the health and the environment of the residents living in the region. The average mortality risk due to exposure to air pollution in Hamilton is 4.6 percent, which contributed to about 186 premature death, 395 respiratory hospital admissions and 322 cardiovascular hospital admissions each year in Hamilton (Moir, 2013). Therefore, Hamilton is confronted with serious environmental challenges in improving air quality.

Even though Hamilton has made considerable improvements in its air quality compared to the past, today's pollution levels are still moderate. This demonstrates that the long-term efforts undertaken in the region, while effective, have not yet addressed their underlying causes. It is essential to learn from the successful experience of cities and towns in other countries that face similar problems.

SMOG-EATING BUILDING

MILAN, ITALY



The Italian Pavilion at Expo 2015 in Milan (Nemesi, 2015)

What can Hamilton learn from Milan?

To sum up, the solution of using TiO2 material to deal with air pollution not only meets SDGs but also solves CEGC. Thus, Hamilton can learn from Milan's approach to solving environmental problems. For example, this kind of paint can be popularized locally and applied to public buildings and some residential buildings. In a word, it is a promising solution to clean up Hamilton's air quality.

As the first European countries to enter the industrial revolution, they have 60 years of experience in dealing with the air pollution caused by exhaust fumes. Compared with most countries that implement long-term governance policies to limit emissions according to their own Clean Air Act, Italy has also applied for the technical support of titanium oxide materials based on the action and achieved remarkable achievements. The city of Milan in Italy was a serious public health hazard during smog events (Baltensperger et al., 2002), has become a successful example for all countries to follow.

With the development of titanium dioxide (TiO2), it is discovered that this semiconductor photocatalyst could contribute to removing air pollution, ability to be coated as a thin film on a substrate, environmentally friendly (Tsang, 2019). These superior characteristics can be applied to the exterior walls of buildings by coating them with TiO2 materials. Special grades of TiO2 can be used to remove harmful nitrogen oxides from the air based on a process of photocatalysis, in which quickly converts nitrogen oxides into harmless by occurring chemical reaction due to light, and in which soluble nitrates that rain can remove from the building's surface (TDMA, n.d.). By painting buildings using preformed materials containing TiO2 can create this reaction on a large scale, as shown in Figure 2.

Pacific Paints (Boysen) Philippines, Inc., is now promoting this paint. The company claims each painted square meter could remove 80 g of nitrogen oxides per year, according to a trial that ran over four years, on a 135 square meters wall in Milan (Burton, 2012). Compared with control areas in other parts of the city, it is reported reductions as great as 60% for the species nitric oxide and 20% for the species nitrogen dioxide

REDUCING AIR POLLUTION WITHIN DENSE URBAN AREAS

TORONTO, ON



Smoggy Day in Toronto/eddiejdf

Toronto is the most populous city in Canada. It is the financial and technological centre of the country, thus attracting people from all over the world. As a result of the rising population, air quality has been slowly worsening in the city. Approximately 1300 premature deaths and 3600 hospitalizations are reported as a result of pollution. (Gower et Al., 2014). The biggest challenge facing Toronto today is to continue the rapid pace of growth while simultaneously improving the quality of air within the city. Many people still rely on cars as their main method of transportation, further worsening the amount of pollution within the city.

"To me, sustainability refers to our consumption habits. Our houses, the food we buy, modes of transportation, etc. If every person on this planet was to copy my habits, would the planet be able sustain it? If the answer is yes then I am being sustainable."

-Anang Bokil

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

VERTICAL FORESTS IN DENSE URBAN AREAS

MILAN, ITALY



Bosco Verticale in Milan/Darsheni

In many dense urban areas around the world, air pollution is becoming an increasing issue. Many people are moving to cities like Toronto every year due to their strong job markets. This results in more construction, more cars, and more anthropogenic activity that produces pollution. One proposed solution to fix this is a vertical forest. These are residential/office buildings that have large amounts of greenery planted on them to absorb CO2 and create a more natural atmosphere in city centres that are normally dominated by glass skyscrapers. An example of this solution implemented in the real world is the Bosco Verticale in Milan, Italy. (Wreg, 2019) Milan is the second-most populous city in Italy with a population of 1.35 million. The city is similar to Toronto, in that it is a metropolitan hub that is the main financial center of the country. (Milan Wiki 2021) In addition to Italians, it is also a very popular tourist hotspot. This makes having clean air even more important. The Bosco Verticale has 900 trees, 5000 shrubs, and 11000 other plants. (Wreg, 2019) This vegetation works to absorb CO2 and as an added benefit it can trap other airborne particulates as well. (Wreg, 2019) If "vertical forests" such as the Bosco Verticale are implemented on a bigger scale within dense urban areas, the air within the city will be cleaned and air pollution will drastically decrease. Furthermore, as stated above, the plants work as a natural air filter for the residents of the building. This reduces the need for any artificial filters and makes these areas safer for people with severe allergies.

What can Toronto learn from Milan?

Toronto can learn from Milan in regards to skyscraper construction. Toronto's skyline is dominated by futuristic-looking glass skyscrapers with many more on the horizon. Building more vertical forests will allow for the pollution to decrease and it will simultaneously increase the health of people living within the city.

CALGARIANS AND THEIR TRUCKS

CALGARY, AB



Traffic in downtown Calgary (Swire, 2017)

“”

-Hidekel Mendoza Cabrer

The city of Calgary has a population of around 1.3 million people, which makes it the largest city in Alberta and the second largest city in Western Canada. It is a large city because it is located at the heart of the oil and gas industry in Canada. Surprisingly, a large portion of the air pollution in Calgary comes from vehicle emissions, ranging from personal cars, trucks, and motorbikes to industrial or service trucks which emit higher amounts of fumes and large quantities of microscopic traces of rubber on the roads (Air Quality in Calgary, n.d.). The high level of pollution arising from vehicles makes sense considering only around 7% of Calgary’s population live in the inner-city, so the remainder 97% need to have a car and use it on a regular basis (Gonzalez, 2020). The high dependency on vehicles results in frequent traffic jams, as depicted in Figure 1.

In Figure 1, it can also be seen that there are many trucks compared to the total number of vehicles. According to Transport Canada, 60% of the vehicles purchased in Alberta in 2012 were trucks (Caygill, 2013). This makes Alberta the province with the highest number of light-duty vehicles on the road per capita (Caygill, 2013). Trucks pollute much more than cars because they burn more gas as they are heavier, less aerodynamic, and usually have all-wheel drive. As many people use trucks on a regular basis in Calgary, their travels pollute much more than they would if they used cars, especially during traffic jams.

In 2019, Calgary’s PM2.5 reading was 6.9 µg/m3, so it is within WHO’s 10 µg/m3 or less target rating for the best air quality (Air Quality in Calgary, n.d.). With that good PM2.5 reading, it was still 71st city in Canada, so there is work to be done to improve Calgary’s air quality further.

SAFE AND SUSTAINABLE CITIES
CANADIAN ENGINEERING GRAND CHALLENGES

A BIKE-FRIENDLY CITY

ANTWERP, BELGIUM



Caption

What can Calgary learn from Antwerp?

Calgary could learn from Antwerp's success and create safer bike paths that do not intersect with motorized traffic. There could also be more stores that sold upright bikes in Calgary, which are more comfortable for everyday use. In addition, there could be more bicycle parking at train stations or stores to encourage people to cycle. Better bicycle routes that are well maintained can be used by Calgarians in any type of weather. The more they are used, the better they will become as there will be more demand for bike paths. Bike paths provide a safe way to arrive at a destination, and can also be used for exercise and recreation, which would greatly contribute to the overall wellbeing of Calgarians.

Biking emits less than 27% of the CO2e emissions of driving while keeping the user healthy (Climate Impacts of Biking vs. Driving, 2016). Antwerp is one of the most bike-friendly cities in the world, their bike usage can be seen in the parking lot depicted in Figure 2. This was achieved with a combination of grassroots initiative, professional expertise, and municipal action (The 20 Most Bike-Friendly Cities on the Planet, Ranked, 2019). A key aspect of the city's bicycle plan was to improve and connect cycling networks with intersection improvements, traffic light management, and lowering speed limits to 30 km/h on 95% of streets (The 20 Most Bike-Friendly Cities on the Planet, Ranked, 2019). Antwerp also expanded bicycle parking at train stations to target commuter trips, and there are plans to expand their 'cycle highways' to connect wider regions (The 20 Most Bike-Friendly Cities on the Planet, Ranked, 2019). Cycle highways are roads made for cyclists so they can travel by bike more easily and safely, so they are long roads with little to not intersections with motorized traffic (What is a cycle highway?, n.d.). Antwerp's investments have clearly worked as their bicycle use increased from 29 to 33 percent from 2014 to 2018 (The 20 Most Bike-Friendly Cities on the Planet, Ranked, 2019).

Another important aspect of Antwerp's success is their bike design. Their bikes are more upright, and some of them do not have chains so they are more comfortable to use for everyday purposes as well as easier to maintain (Using the Antwerp Bike Share System, 2018). Antwerp also has a widely used, completely automated bike share system, which makes it easier for people that cannot or do not want to own or maintain a bike to use the cycle highways.

WOOD-BURNING APPLIANCES 2ND HIGHEST CAUSE OF POLLUTION

MONTREAL, QC



Pollutants from Wood Burning Appliances cause Smog Warnings in Montreal.

“When I practice sustainability at an individual level, I imagine these three pillars/the triple bottom line in the form of an equation:
On the right side is a lifestyle which supports the environment, my social life and my personal finances.

On the left side is a lifestyle which offers the best solutions for the environment, the human society and the world's economy.”

-Neelakshi Prabhakar

AFFORDABLE AND SUSTAINABLE ENERGY
CANADIAN ENGINEERING GRAND CHALLENGES

The issue: Montreal ranks as Canada’s 7th worst city for air pollution (Gao, 2020), a major reason for which is the extremely high use of wood-burning stoves. Wood-burning stoves account for 39% of the particulate air pollutants, making it the second highest cause of pollution in the city after vehicle emissions (Lau, 2019). This is a reason for alarm since 90% more Canadians die of causes linked to air pollution than by vehicles (Mehta, 2021).

The cause: Montreal, with its culture of wood-oven desserts and traditional French patisseries operates over 50,000 wood-fueled appliances (Gao, 2020). These appliances operate through incomplete combustion, which releases CO2, NO2, benzene and particulate matter called PM2.5. Montreal has an average 7.1 µg/m^3 of PM2.5 (Gao, 2020), and 100% of PM2.5 readings above 20 µg/m^3 are sourced from houses with wood-burning appliances (Rokoff et al, 2017).

The effects: PM2.5’s tiny aerodynamic radius makes it extremely dangerous to respiratory health as these particles easily travel into the lungs. WHO reports that PM2.5 from wood fueled appliances is a carcinogen (Lau, 2019), and causes respiratory problems such as asthma, as well as other diseases such as dementia and type 2 diabetes (Mehta, 2021).

Apart from indoor air pollution (these houses report 50% higher concentrations of the carcinogen benzene than non-wood-burning counterparts), the PM2.5 released from these homes depletes the outdoor air quality according to (Rokoff et al, 2017). In Montreal, PM2.5 is the primary cause of smog in the winter months, when wood fueled appliances are at their highest usage, and the cool air confines the pollutants close to the earth’s surface (Lau, 2019).

Wood-burning is environmentally unsustainable as it causes higher carbon emissions than burning coal, and directly contributes to global warming (Mehta, 2021).

BANNING WOOD-BURNING APPLIANCES DECREASED POLLUTANTS

FRESNO, UNITED STATES



The success of Rule 4901 in Fresno, Califonia has lowered the region's concentration of pollutant PM2.5 by 31% in 2008.

What can Montreal learn from Fresno?

Montreal attempted a similar approach to commercial appliances (Lau, 2019), however, Rule 4901 succeeded due to support and adoption from the local community. Instead of immediate policy changes, Montreal can mimic Fresno, where they gradually increased the banned days from 15 to 100 over 3 years. Since wood-burning is culturally integral to Montrealeans, it is important that locals are self-motivated to make this lifestyle change, such as those in Fresno after learning the health hazards in government funded awareness programs (Lighthall et al, 2009).

The San Joaquin Valley comprises mostly rural residential homes, which were known for their wood-fueled appliances, and the resulting second highest levels of PM2.5 in USA in 2001-4 (Lighthall et al, 2009).

In 2003, the air pollution due to wood burning appliances in Fresno, San Joaquin Valley caused an AQI level of 150 (Lighthall et al, 2009). In response to this, the San Joaquin Valley Air Pollution Control District introduced Rule 4901 which illegalized the use of wood-burning appliances in all areas where alternatives were accessible. This government policy was highly successful in reducing PM2.5 concentration by 31% in Fresno by 2008. Infact, the success of this policy has made it feasible to change the allowable limit of PM2.5 from 65 µg/m^3 to 35 µg/m^3 by 2020 (Lighthall et al, 2009).

The policy was successful due to its gradual implementation (increase banned days from 15 to 100 over 3 years), and relaxed restrictions in winter. This let slowly adjust their lifestyles to permanently minimize their PM2.5 emissions. Awareness programs educated the locals who told a survey that many of them had permanently replaced wood-burning appliances after being educated on their health concerns (Lighthall et al, 2009).

This policy was successful in the following ways:

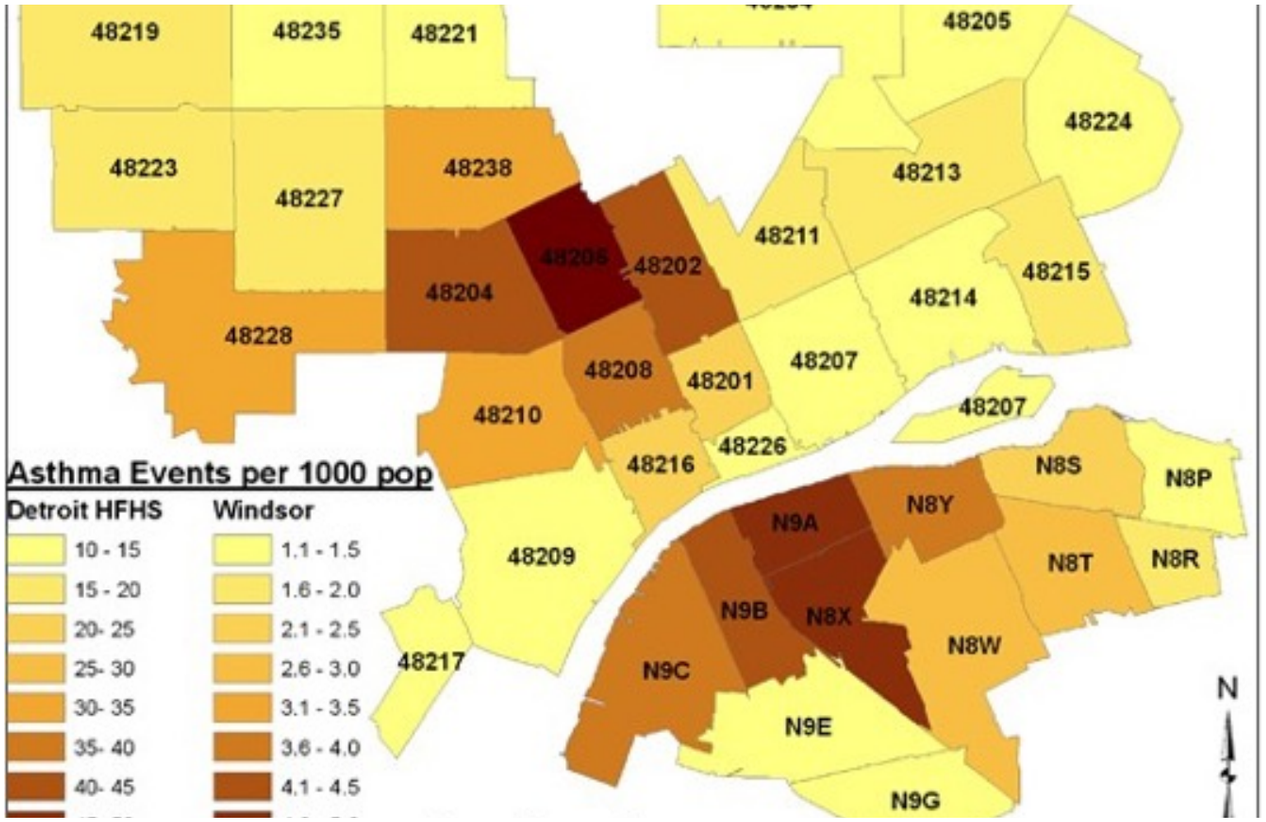
-The days/year where Fresno experienced higher than 150 AQI decreased from 35 to 12 (Yap and Garcia, 2015).

-Before rule 4901, the average levels of PM2.5 were 79.3 µg/m^3 of PM2.5, however, after rule 4901, even on 'off days', PM2.5 levels in Fresno were 76.3 µg/m^3. (Lighthall et al, 2009).

-A study by (Yap and Garcia, 2015) shows a 46.7% decrease in hospitalizations of seniors due to pollution related/COPD diseases in Fresno from 2003-2006.

WHAT IS GOING WRONG WITH ITS AIR QUALITY IN WINDSOR

WINDSOR, ON



Geospatial relationships of air pollution and acute asthma events across the Detroit–Windsor international border (Lemke et al., 2013)

"Sustainability can have both theoretical and behavioural to me. Theoretically, it means an ecological concept that I have to utilize natural resources at a rate that I can make sure our next generation are still able to consume them instead of depleting them at our age. Behavioural, I have to save all natural resources as much as I can although we can afford them. For example, we can use the water from washing vegetables to flush the toilet."

-Jingnan Wu

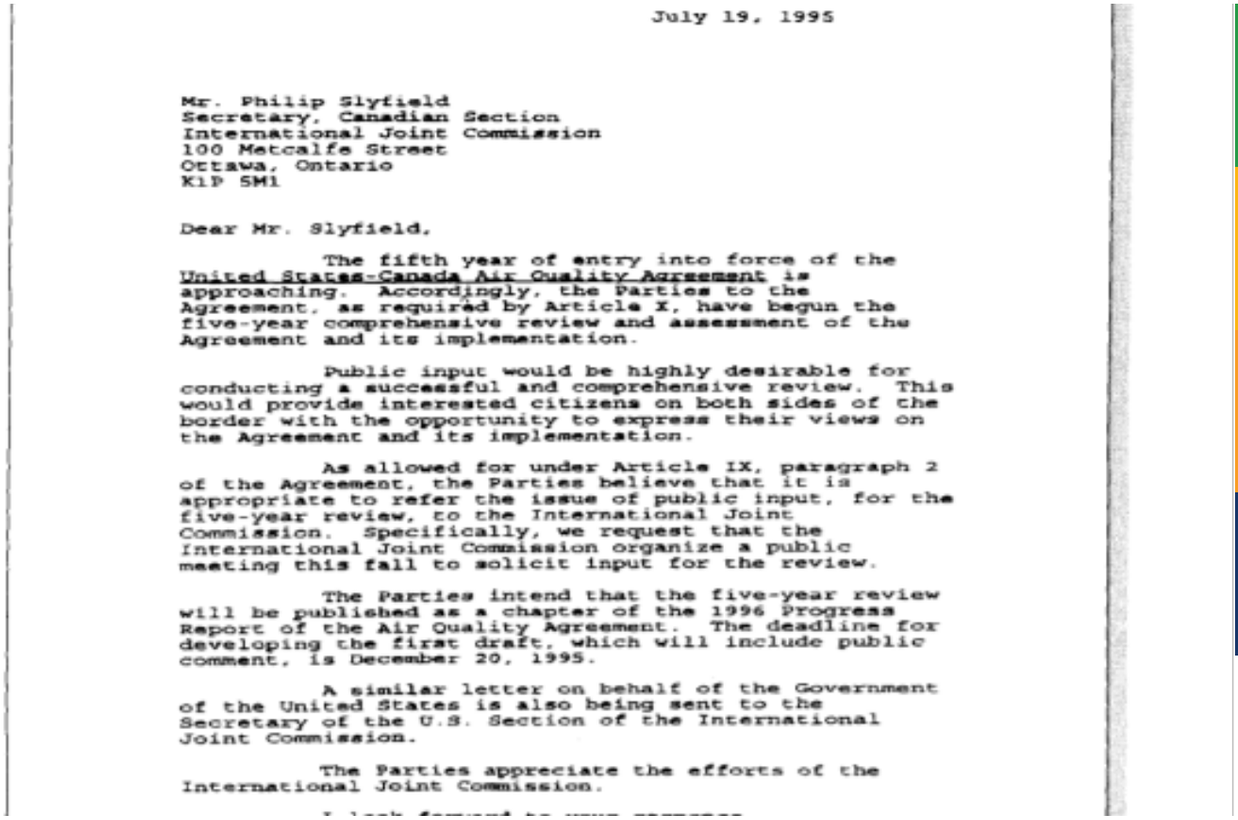
AFFORDABLE AND SUSTAINABLE ENERGY
CANADIAN ENGINEERING GRAND CHALLENGES

It was once known that Windsor is referred to as the "smog capital" in Canada by The Weather Network before 2006, a city where cancers and respiratory diseases associated with air pollution are more prevalent than elsewhere in Canada. The city Windsor is located in southwestern Ontario, Canada, on the south bank of the Detroit River directly across from Detroit, Michigan, the United States, owning a population of approximately 0.28 million. In this area, automobile manufacturing and transportation corridors including aviation, highway, and railroad traffic play important roles in boosting Canada's economy to a new level (Lemke et al., 2013). However, just because of the special geographical position (transborder of the USA and Canada) and the great amount of utilization of public and individual transportation with about 10000 trucks crossing each day the linking bridge, both two factors had made it the most air polluted city in Canada.

Since Windsor and Detroit are neighbouring cities separated by the Detroit River along the USA-Canada border, high air pollution levels of two cities are relative to each other, and according to Lemke and Luginaah, Windsor is downwind from several strong polluters, notably coal-burning power plants from Detroit. In their air pollution case studies researching in the air quality model of Windsor-Detroit area, large scale data sets have shown that in the last two decades in the 20th century, the average concentration of PM1 is 5 μg/m3 in Windsor, compared with that of 7 μg/m3 in Detroit. In addition, average concentrations of NO2, PM2.5 and PM10 respectively are 23 ppb, 9.5 μg/m3 and 19 μg/m3 in Detroit while these concentrations are relatively high in Windsor that touch the warning line of air quality index at that moment, compared with other air-polluted cities in Canada and proving that air pollution in Windsor is evidently influenced by ambient air coming from Detroit according to air sampling t-test methods in both cities. There were 260 premature deaths, 900 hospital admissions and 2,750 emergency visits associated with poor air quality in 2005 in Windsor. As is shown in Figure 1, asthma-related healthcare visits caused by toxic matters in Windsor from industrialization in Detroit

AIR QUALITY STRATEGY (BAQS) IN IMPROVING AIR QUALITY

CANADA BORDER, UNITED STATES



July 19, 1995

Mr. Philip Slyfield
Secretary, Canadian Section
International Joint Commission
100 Metcalfe Street
Ottawa, Ontario
K1P 5M1

Dear Mr. Slyfield,

The fifth year of entry into force of the United States-Canada Air Quality Agreement is approaching. Accordingly, the Parties to the Agreement, as required by Article X, have begun the five-year comprehensive review and assessment of the Agreement and its implementation.

Public input would be highly desirable for conducting a successful and comprehensive review. This would provide interested citizens on both sides of the border with the opportunity to express their views on the Agreement and its implementation.

As allowed for under Article IX, paragraph 2 of the Agreement, the Parties believe that it is appropriate to refer the issue of public input, for the five-year review, to the International Joint Commission. Specifically, we request that the International Joint Commission organize a public meeting this fall to solicit input for the review.

The Parties intend that the five-year review will be published as a chapter of the 1996 Progress Report of the Air Quality Agreement. The deadline for developing the first draft, which will include public comment, is December 20, 1995.

A similar letter on behalf of the Government of the United States is also being sent to the Secretary of the U.S. Section of the International Joint Commission.

The Parties appreciate the efforts of the International Joint Commission.

USA and Canada Leaders Reached Consensus of Improving Air Quality in NA (Band, 2006)

What can Windsor learn from the United States?

Generally, identifying the type of air pollution, which is transborder air pollution type in this case, is the most important thing to know. With understanding how air pollution is caused, reaching an agreement by two countries' leaders in reducing traditional waster emission and promoting cooperation from both sides play significant roles in making the lives of people of both countries happier. The policy-making solution also applies to other transborder air pollution examples in Europe, Asia and other continents due to that it both satisfies Canada's sustainability qualifications and global ones.



After people in Windsor suffered from air pollution and their health problems became more and more serious, both governments of North America (Canada and USA) had recognized the horrible results raising from transborder air pollution flows not only between these two cities but also other territories; in 1995, Canada and USA governments reached a consensus according to the official letter, and in 2003, they launched an agreement on air quality, the stated purpose of which is to establish "a practical and effective instrument that it is necessary and critical to regulate air pollution flows no matter from which country and protect citizens of both countries free from toxic matters mixed in the air mostly brought by emissions of engine plants and other industrialization. That agreement is known as Canada–US Border Air Quality Strategy (BAQS) and has become a successful example for European cities to follow.

In the agreement framework, five main parts are demonstrated. First of all, both governments should establish specific objectives for emissions limitations or reductions of air pollutants and adopt and operate necessary programs or other measures to implement such objectives. Secondly, impact assessments, prior notifications and mitigation measures related to the environment should be undertaken. Moreover, coordination and cooperation in scientific and technical activities should be carried out to further exchange information and research. In addition, institutional arrangements should be set ready in case unexpected issues occur. Last but not least, platforms where reviewing and assessing progress, consulting, addressing issues of concern and settling disputes can be carried out should be provided and express channel can be funded to tackle related problems (Band, 2006; Rossi, 2018).

After implementing this strategy, with over 20 years' recovery period and the Canadian government's assistance in Windsor, health-related issues resulting from transborder air pollution flow had decreased prominently by the end of 2019. Relevant research shows that no significantly increased mortality was observed for

FORT MAC AND KEEPING AIR CLEAN



FORT MCMURRAY, AB



Downtown Fort MacMurray by jasonwoodhead23 is licensed under CC BY-A 2.0

“Sustainability is balancing our human desires and needs with nature's needs. I think that for an idea or product to be sustainable, it has to carry out its function but also make sure nature is disrupted as little as possible. ”

-Ubelejit Oyet

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

The city of Fort McMurray is in Northern Alberta. The settlement was a trading post for the North West Trading company. Eventually, the “Fort of Forks” was taken over by the Hudson’s bay company then rebuilt in 1875 and renamed Fort McMurray after a company factor, William McMurray (The Editors of Encyclopaedia Britannica, n.d.). As of 2016 the city has a population of 66,573 (Statistics Canada, 2017). The city was making headlines in 2016 because of the dire situation caused by a wildfire (McDiarmid, 2017).

Wildfires cause air pollution because of the combustion reaction that occurs. The reaction releases many chemical compounds into the air including: Volatile Organic Compounds (VOC), Nitrogen Oxides (NOx), and Particulate matter (PM) (Daniel A. Jaffe a, 2020). VOC’s and NOx are known as secondary pollutants since they react to create pollutants. When sunlight energy reacts with NOx and VOC’s ground ozone is created as in the equation below:

VOC + NOx + Sunlight Energy = Photochemical Smog (O_3)

Nitrogen Oxides, VOC’s and particulate matter all directly effect air quality. For this paper air quality will be defined as in the CIVE 230 course notes.

For air quality to be considered good, the air must:
1. Minimize public exposure to pollution
2. Reduce global impact of air pollution
3. Have conditions such that physical infrastructure is not damaged
4. Be regulated in such a way that economic growth is not hindered

The 2016 wildfire in Fort McMurray at one time covered 2019 square miles in Alberta and about 10 square miles in Saskatchewan (Jenner, 2016). There are many environmental challenges that arise from a wildfire of estimated $9.0 billion magnitude (Malbeuf, 2021). One of these challenges is maintaining good air quality downwind and in the surrounding areas, specifically maintaining low levels of ground ozone and particulate matter.

BARCELONA SCORES WITH A BIG WIN AGAINST AIR POLLUTION



BARCELONA, SPAIN



An aerial view of Barcelona, Spain and its many trees by M McBey is licensed under CC BY-A 2.0

What can Fort McMurray learn from Barcelona?

Finally in terms of city-to-city learning both Fort MacMurray, Canada and Barcelona, Spain can learn from each other. Fort MacMurray and the surrounding area lost 589,552 hectares of forest lands burned due to the fire (CBC News, 2016). Making an action plan for trees like Barcelona has done (Adjuntment Barcelona, 2017) would be a solid step for Fort MacMurray to keep a good air quality, as people have returned to the community now. Both Barcelona and Fort MacMurray would do well to learn from each other about maintaining a good air quality.

According to an Environment Canada model of the Fort McMurray fire, the ground ozone produced from the fire effected regions throughout the USA and Canada. Climate change will cause temperatures to rise in certain regions and wildfires will increase in frequency and in magnitude (CBC News, 2017). Hence a solution is needed. Looking globally there are solutions that allow us to maintain a good air quality, specifically combating the rise in particulate matter (PM) and O3.

With its rich history and culture, and many architectural sites to see Barcelona, Spain is indeed an amazing city. Barcelona has a population of 5,624,498 as of 2021 (World Population Review, 2021). With a population in the several millions like other cities Barcelona has to deal with the reality of high levels of pollutants specifically greenhouse gases such as NO2 and O3. The city also has high levels of PM10 in the air. One strategy the city has implemented was to plant an urban forest.

Barcelona has a population density of 15,992 people/Km2 (Urban Resilience Hub, 2017) and is highly urbanized. Yet it has managed to have 1.4 billion trees planted within its municipal borders (Neogi, 2017). Industry experts set out to study the effect this urban forest had on air quality (Baró, 2014), and as this section title suggests Barcelona scores a big win for air quality. The study followed five air pollutants, Table 1 showcases the metrics of three of such pollutants PM10 , O3 and NO2 (Baró, 2014).

PM10 proved to be the pollutant removed in the highest quantity, the chemical accounted for 54% of the pollutants removed. It can be concluded that urban forests play a role in mitigating air pollution.

Table Here

WINDSOR'S PROXIMITY TO ITS AIR QUALITY WOES

WINDSOR, ON



Zug Island (Otto, 2016)

"I think it's best to be optimistic about future development and not to grow complacent on the sustainable actions presented today and down the road."

-Hasib Ahmed

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

The city of Windsor is one of the twenty largest cities in Canada, has a population just under 350,000 and is situated on the south bank of the Detroit River, directly across from the major metropolitan area of Detroit, Michigan, USA. The Detroit-Windsor urban area represents a critical link for the commercial trade between the United States and Canada, with the Ambassador Bridge border crossing accounting for more than a third of all trade between the two countries (Perspective News, 2021). Windsor is also one of the most industrialized cities in all of Canada, containing major industries such as automobile and engine assembly plants, a foundry, scrap metal recycling plant, and manufacturers for parts, tools, and die (Luginaah et al., 2005). All these factors have led to Windsor being compromised with a high level of atmospheric pollutants, in comparison to other Canadian cities.

Much of the air pollution that affect Windsor come from upwind sources within Canada and from the United States, such as from coal-powered electricity generating stations, and steel plants – such as the Zug Island steel mill shown in Figure 1, located within southern Detroit. Beyond that, the next largest point source emissions come from, is Windsor-Detroit transportation corridor (City of Windsor, n.d.). Some of the most offending pollutants in the city are carbon monoxide (CO), sulfur dioxide (SO2), nitrogen dioxide (NO2), particulate matter (PM2.5 and PM10), and volatile organic compounds (VOC) such as toluene, xylene and benzene, which are easy to respire and can stay gaseous at lower temperatures (IQAir, n.d.). It is not a surprise that this level of pollution has had a negative influence on the health and environment of residents in the region. In 2005 alone, there were up to 260 premature deaths, 2750 emergency visits and 900 hospital admissions associated with the poor air quality (City of Windsor, n.d.). While in 2011, Windsor had the most smog-advisory days in Ontario (Battagello, 2020).

Over the last few years, Windsor has made significant

LIVING WALLS

LONDON, UNITED KINGDOM



CityTree (Sluijmans, 2020)

What can Windsor learn from London?

The city of Windsor can learn from London's approach, through the implementation of CityTree benches or similar installations in public areas, parks, and near residential and office buildings, Windsor would be able to clean their air quality across different sections of the city.

Being among the first heavily industrialized nations, the United Kingdom has had a lengthy history of, and multiple episodes of poor urban air quality. However, these past mistakes have allowed the UK to place a greater importance on the management of air quality, and the abatement of pollutants from ambient air starting with the Clean Air Acts of 1956 and 1968 respectively (Stein, 2002). The city of London's shear size makes its air pollution problem unique to the rest of the UK, and despite the persistency of certain pollutants – such as ozone (O3), nitrogen dioxide (NO2) and particulate matter (PM10 and PM2.5), the quality of air has significantly improved in London over the past decades (Gil-Alana et al., 2020).

A relatively recent solution adopted by some central London neighbourhoods to address the pollutant concentration, is the implementation of "CityTree benches", a type of free-standing bench/seating structure, attached to what looks like a large section of a wall, covered in a combination of mosses (like the one shown in Figure 2). Created by the German company 'Green City Solutions', the intention behind these benches is to ensure that the air surrounding them remained clean, cool and able to provide a place of relaxation and interaction (Green City Solutions, n.d.). The CityTree installation is powered by solar panels and works by creating an environment for mosses to thrive in. This is done using shade-providing plants, an automated supply of water through rainwater collection/built-in irrigation, and Internet of Things (IoT) technology for the monitoring and analysing of air quality, air filtering, and the plants' requirements. The reason moss is chosen as the natural filter for the CityTree, is due to its effectiveness of fixing pollutants (like particulates), its ability to accumulate fine dust/nitrogen oxides and convert them to plant biomass, and its ability to cool ambient air by evaporating water on its large surface (Splittgerber, 2015).

Through this system, Green City Solutions claims that a single CityTree bench can reduce the pollution of fine dust up to 53% in

THE CITY WITH THE WORST AIR QUALITY IN ONTARIO



HAMILTON, ON



One of the Major Steelmakers in Hamilton (Cathrae, 2006)

""

-Jeremy Tran



With the increase in industrialization and new technological developments requiring the burning of fossil fuels and other harmful chemicals, air pollution has been an emerging challenge in maintaining a healthy and sustainable environment. Negative effects of air pollutants on human health, as well as the negative impact of greenhouse gases on the climate environment are reasons why having a healthy air quality in a city or community is important. The city of Hamilton, containing a large industrial sector and its specific geographical location has caused it to have one of the worst air quality ratings in Ontario.

According to an article done by CBC (2013) on the air quality in Hamilton, air pollutants in the city have contributed to approximately 186 premature deaths, 395 respiratory hospital admissions and 322 cardiovascular hospital admissions each year. In the year 2012, there was a recorded amount of 20 smog days in the city of Hamilton compared to 4 in the year 2009. (Moir, 2013) Research indicates that air pollutants cause a variety of health issues especially in the respiratory system including, asthma, coughing, weezing, bronchitis, lung damage and even lung cancer. (Al-Dabbagh, 2011)

Along with human activities and industrialization, the geographical location and meteorological conditions in Hamilton also contribute to the large amount of air pollutants in the city. There is a high air pollutant exposure rate in Hamilton due to all the iron and steel companies, recycling facilities and chemical production plants all located in close proximity. With winds coming from both the southwest and the northeast a large air pollutant build up occurs in the city. With the varying transportation modes in the city from major highways, to railways and cargo corridors, the local residents, and commuters that often use these roads are exposed to high levels of air pollutants. (Al-Dabbagh, 2011)

DEVELOPMENT AND IMPLEMENTATION OF ZERO EMISSION BUSES

LONDON, UNITED KINGDOM



First Hydrogen Fuel Cell Bus in London (Addison, 2011)

What can Hamilton learn from London?

The implementation of these forms of transportation can easily be done across the globe. In addition to improving the air quality globally, this new form of energy developed by these buses can open up a new energy sector to be used in other industry sectors. Ultimately improving the energy efficiency of cities.

3 GOOD HEALTH AND WELL-BEING

7 AFFORDABLE AND CLEAN ENERGY

13 CLIMATE ACTION

As air pollution starts to have an increasing effect on the environment and climate, many cities around the world are developing new technologies to aid in the prevention and reduction of pollution in the community. Zero emission transit or vehicles focus on eliminating the harmful exhaust and reducing the production of air pollutants into the air. Notably in London, the development of zero emission buses including hybrid, electric or hydrogen buses have started to be implemented in the city.

From a case study done by Ballard, (2020) zero emission buses or fuel cell buses emit only water vapour into the atmosphere, eliminating harmful greenhouse gases such as nitrogen oxides, sulfur oxides and particulate matter. By compressing hydrogen to be used as fuel, these fuel cells on board only produce water and heat as by-products. The eight current buses being operated in London are apart of the CHIC, the Clean Hydrogen in European Cities project, consume approximately 9 kilograms per 100 km, which is more energy efficient than the average diesel bus. As hydrogen can be produced from renewable sources such as wind, or solar power, this is an effective solution to both improve air quality as well as being more energy efficient in the long term. (Ballard, 2020)

The city mayor of London invested 300 million pound into retrofitting the bus fleet in London to slowly phase out diesel double-deck buses since 2018. Starting with the introduction of 3000 ultra low emission buses to be introduced in Central London in 2019, 250 zero emission buses would also be introduced in 2020. The implementation of these buses and 12 new low emission bus zones have decreased the NOx by 84% benefiting the residents in the area to healthier and cleaner air. (Mayor of London, n.d.)

AIR POLLUTION IN HAMILTON AN ISSUE OF THE PRESENT

HAMILTON, ON



Factory Discharge Hamilton

“Sustainability to me means the ability to continue a practice for centuries to come without causing long term economic or ecological difficulties. It means to uphold a balance between depleting the earths resources and letting them recover.”

-Salman Ali

AFFORDABLE AND SUSTAINABLE ENERGY

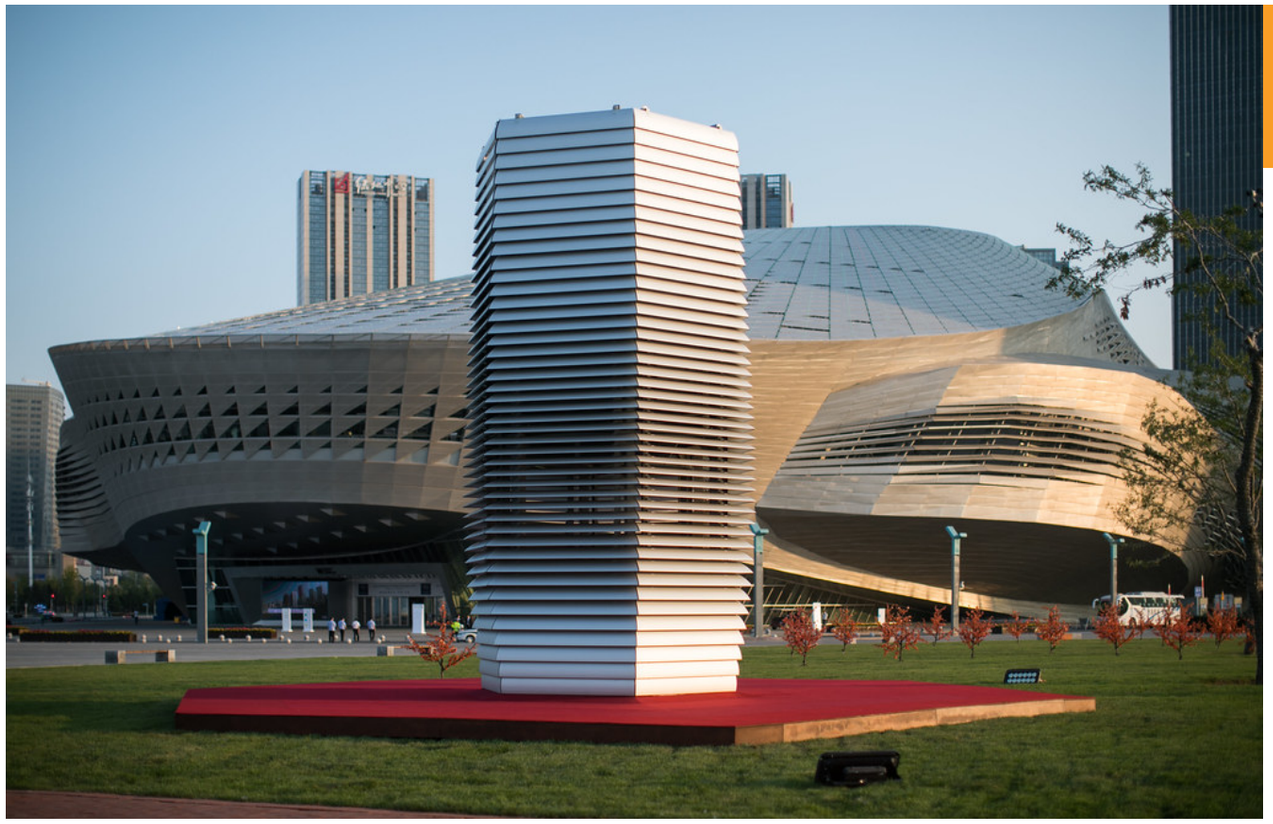
CANADIAN ENGINEERING GRAND CHALLENGES

Hamilton is a port city in the Canadian province of Ontario. With a population of 700 thousand in 2020, it is Canada’s ninth most populated city. The city was established in 1846 and it is situated at the west end of lake ontario. Southwest of Canada’s most densely populated city Toronto. Its transportation routes include highways and rail-roads that go from the United States to the GTA. Thus making the city a prime spot for vehicular traffic. Hamilton is one of the country's most industrialized regions. With over 60% of Canada’s steel produced, the city is known as the “Steel capital of Canada.” It is also home to Mcmaster university one of Canada’s best schools making it a destination spot for many out of region students. All these factors put together have made Hamilton Canada’s most air polluted city. On May 20, 2021 environment Canada issued a special air quality statement which warned people of elevated air pollution in the city of hamilton. This was due to the stagnating weather conditions causing an increase in fine particles and nitrogen dioxide. It was stated that people may experience throat irritation and coughing. This is especially risky for children and elderly with cardiovascular issues.

Over the past few years Hamilton has made considerable improvements in terms of their air pollution. Going from 45 smog days in 2005 to 0 in 2015. The reason being that summers have been cooler and a lot of companies that contributed to the problem have now shut down. However, air quality still remains a significant health issue. According to the statistics air quality in hamilton still contributes to 186 premature deaths, 395 respiratory hospital admissions and 322 cardiovascular admissions each year. (Where have smog days gone? 2015) The big issue is that a lot of Hamilton's pollution reaches there from the United States. The other major sources of pollution are the vast amount of industries and the highways that run through the city. The key takeaway is that while the city has improved there's still work that needs to be done. Whether it’s implementing new strategies to reduce traffic or reducing the production of steel changes need to be made.

THE TOWER OF LIFE

BEIJING, CHINA



Smog Free Tower

What can Hamilton learn from Beijing?

Canada can learn from this and either develop their own smog free towers or use that idea to inspire new innovations that will combat air pollution. Lastly, Canada is fortunate enough to still not be extremely pressured by the air pollution issue. Cities like Beijing, China have much higher levels. With information on what the cause in Beijing was being readily available, Canada can implement measures to tackle the problem way before we reach those extreme levels.

Beijing is a city in china. With a population of over 21 million it is one of the world's most populous national capital cities. It is home to most of China's largest state owned companies and has the most global fortune 500 companies in the world. The city also suffers from some of the worst air pollution in the world. The AQI scales pollution from 0 - 500. WHO claims that a score of 500 is 20 times worse than the safe breathing levels. China now reaches up to 750, the highest it's been since they started recording. (Morrison, S.R) This widespread air pollution can be attributed to a number of things. A few include the economic boom, the rapid population growth, and a large number of motorized vehicles. The triple bottom line relationship is a model used to display the correlation between people, society, and profits. Beijing is a good example, as society and technology grows vast amounts of profit are brought in. This economic success further leads to the purchase of more motorized vehicles which make up 70% of the city's air pollution problem. A dutch artist understood this issue in beijing and came up with the smog free tower. Which is essentially a massive air purifier. The solar powered tower sucks pollutants out of dirty cities, filters them and returns clean air through its vents. The towers' filtering units use ionic filters to charge and remove particles of smog, cleaning 30000 cubic metres of air/ hour. It was confirmed by Eindhoven university of technology that the tower eliminates 70% of the PM10 and 50% of the incoming PM 2.5. (Smog Free Tower, June 8) This type of filtering is done without creating ozone and it can even catch very small particles in the air. The tower can also be used to make jewelry. Under high pressure carbon can become diamonds and nearly half of the pollution powder collected is diamonds. This smog free tower project has also been implemented by Poland and other chinese cities. The goal is to eventually bring it to other polluted areas like the United States and Mexico.

HAMILTON'S SUFFOCATION – RISING CONCERNS OF AIR POLLUTION

HAMILTON, ON



Hamilton's steelmakers emitting large volumes of pollutants.

"Sustainability to me in simple terms means, build for the future, while not only focusing on the short term, but giving relevance to long terms goals, for the prosperity of future generations."

-Jay Patel

SUSTAINABLE INDUSTRIALIZATION

CANADIAN ENGINEERING GRAND CHALLENGES

Air pollution has been on an exponential rise since the industrial age. The uses of fossil fuels and many other contributing factors have increased the parts per million of several harmful compounds that reside in our air. Air pollution can be defined as particulate matter suspended in the air, these particles can be solid or gases. Some examples of these pollutants include car emissions, chemical release from factories, pollen, dust, and mold spores (Radio Canada, 2015). Excessive pollutant levels led to more severe and visible pollution also known as smog and acid rain (Environment Hamilton, 2015). Acid rain is particularly harmful to infrastructure and leads to corrosion of metals and corrosion prone materials. Some of these pollutants in the air are particularly poisonous and harmful to human beings. The inhalation of these pollutants leads to many health issues, people with history of lung and heart disease are more susceptible and have possibilities of developing more serious conditions. Hamilton a city in Ontario, Canada is among the many cities that have both alarming rates of emissions and the release of carcinogens into the environment. The cities economy mostly thriving off industries and mass manufacturing has, entire sectors of the city where plants have been constructed. On the other hand, Hamilton city is surrounded by highways that have large of volumes of traffic (Environment Hamilton, 2019). Cars are a line source of pollution while the factories are point source, both can be modeled to find an accurate representation of pollution released population effected. Although many prevention methods have been implemented in the past and plans for emission reduction were set in place, it will take several years to correct the harm done over the past years. "We just need to have the time to spend the money to achieve what we need" stated Jim Stirling a manager of environment at a large steel production company in Hamilton (Radio Canada, 2015). This has led to growing air pollution in the region.

INNOVATIVE AIR POLLUTION MITIGATION

BEIJING, CHINA



Comparison of same location before and after air pollution control

What can Hamilton learn from Beijing?

Learning from a successful model is a large part of evolving as a society. In the case of Hamilton and Beijing, and their respective air pollution problems, Hamilton and many cities around the world should learn and implement measures in order to avoid the severity of air pollution faced by the people of Beijing. They should start advance tracking of harmful particulate matter in the air and execute plans to mitigate emission from all sectors that are major contributors to the growing air pollution problem.

When air pollution is the topic of discussion, the industrial giant China is always involved. Many cities within the country are know for mass air pollution and poor quality of air, but Beijing emerges a leader amongst all the cities. The efforts of the past to reduce the ambient PM2.5 levels have been insufficient and getting below the National Air Quality Standard of 35 µg/m3 has been a difficult task. Studies show that the implementation of comprehensive mitigation strategies for the residential sector will aid in reducing the overall air pollution levels in the region (Liu, 2019). The plan for mitigation involved replacement of biomass for cooking by liquid petroleum gas and electricity, and substitute coal for heating by briquettes. Together these measures have the potential to significantly reduce the emission of PM2.5 and SO2 by 28% and 11% respectively in turn reducing the death rate from the lack of adequate breathing air (Liu, 2019). Beijing's success in air quality improvement can be attributed to the intensification of the air pollution control programme implemented in 1998, drastically reducing PM2.5 particulate matter in the air. Major reforms were made in various sectors for example energy infrastructure optimization, coal-fired pollution control and vehicle emission control all aided in the betterment of air quality (UN Environment, 2019). The first step to better air quality in Beijing was the monitoring of levels of pollutants in the air. To keep close track of the levels of pollution, Beijing began the construction of the AQM, air quality monitoring system in the 1980s. AQM stations are place in many areas where they can track and monitor the levels of 6 major pollutants some of which included PM2.5 and O3. As the years went by and the technology revolution took place more sophisticated technology was implemented, where monitoring large areas with over thousands of sensors was possible. Through this rigorous process Beijing was able to reduce its air pollution levels significantly but still has much more work to be done.

HAMILTON, AIR POLLUTION LEADER IN CANADA



HAMILTON, ON



Air pollutant emissions in industrial sector in Hamilton ("Hamilton", 2008).

"Different aspects of sustainable development can be assessed either quantitatively or qualitatively. Air quality and pollution is very interesting to me as it is one of the most dangerous issues in my home city, Tehran."

-Kian Ghasemi

SAFE AND SUSTAINABLE CITIES

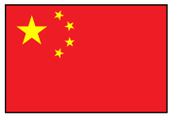
CANADIAN ENGINEERING GRAND CHALLENGES

Hamilton has been one of the most air polluted cities in Canada with an average mortality risk due to exposure to air pollution of 4.6% which is slightly high (Moir, 2013). Hamilton is a medium-sized residential and industrial city with a population of about 747500 people located on the west shore of Lake Ontario (Statics Canada, 2016). Several heavy industrial sectors such 2 largest steel mills in Canada, chemical production factories and recycling facilities are located in Hamilton which have caused this city to experience air pollution problems in the past and present (Al-Dabbagh, 2011). Some of the major reasons of air pollution in Hamilton are:

1. Close proximity of heavy industrial facilities (Al-Dabbagh, 2011).
2. Complexity of metrological conditions (Al-Dabbagh, 2011).
3. Presence of Niagara escarpment and acting as a downwind barrier (Al-Dabbagh, 2011).
4. Presence of various types of transportations modes (Al-Dabbagh, 2011).
5. Long-range transport of air pollutants coming from the industrial areas of the US (Al-Dabbagh, 2011).

Although different kinds of air pollutants exist in Hamilton, 5 major pollutants that have caused premature deaths and hospital admissions in Hamilton each year have been identified (Al-Dabbagh, 2011). These major contaminants consist of Carbon Monoxide (CO), Nitrogen Dioxide (No2), Sulfur Dioxide (SO2), particulate matter (PM) and tropospheric Ozone (O3) (Al-Dabbagh, 2011). The major emission sources in Hamilton are recognized as transportation, industries and open sources. Open sources such as road dusts, construction activities and fireplaces are primary causes of PM2.5 and PM10, Transportation sector is the main cause of CO, NOx and VOCs emissions and industrial sector is accountable for approximately 90% of SO2 emissions in Hamilton (Al-Dabbagh, 2011). More specifically, 226,021 tones of CO, 74,676 tones of PM10, 34,400 tones NOx and 22,287 tones of VOCs had been emitted from point sources as of 2006 in Hamilton alone (Al-Dabbagh, 2011).

INDUSTRIAL RESTRUCTURING AND POLLUTION CONTROL



BEIJING, CHINA



Beijing Smog Comparison (Bobak, 2005).

What can Hamilton learn from Beijing?

Implementing a solution to eliminate air pollution in Hamilton can primarily address Good Health and Well-being and secondarily address Industry, Innovation and Infrastructure, Sustainable Cities and Communities, Climate Action and Life on Land Sustainable Development Goals. Eliminating the air pollution in Hamilton can reach several SDGs targets such as reducing number of deaths and illnesses due to air pollution, developing quality infrastructures that supports human well-being, paying special attention to air quality and reducing the emission of GHGs. In conclusion, different parts of the world may have experienced the problems that we are facing now in our natural environment, and we can use their strategies to face and solve these problems.

The capital city of China, Beijing, is a megacity covering an area of 16400 km2 with a population of 21.7 million people and annual energy consumption of 71 million tons of coal equivalent as of 2017 (UN Environment, 2019). Rapid economic growth in China has applied a lot of pressure on environmental aspects and caused the air pollutant concentrations to significantly surpass Chinese national air quality standards in Beijing (UN Environment, 2019). As a result, in 1998, Beijing Municipal Government, as the first local government, published an announcement to control and reduce the concentration of air pollutants, namely: PM, CO, NO2 and SO2 (UN Environment, 2019).

Beijing as a city with long records of air and environmental pollutions has implemented a series of measures to optimize industrial structures and reduce industrial pollutions such as strict requirements for new development projects, eliminating obsolete technologies, rectifying polluting plants and encouraging end-of-pipe treatments (UN Environment, 2019). Following these measures in 2006, large-scale industrial sectors in or near Beijing city such as Coking and Chemical Plant, Beijing Capital Steel Group Plant and Dongfang Chemical Plants as enormous pollutants were either closed or relocated (UN Environment, 2019). The number of cement manufacturing plants was also significantly reduced from 19 to 2, which are only used for integrated disposal of hazardous material (UN Environment, 2019). Following this trend, since 2013, approximately 1900 smaller manufacturing plants in printing, casting and furniture were relocated or closed and the remaining polluting enterprises were identified to be treated according to their polluting situation (UN Environment, 2019). Furthermore, more than 400 pollution renovation projects took place in Beijing with a great focus to control NOx and VOC emissions (UN Environment, 2019). As a city with high industrial capacities, Hamilton can also use the same measures to significantly reduce its emissions related to industrial sector (UN Environment, 2019).

THE HIGHEST LEVELS OF AIR POLLUTION IN CANADA

SARNIA, ON



Greenhouse gases emitted at Sarnia-Chemical Valley daily. (Al Jazeera English, 2012).

Sarnia is a city located in Ontario on the east side of the St. Clair River and at the south end of Lake Huron. In 2016, it had a population of about 71,000 people. Sarnia has one of the greatest concentrations of chemical industries in Canada and has been declared by the World Health Organization as the city with the highest level of air pollution in Canada with the most particulate matter per cubic meter of air. The populations that are mainly affected by these pollutants are First Nations communities and Sarnia citizens since Sarnia is located approximately 5 km to the Aamjiwnaang reserve. This area is called "Chemical Valley" and has about 40 percent of Canada's chemical industry. It consists of 62 large industrial facilities like petrochemical and oil refinery industry which produce gasoline, plastics, fertilizers, etc. The sales made by all these facilities in 2013 were approximately 20 billion dollars.

Dangerous pollutants are emitted in Sarnia such as particle matter, benzene, sulfur dioxide, hydrogen sulfide, among other hydrocarbons. These chemicals are known for being responsible for health issues like cancer, asthma. Also, they can affect female hormones which cause gender-bending in living beings. This means that the normal percentage of females and males in a population can be affected, for example in Sarnia for every boy, there are 2 girls (Al Jazeera English, 2012).

The health issues stated before are commonly seen in people living in this area and these occur more frequently than in other Canadian cities; however, the facilities in the Chemical Valley are not being responsible for these health issues since an environmental assessment in Sarnia has not been completed.

The emissions released in Sarnia represent about 16 percent of Ontario's NPRI (Canada's National Pollutant Release Inventory) air pollution. During 2005, 16.5 million tonnes of carbon dioxide equivalents were release in this area and it is equivalent to more than one-fifth of Ontario's total industrial greenhouse gas emissions (EXPOSING CANADA'S CHEMICAL VALLEY. An

"For me, sustainability means every action that is taken in order to save natural resources. For example, there are multiple ways to produce energy, but some are going to be better than others. If we produce energy in an environmentally friendly way, the resources are going to be preserved over time and for me, that is sustainability."

-Jhenyffer Mishell Villarreal Fuel

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

FIRST SMOG FREE TOWER IS INSTALLED

ROTTERDAM, THE NETHERLANDS



Smog Free Tower – the largest air purifier device created until today. (Rogers, 2021).

What can Sarnia learn from Rotterdam?

Now, some countries around the world are using Smog Free Towers to reduce their number of particles in the air. China is implementing this device as a solution for air pollution and has been testing it in four different cities. This is a clear example of how a device that is helping to reduce our greenhouse emissions can be used in any country to help the environment.

The number of emissions emitted in Sarnia is high and the best way to stop this is by shutting down some of the facilities that work there. This will diminish the air pollution to acceptable levels. Furthermore, an environmental assessment is necessary to know exactly what is happening in this area and the consequences that it can have on the people living near these facilities.

In the meanwhile, another way to reduce air pollution is by implementing Smog Free Towers. A Smog Free Tower is an air purifying device that is seven meters tall and can absorb fine particles from the air and release clean air. The first Smog Free Tower was installed in Rotterdam in 2015. The tower absorbs the particles from the air at the top of the tower and then it expulses the purified air through six vents on its sides (Garfield & Thompson, 2018).

The Smog Free Tower uses ionization to catch very fine particles that are suspended in the air. This device is able to clean more than 30,000 m^3 of air per hour. The way this Smog Free Tower works is by releasing positive ions that will attach to the fine particles in the air. After this, the particles along with the ions will be attracted to a surface with a negative charge (Garfield & Thompson, 2018). Finally, they will be stored inside the Smog Free Tower and the carbon particles that were absorbed can be used to make jewelry. It is estimated that each piece of jewelry contains particles coming from about 1000 m^3 of air.

A CITY NOT REACHING ITS POTENTIAL IN REDUCING AIR POLLUTION

TORONTO, ON



Toronto Suffering the Consequences of Smog (Kane, 2013).

"Sustainability to me, means that decisions are being made that will not hinder future generations."

-Akshar Gurajada

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Toronto is the largest and most influential city in Canada with 6,254,571 people inhabiting it (Toronto Population, 2021). It is known as both the economic and cultural heart of Canada. Due to this, it is constantly growing with construction constantly increasing in demand for new residences and infrastructure. Toronto is also infamous for its transportation systems. The Gardiner Expressway is known for congestion and serves around 140,000 vehicles on every weekday (City of Toronto, 2019). The 401, another critical highway serves around 500,000 vehicles on every weekday (Staff, 2015). The congestion and the high volumes of vehicles using these highways cause for high levels of air pollution through vehicular carbon emissions.

Toronto also used to be in a much worse situation than it is now. Air pollution was cited to have directly contributed to 1,700 premature deaths along with 6,000 hospitalizations annually by Toronto Public Health in 2004(Gower, et al 2014). In 2014, those numbers dropped to 1,300 and 3,550(Gower, et al 2014), respectively. The biggest cause of air pollution in Toronto is cited to be caused by vehicular traffic of both personal and freight varieties. In 2007, this accounted for 440 deaths and 1,700 hospitalizations annually (Gower, et al 2014). In 2014 however, those numbers dropped to 280 deaths and 1,090 hospitalizations (Gower, et al 2014). The next most impactful factors on Toronto's air pollution are residential, commercial, and industrial. These changes are admittedly large; however far too many people are still being negatively impacted by air pollution to simply declare victory. Progress is being made by policy changes such as reducing the amount of coal fired powerplants and the exploits of organizations such as the Toronto Environmental Alliance and Greening Greater Toronto; however, it is not being made fast enough.

CAR-SHARING AND BIKEWAYS INFRASTRUCTURE



BREMEN, GERMANY



Bremen's Bikeways (Dilling, et al, 2020)

What can Toronto learn from Bremen?

In conclusion, the solution that was used by Bremen of creating more bikeways and allowing more access to carshare vehicles and stations does not only help achieve SDGs but also helps achieve the CEGC. Bremen's plan applied in Toronto would change the way that Torontonians viewed travel and sustainable development. Toronto already has bike lanes but they are often crowded and are used beside oncoming chaotic traffic. Added separate bikeways would severely encourage ditching the car and using the bike ensuring the improvement of Toronto's air quality.

A viable solution to Toronto's problem lies in the ability to deal with emissions formed by the incredible amount of traffic on the roads. Emphasis must be placed on better and more environmentally sustainable alternatives such as public transit. An example of such a solution would be the car-sharing and bikeway system put in place in Bremen, Germany. In 1990 climate change was popularly accepted as a concerning problem. Since then, in Europe emissions have decreased by 23%(cite). All areas had emissions decrease, with the only exception being transportation.

To address this problem, Bremen decided to attack it by authorizing the construction of "bikeways", which are highways for bicycles. Citizens were encouraged to travel short to medium distances by bicycles due to not needing to share the road with cars. Biking 100km saves 15.518kg of emissions in opposition to driving a car (Grassick, 2019). 42% of 2-5km and 26% of 1-2km journeys are made by car (Grassick, 2019). Making bikeways accessible reduces those values significantly. Bremen also considered the demographic of people who would be physically unable to ride a bicycle. If everyone able to ride a bike did ride a bike, they would have a cycling modal share around 40% (Grassick, 2019). These policies saved about 180 kilotons of emissions from when they were introduced in Bremen (Grassick, 2019). Bremen also offers 344 carsharing vehicles at 102 stations (Klimaki, 2020). Each one of these carsharing vehicles reduces the number of vehicles on the roads of Bremen by 16 (Klimaki, 2020). Therefore, the entire fleet of vehicles replaces around 5,000 privately owned cars. Cars account for approximately 15.25 tons of emissions annually (Ingram, 2014), therefore this undertaking saved about 76.25 kilotons of emissions.

CHOKED BY ITS OWN OIL SANDS PRODUCTION



FORT MCMURRAY, AB



An oil sands mine near Fort McMurray

Fort McMurray is an oil boomtown of 66,000 people located in Alberta, right in the middle of the Athabasca oil sands. The Athabasca oil sands are one of the largest natural bitumen deposits in the world, and as such are of great economic value to energy companies and the government. However, the process of extracting bitumen and diluting it from oil sands requires an extensive amount of highly toxic chemicals (Finkel, 2018).

It is estimated that the mining of oil sands creates more carbon pollution than conventional crude oil extraction. Producing oil sands emits three to four times more greenhouse gases than ordinary oil, and every gallon of gasoline made from oil sands produces about 15% more carbon dioxide emissions than one made from conventional oil (Finkel, 2018). Both these factors mean oil sands production accelerates climate change faster than conventional crude oil production.

Oil sands production also increases the level of polycyclic aromatic hydrocarbons (PAHs) in the air. PAHs can bind to or form small particles in the air, leading to respiratory problems. High concentrations of PAHs have been found in snow and water extending as far as 30 miles from the mining facilities at Fort McMurray, Alberta. Skin and respiratory conditions are also typical of short-term exposure to PAHs, and the impact of long-term exposure to PAHs is still not fully understood. In fact, the few studies done to assess health impacts of oil sands reported that people living near oil sands operations have complained of nausea, headaches, skin rashes, joint pain, and respiratory problems (Finkel, 2018).

“To me, sustainability is minimizing the effect of human activity on the Earth so that future generations can live without fear of climate change.”

-Kaiyan Zhang

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

HOW BEIJING CONTROLLED ITS AIR POLLUTION

BEIJING, CHINA



Smog covering the Forbidden City in Beijing in 2013

What can Fort McMurray learn from Beijing?

Fort McMurray would benefit from firm action by politicians, mirroring Beijing's drastic steps to reduce air pollution. The Alberta oil sands are constantly stuck in a state of bureaucracy; the monetary gain is enough incentive for many to be on the fence about the issue. However, other nations have begun to to take action themselves and reject buying the "dirty fuel" harvested from the oil sands. Recently, US president Joe Biden cancelled the Keystone XL Pipeline extension that would bring Canadian oil from Alberta to the US. Canada must also reduce the economic incentive for oil by creating laws and policies that subsidize clean power generation and taxes oil production.

For years, Beijing has been a heavily polluted city, with smog levels unbearably high on a daily basis. This trend however is on the decline, as from 2013 to 2017 Beijing reduced its fine particle levels by 35% (UN Environment, 2019). No other city or region has achieved this level of air pollution reduction. This feat was accomplished through industrialization control, vehicle emission control, and economic incentives.

In order to reduce vehicle emissions the government introduced subsidies to scrap fuel-inefficient vehicles and produce new fuel-efficient trucks, as well as enforcing driving restrictions by stopping car driving one weekday per week for citizens. Improvements to gasoline and diesel quality were also made, phasing out leaded gasoline and reducing sulfur content in fuels. The government also implemented and enforced stricter emission standards, as well as subsidizing clean energy and closing down major coal power plants. Additionally, residential heating was overhauled with replacement and renovation of older homes and heating systems (UN Environment, 2019).

All these aforementioned methods were either heavily subsidized or strictly enforced by the Chinese government. This shows that through financial investment and politicians "buying in" to the process of sustainability, it is possible to reduce air pollution. Drastic environmental policy changes then allow individual citizens in a developing country to have the financial support they need to reduce their carbon footprint. Additionally, enforcement of said policy changes also forces private enterprises to respect the environment and not flaunt rules and regulations.

WILDFIRES



HIGH LEVEL, AB



Helicopter drops water on Chuckegg Creek Wildfire

“”

-Margaret Wang

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

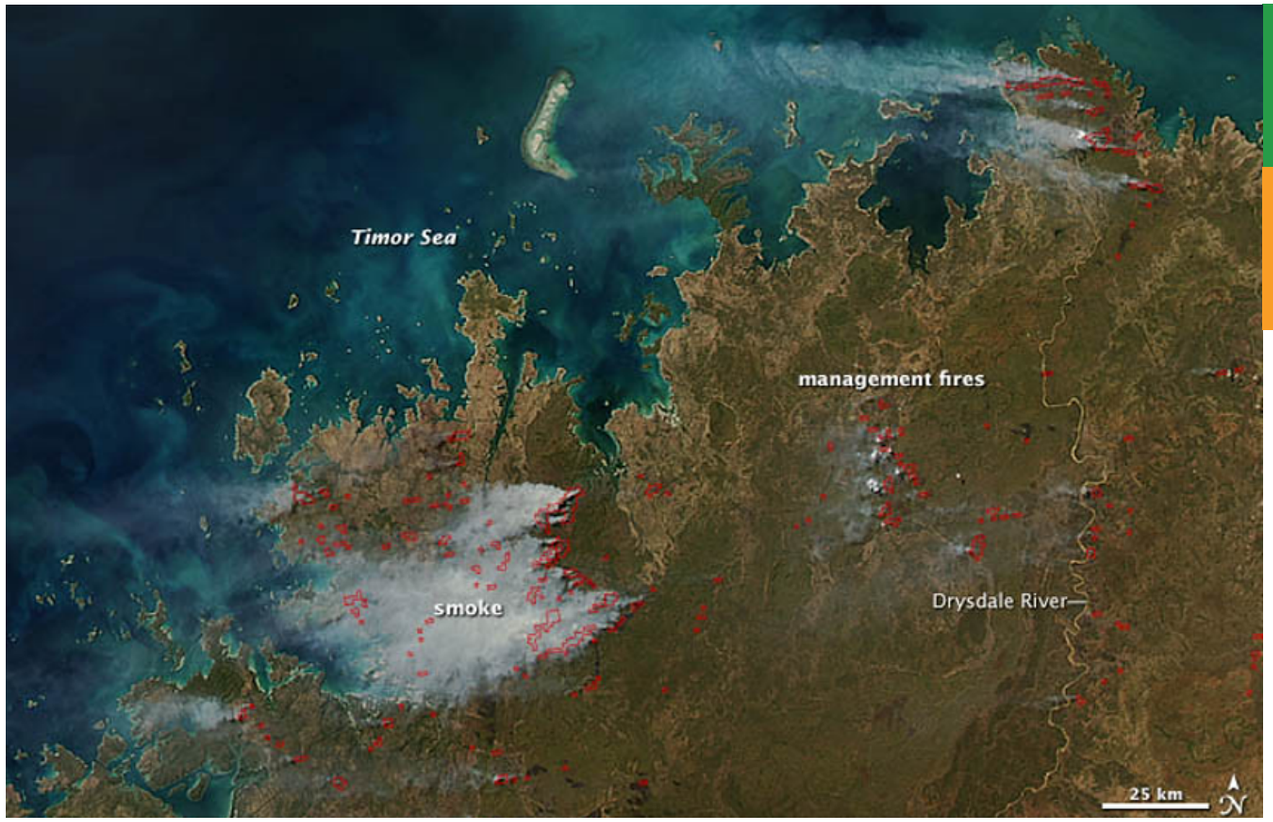
Wildfires are hazards in regions containing forests and originate from lightning strikes or human causes. Numerous air pollutants are present in wildfire smoke, including fine particulate matter, carbon monoxide, and volatile organic compounds. Most of these pollutants have no safe exposure level, with PM2.5 having the greatest health risk (Government of Canada, 2021). Wildfires are the largest source of PM2.5 in Canada, representing 17.1% of population-weighted exposure. PM2.5 exposure has been strongly associated with respiratory morbidity and all-cause mortality, with effects being more pronounced in regions with frequent wildfires (Matz et al., 2020).

High Level, population 4,000, is a town in northwestern Alberta near the Boreal forest (Town of High Level, n.d.). On May 12, 2019, one of the largest wildfire incidents of the year, known as the Chuckegg Creek Wildfire, started from lightning and travelled as near as 3 km from the town. Residents evacuated on May 20 and were not permitted to return until 2 weeks later (Bourne, 2020; Ramsey, 2019). The fire burned out of control for 98 days over 350,135 hectares. Firefighters across Canada and the US helped contain it (Government of Alberta, 2019). Visibility and air quality was impacted in areas far from the fire. 740 km from High Level, the AQHI for Edmonton reached 10+, peaking at 72, on a 1-10 scale on May 30, indicating a very high health risk (CTV Edmonton, 2019).

Alberta’s 2019 fire season was extreme with 993 wildfires burning 880,000 hectares. Though the number of wildfires was below the past nine-year average, the total burn area was nearly 2.5 times the nine-year average. The abnormally dry and windy conditions contributed to the severity (MNP LLP, 2020). Extreme wildfire activity is becoming more common due to climate change.

PRESCRIBED BURNING

KIMBERLEY, AUSTRALIA



Dozens of management fires burning in Kimberley, Australia

What can High Level learn from Kimberley?

Carbon credits could provide Alberta with funding needed to do controlled burns more frequently. The Indigenous peoples of Canada also practised prescribed burning- this program could allow them to reclaim that part of their culture. It will be challenging to convince residents near burned areas to accept that creating fires reduces wildfires as the concept is counter intuitive and controlled burns still release pollutants to nearby communities. Climate change lengthens the fire season, reducing the opportunity for prescribed burning. Both the Kimberley and High Level will have to adapt to this. Strategies need to be customized to each area based on factors like forest composition and population density.

Wildfires are an important part of the forest ecosystem. Several plant species depend on the heat for seed germination. Prescribed burning is the practice of setting short duration, low intensity fires under controlled conditions to decrease the amount of dead organic matter, which serves as fuel for wildfires. Performed in cooler months, it reduces the risk of intense out-of-control wildfires occurring in hotter months (National Geographic, 2020).

Aboriginal cultures across Australia used fire to manage forests. Following European settlement, the practice was lost. Wildfires became more frequent and destructive (Bowman et al., 2020). To combat this, the Federal Government's Emissions Reduction Fund encourages prescribed burning in northern Australia. The goal is to reduce greenhouse gas emissions by preventing wildfires. Australian Carbon Credit Units (ACCUs) are issued for each tonne of CO_2 equivalent diverted from being released into the atmosphere. Credits are sold back to the government or to businesses, which pay a premium price to offset their own emissions. Since 2012, 7 million ACCUs, valued at $98 million, have been earned. Nearly half of the projects are carried out by Indigenous Australians (Kim, 2020).

The Kimberley region of northwestern Australia contains 40,000 people and has one of the lowest population densities on the Earth (Kimberley Australia, n.d.). Since 2014, four North Kimberley native-title groups amassed 400,000 ACCUs through traditional burning methods, equivalent to saving GHG emissions produced by 84,493 cars in a year. Funds earned have trained over 50 full-time rangers. Prescribed burning has led the region to be one of few in Australia to have no species extinctions (GE, 2016). The federal program has significantly decreased the area destroyed by wildfires from 26.5 million hectares in 2000 to 11.5 million hectares in 2019 (Allam, 2020).

CHAPTER 3: WATER RESOURCES AND WATER SCARCITY ISSUES



View of Village Well/Pinterest

CHAPTER INTRODUCTION

The quality of our life very much depends on the sustainability of our water resources, as such, the sustainability of water resources requires a look at both the quantity and quality of water. This module looks at the "quantity" part of water, by exploring water availability and scarcity globally. An understanding of the hydrologic cycles puts in perspective all our water resources, and an understanding of the biogeochemical cycle highlights pathways of substances through air, water and land. This module introduces the water budget equation, and tracks water use in society by analyzing the water footprint and tapping into the meaning behind virtual water.

Learning Outcomes

By the end of this week, you will be able to:

- Analyze global trends of water resources by mapping water availability and scarcity
- Review the hydrologic cycle
- Locate water resources and human influence on the natural water cycle
- Define very briefly the biogeochemical cycle to identify the magnitude of water repositories and residence times
- Explain the parameters of the water budget equation
- Determine the objectives for sustainable water resources and uses
- Track water use in society
- Define virtual water
- Interpret the water footprint of products

DROUGHT IN STARBUCK, A “DRY JOKE”



STARBUCK, MB



Panorama View of Starbuck, MB, with all of its vast agricultural plains in view (Dyet, 2006)

“I personally think that the human population has the potential to become very sustainable, however, the population also needs to be educated on the dangers of unsustainable development. Once we are all aware of the issues at hand, we can start to move forward as a society.”

-Ali Qussay Ibrahim Al-Saeed

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Historians, political geologists and people with tinfoil hats have always clamored that the next global warfare event will be about water, and that Canada will be the crown's jewels in this hypothetical event. It's not hard to see why, Canada has more than 50% -yes FIFTY- of all the natural lakes on Earth (Andrei, 2021). Furthermore, 9% of Canada's surface is covered with fresh water (Andrei, 2021). Therefore, it is indeed some sort of joke when one comes to realize that a large portion of Canada goes through drought regularly and is quite vulnerable to it. Last month, farmers in the rural agricultural town of Starbuck, Manitoba have experienced unprecedented drought, one farmer stating that he "has never seen his fields this dry" (MacIntosh, 2021).

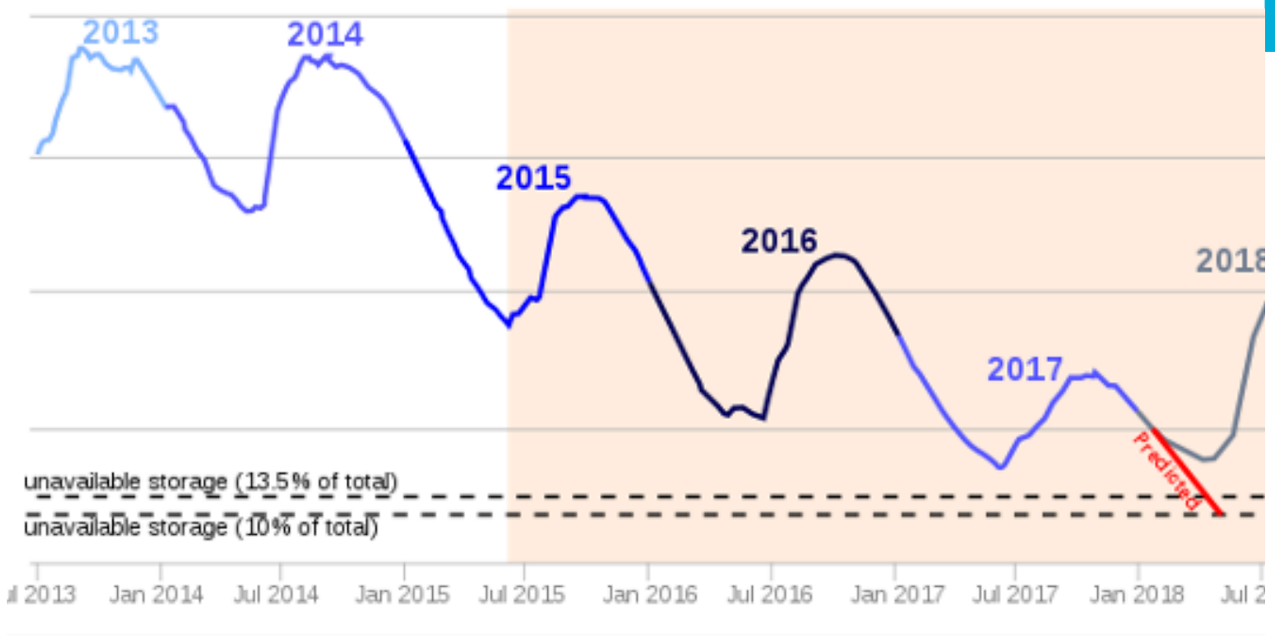
The community of Starbuck is as quiet and unassuming as a community may be, with a small population of 342 (Statistics Canada, 2019) it is truly the definition of a farm town. Its only apparent importance is that it houses a hotel that is quite close to a golfing range. But Starbuck does something very important to our case study of the water scarcity issue in Canada, it represents a sample of a much larger problem.

The challenge being faced by Canada is that geographically speaking, Starbuck is just a part of the great Prairies of Canada, a region stretching from the shore of the Hudson Bay to the Eastern slopes of the Rocky Mountains. These Prairies are extremely susceptible to drought, which can have adverse effects. First of all, much of Canada's grain comes from the Prairies and from towns like Starbuck (Hedlin, 1995), hence being dubbed "the Breadbasket of Canada". It is possible to spend hours deciphering the physical geographical causes of this issue, but, it is more vital to decipher its solution.

SCARING CAPE TOWN INTO HAVING WATER AGAIN



CAPE TOWN, SOUTH AFRICA



Caption

What can Starbuck learn from Cape Town?

All in all, Starbuck can learn from Cape Town. What solved the problem in Cape Town was not a clever engineer or a sly politician, it was the people themselves. We can look at the people of Manitoba, and more generally at the people of Canada. By reducing how much water we use, we can make sure that Canada's breadbasket is always filled with freshly baked bread.

Cape Town, the Capital of South Africa, a country situated at the southernmost tip of the African continent. "The Mother City" as it is dubbed by locals (Vellai, 2021), it enjoys being a cultural hub to South African history with the Iziko South African Museum (Vellai, 2021) with its showcase of fossils and historical tools. An economic hub as South Africa's 2nd largest city, its sprawling urban infrastructure is juxtaposed with the mountainous terrain that has been naturally eroded and shaped by ocean's currents (de Bruyn, 2020). Culture, food, history, economy and nature, clearly, this city has everything.

Except at one point, the city was scarily close to running out of water, the most vital resource for ANY community, city, and civilization. Cape Town was close to running out of water in 2017, and on the verge of undergoing drought, which is unheard of in modern history for a city of its size (Mahr, 2018). Should have disaster struck, it would have been a free for all for water for Cape Town's residents. Not only that, industries that require water for functionality (so ALL industries) would have been halted if not severely hampered by this imminent water issue.

So what did South African Government do? Did they call upon the finest engineers to figure out a complex mechanism of desalination? Or did they strike a genius deal with a water rich country to fulfill their water demands? No and no. Simply put, the South African Government warned Cape Town's residents of "day zero" a day where the water levels at dams would get so low, that taps would not turn on (Mahr, 2018). This scary notion worked as Cape Town residents reduced water usage and Cape Town never ran out of water. Proving that often the best solution is education. Cape Town was warned of a civil war and political unrest should "day zero" strike, and Cape Town listened.

A SMALL STEP TOWARDS SOLVING FIRST NATIONS WATER CRISIS

LYTTON FIRST NATIONS, BC



Lytton's nearby waterways and water supply (Shaund, 2005)

"To me, sustainability means using Earth's natural resources in a way that does not exhaust all of these resources in a relatively short amount of time, or cause harm to the environment in order to mine these resources."

-Gaurav Dosanjh

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

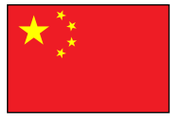
Lytton, British Columbia, is one of hundreds of Canadian First Nation communities that have undergone a water crisis. 50 of these communities have been under boil water advisories for decades. Karen Dunstan, one of 945 First Nations people living in Lytton, describes the situation as "You would have flu-like symptoms and have diarrhea and vomiting from drinking the water [without boiling]," (Nadeem, 2018). This is due to the animal feces and agricultural activity upstream from Lytton's water supply that release bacteria such as E. Coli into the water. Elders in the community attribute drinking the untreated water as the reason for the deaths of several children (Nadeem, 2018).

When Lytton's aging water facility was not providing clean water, the Lytton residents submitted a proposal to the federal government, which was rejected for not being cost-effective. Resolute in getting clean water for their community, Warren and Jim Brown, worked with RES'EAU-WaterNet, a research network at the University of British Columbia. After studying the facility, RES'EAU decided to implement a brand new facility, costing only $500,000, that would service six homes in the Lytton community. However, even after the facility's completion in 2015, Lytton's water crisis was still not solved (Nadeem, 2018).

Warren and RES'EAU came up with a new system to treat water in five more homes in the Lytton community, costing only $10,000 per unit. Even though eleven houses have clean water, there are still thirteen homes that still boil their water, as their sources of water are not reliable enough to support this new system (Nadeem, 2018).

Dr Majid Mohseni, scientific director at RES'EAU, says "there is great potential" in scaling the small success in Lytton nationally (Nadeem, 2018). Warren Brown says that if Lytton are to continue their success, the necessary work needs to be done to maintain its water systems (Nadeem, 2018).

DESALINATION STRATEGY FOR WATER SCARCITY CRISIS



QINGDAO, CHINA



The city of Qingdao, China (风之清扬, 2009)

What can Lytton learn from Qingdao?

The desalination plant in Qingdao proved to be a good solution to their potable water scarcity issues, but would a similar strategy work for Lytton, or other First Nations communities suffering from water crises? Well, as mentioned previously, Qingdao's desalination plant costed a lot of money to build and costs a lot of power to use. Additionally, the desalination plant provides water for 500,000 citizens a day, a population much larger than Lytton or any other First Nations community. Therefore, a desalination plant may be a viable solution for communities such as Lytton, if a smaller one was built that was still able to produce potable water at a reasonable rate.



Qingdao, a coastal city with a population of nearly 6 million (World Population Review, 2021), is the largest economic and industrial centre in China's Shandong province. Due to the amount of water used by residents exceeding the city's water supply capacity, Qingdao decided to commission China's largest desalination plant (Urban Water Blueprint, n.d.).

The plant uses reverse osmosis to filter ocean water, getting rid of salt, micro-organisms, impurities, and any other pollutants to produce water for 500,000 Qingdao residents a day. For the centralized pumping system, the plant integrates isobaric energy recovery devices to reduce the amount of energy used by the reverse osmosis process. These devices, with an efficiency of 98%, reduce the energy consumption by up to 60% (Water Technology, n.d.). They will save above 2,000 kW of energy, reduce annual carbon dioxide emissions by 10,000t, all while delivering potable water to Qingdao's residents (Water Technology, n.d.).

However, by costing $176 million USD (Water Technology, n.d.) and consuming 4 kWh of power per cubic metre of water produced (Zhong, 2014), the desalination plant strategy is not necessarily a viable solution for every city facing a water scarcity crisis. That being said, it has been a very effective strategy for the citizens of Qingdao, China.

With 33 countries likely to experience severe water crises by 2040 (Maddocks, 2015), innovative technology such as Qingdao's desalination plant may be crucial in solving this issue. Steps will need to be taken to reduce the cost, both monetary and environmentally, of desalination plants to make them the leading strategy in solving water scarcity crises.

COMMUNITIES ARE HIT HARDEST WITH CANADA'S WATER CRISIS

LYTTON FIRST NATIONS, BC



Village of Lytton

""

-Juntaek Lim

RESILIENT INFRASTRUCTURE

CANADIAN ENGINEERING GRAND CHALLENGES

Despite Canada being the globe's third largest per-capita freshwater reserve, it is quite unconvincing many indigenous communities in the country face a drinking water problem. The drinking water sourced to the tap faces deteriorating water quality issues, and regulatory and transportation complications that account to unsafe water pollution. It is important to understand the mechanism of water filtration, regulation, and transportation varies by municipality and geography. Therefore, the source of contamination also correlates to environment, it is usually probable for chemical contaminants to be discharged into water reserves in developed areas through industry, whereas in developing regions, usually organic contaminants through agriculture. Most Canadians take pride and appreciate having easy access to freshwater wealthy reserves, however most microbial contaminants cannot be simply detected through one's primary senses. It is vital to have access to safe drinking water for good health, as consumption of such contaminated water can lead to diarrheal diseases and chronic enteropathy.

The Lytton First Nations has more than 2,000 members, who live on small reserves scattered along the Fraser and Thompson rivers near the Village of Lytton. The primary water source for the water connections to the Lytton First Nations reserves come from the nearby Lytton Creek. The single treatment method is utilized by treating the discharged water with 12% liquid sodium hypochlorite(bleach/chlorine) then dilution to safer levels (City of Lytton, 2011). Despite treatment, all nine water systems on Lytton First nations land in BC have all been under boiled water advisories. Boil water advisories are set in place by the federal government where tap water should be boiled for safe consumption, and for decades the residents have had to depend on this daily routine because of inefficient transportation, severe contamination, and faulty treatment systems.

PORTABLE SOLUTION THROUGH REVERSE OSMOSIS

NIGER DELTA REGION, NIGERIA



Amnesty International slams Nigerian gov't, Shell over Niger Delta oil pollution

What can Lytton learn from the Niger Delta Region?

Although Nigeria and Canada faces a much different level of development, it is important to note the areas affected by safe water issues are both rural. With many overlapping environmental factors and social factors such as being small communities, Reverse Osmosis Systems can be viable in providing Safe Water to Lytton.

Regardless of the state of development in a country, rural areas and their municipalities face common issues of providing safe drinking water to its residents. Much of the water found on reserves in the Niger Delta region of Nigeria are brackish water containing heavy ionic contamination and are polluted through industry and other human alterations of the environment. Specifically, for this region, the petroleum industry posed as the largest source of ionic contamination, as the nation's crude oil contains heavy metals and hydrocarbon contaminants. The constant drilling of fluids through the country's industry as introduced myriads of nickel, vanadium, and cobalt. The heavy metal content required a substantial desalinization process with the added restrictions of it being a rural community, such as lack of constant electricity and lack of technical professionals.

A Reverse Osmosis filtration system works by using a pressured pump to increase pressure on the salt side of the system and forces the water across a semi-permeable membrane, leaving most of the ionic salts in a reject stream. The system is efficient as the heavy ionic concentrated water in the reject stream could be recirculated back in the system for filtration. The pressure required would depend on the ionic concentration in the initial feed, as enough pressure is required to overcome osmotic pressure. With a low pressure of 1.5 MPa, the membrane revealed the highest selectivity of 98.8% for CoCl2 and 99.3% for NiSO4.(National Water Research Centre, 2018). The selected cellulose membrane was most effective at directing the nickel sulfate into the reject stream. The employment of portable reverse osmosis filtration systems showed effective results and proves to be a viable solution tailored to the rural geography with a low electricity consumption and a successful desalinization process.

THE INDIGENOUS WATER ISSUE; SCARCITY OF WATER



NESKANTAGA RESERVE, ON



A signpost in Neskantaga shortly after the incident, detailing the frustration regarding the treatment of indigenous peoples by Canada

“Sustainability to me means trying to balance the resources and time to ensure a better present and future.”

-Michael Tan

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

The environmental issue being studied is the scarcity of clean drinking water for various communities. Worldwide, over 900 million people have no access to a clean drinking water supply, with 3900 children dying every year due to sanitation, water access, or hygiene related diseases. This environmental problem occurs when there is not enough clean water for necessities such as drinking water, washing, and cooking. When the demand for these necessities is more than the amount of water stored, the water withdrawn is deemed unsustainable. This trend is a major environmental issue as it will continue to grow with population. With more people, more communities, and limited clean water supply, water scarcity will increase greatly in the future.

This is further exemplified in Canada, where indigenous communities have been experiencing clean water issues for over 25 years. Though the issue is one that should be dealt with immediately, it has not been, and speaks to the underlying racism that indigenous people deal with to this day. An example of this is the Neskantaga Reserve, alongside the shore of Attawapiskat Lake in the District of Kenora. It is 2054 acres of land, containing the area of Lansdowne House Indian Settlement where the issue stems from.

250 members of the reserve were evacuated as oil was found covering the reservoir, which led to the community having no access to clean water. However, they already had a boil-water advisory for over 26 years, a much larger issue than the evacuation. Though the cause of clean water issues varies from reserve to reserve, the reasons usually stem from the water’s source and how far away the community is. Although the oil coverage has displaced these members of the community, the real issue that remains is the lack of clean water they received to begin with.

RECLAIMING WATER: SOLUTION TO WASTEWATER



SINGAPORE



One of the many NEWater treatment plants in Singapore, implemented to increase water sustainability within the region.

What can the Neskantaga Reserve learn from Singapore?

There is a major difference in the solution to this issue between Singapore and the Neskantaga reserve. Though Singapore's resources are far greater than that of the reserve, it is important to note the federal responsibility that the Canadian government holds, as they have yet to implement a viable solution. The Canadian government must follow Singapore and use their resources accordingly to resolve the clean water issue faced by countless indigenous people daily.



A technological solution to the clean water crisis is recycling water by reclaiming wastewater for future use. By doing so, the amount of clean water that can be consumed increases, which is a viable solution given the right funding and direction for the project. This process can be used for agricultural, urban, and industrial use; usually starting from the plant where water is treated and processed to a usable standard. To do this, the water must be freed from pathogens, which is usually done through several processes including forward osmosis, reverse osmosis, and ultrafiltration. The treatment of the water depends on its usage after treating it; for example, it is only a secondary level treatment when irrigating crops and does not have to go through much of the processes that a first level treatment would normally. The second stage is to distribute the reclaimed water through piping, where a dual piping process is prescribed, separating the recycled water pipes from the regular ones, and distributing to its respective area of use.

Though there are many social and economic barriers that limit the solution from being used worldwide, Singapore has implemented reclaimed wastewater seamlessly. In 2017, Singapore opened its fifth reclamation plant, which combined can take in almost 40% of Singapore's daily water demand. Titled NEWater, the project covers over 228,000 m3 of water per day under BEWG International.

The project is one of the four sustainable water sources in Singapore, the others being local imported water, catchment water and desalinated water. It was built with concerns to water sustainability in the region, as the Linngu water reservoir had dried up prior to its creation. Alongside the rising costs of production of water, Singapore's response to the situation was exemplary, and it now leads the world in reclaimed and retreated wastewater.

RAPID DEGLACIATION CAUSING WATER SCARCITY

VARIOUS COMMUNITIES, AB



Runoff water form the melting glaciers in Alberta (Sund, 2014)

Without a doubt, the rising temperature caused by CO2 emissions and the ocean warming is responsible for the glaciers melting which will soon leave us with nothing. According to David Hik, an ecology professor at Simon Fraser University, 80 percent of the mountain glaciers in Alberta, will disappear within the next 50 years (Alam, 2018). This will cause a vulnerability in four areas, Lake Louise, the towns of Hinton and Rocky Mountain House, and the Bighorn Dam as the glaciers are a main source of fresh water to over 4.4 million people (Herring, 2020). The towns of Hinton and Rocky Mountain House are currently provided with fresh water from the glaciers that run into the river. The warm climate over the summers create a natural run off of water and during the winter, there is a balanced turn around where there is a replenishment of ice which keeps the cycle moving. However, due to climate change, there has been a net loss in glacial ice in which a rapid deglaciation decreases the flow in the river near these communities making them susceptible to unpredictable water levels. These glacier fed rivers are used for more than just fresh drinking water, it is also used for irrigation in agriculture, producing hydroelectricity, and other purposes (Rieger, 2020). With the current trend in deglaciation, the communities must beat the curve and plan to implement water management strategies if a solution cannot be implemented. If changes are not implemented, whether they are strategies or infrastructures, these communities would have to relocate to places that have sufficient fresh water.

"Sustainability to me means finding ways to make the world a better place not just through looking at aspects of the environment but also looking at social and economic resources."

-Thushnica Villavarajan

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

THE FORMATION OF ICE BABIES TO SLOW DOWN DEGLACIATION



ILULISSAT, GREENLAND



Iceberg in Ilulissat Icefjord, Greenland (GRID-Arendal, 2011)

What can Alberta's Communities learn from Ilulissat?

Although the submarine is a quite large device that processes sea water but altering the size and process of the device can help tackle smaller glaciers that are inland like the ones in Alberta. At the same time, Greenlanders can learn from the towns of Alberta that it is important to look ahead at problems that can arise are start making minor changes to policies and strategies around their lifestyle.

The melting of glaciers has become a phenomenon in the past two decades. Around 10% of land on Earth is covered with glaciers which stores 70% of Earth's fresh water (Tandon, 2021). If glaciers keep melting at the same rate, sea level will rise, the climate will be impacted, species will dissapear, and fresh water will be at minimum (Corporativa, n.d.). The town of Ilulissat in western Greenland have yet to be impacted however, Jakobshavn Glacier, one of the largest outlet glaciers located near the town, is melting due to the warming sea that is eroding the glacier's base. If the effects are not minimized, the town will lose their main source of fresh water and the increase in sea level will cause the entire community to evacuate from the coastal area. Over recent years, glaciologists and other scientist have determined that glaciers can still be saved and thus have been working to find a solution. Indonesian architect and scientist, Faris Rajak Kotahatuhaha, was awarded for designing a submarine-like device to revitalize the glaciers through the creation of artificial icebergs (Griffiths, 2019). The submarine with a hexagonal tank collects the seawater and separates the salt and water through reverse osmosis. A month later, it releases 2,073 cubic meters of ice that has been blasted with cold air into the water which combined can form a larger ice floe. The design is meant to counter the sea level rising caused by glaciers such as the Jakobshavn Glacier as it ends near the sea. This design will not only balance the polar ecosystem but the technique can be used to spread over ice caps which will strengthen the consistency. This will help continue to contain the fresh water that is being provided to towns like Ilulissat, Greenland and others around the world.

THE POTENTIAL INCOMING WATER SUPPLY GAP

VANCOUVER, BC



The mountain pair, The Lions, with snow on the verge of melting (Devynia, 2006)

"Sustainability is being able to improve on something with minimal effects, if any, on future generations while also being cost-efficient."

-Mahmoud Abouelhassan

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Despite the myth of water abundance across the country, Western Canada, which is well-known for its rainfall, has never been more prone to a water crisis than now. This is evident by the seasonal water restrictions Vancouver residents have constantly been facing. Due to the region's annual precipitation patterns showing a lack of rainfall over the summer seasons, heavy reliance on snowpacks is a necessity to maintain water reservoir levels for the population to make up for the anticipated shortages during those times (CBCnews, 2019). However, with global temperatures, including Canada's, rising at such an alarming rate and the melting of glaciers, the mountain snowpacks the city depends on have been melting earlier into the year than ever before. Hence, even less water is available during dryer parts of the year as the water runs through river basins quicker and dries out faster (Collins, 2018). This is extremely worrying as it is projected for the population of Vancouver to almost triple within the next thirty years, and with that comes a somewhat proportional demand for water as well, considering that at least a quarter of the current population of the country relies on groundwater for drinking (Bakker, 2019; Chan, 2021). Moreover, the snowpack is expected to halve in size around that same time, coupled with the fact that just in 2015, three Metro Vancouver reservoirs have undergone critical water levels due to a lack of precipitation, which is on the way to a decline of 13% by the end of the century (Low, 2019).

Even though short-term solutions that tackle that dilemma are in the works, such as upgrading the infrastructure for water reservoirs to increase their capacities, this will simply not be enough to withstand the region's increased demands by the latter half of the century (Metro Vancouver, n.d.). If this trend continues and no precautions are taken, it is expected that by the beginning of the next decade, Vancouver will face a major water supply gap and potentially even multi-year droughts (Collins, 2018).

UNDERSTANDING O.A.S.I.S. BOXES FOR ITS WATER SHORTAGES

JURR VILLAGE, PAKISTAN



Solar panels powering up water filters in Pakistan (PrinceGabol, 2020)

What can Vancouver learn from Jurr Village?

By adopting similar strategies around the world, in addition to heavily encouraging communities to contribute on a larger scale and implementing long-term solutions associated with the over-consumption of the valuable resource, we can not only tackle the water scarcity problems we are about to face in Canada, but the entire world's as well. Therefore, it should be among our utmost priority to do our part and help with problems in the grand scheme of things to make up for the demands that have and always will continue to be on a constant incline.

Even though first-world countries might face occasional water restrictions, water scarcity issues experienced by those around the globe should not be dismissed where families remain unsure about the next time they will be having a cup of water to drink (Sen, 2019). Unfortunately, Jurr Village in Punjab, Pakistan, is one of the many places that face this challenge. To address this issue, Hamza Farrukh and his team at Bond-E-Shams decided to design an innovative sustainable plan that helps provide access to clean water to the people of his village (Martin, 2018). They developed "O.A.S.I.S. Box," a solar-powered container that utilizes water pumps to collect and filter water from boreholes and springs, and harvests rainwater using a funnel-shaped collector on top of the device. Besides Jurr Village, the idea has been successfully implemented across other communities in Pakistan and rural villages in Sudan. Moreover, there are plans to expand to other countries such as Yemen and Bangladesh (Bond-E-Shams, 2020).

Based on the results in Bond-E-Shams's brochure (2020), the project has been proven to be able to provide 10,000 litres daily per container, and each container is expected to last at least twenty-five years with virtually no maintenance, all while costing less than ten thousand dollars and taking around seven minutes per set-up. Furthermore, as a part of the emphasis on sustainability, the collected rainwater helps restore groundwater reserves to maintain ecological balance, and the excess stored solar energy can be utilized to provide grid-free electricity. Considering all the cost estimates, each litre of water would cost around three-hundredth of a cent, making it more than three-thousand times cheaper than a water bottle (TEDx Talks, 2019). It is important to note these estimates do not account for the tons of plastic waste and transportation complications associated with the bottled water industry.

ABUNDANT BUT INACCESSIBLE — WATER CRISIS IN NESKANTAGA FIRST NATIONS, ON



Public notice of the boil-water advisory in Neskantaga (Christina Jung/CBC)

“To me, sustainability means living in such a way that what we take from the planet does not vastly exceed what we contribute. It means to meet our needs while replenishing our planet's resources so that future generations can meet their needs.”

-Tayaba Tunio

Even though Canada has the third largest per-capita freshwater reserve in the world, the water many Indigenous communities depend on is contaminated, difficult to access, or at risk due to faulty treatment systems. The Neskantaga First Nation is just one of the hundreds of First Nation communities and reserves that are suffering from a water crisis in Canada.

The Neskantaga First Nations Reserve is a remote community located in Northern Ontario that is only accessible by air and an icy road in the winter. The nation's main water source is Attawapiskat Lake, which has poor water quality because of the decaying organic material from trees and plants. It has been under a boil-water advisory for over 25 years, the longest advisory of this kind in Canada (Omar Sachedina & Ben Cousins, 2020). The reserve's water treatment plant was built in 1993 and has "never produced safe drinking water" (Olivia Stefanovich, 2020); residents have been using bottled water since 1995 (Olivia Stefanovich, 2020). Many of the residents have never experienced life with potable tap water at home and hundreds were even evacuated out of their homes in October 2020 for months due to a water crisis.

The Neskantaga water crisis is by no means an isolated event as there are currently 54 long-term water boil advisories in Indigenous communities (Government of Canada, 2021), meaning that they have no access to clean drinking water. “‘There's not a drop of any water going to any building in this community. Not to the nursing station, not the school. That's what people don't get. There's absolutely no water going to anywhere.’ - Neskantaga Chief Christopher Moonias” (Madison Ketelaars, 2021).

SAFE WATER IN OUR COMMUNITIES
CANADIAN ENGINEERING GRAND CHALLENGES

CLOUD FISHERS

AÏT BAAMRANE, MOROCCO



Cloud Fishers on Mount Boutmezguida

What can Neskantaga First Nations learn from Aït Baamrane?

While the specific technology of the CloudFishers can not be used by every rural community facing water scarcity, the actions taken by the people to ensure that such communities receive safe water can be adopted by every community, city and country. Compared to the Canadian government who turned a blind eye to the problems their indigenous population was facing, Dar Si Hmad went above and beyond to ensure that the Berber population had access to water in their homes.

The Aqualonis CloudFisher (also known as fog catcher) is a device that harvests fog from the air when it is blown into the CloudFisher's 3D mesh nets (E4C Solutions Library, 2021). The mesh nets intercept the droplet stream, producing suspended water droplets. Then the water runs down into either a storage tank or a distribution system (Manzoor Qadir et al., 2021). The process requires no energy and the water harvested from these nets in clean and complies with WHO safe water drinking standards (Aqualonis, 2021). These fog nets best in rural or coastal areas where there is plenty of mist to draw water from. They have been successfully implemented in California, Tanzania, Peru and Morocco (E4C Solutions Library, 2021).

Aït Baamrane is a region located on top of Mount Boutmezguida in southwest Morocco, on the edge of the Sahara Desert. In recent years, this region has been under the threat of drought and many of its residents suffer from frequent shortages of water during the summer months. Local communities have had to either collect rainwater in cisterns or walk miles to collect water from wells (Emma Grillo, 2018). While the arid region receives an annual rainfall of only 112 mm, it is located near the Atlantic Ocean and therefore experiences frequent fog events (Manzoor Qadir et al., 2021). This made it an ideal region to implement the CloudFisher.

The Water Foundation installed the first CloudFisher, developed by Aqualonis on Mount Boutmezguida in 2013 in collaboration with Dar Si Hmad, a local non-profit organization. In 2021, they have been expanded to meet the needs of 16 local villages which all together have a population of about 1000 residents (Tara Stevens, 2021), most of which are indigenous Berbers. About 22 liters of water can be collected on a foggy day per square meter. This means that one CloudFisher with 24 square meters of collection surface can produce 528 liters of water per day (Andrea Nyilas, 2021). Overall, the project has been a huge success in sustainably providing potable water to the local rural population which previously had no convenient source of clean water.

AT RISK OF WATER SHORTAGES DUE TO CLIMATE CHANGE

OSOYOOS, BC



Osoyoos Lake Potentially Facing Water Scarcity Issues

"To me, sustainability means being able to transition and rely on renewable energy sources in the future. Currently, the world is relying on fossil fuels as a main energy source which won't be sustainable in the future as the supply will eventually run out."

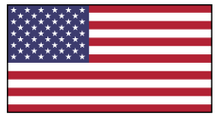
-Daniel Ro

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Rising global temperatures have caused more and frequent droughts which is ultimately leading to water scarcity issues. Climate change has been interfering with weather patterns causing severe natural disasters such as floods and droughts, making water availability to be unpredictable. A water shortage could occur when a severe drought causes a dry period and surface water begins to evaporate; this ultimately accelerates the rate of water depletion. When a city or region is unprepared for water shortages, the quantity and quality of water that a population, specifically children, need to live healthy becomes at risk. In fact, UNICEF states that 1 in 4 children will live in areas of high-water stress by 2040 which means that access to safe drinking water would be limited (UNICEF, 2021). In addition, underdeveloped communities are likely to be affected the worst as they already face threats to water supply (UN-Water, n.d.). A Canadian town that is potentially facing water shortage issues due to rising temperatures and climate change is Osoyoos, a town located in the Okanagan Valley of British Columbia (Tamminga, 2021). British Columbia may be perceived as a province with an extensive supply of water however this is no longer the case as global warming has caused more long-lasting droughts which is making region susceptible to water shortages (Gower and Barroso, 2019). As a matter of fact, Osoyoos' average amount of precipitation in the month of May has been 34.7 millimetres over the past 30 years, however in May of 2021, Osoyoos only received 2.5 millimetres of rain (Tamminga, 2021). Also, with the population continuing to grow and farmers already requiring a high demand of water, the situation has already become quite severe (Gower and Barroso, 2019).

SOLVING WATER SCARCITY THROUGH DESALINATION



SAN DIEGO, UNITED STATES



San Diego on the Coast of the Pacific Ocean

What can Osoyoos learn from San Diego?

In terms of city-to-city learning, Osoyoos may want to adopt desalination on the scale that San Diego has to combat water scarcity but should ultimately consider its limitations. Specifically, the fact that desalination is energy intensive and mainly uses fossil fuels. Nonetheless, this solution is helping solve water scarcity around the world and if Osoyoos can balance the trade-offs effectively, sustainability can be achieved through desalination.

To combat the growing problem of water scarcity as global temperatures rise, many cities around the world have adopted a process called desalination. In short, desalination is the process in which water molecules are separated from ocean seawater with the use of reverse osmosis technology, thus creating safe drinking water (SDWCA, 2019). While this solution is quite revolutionary and on paper does solve water scarcity issues around the word, there are some serious limitations. For instance, desalination requires a great amount of energy to separate salt and water molecules apart from each other and this is mainly achieved through the use of fossil fuels (Robbins, 2019). This is a severe drawback as water scarcity is a result of climate change and desalination increasing greenhouse gas emissions adds onto the problem rather than solving it. However, San Diego, a city on the coast of the Pacific Ocean in the state of California, has very limited options as they their natural water supply has greatly diminished over the last two decades (Robbins, 2019). As of 2019, there are 11 desalination plants in California and 10 more have already been proposed (Robbins, 2019). A noteworthy desalination plant in San Diego is the Claude "Bud" Lewis Carlsbad Desalination Plant which provides 50 million gallons of fresh water a day to the entire city (Robbins, 2019). San Diego has adopted desalination to combat water scarcity as they only receive 12 inches of precipitation a year and their natural water supplies are extremely low (Robbins, 2019). While desalination currently affects the environment in a negative way, sustainable and energy- efficient desalination has been a major research topic around the world (Maya, 2020). It would be revolutionary if desalination could be powered by renewable energy sources while also being cost efficient at the same time.

NO CLEAN WATER FOR DECADES



CURVE LAKE FIRST NATION, ON



Buckhorn Lake, a Freshwater Lake (Non-Potable Water), Surrounding Curve Lake First Nation

“Sustainability is a complex topic that involves the balance of addressing the needs of society and the environment without exploitation, such that future generations can access the same resources the past and present generations are able to. It ensures that all components of the world's systems are sustained, supported, and distributed in a just manner.”

-Koreen Legaspi

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Curve Lake First Nation is an Indigenous reserve with an area of approximately 9 km2 around 25km northeast of Peterborough, Ontario (About Us « Curve Lake First Nation, n.d.). The reserve consists of a peninsula and an island surrounded by two freshwater lakes -- Buckhorn Lake and Chemong Lake, the former of which is pictured below. There are roughly 700 members living on the reserve (About Us « Curve Lake First Nation, n.d.); many of these members have experienced several recurring water advisories placed in their community for decades, including a drinking water advisory from August 2015 to June 2018 (Whetung, 2021), and a presently effective boil water advisory issued in 2018 (Daily Updated Listing of Canada’s Boil Water Advisories (BWA), n.d.). These water advisories have essentially created a scarcity of potable water on the reserve, attributing to complex, unsustainable consequences in the environment, economy, and health of the community members. The root cause of this water scarcity is the lack of federal government funding towards the community’s water treatment infrastructure, operations, and maintenance. In 1983, a water treatment plant was built on the reserve with a lifetime of 20 years; the plant has yet to be rebuilt upon (Kovach, 2021). Since the end of its lifetime, community members mainly receive potable water from private wells – if they are not already dried out – or depend on water bottle deliveries imported to the reserve by trucks (Kovach, 2021), an expensive process from an economical and environmental perspective. As of mid-2021, the chief of Curve Lake First Nation has joined a $2.1 billion class-action lawsuit against the Government of Canada, citing their obligation to fund and provide access to clean, potable water to First Nation communities (Whetung, 2021). It states that a new, $50 million water treatment plant is to be implemented on Curve Lake First Nation, which will take in fresh water from Buckhorn Lake, giving community members reliable access to clean water.

RAINWATER HARVESTING FOR CLEAN DRINKING WATER

ISLAMABAD, PAKISTAN



6 CLEAN WATER AND SANITATION

Storage of Rainwater in Pakistan

What can Curve Lake learn from Islamabad?

Canada's federal government should reflect on Islamabad's strategies to increase clean drinking water for their citizens; namely, by collaborating with appropriate stakeholders, such as the UNDP, to invest and maximize in relevant research and funding for sustainable infrastructure design of a rainwater harvesting system, and prioritizing the implementation of these successful and affordable systems for communities suffering the most from water scarcity. This could involve, for example, the installation of reservoirs collecting water run-off from Curve Lake First Nations' surrounding lakes, slow sand filtering for filtration and cost optimization, and more.

In 2010, to address water scarcity in Islamabad, the Pilot Rainwater Harvesting Project was implemented at Faisal Mosque, a mosque in the city, funded by the United Nations Development Program and the Pakistan Council of Research for Water Resources (Teepu, 2010). The project consists of an urban rainwater harvesting system that aims to provide the city's population of approximately 1 million people with consistent, clean drinking water (Walton, 2016). Large reservoirs collect rainwater from rain, seasonal floods, streams, and local runoff from the mosque's drainage water. The water is then processed through slow sand filter beds -- which have a large filtration surface and no required pumping (Esposto, 2009) -- to filter out particulate matter, and finally inverted recharge wells towards the city's groundwater table for human use (Schwengsbier, 2010). There is also a on-site monitoring system that evaluates the rainwater collection and performance of the project, which aims to increase the city's availability of water per capita that has decreased by over 100% from 1951 to 2010, and attribute to a rise in the local groundwater table (Teepu, 2010). Since the project's implementation and success in 2010, its design has been adapted for rainwater collection in buildings across the city; Islamabad's building code has been updated to mandate similar harvesting system designs in buildings with an area over 330m2. As of June 2021, city officials have made rainwater harvesting mandatory for all buildings in Islamabad during the monsoon season. These systems have ultimately contributed to reaching Islamabad's daily need of 200 million litres of water per day and the city's progress towards eradicating its water scarcity issues.

WATER TROUBLES



LYTTON FIRST NATIONS, BC



River near Lytton, British Colombia (Pearce, 2018)

"To me, sustainability refers to the responsible consumption of natural resources at a rate that does not compromise the ability for future generations to access these natural resources."

-Adrian Ng

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Over the past century, global water use has increased at double the rate of population growth (United Nations, 2021). As a result, significant stress has been placed on global water resources, which is compounded by the growing challenges countries face due to water pollution, degraded water-related ecosystems, water scarcity caused by climate change and cooperation over transboundary waters (United Nations, 2021). As of 2017, 2.2 billion people lack safely managed drinking water, and 4.2 billion lack safely managed sanitation globally (United Nations, 2021), which are vital in maintaining human health and preventing the spread of the current Covid-19 pandemic.

Despite Canada having access to 7% of the world's renewable freshwater supply, not every Canadian has access to clean water (Lee, 2021). Lytton First Nation, located in British Colombia, is one of many rural on-reserve Indigenous communities in Canada, and is home to 945 people (Nadeem, et al., 2018). Like many other small rural Indigenous communities, Lytton suffers from acute water scarcity due to contaminated water sources, difficult to access water sources and faulty treatment systems (Nadeem, et al., 2018). The community relies on water from nearby rivers and creeks, but animal faeces and agricultural activity upstream releases coliform bacteria such as E. Coli into the water, making it unsafe to drink (Nadeem, et al., 2018). While Lytton does have a water treatment facility, it is old and cannot provide safe drinking water for the community (Nadeem, et al., 2018). Even though a new water treatment plant was introduced in 2015, it only serves a certain number of houses in the reserve (Nadeem, et al., 2018). Government funding for providing clean water for Indigenous communities is only eligible to communities of 5 households or more. However, like many other reserves, Lytton has reserves with fewer than 5 houses spread out over long distances (Nadeem, et al., 2018), preventing these households from receiving financial help to access clean water.

MYSTIFYING SOLUTION TO MOROCCO'S WATER PROBLEM

AÏT BAAMRANE, MOROCCO



Moroccan Fog Catching Nets (Prisco, 2016)

What can Lytton First Nations learn from Aït Baamrane?

I believe that the Lytton First Nations community could learn from the ingenuity of the NGO's implementation of fog catching techniques to achieve water security for the Ait Baamrane community in Morocco. The mountainous geography of British Columbia, combined with the humidity, considerable precipitation and warm temperature during the summer could be an indicator that fog occurs often (McDonald, et al., 2020). As a result, fog catching technique might be a viable solution to some of the water scarcity issues First Nation communities in the area are facing.

In southwest Morocco on the edge of the Sahara, the rural community of Ait Baamrane, located around Mount Boutmezguida, have traditionally had women walk approximately 5 km to collect water from open wells to bring back to their families (Cardi, 2018) (United Nations Framework Convention on Climate Change, 2021). However, with groundwater levels decreasing due to increased consumption and weather events exacerbated by climate change (Cardi, 2018), the daily challenge to find water has become much harder. As a result, approximately 50% of the population in these rural communities had left for the city in search of better living conditions (Cardi, 2018). Fortunately, these communities are blessed with an abundance of mist that rolls over the slopes of Mount Boutmezguida on an average of 130 days per year (Cardi, 2018). With assistance from the non-governmental organization (NGO), Dar Si Hmad, a system of special nets has been deployed out over an area of 600 square meters, collecting an average of 6,300 liters of water per day (United Nations Framework Convention on Climate Change, 2021). Using a technique where one uses special nets hung between two poles, to trap water droplets suspended in mist. The winds push the mist through the mesh, where the water droplets are then trapped, condense, fall, and collect in a container at the base of the unit (United Nations Framework Convention on Climate Change, 2021). Afterwards, the water is then filtered and transported via pipes to water reservoirs supporting the villages and families. In fact, similar methods of water collection have been deployed in various tropical parts of the world. Starting from South America in the 1980s, the method of fog collection to achieve water security for communities has been utilised in countries like Guatemala, Ghana, Eritrea, Nepal and even the tropical regions of the United States (Cardi, 2018). The pilot project served 5 villages with 92 large households and livestock, and has succeeded in empowering women, decreasing water-borne diseases and environmental degradation, and achieving water security for the villages (United Nations Framework Convention on Climate Change, 2021).

Water Sample/Power

CHAPTER 4: WATER POLLUTION AND METHODS TO IMPROVE WATER



CHAPTER INTRODUCTION

Water that has been withdrawn from a water source to serve some purpose for human activities is returned back polluted in some way or another. Since the list of water pollutants is a lengthy one, this module groups these pollutants in terms of human influences: atmospheric influence, ground influence and accumulating influence. To cover this very broad topic in one week, this module touches upon atmospheric influence conceptually; ground influence insofar as it relates to surface water and stormwater runoff and understanding the solids in waters; and accumulating influence as it relates to impacts of agriculture on water quality. Quantitative models of water quality that are introduced include the biochemical oxygen demand, oxygen sag curve, and the Streeter-Phelps Equation. Methods to improve water quality are presented in terms of reducing quantity of runoff, reducing quantity of pollutants, and application of engineering methods to mitigate the impacts.

Learning Outcomes

By the end of this week, you will be able to:

- Identify water pollutants
- Describe water quality parameters
- Review the atmospheric influence of human activities
- Describe the concept of buffering in lakes
- Identify surface water sustainability
- Identify measures of surface water transport effectiveness
- Demonstrate the characteristics of storm water runoff
- Categorize and calculate solids in water
- Describe impacts of agriculture on water quality
- Identify measures of aquatic health
- Analyze the biochemical oxygen demand
- Describe the Oxygen Sag Curve
- Execute computations using the Streeter-Phelps equation
- Identifying sustainable mitigation measures to reduce human influence on waterways
- Describe methods to reduce the quantity of runoff
- Describe methods to reduce the amount of pollution entering waterways
- Describe engineering methods to mitigate impacts of water pollution

HOW WATER BECAME OVERWHELMED WITH ARSENIC

YELLOWKNIFE, NT



The Giant Mine, Northwest Territories. (Jacques, 2018)

"Sustainability means solving problems with solutions that don't cause bigger problems in the future. It's all about seeing how we can positively impact the present without hurting ourselves in the long run."

-Noah Hayter

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Canada is one of the world's richest countries in terms of mineral production. Canada is the global leader in the production of potash and ranks among the top five global producers for cadmium, cobalt, diamonds, gemstones, gold, graphite, indium, nickel, uranium, and many other minerals. Yellowknife, Northwest Territories, is one such city that grew because of its proximity to valuable gold deposits. There are drawbacks to extracting this wealth. More than 213,000 tons of lethal arsenic trioxide dust was produced as a byproduct of extraction and dewatering during the lifespan of the Giant Mine, a massive producer of gold just thirty minutes from the city. Arsenic in its inorganic form is extremely poisonous, and this amount of arsenic is enough to be lethal to all people on earth ("A step toward a permanent solution to the arsenic remediation puzzle," 2017). The arsenic from mine tailings is highly water soluble, and readily dissolves into groundwater. As a result of the Giant Mine's operation, Yellowknife's groundwater and lakes are contaminated with high concentrations of Arsenic Trioxide. The Government of Northwest Territories advises against drinking water from natural sources, as well as swimming, fishing, and growing food near contaminated lakes (Government of Northwest Territories, 2017). Yellowknife has attempted to avoid the highly contaminated groundwater by piping water at great cost from upstream of the Giant Mine, but the infrastructure needs replacement (Williams, 2018). Tailing ponds near Yellowknife Bay contain extremely high concentrations of arsenic and other toxins when compared to the legal limit, and these ponds are at a higher elevation than Yellowknife Bay. Failure of the retaining structures would be catastrophic in further contamination. Yellowknife is grappling with finding a way to source uncontaminated water to its people, and the region is desperate for solutions.

HOW POLLUTED GROUNDWATER INSPIRES HOPE



SAN JOSE, CHILE



Reverse Osmosis Plant (Grellier, 2010)

What can Yellowknife learn from San Jose?

It is not realistic nor a desirable conclusion to suggest that mining enterprises should be stopped, but we must prioritize our water quality over our economic and technological pursuits. Countries all around the world have grappled with this issue and have found solutions: Canada can do likewise. With the implementation of advanced water treatment systems, hygienic mining practices, monitored waste control, and effective cleanup of past pollution, our society can deal with the problem of arsenic in our waters, and hopefully achieve a healthier, cleaner world.

San Jose, Chile, a city of more than a million people in South America, has had similar problems to Yellowknife. Tailings from nearby mines have dispersed and deposited arsenic in the air, soil, and water. Groundwater has become heavily contaminated from this arsenic. In addition, greater concentrations of arsenic are found in groundwater throughout Chile because of its geology, and natural groundwater in San Jose has high concentrations of arsenic, up to 700ug/L (Bryjak, Kabay, Rivas, & Bundschuh, 2016). Drinking water with high concentrations of arsenic can contribute to increased risks of cancer, cardiovascular disease, cognitive deficiency, and deaths in babies and young adults (Government of Northwest Territories, 2017). Mines near San Jose have found safe and productive ways to mine and minimize the impact of arsenic contamination. Firstly, tailings need to be disposed of properly. Tailings are disposed of in impermeable ponds, rather than allowing them to be deposited in streams or rivers as they have been in the past. Once the tailing evaporates, residues can be scraped up and contained within impermeable containers away from water. Tailings can also be disposed of in dry quantities and encased so that dust contamination is reduced. After tailings are processed, the arsenic can be treated to take a non-poisonous form. This involves treatment with ferrous salts to absorb the arsenic. Once the bulk quantities are secured and protected from the open environment, arsenic quantities in groundwater must be addressed. The best way to remove arsenic is to install a complex filtration system using reverse osmosis (Bryjak, Kabay, Rivas, & Bundschuh, 2016). These solutions have in large part been responsible for improving the health of residents of San Jose and reducing the impact of arsenic.

WATER POLLUTION FROM OIL SANDS OPERATIONS

FORT MCMURRAY, AB



Tailing ponds from oil sands near Fort McMurray utilized for storing wastewater from operations.

“I believe we need to live our lives with an approach that there are limits to everything and that we cannot and should not have everything in large amounts.”

-Mayyar Al-Atari

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

The environmental problem of water pollution faced by Canadian cities such as Fort McMurray and Athabasca is due in part to water pollution from oil sands operations. This is a major contributor to both unsustainable water consumption for operational needs and for large scale damage to the water shed in the region with over 11 million liters of toxic waste from oil sands leaking into the Athabasca River chemicals such as mercury and lead (Climate Action Network, 2013). One of the main operational utilization of water is to utilize fresh water to separate the sand and the bitumen components from the physical oil sand. The storage of the subsequent wastewater is done through trailing ponds which overtime outgrow their capacity and lead to large scale run offs such as the 11 million liters released. Another negative impact of the oil sands in the Athabasca River is the that if unsustainable water consumption practices by the oil sands are not changed then it estimated that by 2050, the downstream flow of the Athabasca River will be reduced by 30% (Afewor,2018). Fort McMurray has a population of about 70,000 with an urban area of 60 km², with the increase in water contamination in the Athabasca River from the oil sands operations the city has had a drastic spike in the water treatment costs. Furthermore, the oil sands are adding to the increase of water pollution problems that are caused by the forest fires.

OIL FIELD, INNOVATIVE SOLUTION OF WASTEWATER RECYCLING

KINGFISHER COUNTY, UNITED STATES



Image of water recycling operation for the recycling wastewater from oil fields in Calumet, Kingfisher County Oklahoma

The city Calumet in Kingfisher County Oklahoma in the United States has utilized developed an innovative solution with the help of government incentives to help mitigate the impact of water pollution due to oil extraction operations. The solution is to use recycled wastewater from the output of the operations as the source of the input of the operation, this helps both reduce the amount of fresh water the oil operation consumes, while also drastically reducing the amount of wastewater the oil operation releases into the local environment, which in the case for the city of Calumet (Saunders, 2017). For example, the city of Calumet in Kingfisher County Oklahoma was able to recycle up to 30000 barrels oil production wastewater a day, which is the same amount as the amount of water needed for the operation to run meaning it has achieved a high level of optimization (Wertz, 2017). The technical process of recycling the wastewater has multiple steps. Step one is to pump the wastewater into a series of tanks, where oil is separated from the wastewater, as oil rises to the surface of the water due to oil having lower density than water. Step 2 is to pump the tanks of wastewater with chemicals and helpful bacteria. Step 3 is to pump air to help the helpful bacteria grow and oxidize the iron sulfates in the wastewater tanks. The idea with the bacteria is for the helpful bacteria to outgrow and remove the unwanted bacteria present in the wastewater. Step 4 is to remove the treated wastewater from the tanks and treat it with other chemicals, which will result in water that can now be used again. The city of Calumet has a population just under 500, with Kingfisher County having a population of 16000 and an area of 2500 km².

What can Fort McMurray learn from Kingfisher County?

The city-to-city comparisons that with the correct industry rules, regulations, and standards to help incentives innovative solutions such as in Oklahoma where oil fields began to recycle wastewater, the city of Fort McMurray can utilize the same model as Oklahoma to help reduce the impact of clean water consumption and wastewater spillage in the local environment.

WATER CRISIS IN NESKANTAGA FIRST NATIONS RESERVE



NESKANTAGA FIRST NATIONS, ON



Chartered flight to Neskantaga ....

“To me, an action or decision is sustainable when it can be repeated at the same energy/rate for a relatively long period of time (without detriment or harm).”

-Nathan Lee

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Canada is known to have access to incredible amounts of safe drinking water in comparison to many of its counterparts, but several Canadian communities are still fighting for a glimpse of the fair, equitable access to drinking water that the nation is so proud of. A region in Neskantaga, home of the Neskantaga First Nations, has been advocating for clean running water for multiple generations (Stefanovich, 2020).

The Neskantaga region is situated ~450km North of Thunder Bay, ON. Since 1995, the region has been placed on a water boil advisory, which was issued to prevent the risk of water-borne illness due to compromised water quality (North Western Health Unit, n.d.). Neskantaga was initially placed under this advisory due to the decaying organic material found in Attawapiskat Lake - its main water source since the community was established. To put this into context on a nation-wide scale, there are 3,100 Indigenous Reserves in Canada … 54 of them are currently under long-term boil advisories (Government of Canada, 2021).

Although Neskantaga has had a water treatment plant since 1993, the facility has not produced safe drinking water since its inception, leading to decades of reliance on plastic water bottles, exposure to water-borne illnesses, and primitive methods of purifying water. Additionally, this water quality issue has accelerated related issues, such as: solid waste management, inadequate infrastructure, and overall efficiency for the region’s over 300 inhabitants.

Attempts have been made to mitigate the water crisis in Neskantaga, but funded expansionary work for the regional infrastructure fell through. The licensed contractor made claims regarding inadequate federal funding and inadequate scopes of work (Stefanovich, 2020). With the COVID-19 pandemic, major projects in inaccessible regions such as this one are becoming more and more scarce; unfortunately, the Government of Canada seems to have used the pandemic as a scapegoat for decades of negligence towards their Indigeneous communities. The water

HARMONIZING BEAUTY AND PURPOSE GREEN INFRASTRUCTURE

WATERLOO, CANADA



Silver Lake, Waterloo Region
An example of a well-integrated stormwater pond in the KW Area

What can Neskantaga First Nations learn from Waterloo?

With the abundance of physical water supplies in Canada, the action taken must be economic and political. Building new infrastructure is the only thing stopping dozens of First Nations communities from accessing the resources they deserve. Unfortunately, the Neskantaga Region is only one of hundreds of overlooked communities. For every 10 people, 3 do not have clean water available at home (Reid, K. 2021). Millions face water-related issues that often lead to dehydration, starvation, illness, and death. As engineering students, we can take the lessons we've learned in our own backyard as a reminder of what we are studying to improve.

Water pollution in Canada is caused primarily by industrial pollution/waste, stormwater/agricultural runoff, and inadequate infrastructure (ie. sewage systems, stormwater management facilities). (The Conference Board of Canada, 2013) Green infrastructure plays a big role in maintaining safe levels of stormwater runoff, one of the aforementioned influences, which also happens to be one of the fastest growing sources of pollution (Environmental Protection Agency, n.d.). This is likely due to the exponential increase of urbanization in developing cities.

Stormwater runoff occurs when rain hits impervious surfaces such as rooftops, parking lots, and sidewalks instead of wetlands, forests, and grass. The rain feeds into storm drains that run directly into our waterways. Runoff can be harmful because it can pick up pollutants such as road salt, sediment, trash, oil, heavy metals, automobile-related toxins, and even animal bacteria/viruses before entering our water mains (Denchak, 2020).

Green infrastructure keeps waterways clean in two ways: water retention and water quality. In terms of water retention, green infrastructure prevents runoff by capturing rain where it falls. This allows the water to filter through the green infrastructure and either run down into the groundwater or return to the atmosphere through evapotranspiration. In terms of water quality, the soil and plants found in green infrastructure assist in capturing and removing pollutants from the stormwater before it re-enters the water cycle. Examples of these methods include permeable pavements, rain gardens, bioretention cells, green roofs, and rain barrels. All of these methods have their merits, and can be implemented on both individual and municipal levels.

The Region of Waterloo is actively employing stormwater ponds to reduce flooding, control erosion, and collect pollutants primarily coming from stormwater runoff (City of Waterloo, n.d.). With over 81 stormwater ponds in the region (City of Waterloo, O.D., n.d.), this strategy has become a well-integrated part of the KW area, and

INDUSTRIES THAT HELPED BUILD CITY ARE DESTROYING ITS WATER

HAMILTON, ON



Steel Mill in Hamilton, Ontario/Russ Heinl / Shutterstock

Hamilton is a port city with the 7th largest port in Canada and has the highest industrial activity in the Toronto–Hamilton region. Hamilton is one of the biggest manufacturing hubs in Canada where more than 60 percent of Canada's steel is produced in Hamilton. However, one of the biggest concerns in Hamilton is the water pollution in the water bodies within and near the city. The government of Canada has labelled the Hamilton harbour as an area of concern where Randle Reef in the Hamilton harbour is the largest Canadian contaminated sediment site (Government of Canada, 2021). According to Numbeo (2021), Hamilton has the highest water pollution rating out of any other Canadian city with a moderate rating of 54 on a scale of 100, whereas other big cities of similar size such as Mississauga in Ontario has a low rating of 32. Water in Hamilton is highly polluted due to manufacturing waste such as coal, metal, and oil spills that are ending up in Lake Ontario. For instance, a 60-hectare blob of coal tar has been discovered from the bottom of Lake Ontario which is found to be releasing cancer-causing chemicals into the air (Kelley Bennett, 2021). Similarly, a 24 billion-litre spill of sewage has been discovered in Chedoke Creek which is further polluting the water. An ecological risk assessment from SLR Consulting says dredging the creek bottom would harm whatever wildlife still survives (Mitchell Don, 2020). Water pollution in Hamilton is a serious concern that is causing a hazard for the residents of Hamilton as well as the wildlife in the area. The government of Canada has started to take steps to help improve the quality of water in Hamilton but it will take many years to fully clean the water which is highly contaminated.

"Sustainability is the practise of ensuring that the things humans create, does not negatively impact the earth and all the living things on earth. Sustainability also refers to creating things that will sustain themselves such that they do not break down easily and will not require a lot of maintenance or use up a lot of earth's natural resources."

-Hamza Kazmi

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

USE OF HYDRO PLANTS PLAN TO TACKLE ITS WATER TOXICITY

MCDOWELL COUNTY, UNITED STATES



6 CLEAN WATER AND SANITATION

Hydro Panels in McDowell County/Zero Mass Water

West Virginia is one of the biggest coal mining states in the United States of America with a population of approximately 1.2 million residents. However, the coal mining in West Virginia has led to high levels of contaminants in its groundwater. In an interview with BBC, Casey, a resident of West Virginia explained that the taps in her house have been worn down, her washing machine frequently stops working, and the tap water poured in a cup has a strange smell and a sticky texture and within minutes begins to turn dark orange and a layer of black sediment soon sinks to the bottom of the glass (Evans Gareth, 2019). To tackle this problem, the State is implementing a variety of different solutions, for instance, EPA awarded $24.7 million to the state for the creation of water treatment plants that will help purify the groundwater by treating it with filters and chemicals (EPA, 2020). Furthermore, to target rural areas such as McDowell County which are greatly affected by coal pollution, water-generating Hydro Panels are being installed. Hydro Panels are new technology created by a partnership between one2one USA Foundation, DigDeep, and Zero Mass Water, and these panels will make clean water from air and sunlight by absorbing water vapour from the air onto a hygroscopic material (one2one, 2019). Each Hydropanel array will create up to 3,600 litres of clean, renewable drinking water each month which will allow residents of West Virginia who do not have access to any clean water due to toxicity by coal to get access to safe water while water treatment plants are being built to clean the groundwater.

What can Hamilton learn from McDowell County?

Hamilton, Ontario is approaching the problem by containing the contaminated water such that it does not further spread, and then further purifying the water in the contaminated area. Whereas in contrast McDowell County, West Virginia now creates water treatment plants that will slowly purify the groundwater and until that they have built Hydro Panels to generate water. Here McDowell County should follow Hamilton's water containment box project to find the most contaminated water bodies, containing them and then purifying them first such that wildlife survives in the area. Similarly, Hamilton, Ontario can also build Hydro Panels as it is a very sustainable source of clean water and will help ensure that the city will have enough water for the future.

FILLING UP FOR A ROAD TRIP TO DISEASE AND CONTAMINATION

FORT MCMURRAY, AB



Flow into Tailing Pond, near Fort McMurray

“”

-Jose Kulamkuthyil Sebastian

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Water is life. It is one of the most vital substances for life to sustain and when water gets polluted, it can create a detrimental impact on small to large populations worldwide. Water’s ability to be a good solvent has allowed humans to use water to transport waste and substances effectively, which includes pollutants. The release of untreated contaminants into bodies of water has raised concerns about how corporations and governments are dealing with habitat destruction and toxins being transported up the food chain. This is an ongoing issue along the Athabasca River in Fort McMurray, and it is discovered that toxic waste from nearby tailing ponds is getting into the river and groundwater. The leakage from these tailing ponds was brought to the attention of the Canadian federal government and it is confirmed the evidence of “compositions of tailing fluid and natural bitumen-influenced groundwater in recent years” (Riley, 2020). The study found that naphthenic acid concentrations were a sign of anthropogenic affected groundwater containing toxins and found levels ranging from 6-2 mg/L, where 2 mg/L NAs is normal (CEC, 2020). The indication of toxins can have detrimental impacts on the people and wildlife that use groundwater and the river for drinking water as these toxins can lead to a higher risk of disease and cause cancer. Fort McMurray, a small emerging city located in northern Alberta is famous for its oil-rich sands which brought several energy companies and employees to the population (Campbell, 2013). Though these companies have offered economic prosperity to the area, they have violated environmental laws. These laws were established to keep away chemicals from the extraction process so that they will not affect the health of the residents and wildlife. If no further action is taken against violating environmental laws and no new solutions are found, the ecology and people will find the region no longer be viable.

USING GEOMEMBRANE LINERS PREVENT CONTAMINANT LEAKS

THURLES, IRELAND



Tailing Pond with a Geomembrane Liners underneath

What can Fort McMurray learn from Thurles?

As seen from the Lisheen Mine in Ireland, the use of multi-layered liners is effective at mitigating leakages from tailing ponds and preventing the groundwater of nearby communities from being negatively impacted. Through this, the tailing can sit in ponds longer until they have broken down and can be properly disposed of. Fort McMurray should be able to make sure the companies are using this technology to alleviate the impact of the oil extraction process on its inhabitants not only on living things but also the water, the sustainer of life.

The issue of contaminations from tailing ponds mixing with groundwater and nearby river systems is quite common worldwide. The process of diverting the leaked water into seepage is deemed not enough in resolving the ongoing leaking issue that many mines and regions of energy extraction face. One solution that many tailing ponds are starting to use is geomembrane liners that reduce the permeability for the toxins to leak out of tailing ponds (Tuomela et al., 2021). One location that has used this technology is at the Lisheen Mine in Thurles, Ireland. Thurles is known to be rich in lead/zinc mining and many mines have been established nearby of which faced issues during the planning phases from the usage of lined tailing management facility (TMF). To prevent this issue, the Lisheen Mine had implemented the use of composite liners which are made of a complex geomembrane, like low-density polyethylene (LLDPE) that is infused with a traditional clay liner. The two liners are placed on embankments and underneath the tailings of the ponds that prevent the tailing from mixing with the groundwater. Modelling has shown that the leaks in the two layers of liners would be less than 10 mm2, which is considerably low comparing to the leaks in the past (Dillion et al., 2004). The use of these geomembrane liners is used in large-scale mines like the Lisheen Mine in Thurles, which has a population of just eight thousand people (City Population, 2017). Solutions as these can be implemented by the companies doing extraction of oil and minerals. Governments should create policies and laws that force large corporations to take leakage measures. By implementing a combination of both these liners law enforcement can help to reduce the leaks from tailing ponds into groundwater and rivers.

EXCESSIVE AMOUNT OF WASTEWATER



HAMILTON, ON



Harmful algal blooms at the Hamilton Harbor in September 2017 (Zastepa, Arthur, and Camille Chemali, 2021)

"When sustainability is mentioned, people may usually think about environmental sustainability or economic sustainability. In my opinion, sustainability means the ability to meet and maintain our own need without affecting other environment or resources."

-Hao Thi Lam

SUSTAINABLE INDUSTRIALIZATION

CANADIAN ENGINEERING GRAND CHALLENGES

The city of Hamilton, located on the west side of Lake Ontario, is one of the largest cities in Canada. Due to past dominating in steel and iron industry, the city remains to be one of the largest concentrations of heavy industry in Canada up to date (Hamilton Harbor: Area of Concern, 2021). However, Hamilton Harbor has had a record of cultural eutrophication and anthropogenic pollution since the 19th century due to experiencing the discharge from the two large wastewater treatment plants - the Woodward Avenue Wastewater Treatment Plant and the Skyward Wastewater Treatment Plant-, as well as urban runoff directly from city of Hamilton and Burlington (Zastepa, Arthur, and Camille Chemali, 2021).

Even though the eutrophication and water pollution problem were noted very early in the 19th century, the Hamilton harbor is still identified as one of the most polluted regions by the Water Quality Board of the International Joint Commission (Charlton, 2001). In July 2017, a sample of bloom was tested to have approximately 150 mg/L in phytoplankton total biomass. This number had significantly increased to beyond 3,000 mg/L and 4500 mg/L, respectively, in October and November (Zastepa, Arthur, and Camille Chemali, 2021). Figure 1 below was taken in September 2017, showing harmful algal blooms at the Hamilton Harbor.

The water quality has significantly improved since the control measures was implemented in 1970, water quality degradation being present up till date. Therefore, it is essential to learn from successful experiences from cities in other countries.

PHTHALATE REMOVAL THROUGHOUT WASTEWATER TREATMENT

NOISY-LE- GRAND, FRANCE



Marne Aval wastewater treatment plant in Paris, France (The Marne Aval wastewater treatment plant, n.d)

Paris was known to have very serious water pollution problem due to industrial contaminants, agricultural nitrates, and urban waste produced from cities. Therefore, we can consider it as a case study for successful wastewater treatment solution. The water from Marne River which located in the southeast area of Paris, was found to have high level of phthalates. Wastewater Treatment at Marne Aval station included the pretreatment process, suspended sediment settlement process, biological treatment to remove organic compounds, and nitrification process (Dargnat, Teil, Cheureuil, and Blanchard, 2009). More details of the wastewater treatment process are shown in the figure 2 below.

The Marne Aval wastewater plant produced excellent result as the treatment process average removal efficiency 78% for phthalate. The plant also has significant impact on the Marne River under dry conditions as the concentration of six phthalates was found to be low. However, Marne Aval plant plays very minor influences on the Marne River under rainy conditions (Dargnat, Teil, Cheureuil, and Blanchard, 2009). Figure 3 below shows the Marne Aval wastewater treatment plant.

What can Hamilton learn from Noisy-le-Grand?

While Marne River and Paris are benefit greatly from the Marne Aval water treatment plant with the advanced biological treatment to remove organic compounds, and nitrification process to reduce the Phthalate underwater, the Hamilton harbor might not as the it was reported to have the excessive amount of phosphorus in the water at the Hamilton harbor. Research on more suitable alternative solution is still needed to be done. However, the city of Hamilton may benefit greatly from looking at the impact of Marne Aval station on the Marne River.

THE BLOOMS YOU SHOULD NOT STOP AND SMELL

GRAND LAKE, NS



Detroit River Blue-Green Algae (NOAA Great Lakes Environmental Research Laboratory, 2007)

"Sustainability, to me, means taking only the resources that I need from nature to achieve my ends, and using every single part of a resource that I am able to in order to both maximize the benefits that I gain from the resources and avoid unnecessary waste."

-Zachary Betts

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Grand Lake, Nova Scotia, is located partially in the Halifax Metro Area, in the vicinity of the Halifax International Airport (Shubenacadie Canal Commission, 2019). It is part of the Shubenacadie Canal Waterway, and is a popular spot for fishing enthusiasts, and a tourist attraction due to it having the only fully restored lock in the waterway (Shubenacadie Canal Commission, 2019). As of this writing, in the summer of 2021, communities around Grand Lake, such as Enfield, Nova Scotia, have been plagued by an outbreak of blue-green algae within the lake (Petracek, 2021). An advisory for people to cease taking water from the lake for personal use has been issued by the province in response to the hospitalization of a woman and the death of her dogs after they interacted with the lake water in Oakfield (Petracek, 2021). Samples taken from Grand Lake on June 11th, 2021, had indicated levels of blue-green algae dangerous to dogs (Environment and Climate Change Nova Scotia, 2021). Locals who have shallow wells close to the lake and draw lake water have been driven to obtain bottled water and take their shower at the local aquatic centre (Petracek, 2021). Blue-green algae, or cyanobacteria, spread especially during the summer, and can form blooms where the water becomes green and the texture thickens (Gouvernement du Québec, n.d.). Some species of the blue-green algae produce toxins that can be dangerous for people (Gouvernement du Québec, n.d.). Symptoms of this exposure include a stomach ache, headache, vomiting, and throat irritation (Gouvernement du Québec, n.d.). It is recommended to avoid interacting with water resources nearby in algae-affected areas, including eating fish from the affected area (Gouvernement du Québec, n.d.).

ANSWER TO THE ALGAE ATTACK: MEASURES TO STOP ITS GROWTH

AUSTIN, UNITED STATES



Austin, Texas-Lady Bird Lake by Day (Worner, 2010)

Austin, the state capital of the US state of Texas, is one of the fastest-growing cities in the United States of America (Marty, 2019). Its metropolitan area, Austin-Round Rock (Marty, 2019) , increased in population by 22.5% between 2010 and 2017 (Stebbins, 2019), (Eubank, 2019). It is a major education hub, as the location of the University of Texas at Austin (Marty, 2019), and hosts offices of many large corporations such as Google and Amazon (Marty, 2019). Austin is home to many outdoor amenities, including water features such as Lady Bird Lake and Lake Austin (Marty, 2019). To preserve peoples' and animals' safety when they wish to use these water features, for activity or otherwise, it is vital that these water features be free from any potentially dangerous substances, namely blue-green algae. Lady Bird Lake has already had blooms of algae that have killed people's pet dogs (City of Austin, 2021), (Ragas, 2021).

The city of Austin has put prevention measures in place to prevent any future blue-green algae blooms from occurring. In a memo sent out by Jorge Morales, the director of the Watershed Protection Department, $ 1,480,000 in funding was requested for a 5-year contract with SePRO Corporation to provide a phosphorus-binding compound, Phoslock, (Morales, 2021). Phoslock binds phosphorus in water and sediment within it, and this phosphorus becomes a form that algae is unable to use for nutrition (Morales, 2021). This project will initially consist of 3 Phoslock applications around the algae-affected area, Red Bud Isle, over a 9 week period (Morales, 2021), established after consultation with numerous reputable sources on the matter, such as the US Army Corps of Engineers, and Texas Parks and Wildlife (Morales, 2021).

What can Grand Lake learn from Austin?

With restricted access to the water in Grand Lake and its surrounding communities (Petracek, 2021), these communities could use the preventative measures that the city of Austin has employed to limit the spread of blue-green algae in the lake, such as using compounds that take up nutrient sources like phosphorus such that the algae cannot feed itself and therefore, it will not be able to spread (Morales, 2021). They could also employ this method in other water resources in the nearby communities to maintain access to safe water for these communities.

AGRICULTURAL POLLUTION SOLVED BY MOBILE WATER TREATMENT

LYTTON FIRST NATIONS, BC



RES'EAU-WaterNet's Point of Entry Water Filtration System

"Sustainability, to me, means living within my means for the present to ensure my future can be equal if not better. This can apply to protecting the environment around me to ensure it exists in the future or using my money in a way that means I am able to be comfortable and have opportunities now while still having money to be comfortable and still have opportunities in the future."

-Cameron McInnis

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Water is necessary for everyone to survive, and here in Canada we have more fresh water per capita than almost any other country in the world. This makes the number of communities affected by water advisories in our country alarming, and it is even more alarming that the disproportionate amount of these communities that are First Nation communities. 75 communities across Canada were affected by these water advisories in 2018, 50 of these being First Nation communities, and some of these communities have been under water advisories for years. Lytton, B.C. is one of these communities that has, until recently, struggled with polluted water. Lytton's water source is contaminated by upstream agricultural runoff and livestock waste that results in pollutants such as E. coli being present in their water. This has resulted in the water supply being too dangerous to consume, and when their outdated water treatment system finally stopped providing clean water, the community turned to federal government to upgrade the facility, but were denied based on financial reasons. The solution they eventually found was a mobile water treatment plant, and it fits on the back of a truck in a shipping container and costs only half of upgrading their previous facility, while still providing safe drinking water. Designed by RES'EAU-WaterNet, a University of British Columbia research network, this portable and low maintenance facility was installed in 2015 and provides six households with clean water. Meanwhile, houses in the community that are too far from the facility have had RES'EAU install a Point-of-Entry system that filters the dangerous water as it enters households to make it safe to consume. Currently Lytton's leaders and RES'EAU-WaterNet have been able to provide 11 households with clean and consumable water in the community and they have plans to expand across the country with their life-changing technology.

POTENTIAL SOLUTION TO E. COLI WATER POLLUTION



RURAL COMMUNITIES, ECUADOR



Ceramic Water Filter

What can Lytton learn from Ecuador?

There are many things that other communities who are struggling with water advisories and pollution can learn from Lytton and the systems that they implemented. The portable water treatment facility is small and can be recreated in any of the communities that need water, and if they cannot afford the entire system the Point-of Entry system has also been a success. Lytton is just one of the first of what should be many Canadian communities using these innovative water treatment technologies.

3 GOOD HEALTH AND WELL-BEING

6 CLEAN WATER AND SANITATION

One of the most dangerous parts of the water pollution in Lytton was the E. coli that was present in the water, and this was most likely due to the animal waste from the upstream agricultural activities. Hundreds of thousands of people are made sick by this bacterium each year and it can even cause death, making it highly undesirable in drinking water. Less developed countries are more susceptible to have E. coli in their drinking water because they may not have sufficient water treatment or sanitation resources where they live which is the case in several communities in Ecuador. There was a study done that tested how effective black ceramic water filters would be in reducing the amount of E. coli in each households tap water. The experiment involved a rural community called Santa Marianita, which lies just north of Quito, and consisted of Group A, the control who would continue filtering their water as they always have (mostly through boiling or not filtering at all) and Group B, who were given the black ceramic water filters. The experiment lasted 6 months and water samples were gathered after this period and compared. The control group was found to have been drinking water that had a moderate to high amounts of E. coli present, while the samples that were taken from the families who had gotten the water filters mostly had low to almost no E. coli present, with the outliers being attributed to poor maintenance and cleaning by the families. This experiment shows that although this rural Ecuadorean community had a similar problem to Lytton, B.C., and they were able to find a different potential solution to the E. coli in their water that has shown promising results for multiple households, and could be more widely implemented in surrounding communities in the future.

THE IMPACTS OF MERCURY POISONING ON THE COMMUNITY OF GRASSY NARROWS, ON



The Empty Wabigoon River

"One of the largest issues facing us right now as a society is climate change and a reliance on non-renewable resources. These problems we face now are a direct consequences of decisions made in the past. Just like these decisions affect us now, our decisions will affect those in the future."

-Christian Martin

"There was a time when you could paddle down the creek, the river and just dip your hand, when you're thirsty, and just drink the water. That's how clean it was." (Turner, 2021). Unfortunately, this will never again be the reality for the people of Grassy Narrows. What faces this community now is a crippled economy, a deteriorating culture and a changed lifestyle where 90% of people suffer from symptoms of mercury poisoning (Philibert, Fillion, Mergler, 2020).

Asupeeschoseewagong First Nation (Grassy Narrows), a community of around 1500 people lies about 120 miles east of Winnipeg (Ilyniak, 2014). The territories of Grassy Narrows include the Whiskey Jack Forest and the English-Wabigoon River (Ilyniak, 2014). For centuries, the people of Grassy Narrows lived off the land and prospered. The land was an essential element of their culture and identity (Ilyniak, 2014).

This all changed in the 1960s, when The Dryden Chemical Company dumped over 11 tons of mercury into the river, 320 kilometers upstream from Grassy Narrows (Chow, 2021). Recently, it was also discovered that the company had buried over 50 drums of mercury underground, poisoning the groundwater in the area as well (Chow, 2021).

The mercury dumped into the water undergoes a process of biomethylation, by which it reacts with organic bodies to become a lethal organic substance (Ilyniak, 2014). Overtime, organisms in the water consume the mercury and it gradually accumulates in higher concentrations at increasingly higher levels in the food chain (Ilyniak, 2014). This happens because the mercury cannot be broken down by digestion (Ilyniak, 2014).

Once ingested by members of the Grassy Narrows community, the mercury never goes away. The mercury poisoning passes on from one generation to the next through the placenta, forever leaving a dark cloud over the people of Grassy Narrows (Turner, 2021).

LOCAL AND GLOBAL MEASURES TAKEN AFTER MINAMATA DISASTER

MINAMATA, JAPAN



Memorial to victims of mercury poisoning in Minamata

What can Grassy Narrows learn from Minamata?

When considering the differences made in Grassy Narrows compared to Minamata one thing is clear, the situation in Minamata was taken more seriously than in Grassy Narrows. The Japanese government was quick to address the problem and make policy changes as necessary. For the people of Grassy Narrows, mercury poisoning continues to affect the community today as proper sanitation efforts, compensation or policies have yet to be made as mercury continues to be discovered in their waterways. As Canadians, we must realize the importance of safe drinking water for all who live in this country.

The Minamata Disease is a neurological disease caused by severe mercury poisoning (Ministry of the Environment, 2002). First discovered in 1956 around Minamata Bay, and then again in 1965 in the Agano Basin, the disease was caused by the release of methylmercury in the wastewater from different chemical plants (Ministry of the Environment, 2002). As of March 2001, 2,955 disease patients have been recognized (1,789 have died) and over 10,000 have received compensation (Ministry of the Environment, 2002). The Minamata Disease is considered one of the Four Big Pollution Diseases of Japan and has had a significant effect on mercury policies worldwide (Atsuko, 2018).

Once the problem was identified, the first step taken was to immediately close the pollutant source (Ministry of the Environment, 2002). This was done by ensuring that no methylmercury compound was discharged outside the plant (Ministry of the Environment, 2002). Next, policy changes were made to regulate effluent containing methylmercury (Ministry of the Environment, 2002). In 1969, the drainage of methylmercury into Minamata Bay was regulated and in 1970, the Water Pollution Control Law was enacted, which controlled the discharge of toxic substances across Japan (Ministry of the Environment, 2002). Lastly it was necessary to restore the environment. From 1974 to 1990, the Kumamoto Prefecture carried out a 48-billion-yen project to deal with the 1,500,000 cubic meters of bottom sediment contaminated with mercury by means of dredging (Ministry of the Environment, 2002).

The Minamata Disaster has also impacted environmental policy on a global scale. On October 10th, 2013, in Kumamoto, Japan, The Minamata Convention was adopted into effect (UN, 2021). Signed by 128 countries, highlights of the Convention include a ban on new mercury mines, the phase out of old mines and requirements for the proper disposal of waste mercury (UN, 2021).

SUMMER ACTIVITIES HALTED DUE TO ALGAL BLOOM



SHUBENACADIE-GRAND LAKE, NS



Harmful Algal Bloom in Lake Erie, Ontario (Haslick, 2017)

"To me, sustainability means leading our lives in a responsible way such that future generations inherit an Earth and a civilization that is healthier than what we inherited. It involves living in harmony with nature and ensuring that our actions do not have lasting and harmful impacts on the environment. It is being able to fulfil our own needs and wants without causing ill effects on the things around us in our world."

-Wesley Babulal

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Most Canadians know that Blue-Green algae is dangerous and should be avoided. Unfortunately, this is the reality for people intending on enjoying summer at Shubenacadie-Grand Lake in Nova Scotia. According to an article by CTV News Atlantic, Julie Towers states that "The National Research Council lab did confirm that there are the microorganisms, the toxins associated with blue-green algae that were collected on Friday," (Petracek, 2021). The presence of Blue-Green algae in Shubenacadie-Grand Lake has forced the local government to prohibit use of the lake's water for all activities (Petracek, 2021). This suspected algal bloom has become a major inconvenience for anyone in the surrounding area and highlights the importance of proper water management practices.

Shubenacadie-Grand Lake is part of the larger Shubenacadie Canal Waterway (Shubenacadie Canal Commission, 2019). The waterway itself was a crucial part of Nova Scotia's development providing a means of transportation of people and cargo (Shubenacadie Canal Commission, 2019). Like many bodies of water, parts of the Shubenacadie waterway were formed as glaciers carved the Earth during ice ages (Shubenacadie Canal Commission, 2019). Although it is disputed, some scientists argue that human induced climate change is prohibiting the next ice age (Shubenacadie Canal Commission, 2019). However, this is not the only way that climate change is influencing the Shubenacadie Canal Waterway.

As previously mentioned, an algal bloom is the suspected cause of an increase in Blue-Green algae at the lake. Algal blooms can be caused by eutrophication: favourable growth conditions for micro-organisms caused by an increase in nutrients (U.S. Geological Survey, n.d.). This increase in nutrients can be caused by many factors. However, an increase in nutrients might not be to blame for this Blue-Green algal bloom. Algae are known to respond to changes in the weather (Cooke, 2021). Recent warmer weather may have provided conditions that promote algal blooms (Cooke,

NUTRIENT CONTROL: PREVENTING ALGAL BLOOMS



LAKE VOMBSJÖN, SWEDEN



Lake Vombsjön with Agricultural Land Nearby (Jepsen, 2007)



What can Shubenacadie-Grand learn from Vombsjön?

With any case study there are learning opportunities. Lessons learned at Shubenacadie-Grand Lake in Nova Scotia can be applied to the situation at Lake Vombsjön in Sweden and vice versa. The community surrounding Shubenacadie-Grand Lake can observe how coordination of responsible parties, those affecting the health of the lake, can lead to a positive outcome for the entire community. Contrarily, residents and policy makers near Lake Vombsjön can realize that occasionally no amount of planning can prepare for the forces of nature and despite proper nutrient control there should be framework in place to serve the community should forces like climate change render the lake unsafe.

It is important to note that since every case is unique, preventative measures of harmful Blue-Green algal blooms might differ around the world; what works for one region, country, or climate might not work for another (Li, Hansson, & M. Persson, 2019). One solution to preventing Blue-Green algal blooms is to eliminate conditions that promote algae growth. The solution employed at Lake Vombsjön is nutrient control: changing the surroundings of the lake to reduce the amount of Nitrogen and Phosphorous from entering the lake (Li, Hansson, & M. Persson, 2019). Approximately 72% of the land that drains to Lake Vombsjön is of agricultural use so nutrient control of the lake is heavily dependent on controlling the runoff from these lands (Li, Hansson, & M. Persson, 2019). One proposed solution is increasing the amount of Phosphorous consumed by crops surrounding the lake, this would effectively reduce the amount of Phosphorous present in the runoff and consequently in the lake (Li, Hansson, & M. Persson, 2019).

Lake Vombsjön is located about 20km East of Lund, the largest city in the lake's vicinity (Li, Hansson, & M. Persson, 2019). The lake's location close to a city and other small towns means that about 20% of the water that flows through the lake is used for drinking water (Li, Hansson, & M. Persson, 2019). The region's dependence on the lake for drinking water highlights the importance of coordinating nutrient control between the groups that impact the amount of nutrients in the lake. As previously mentioned, 72% of Lake Vombsjön's catchment area is agricultural. The remainder of the catchment area is used for forestry (23%), urban areas (3%), and water bodies (2%) (Li, Hansson, & M. Persson, 2019). The human activity within the lake's catchment area means that the chemicals in the lake are greatly affected by human activity and pollution, roughly 85% of the Phosphorous and Nitrogen in the lake comes from agricultural runoff alone (Li, Hansson, & M. Persson, 2019).

RESILIENT FIGHT AGAINST MERCURY CONTAMINATION

GRASSY NARROWS FIRST NATIONS, ON



Figure 1. Warning sign indicating dangerous levels of mercury in English-Wabigoon River (Turner, 2021)

"Sustainability is a very important thing to me. I think every human has a role to play when it comes to sustainability, whether it means taking the daily steps to ensure you are living cleanly or investing long term into sustainable businesses and products. I believe that engineers are the driving force of innovation and sustainability."

-Tehnaad Sandhu

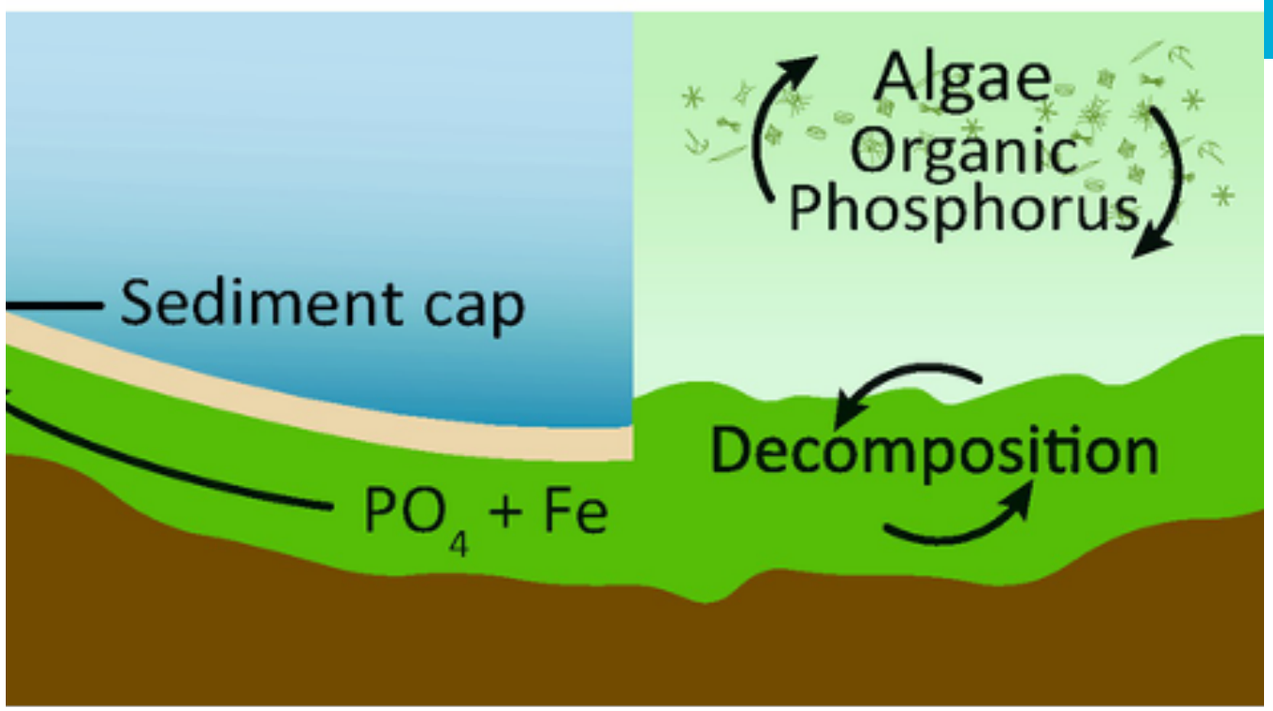
The Grassy Narrows First Nation, also known as Asubpeeschoseewagong Netum Anishinabek, is a community located in northern Ontario in the district of Kenora. Their members have suffered for decades due to mercury poisoning in the waters and earth. The English-Wabigoon river was the source for food, water and life for the people of Grassy Narrows, however due to the release of 9000 kilograms of mercury from the Reed Paper mill in the late 60's and early 70's, many people have died while trying to obtain basic human resources (Porter, n.d.). The fish, which were the main source of nutrition for the community, were contaminated. The paper mill also poisoned the groundwater in the area through drums of mercury that were buried underground (Gilson, 2019).

As mercury bioaccumulates, numerous generations have been affected by these actions, leaving Grassy Narrows with fewer elders, consequently burying the peoples deep and rich culture and history (LaFortune, 2019). Many people still face the symptoms such as ataxia, damage to speech and hearing, with more serious cases including brain and kidney damage and early death. Not only has their health been compromised, but once the mercury contamination was exposed by the government, all fisheries were shut down, leading to an immense decrease in tourism.

The mercury poisoning left by Reed Paper mill decades ago still severely affects the people who live on the land today. Mercury in the water converts to methylmercury, which is a neurotoxin that damages the nervous system (LaFortune, 2019). After that, the levels of this neurotoxin accumulate in the fish and then when people ingest it, it accumulates in humans to a point where it poses a serious health risk. The people of Grassy Narrows have spent years trying to gain the attention of the government, but besides empty promises and rejection, there has been no progress to the situation.

EPA'S SEDIMENT CAPPING SOLUTION FOR MERCURY CONTAMINATIO

CLEAR LAKE, UNITED STATES



Detailed figure showcasing aquatic environment with and without sediment capping. (Gibbs & Hickey, 2018)

What can Grassy Narrows learn from Clear Lake?

In terms of city-to-city learning, it is important to ensure that the source of contamination is shut off first and foremost. This would be the first step in any water pollution problem, and in the case of mercury contamination in water, it would mean ensuring paper mills and mines are shut down. What Grassy Narrows can learn from Clear Lake is ensuring proper testing with sediment capping to determine the ideal solution for their situation. Sediment capping can consist of a variety of natural or man-made materials, and since every case is unique, every solution will be different. It is important to ensure the right amount of sample experiments have been taken before implementing a large solution.

Clear Lake is in Lake County, California and has an abandoned open pit mercury mine, called the Sulphur Bank Mercury Mine, situated along its shoreline (EPA, 2021). In the current situation, the soil, surface water and groundwater near the site have all been contaminated with mercury. Additionally, mercury was introduced to the sediments at the bottom of Clear Lake and has accumulated in much of the fish in the lake.

Although the EPA has implemented a variety of solutions to minimize and prevent more mercury from being released into the soil and water, this section will focus on their implementation of Lake Sediment Capping, as a method of containing mercury sediments in Clear Lake. According to the EPA, their tests showed that sediment capping was a viable technology, especially with the site conditions in Clear Lake (EPA, 2021).

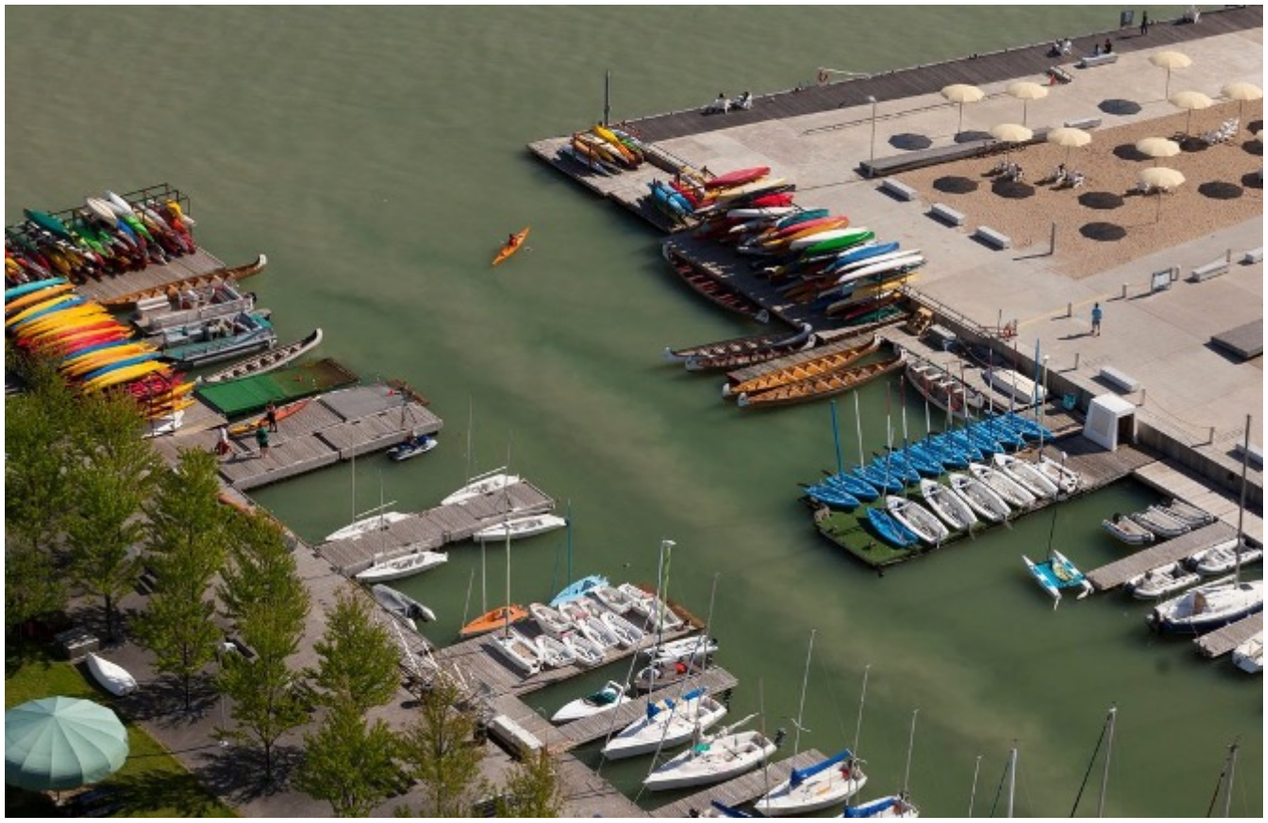
Through aqueous capping, the contaminated sediments can be sealed off from the surrounding aquatic environment. There are two types of capping that can be implemented. Physical capping prevents the aquatic wildlife from consuming the contaminated sediments, while chemically activated capping implements chemical isolation and creates a barrier for dissolved metals and activated carbons (Chortek, 2017). A common material used in capping is geotextiles. In the case of Gull Creak, Michigan, a geotextile layer was placed on top of contaminated sediments. Additionally, there was also a 3 cm layer of sand and pea gravel in the cap. After a 7-month experiment, only 4.26 ± 2.47% of benthic organisms passed through the cap (Chortek, 2017). These findings suggest the capability of sediment capping.

Ultimately, the implementation of Lake Sediment Capping has shown successful results in Clear Lake, California. By using this technology to target water pollution, it helps improve water quality by preventing excessive exposure of contaminants to the aquatic environment physically and chemically. Over time, this would decrease the mercury we are exposed to in the water and the

SEWAGE POLLUTION – SHORELINE'S OVERDUE PROBLEM



TORONTO, ON



Visible Sewer Overflow at Toronto Harbour (Panou, n.d.)

Home to over 6 million people, Toronto is the Canada's largest populous city that is located on the shores of Lake Ontario. Throughout its history, the lake has been essential to the city's rapid industrialization as well as leisure activities for the people. In order to manage and filter the water outflow into Lake Ontario, Toronto has adapted the combined sewer system, which collects both stormwater runoff and wastewater in the same pipe. While it has been usually effective since the urbanization of Toronto, there has been more frequent malfunctions starting in the 2000s. The problem is that the combined sewer system can be overwhelmed by various factors, such as heavy precipitation and sudden snowmelt (Rabson, 2018). In such cases, overflow is discharged directly into the lake.

The severity of this occurrence has been observed - according to The Toronto Monitoring Hub, approximately 3.7-million combined sewage overflows were spilled into Toronto Waters in 2015 alone. In addition, the most recent water sample taken from the West Island Beach district on June 24th, 2021 reported an E.coli count of 17.37 MPN/100ml (Toronto Monitoring Hub, 2021), which is deemed unsafe for leisure activities defined by Health Canada. Indicated by visible algae growth and plastic waste along the shores, the aquatic biodiversity of the lake is also evidently low. In all physical, aesthetic, and chemical characteristics, Lake Ontario fails to adhere to clean water requirements (WHO 2006).

""

-Bryan Cho

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

UNDERGROUND TANK SOLVES WATER POLLUTION AND FLOODING

TOKYO, JAPAN



The Metropolitan Area Outer Underground Discharge Channel (Kasukabe, 2006)

6 CLEAN WATER AND SANITATION

14 LIFE BELOW WATER

Due to the unique topography and climate, Tokyo in Japan has always been vulnerable to natural disasters such as tsunamis and typhoons. The distinct rain season has also been a contributing factor to swelling up Tokyo's five river systems each time of the year. As the city industrialized and urbanized intensely, they became prone to sewage waste contamination and infrastructure damage during these periods.

To counter this, Japan has been dedicating 6~7% of the national budget to disaster and risk reduction, even during recovering times from the war (Ortiz, 2018). One of the results from this investment is the floodwater tank located 22 metres underground called the Metropolitan Area Outer Underground Discharge Channel (MAOUDC), which is a 6.3 km long system of chambers and tunnels to discharge water at flooding levels. Completed in 2006 after 13 years of construction, it consists of 5 dozen 60-foot pillars of reinforced concrete (Mallonee, 2017). MAOUDC intakes floodwater from small and mid-sized rivers in Northern Tokyo and transport it to Edo River, which handles the enormous volume of water without cross-contamination from sewage. The city planner authorities have designed this facility to withstand 50ml of rain per hour based on the historical rainfall records. As precipitation in Japan is predicted to increase by 10% within the 21st Century due to climate change, Tokyo's Metropolitan Government Bureau of Construction plans to expand the project to withstand between 65 to 65mm of rain per hour (Ortiz, 2018).

What can Toronto learn from Tokyo?

Toronto can take Tokyo as a model for sewage contamination prevention in these factors: directing floodwater in ways that treatment plants can function, dedicating a steady funding for clean water solutions, and preparing ahead for natural disasters as well as climate change.

THE STRUGGLE FOR CLEAN WATER

OJIBWE COMMUNITY, ON



Neskantaga

“Something that is sustainable should be able to simply exist without the need to hinder its surrounding environment. This to me allows for something sustainable to eventually grow into something bigger and better.”

-Jeevan Johal

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

The Ojibwe community located 180 kilometers northeast of Pickle Lake, Ontario is home to Neskantaga First Nations; The only method of travel to and from is possible via air, boat and winter roads (road carved from ice and snow). The history surrounding this area dates to around 3000 BC with ancient communities settling, as well as grounds for fur trading within the earlier 1800’s. With a population of nearly 400 people, of which 300 live directly on the reserve, the Neskantaga First Nations is a community that strive to live in dignity and in harmony.

With an effort to live in harmony, they face a huge obstacle being the accessibility to clean drinking water. Initially in 1993 a natural sand low filter water treatment plant was built but has “Failed to adequality disinfect the water and on Feb 1, 1995. Neskantaga went under a boil-water advisory” (Stefanovich, 2020). This first established boil-water advisory is still in effect to this day, marking a quarter century in February 2020. According to Roy Moonias, an Advisor to Chief and Coucil of the Neskantaga First Nations, the “water was designed to circulate the system, instead there are three dead ends – the chlorination can’t circulate… It was a flawed system from the start” (Roy Moonias, Human Rights Watch, 2016).

With the most current solution failing to rectify the water crisis it has additionally led to a failure causing an oily sheen found within the reservoir. Reports and “initial testing results found high levels of hydrocarbons in the drinking water” (Sanchedina & Cousins, 2020). The extent of the water quality is unbearable and without the ability to clean drinking water can “cause cancer, diarrhea, skin infections, influenza, whooping cough, increased rates of pneumonia and other illnesses” (Hartline & Wiley, 2019).

THE BENEFITS OF OZONE

DEVELOPING COMMUNITIES, MOZAMBIQUE



Location unknown, Inlet to Oxidization Pond/Treatment Center

What can Ojibwe community learn from Mozambique?

In conclusion these remote electro chemical oxidation water treatment centers are a viable solution to not only deal with water pollution, but as well as a solution to help achieve the CEGC and SDG's. With the implementation of the treatment plant in Ressano Garcia, the Neskantaga First Nations can learn from their approach to the same situation at hand as it is a step in the right direction to a more sustainable city.

Mozambique is a Sub-Saharan country located in south Africa's developing communities. Approximately 40% of this community lacks the ability to access clean water. Ressano Garcia is a small town that borders south Africa and has a population of approximately 11,200 residences. Out of all the residences a large majority of them do not have access to safe clean drinking water, so they find alternatives such as rivers. These rivers tend to be untreaded and have properties that cause "diarrhoea and other water-borne diseases" (Mario Trigo, Euronews, 2019).

With the development of an experimental system, it utilizes the process of electro chemical oxidation to destroy pollutants that are harmful to humans, these include inactive microbes and pathogens.

Prior to the untreated water entering the system, an iron salt is added to the water as a pre-treatment in hopes to turn the organic matter present into bigger chunks making it easier to separate. The process of electro chemical oxidation is solely based off the use of a special type of metal electrodes and uses ozone as a cleaning agent. The entire process utilizes the electrochemical cells that are coated with diamond electrodes, the applied low voltage to the electrodes enables the creation of ozone. The addition of ozone dissolves within the water and helps deactivate the germs. Ozone is a "characteristic of high quality of water; it effectively cleans the water…studies have shown it cleans between 80-90% of all dirt present in the water" (Abdula Martins, EuroNews, 2019). From having a very limited access to clean and safe drinking water, this plant now produces approximately 10,000L per day of water safe for consumption.

INTRODUCTION TO THE WATER POLLUTION



TORONTO, ON



Water Pollution

“Engineers should maintain a lot of roles in sustainable development. Engineers are the backbones of projects and developments, so they need to take initiative and maintain a role to plan the most environment-friendly, cost-effective, and sustainable developments in their respective field.”

-Adesh Sandhu

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

An environmental problem which is predominant in the city of Toronto is in regards to water pollution. Water pollution arises when substances such as chemicals and other microorganisms tarnish large bodies of waters, such as rivers, lakes and oceans. Consequently, the body of water degrades greatly in terms of its quality, making it toxic to the surrounding environment.

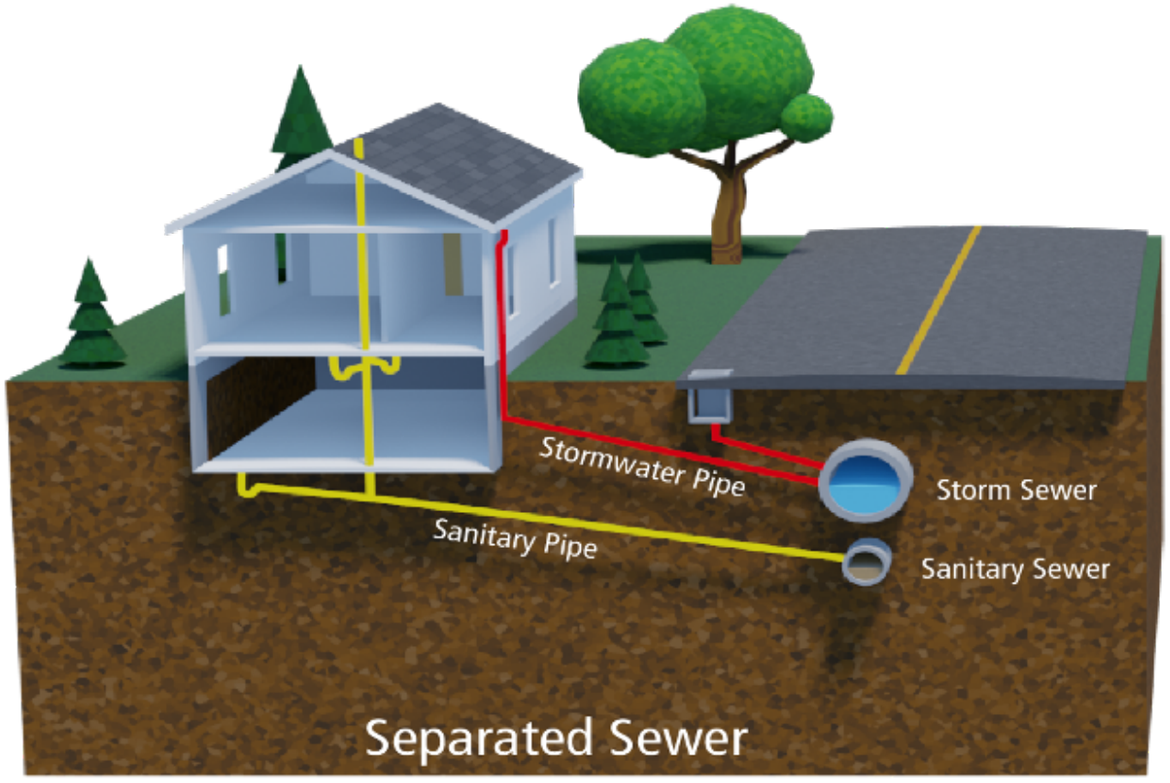
Naturally, the city of Toronto, which is the most populated city in all of Canada, heavily pollutes its main drinking water source, Lake Ontario. The main reason why Toronto has a substantial water pollution problem is because of the outdated sewage infrastructure which are present in their waste-water management systems. The city mainly uses combined sewers, which use the same pipes to manage storm water and sewage. Large pollution occurs when a lot of rainfall takes place, eventually overwhelming the sewers and causing chemicals and untreated sewage to leak into Lake Ontario.

Local businesses and residents are also not taking enough precautionary measures to deal with the problem at hand. Day by day, Toronto’s businesses and home flush severely polluted water down the drain. Besides the ordinary bacteria and human waste that is flushed, Lake Ontario is also polluted by its residents and institutions with many others chemicals such as pharmaceuticals, cleaning products, heavy metals and other types of hazardous waste.

Most of these contaminants are not able to be treated effectively which ultimately is degrading the water quality of Lake Ontario. Just in 2019 itself, billions of litres of raw and partially treated sewage were discarded into Lake Ontario. In the same year, 7 tonnes of cadmium, lead, nickel, and cadmium was also released into the lake. It is clear that water pollution is a great problem in terms of the environment for the city of Toronto, and further measures need to be taken to help diminish the issues.

UTILIZATION OF SEWER SEPARATION

LYNN, UNITED STATES



NetWORKS 3- technology of heat recovery and greywater reuse

What can Toronto learn from Lynn?

The city of Toronto can learn many valuable methods from other cities/counties that have practiced sewer separation. For example, some cities have executed sewer separation by using their existing combined system as a storm sewer and then constructing a new sanitary sewer, and some cites have executed it by doing the vice-versa. It would be proactive to learn from similar cities as Toronto to find out which method would be the most effective for them.

3 GOOD HEALTH AND WELL-BEING

6 CLEAN WATER AND SANITATION

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

As mentioned, the main cause of water pollution for Toronto is the continuous use of combined sewers. During inordinate rainfall, the capacities of the combined sewer pipelines are exceeded, which eventually causes overflow at the exit points in the sewer system. This overflow is then discharged directly to Lake Ontario in Toronto's case. An infrastructure solution to address this problem would be to implement sewer separation for the sewer channels in the City of Toronto.

Sewer separation can directly resolve this problem by using the combined system as a storm sewer and building a new, separate sanitary sewer. This solution would not only ease the excess spillage which would normally take place in a combined sewer system, but would also add many other benefits to the overall waste-water management practice.

Recently, in Lynn, Massachusetts, a $48 million contract was awarded to the city in order to combat combined sewer outflow (CSO). The city's solution was to convert the present combined sewer system into a stormwater sewer system and developing a new sewer passage for sanitary flow. The city made sure that the stormwater pipes were to be used as an outlet to the Atlantic Ocean, and the sewage pipes were to travel in separate pipes to a nearby treatment plant.

The new sewer separation technique is also saving the city of Lynn approximately $100 million because sewerage pipes can be much smaller than regular stormwater channels. The total construction time was around 5 years, which is a fair deal as the city laid around 35,576m of new pipelines under city streets and homes. Lynn has successfully implemented the usage of sewer separation to help combat their previous water pollution matters, and it is completely plausible for the city of Toronto to start developing their own projects to apply this technique. More and more cities are recognizing the advantages of using this solution in regards the environment. It is projected that the number of communities that

ONGOING BATTLE WITH POLLUTED WATER



GRASSY NARROWS FIRST NATIONS, ON



Grassy Narrows Voicing their Opinion on Unequal Treatment (Howl Arts Collective 2006)

"To me, sustainability describes something that can reliably meet our needs without having to compromise or worry about the negative effects on the planet, animals, plants or other humans. An example that always comes to my mind is renewable energy sources. Wind and solar energy are sustainable since they able to provides us with the energy that we need without causing too many pollutants/greenhouse gases."

-Evan Tjie

SAFE WATER IN OUR COMMUNITIES
CANADIAN ENGINEERING GRAND CHALLENGES

Canada is known for having an abundant amount of clean drinking water thanks to its multiple sources of freshwater lakes found throughout the country. Despite this, not all communities in Canada have access to clean water that can be used for their everyday needs and poor water quality is to blame. Water pollution is a by-product of human activity and occurs when unwanted chemicals or substances enter a body of water. Some of these pollutants include industrial waste, pesticides, heavy metals, and pathogens. If a large enough concentration of any one of these pollutants is present in a body of water, the safety of the water is compromised. Poor water quality has many negative impacts on the surrounding communities and ecosystems. The animals in the water may become toxic if consumed, while the water itself will become unsafe for basic needs such as drinking and sanitation (Bruser 2020).

These negative outcomes happen to be reality for the small Indigenous community in Grassy Narrows, ON. Grassy Narrows is a small community home to 1594 people (Anderson 2020). During the 1960s to 70s, Dryden Chemical released over 9000 kg of mercury contaminated wastewater into the Wabigoon River. The contaminated water traveled over 100 km downstream to Grassy Narrows (Bruser 2016) and the community continues to suffer from the negative effects. The community relies on the lakes as their main source of food; however, the high levels of mercury found in the water has contaminated the fish they eat with mercury concentrations over 150 times the US EPA Standards (Poisson and Bruser 2016). Mercury poisoning is a serious issue and unfortunately, around 90% of the population is suffering from some form of mercury poisoning (McGrath 2016). Although mercury levels have been slowly decreasing over time, the current levels still exceed Ontario's standards (Ontario 2020). The Grassy Narrows water crisis is an ongoing battle and it's disappointing to see the government take such a slow approach.

MICROORGANISM AND THEIR MACRO ROLE IN THE OIL SPILL



CHENNAI, INDIA



Aerial view of Chennai and a clean Marina Beach (SlowPhoton 2019)

What can Grassy Narrows learn from Chennai?

Bioremediation played a big role in protecting Chennai's marine environment during the oil spill. After seeing how effective it was at cleaning up the oil, mayhap Grassy Narrows can turn to bioremediation as a solution to their mercury polluted water. Bioremediation can treat a variety of pollutants including heavy metals—so why not use it to filter out the mercury? Not only will it finally give them access to clean water, but it will also result in a safer diet as the fish will be living in mercery free water. Hopefully the government sees the potential in this method and use it to resolve this issue because everyone deserves equal access to safe water.

Oil spills are one of the worst ecological disasters that humans have introduced to the planet. The large amounts of petroleum that end up in the waters have catastrophic effects on the surrounding animals and their ecosystems. As a result, humans are responsible for having a quick response to limit the damage that will be done. Bioremediation is one of the various methods that can be used to clean up oil spills. Bioremediation is the act of using organisms to help absorb contaminants or neutralize toxins that are found in polluted waters. These organisms can include biomasses such as plants or plant roots which can absorb pollutants and later be safely disposed (Ibrahim 2021). Bioremediation organisms can also include different types of bacteria that are able to consume and nullify contaminants in water (India Science Wire 2020). Depending on the organism used, bioremediation can remove a wide range of contaminants. A couple of them include oil/petroleum (India Science Wire 2020) and even heavy metals (Kapahi and Sachdeva 2019).

In 2017, an oil spill occurred off the coast of Marina Beach in Chennai, India and around 37 million litres of oil were released into the ocean (India Science Wire 2020). To clean up the spill as quickly as possible, the Coast Guard turned to bioremediation and ordered for the use of bacteria to clean up the areas with the most damage (DTE 2017). The Indian Oil Corporation also aided the clean up efforts by supplying "bio-remediation material [that can treat] the collected oil sludge for safe disposal" (DTE 2017). About one week after the spill, D Jayakumar, minister of fisheries in Tamil Nadu, reported that around 85% (or 7200 kg) of sludge was cleaned from the ocean. If polluted waters are ever an issue in the future, hopefully we can turn to bioremediation as a method of cleaning as it has proven to be effective in disasters such as the Chennai oil spill.

CHAPTER 5: ENERGY - FOSSIL FUELS AND RENEWABLES



Oil Jack with Wind Turbine/energywarden.com

CHAPTER INTRODUCTION

Energy is a broad and complex topic and would be the largest of all modules to truly reflect a comprehensive coverage, so we barely touch the surface of energy issues and sources in this module. The module begins by defining a number of energy-related concepts, and then delves into non- renewable sources of energy (i.e. fossil fuels), and renewable sources of energy, in addition to nuclear energy which is tucked between the two, since nuclear energy is usually considered another non- renewable energy source, although nuclear energy itself is low carbon like renewable energy, the material used in nuclear power plants is not. For the non-renewable and renewable energy sources, the global and Canadian generation and/or production sources, technology demonstration, and sustainability implications are explained very briefly.

Learning Outcomes

By the end of this week, you will be able to:

- Define energy-related concepts of energy poverty, energy security, energy cycle, energy chain, energy efficiency, energy density, energy ladder, and energy reserve
- Identify the context for global energy consumption
- Classify non-renewable energy sources of oil, coal, natural gas
- Analyze energy reserves
- Discuss a mathematical model to assess sustainable energy
- Describe the technical functioning of electricity generating technologies
- Identify the major negative environmental impacts of fossil-fuel based electricity production.
- Describe mitigation technologies for PM, SOx, NOx
- Describe nuclear energy production
- Assess the sustainability of nuclear energy
- Recall nuclear energy disasters
- Describe renewable energy sources of solar, wind, hydropower, geothermal, biomass/biofuels

TOXIC TAILING PONDS IN OIL SANDS DESTROYING SMALL TOWNS

FORT SMITH, NT



The Oil Sands in Fort Smith, N.W.T (McIntosh, 2011)

"To me as a person, sustainability means that a process or task can be duplicated or repeated without impacting or influencing the surrounding environment around it. For me the word is usually synonymous with being environmentally friendly and ensuring that we are not hindering the future generations of people."

-Frank Cheng

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

It is imperative to understand that non-renewable energy sources such as crude oil play a huge part in the lives of humans today, as crude oil is the base for many products such as transportation fuels, generating heating and electricity in homes. In contrast however, crude oil (mostly consisted of hydrocarbons), is usually extracted and refined from oil sands which are processes that come with risk, as volatile waste products can be produced to the detriment of the environment (Amadeo, 2021). This is the case, for the town of Fort Smith and the Peace River Delta in the Northwest Territories as they are under danger from residual bitumen, hydrocarbons and benzene made as a by-product of the crude oil extraction process. Currently in Western Canada, the total area that is occupied by the tailing ponds of oil sand refineries is about 77 square-kilometers, and for every barrel of bitumen/crude oil produced from these oil sands, 1.5 barrels of tailings waste is also produced (Amadeo, 2021). The 44,807 square-kilometer UNESCO heritage site of the Peace River Delta also houses the endangered Wood Buffalo species that is native to the natural environment, however the population of the species has slowly decreased ever since the conception of oil sand refineries near the area due to the enormous amounts of waste emissions from the refineries (Lavoie, 2021). As of 2016 the Wood Buffalo population is only 74,158 buffalo decreasing 3.91% over the last 5 years mainly due to human development, the buffalo normally resides in the southern tip of the Northwest Territories and northern Alberta (Regional Dashboard Alberta, n.d.) . Furthermore, this is especially unfortunate for the native Mikisew Cree people who now must rely on government support to fix their jurisdictional water issue as there are oil sand water licenses that are contracted to the Peace River Delta, the primary water source for the Cree natives (Lavoie, 2021). Recently there have been steps taken to galvanize the process of reducing the carbon footprint and expansion of these massive oil sand projects through committees, reports and a $60 million action plan made to the federal government however although momentum is building more must be done to save this community. To the indigenous people, the Wood Buffalo is a very

SOURCING 100% OF ELECTRICITY FROM RENEWABLE

BURLINGTON, UNITED STATES



A View of Burlington, Vermont (Champlain College, n.d.)

What can Fort Smith learn from Burlington?

As mentioned before, Burlington, Vermont is now capable of sourcing 100% of their electricity to a city of 42,000 inhabitants through only renewable energy sources which are affordable to the community as well, however establishing renewable energy sources as the main source of energy for the city also dictates a participation in climate action as well, as renewable energy sources have little to none pollutants or carbon emission compared to non-renewable energy sources which most cities are still relying on today. All in all, Burlington's sustainability strategy and policies of converting all their energy sources to renewable energy sources is something that all cities around world should be pushing toward, so that critical situations such as the threat of extinction of species and the turbulent troubles of local communities can be avoided regarding the dependency of non-renewable energy sources.

A general solution to the toxic wastes and carbon emissions produced by toxic tailing ponds as a result of the oil sands would be implementing renewable energy sources to create a sustainable energy supply. This is the case in Burlington, Vermont where 100% of the city's electricity comes from renewable sources, the city is also touting the fact that not only is the electricity clean it is also affordable as well (CDP, n.d.), as the energy rates of the city have not been raised in 8 whole years. Burlington can source 100% of the electricity because of four major sustainable sources: biomass, hydro, wind and solar energy sources. This sustainable venture began in 1978 where, the aging coal plant in Burlington was replaced with a 50-watt biomass station known as the McNeil Generating Station where sustainable local wood is used to generate renewable electricity. This then spiraled to the construction of a hydroelectric power plant on the Winooski River to bring in hydroelectric energy, and wind turbines at the nearby Georgia Mountain along with solar panels throughout the city at airports, schools and the Burlington electric department to round off the renewable energy sources. Furthermore, in measurements of g/kWh, hydro and biomass energy sources produce more than 50 times less carbon emissions than standard fossil fuels, whereas solar energy produces 5 times less carbon emissions than the standard fossil fuels (Arif, 2013). Ultimately by Burlington switching to a reliance on wind, hydro, solar and biomass renewable energy sources this significantly reduces the amount of standard carbon emissions that they would have had instead on a sole reliance of non-renewable energy sources. Looking forward to the future, Burlington is looking to build a zero-carbon future with investing in charging stations to promote electric vehicles and planning to use steam from the biomass plant to heat homes.

THE STRUGGLE OF ADAPTING TO RENEWABLE ENERGY

TUKTOYATUK, NT



Image of the landscape and lack of infrastructure in Tukoyatuk, NWT

"Engineers build and design the community our society lives in. With this we have a great duty to make sure we use the information we have to safely design and develop sustainable products. It is necessary for us to take into account the aspect of sustainability to fulfill the requirement of the design."

-Evan Serra

AFFORDABLE AND SUSTAINABLE ENERGY
CANADIAN ENGINEERING GRAND CHALLENGES

Adapting to renewable resources for the northern communities of Canada has numerous challenges. These stem from their limited infrastructure and reliance on off-grid systems in the communities. Being so remote, the energy needs of these communities have been supplied mainly by diesel. However, a shift away from non-renewable energy sources is underway. As the cost of renewable energy resources decreases (International Renewable Energy Agency, 2020) and with already "higher than average energy prices [from non-renewable resources]" (Government of the Northwest Territories, 2011), renewable energy is becoming more viable.

One difficulty facing the northern demographic is finding suitable energy sources for their extreme northern conditions. However, a push is underway. The Northwest Territories Energy Report (May 2011) explained that building expertise in this sector has been a highlighted objective since the Energy Plan (2007). Which today, is still being pursued.

Wind energy development in the NWT is considered to be one of the most viable renewable energy sources. So far, significant progress has been achieved. In 2007, the Energy Plan proposed the development of a single wind turbine in Tuktoyatuk to assist in building an understanding of the technology and determine its viability. A challenge they faced was the slow wind speeds in the area, at approximately 5.3 m/s. This is lower than other established wind turbine developments. However, from the research of this technology, it has been shown wind turbines have the potential to be successful in transitioning the NWT to a renewable energy source. There is hope of expansion in the future.

The push toward transitioning to this method is being prioritized, but it is slow. With support from the government to implement these resources, communities in the NWT will be more successful at addressing and tackling this issue head-on.

WIND ENERGY - AN ALTERNATIVE TO NON-RENEWABLE ENERGY

OREGON, UNITED STATES



Image of turbines from the Sheppards Flat Wind Farm in 2011 (during construction)

Wind energy has been implemented all over the globe. This energy resource uses turbines to harness the wind to generate mechanical power. This solution demonstrates the viability of wind power as an alternative to non-renewable energy sources. In 2019 it was recorded that 62% of Oregon's energy comes from renewable sources (U.S. Energy Information Administration, 2021). Wind energy accounted for 11.6 percent of this (Oregon Department of Energy, 2019).

The Shepherds Flat Wind Farm in Oregon was deemed fully commercially operational in November 2012. With an installed capacity of 845MW, it was the second-largest wind farm in the world. The farm is split into three facilities, which were developed in three phases. The turbines used had permanent magnet generators which ensure high efficiency in low wind speeds and reduces electrical loss. (Renewable Technology, 2021)

In addition to the positive economic impact of $37m per year, the farm, "helps in displacing 1.5 million tonnes of carbon emissions a year" (Renewable Technology, 2021). With many successful operations around the world, the Sheppards Flat Wind Farm is only one example of how this resource is a feasible and economically prosperous renewable resource.

What can Tuktoyatuk learn from Oregon?

Wind Energy is a viable solution to assist in the development of sustainable energy throughout the globe. Sheppards Flat Wind Farm helped give an example of how this technology can be used in cities including the northern communities of Canada. As an economically profitable and environmentally sustainable source, the uses of this energy have been shown to be an alternative for many cities and communities.

INTRODUCTION OF MORE FOSSIL FUEL PRODUCTION IN CARSELAND, AB



Diesel Processing Plant

"To me sustainability means being responsible for consumption and production on earth. Individuals, companies, and governments are all affected and affect sustainability."

-Paige Ackerman

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

Fossil fuels are still predominantly used in many areas of Canadian energy consumption due to their accessibility and economic value. This causes conflict within sustainable energy goals because they pollute our atmosphere, soils, and water. Fossil fuels can be processed in less environmentally detrimental ways but are not a long-term or clean energy source. The movement to produce renewable and sustainable clean energy has put pressure on technological advancements in transportation, construction, and general energy use. Carseland Alberta is a small hamlet south-east of Calgary, surrounded by Wheatland County. The majority of local energy is produced through fossil fuels and non-renewable energy sources. In Carseland, there is a demand for further economic growth and the favored solution is a new synthetic Diesel plant (McLeay, 2018). This plant requires the connection to the local pipeline network where it will process raw natural gas in a process that removes sulfur emissions and creates fewer greenhouse emissions than the average diesel processing plant. The project is projected to cost 15 million dollars and has outlined future costs for maintenance (JWN, 2019). A similar layout and plan for the plant can be seen below in Figure 1. This is a productive step in the field of fossil fuel energy, but the plant still produces large amounts of methane, ethane, and butane. The introduction of a new plant in the local area will also add demand to oil abstraction from local resources. The efforts to make fossil fuels cleaner helps reach short-term sustainable energy goals but may fall short in respect to long-term goals.

PROCESS TO TURN CARBON FROM THE ATMOSPHERE INTO FUEL

SQUAMISH, CANADA



Carbon Engineering's Direct Carbon Capture Device in Squamish, BC

In Squamish, British Columbia a company, named Carbon Engineering, has created a Direct Carbon Capture device the propels carbon from the atmosphere into a series of chemical processes that convert the carbon from the air into pure carbon dioxide. This Carbon Dioxide can then be stored and sold, or it can be converted into synthetic crude oil (Chua, 2019). Due to the carbon recycling process, this oil is nearly carbon-neutral and can be processed into gasoline for transportation. There is a small amount of fossil fuels needed to run the machine, but for every ton of carbon dioxide removed from the atmosphere, a half-ton of fossil fuels are emitted, giving the direct carbon capture device a carbon footprint 70% lower than regular fossil fuel production (Weber, 2018). Overall gasoline produced from the Direct Carbon Capture will be 25 cents more than average gasoline (CE, 2020). This method could solve the economical issues in Carseland allowing for full-time employees, as well as meet the demand for gasoline production. This Direct Carbon Capture device costs 100 USD per ton of carbon dioxide (CE, 2020). The device works to reverse carbon pollution while also being economically beneficial to the company that purchases it. The company Shopify is the first to invest in this device as part of its sustainability fund. The type of Direct Carbon Capture Device bought by Shopify can be seen below in Figure 2. In this specific purchase, Carbon Engineering has paired with an American company 1PointFive to help roll out the development and production of the device. Carbon Engineering has a future goal of capturing 100 million tons of carbon dioxide a year, equivalent to the carbon absorption of 40 million trees.

What can Carseland learn from Squamish?

The Direct Carbon Capture Device is an impactful solution that makes positive movements in the sustainability stratosphere, helping reach Canadian Grand Challenge goals as well as United Nations Sustainable Goals.

A SLAVE TO FOSSIL FUELS

EDMONTON, AB



Edmonton Greenhouse Gases

The world depends on fossil fuels, they power our cars, our factories, and overall our quality of life, but at what cost? Fossil fuels take a huge toll on the environment and they cause problems such as oil spills, GHG emissions, ACID rain, smog-filled air and many other issues that pollute our environment. Many believe that global warming is due to burning fossil fuels. Edmonton in particular was named one of the cities with the highest emissions in Canada due to its coal based electricity supply and has their fair share of emitting GHG into our atmosphere. In 2019 Edmonton has emitted approximately 17,216,00 tonnes of CO2 (Dashboard Edmonton, 2021) and has definitely contributed to the rise of climate affecting its many aspects of the environment such as it's biodiversity and temperature rises. This practice of using fossil fuels raises an issue because this type of energy is not sustainable and causes a gradual harm to the planet earth by contributing to global warming. With Edmonton being the Capital of Alberta which is the most polluting province in Canada, they are also Canada's largest oil producer and its oil sand is the majority of emissions. However that industry is always rewarded with subsidies which may have deterred themselves from looking at alternative sources of energy.

"I am more optimistic about the future when it comes to sustainable development. Most notably, I am impressed with people who engineered technology such as the Tesla. I believe electric cars will eventually replace all gasoline cars in the future."

-Sebastian Shek

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

TO FOLLOW THE FOOTSTEPS OF VANCOUVER, CANADA



7 AFFORDABLE AND CLEAN ENERGY

BC Hydroelectric dams that generate renewable energy

What can Edmonton learn from Vancouver?

Although Edmonton does not necessarily live near the coast, they can make better use of their resources into building hydro energy generators which can help their challenges with their reliance on fossil fuels as energy.

In order to solve this problem of our dependence on fossil fuels and it's GHG emissions, first we need to look towards alternative sources of renewable energy. There are many options here that we can worry about such as hydro, wind, solar or biomass which can be a solution to Edmonton becoming more climate-friendly and cause less environmental damage to overall offer a better quality of life. In this regard, I believe we can follow in Vancouver's footsteps in its mission to become the greenest city in the world by first focusing on how electricity should be generated. In BC about 94% of electricity is generated by hydro all while being one of the most efficient and low cost options in BC. Its renewable capacity is more than 16 000 MW, which is approximately 90% of total installed capacity. They generate power by utilizing falling water and transforming that into mechanical/electrical energy by building hydroelectric dams. Currently they are able to generate over 43,000 gigawatt hours of electricity annually to supply more than 1.9 million residential, commercial and industrial customers. (BC Hydro, 2021). If Edmonton were to be able to adopt this plan of using hydro energy and follow in Vancouver's footsteps, they will be doing a part in helping reduce the effects of climate change and their GHG emissions.

THE FINANCIAL BURDENS OF DIESEL

PAULATUK, NU



A Diesel Generator

“I believe sustainability is about the responsible and efficient use of the earth's limited resources to foster a healthy environment for future generations. Although resources must be used everyday to power our economy and ways of life, a balance must be maintained through careful conservation.”

-Eunice Choi

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

Remote communities in Canada already face the issues of ridiculously expensive food, housing, and travel. Due to the geography and climate of these locations, high electricity costs have also been a major factor for challenging life in the north. Energy usage is significantly higher than the national average due to cold climates and the lack of energy efficient building design. Most Canadian households are part of the electricity grid, which provides electricity from various sources such as hydro, natural gas, and wind. On the other hand, remote communities are disconnected from the national electricity grid and have no choice but to produce electricity locally using inefficient diesel generators. These isolated communities consume more than 90 million litres of diesel fuel each year (Lovekin & Heerema, 2019). Paulatuk, a hamlet in the Northwest Territories, is an example of a diesel-reliant community with energy restrictions due to the cold climate. In October of 2018, harsh ice conditions sealed off the Amundsen Gulf, prohibiting shipments of fuel, lumber, and food to Paulatuk and two other communities in Nunavut (Cecco, 2018). The government of the Northwest Territories prioritized the airlift of 600,000 litres of diesel to Paulatuk to ensure that residents could withstand the cold winters (Cecco, 2018). This demonstrates how the geography of isolated northern communities poses a challenge for reliable energy sources from elsewhere. The average Canadian electricity price is 12.9 cents per kW.h, while households in the Northwest Territories and Nunavut pay more than 30 cents per kW.h. (Canada Energy Regulator, 2017). High fuel poverty rates are prevalent in remote Indigenous communities, which is described by a household spending more than 10% of their income to utilities (Quitoras, 2020). These isolated northern areas face a multitude of economical challenges every day, it is unjust that incredibly expensive energy bills are another concern for these individuals.

COST-EFFECTIVE SOLAR PANELS

TENNANT CREEK, AUSTRALIA



7 AFFORDABLE AND CLEAN ENERGY

Solar Panels on a Roof

East of Tennant Creek in Australia, the Mununguurra Aboriginal Corporation live off-grid and power their homes through diesel generators. For just two houses, diesel would cost $600-$700 a week (Wild, 2016). The substantial cost to provide power to the remote location prevented the individuals from developing an economy on their land. Due to unemployment in the community, members could not afford to pay the high rates of electricity use from the diesel generators and would live solely on unemployment benefits. This would all change when Mr. Smith, the Corporation's chief executive, took initiative and leased a solar power system from Indigenous Business Australia (IBA), consequently shutting off the diesel generators (Wild, 2016). In the span of 3 months, the community's power bill decreased by more than 50% which brought an increase in the population and employment (Wild, 2016). The technological solution implemented is a panel and battery system which allows energy from sunlight to be used throughout the day, while unused energy simply gets stored in the batteries to use at night. IBA purchased the system from Allgrid Energy, an Indigenous power company, and leased it to the Mununguurra Aboriginal Corporation. Leasing the system was an efficient way for the community to update their energy system along with developments in technology, without making a substantial withdrawal. The drastic change in power generation from outdated diesel generators to a renewable source like solar energy brought cost benefits as the electricity bills dropped significantly. However, the Mununguurra Aboriginal Corporation's transition to efficient power sources demonstrates additional advantages. The community could now allocate money to opening a new school and the increased population had also opened many new job opportunities. If we gradually introduce renewable energy sources and reduce the dependency for diesel in similar isolated locations around the world, there would be a significant impact through social, economical, and environmental benefits.

What can Paulatuk learn from Tennant Creek?

As we introduce more renewable energy sources in electricity sectors worldwide and consequently reduce the amount of harmful non-renewable sources, we can make significant process towards improved energy efficiency. Constantly running outdated diesel generators to output such little energy is not sustainable for the long term. Paulatuk as well as other communities in Northern Canada can learn from Mr. Smith, the Mununguurra Aboriginal Corporation's chief executive. With initiative and collaboration with like-minded individuals, there can be great shifts in systems that seem to be set in stone. Although improved energy efficiency and low electricity bills may be the primary focus of incorporating renewable energy, it is evident that complementary benefits also come with the change. Communities would experience population growth, an increase in job opportunities, and satisfaction overall.

THE WIND POWER DEVELOPMENT POTENTIAL



GUELPH, ON



Traditional wind turbine around Guelph (James Wheeler, 2012)

“”

-Kailong Ni



Community energy plans (CEPs) are widely used by municipalities all over the world to promote the process of sustainable development and the development of renewable energy. Wind energy is an important part of renewable energy and has great potential for development. One of the cities in Canada, Guelph put wind energy as a significant component of its CEP. The purpose of this approach is to assess the potential for wind power generation on the border of the city (McIntyre, Lubitz, & Stiver, 2011). In fact, it is also pushing the level of local wind power generation further to adapt to the more demanding sustainable development trend.

Take the whole world in view, the trend of sustainable development is inevitable and necessary. Wind energy is also valued by more and more countries. There is great potential for the development of wind energy in cities. The installation of wind turbines in areas surrounding cities is becoming more common in Europe and North America (McIntyre, Lubitz, & Stiver, 2011). Guelph must also contribute to global sustainable development trends by developing wind energy.

The city of Guelph covers an area of 86.72 km2, which located around 100 km southwest of Toronto in Canada. According to 2016 Census profile, Guelph had a population of 131794, and from 2011 to 2016, the average growth rate is 1.66% per year. The population growth has increased the local energy pressure. The Guelph government had planned before to deal with this situation. In 2007, Guelph approved its CEP. This CEP advocated reducing energy demand in 25 years and gradually shifting the energy use structure to renewable energy (McIntyre, Lubitz, & Stiver, 2011). As mentioned above, wind energy is a component of its CEP, which requires Guelph builds more advanced wind turbines. This article provides a possible reference of wind energy developing for the city of Guelph.

4.XMW PLATFORM TURBINE

SHANGHAI, CHINA



The new wind turbines for both land and sea in Shanghai (Wikimedia Commons)

What can Guelph learn from Shanghai?

In conclusion, Guelph is worth learning from Shanghai's development of wind energy. Including greater policy support and more aggressive corporate actions. The purpose of both is to improve the level of wind power generation to provide cleaner energy.

Shanghai (China) is a rapidly developing and highly modern city. Wind energy is playing an increasingly important role in Shanghai's energy generation. In order to promote the technological progress and industrial development of wind power, the Shanghai Government has issued a series of support and incentive policies. For example, a total of 200,000 kilowatts of wind power development and construction scale issued to Shanghai by the National Energy Administration in 2016 (Commission, 2016). The policies help Shanghai's local wind power companies gradually formed a complete wind power industry chain, and set up a R&D center in Denmark. Based on rich experience in R&D of large megawatt units, Shanghai Electric Corporation adopts advanced platform and modular concepts, and integrates the latest technological elements in the industry to launch 4.XMW large-capacity low-LCOE Wind turbine platform, 4.XMW platform turbine impeller diameter includes 146 meters and 155 meters. The 4.XMW platform is designed with good malleability and can meet the requirements of IEC Class I and below medium and high wind speed areas. According to the site environment, it can be upgraded to 5.0MW (The 6.0 MW is also on trial in 2018), which greatly saves the number of seats and reduces the cost of roads and power collection lines. BOP (Wind Turbine Peripheral Equipment) cost, which can fully meet the demand for low-cost Internet access (The Shanghai Electric Corporation, n.d.). Therefore, it is a possible option to update or replace the old wind turbines according to the demand to increase the wind energy conversion rate and save costs.

STRUGGLES WITH STORING ITS TOXIC WASTE



KINCARDINE, ON



Bruce Nuclear Generating Station

"Sustainability to me means making informed decisions on the capacity in which to use limited resources in a manner that considers trade-offs and meets basic needs without compromising the lack of resources for future generations. The use of resources in every industry is inevitable but by being educated about sustainability enables individuals to make a conscious effort on the use of energy and raw materials and their impact on the environment."

-Seher Kaur Sarin

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

Canada has been at the forefront of nuclear energy for almost 80 years, with 19 nuclear reactors in operation at six power plants, all but one of which are located in Ontario (Flanagan, 2021). Currently, nuclear provides 60 percent of Ontario's electricity (Thompson & Reporter, 2020). It is a popular energy choice since it is a powerful, cost-effective, and a zero-emission technology which largely enabled Ontario to phase out coal plants. However, they do create significant radioactive waste which remains toxic for thousands of years. The Canadian government has enforced regulations on storing the waste in a manner that minimizes risk to humans and the environment. However, current solutions are proving ineffective and storage locations away from homes or drinking water are challenging to find. Bruce Nuclear is North America's largest Nuclear plant and is located in Kincardine, Ontario which has a population of 11,389 (Government of Canada, 2019). Due to plant operations, low and intermediate level wastes are accumulating and can be hazardous for 100,000 years (Sorensen, 2019). Presently, much of it sits in large tanks with rows of cement lids poking above the surface (Sorensen, 2019). One approach towards long-term storage is the use of a deep geologic repository though, due to risks associated with repository leakage and potential threat of attack, this method was re-evaluated. Ultimately there exists a need to find an area willing to host what amounts to 57,000 tonnes of used nuclear fuel (Sorensen, 2019). As of now, discussions amongst environmentalists and politicians are ongoing, though no decision is expected until 2023. A greater urgency needs to be placed, to help resolve the accumulating issue regarding hazardous waste long-term storage.

SETTING THE GLOBAL BENCHMARK FOR USED FUEL RECYCLING

ORANO LA HAGUE, FRANCE



Orano Nuclear Reprocessing Site

What can Kincardine learn from Orano la Hague?

La Hague is a community in the department of Manche in Northwestern France, with a population of 11,387 (Wikimedia Foundation, 2021). In 1966, the la Hague treatment plant was created as a sustainable solution to help the French nuclear industry with fuel management and has treated 34,000 metric tons of used fuel till date. The 10 year-long production cycle commences when used fuel is removed from nuclear reactors where it produced power and packaged in casks weighing 110 metric tons. Upon arrival at the la Hague site, the fuel is removed from the cask, using specialized robots and remote manipulators, and cooled in a bath for approximately five years. Nine meters below the storage pool of water, the fuel temperature drops as its radioactivity decreases through natural processes. After this first bath, the fuel is divided into smaller pieces for its second bath in a nitric acid solution to dissolve its nuclear material. Finally, the recyclable material, non-recyclable material and waste are separated in a chemical facility (Orano la Hague, n.d.). Gerard Mourou, one of three winners of the 2018 Nobel Prize for Physics claimed that the lifespan of radioactive waste could be cut to minutes (Bloomberg, n.d.). Gerard's idea is to transmute nuclear waste into new forms of atoms which aren't radioactive, using a high-speed laser. Research is still in early stages however; this new advancement has the potential to address the time-based inefficiencies with the Hague site. France produces overwhelming quantities of waste, amounting to 2 kilograms of radioactive waste per person per year (Bloomberg, n.d.). Thus, despite the complexities with the laser solution the idea can truly revolutionize the nuclear sector and aid countries, such as France, in the long-term.

NEEDS TRANSFORMATION IN ITS ENERGY SOURCE



REGINA, SK



Emissions from the refinery rise into the sky at dusk on a winter evening. (Harder, 2021)

As the second largest supplier for Canada's electricity generation from coal and natural gas, Saskatchewan generates 83% of its electricity from fossil fuels, with approximately 43% from natural gas and 40% from coal. The high reliance on fossil-fuel-based electricity generation makes the province's electricity sector produce the second highest greenhouse gas emissions in Canada (Provincial and Territorial Energy Profiles – Saskatchewan, 2021). Its capital city and commercial center Regina is a plain city located in the south-central area of Saskatchewan, known as the second most polluted city in Canada due to its high greenhouse gas emission (Pollution in Canada, 2021).

As a city that is highly dependent on fossil fuel, most of the residents and businesses in Regina have their electricity generated by natural gas, and the greenhouse gas emission from electricity production is responsible for 20% of the city's total emissions (Greenhouse Gas Emissions, n.d.). Besides the environmental issues arisen from burning fossil fuels, there would be an increase in natural gas prices due to the introduction of Federal Carbon Tax. Starting from April 2021, residents of Regina would see an annual increase of 6% on their electricity bill, and commercial customers would experience a 10% increase (Federal Carbon Tax, 2021).

Considering greenhouse gas emissions and the increasing trend in electricity price, Regina should seek for a transformation in its energy source and utilize its great potential for solar and wind energy. Although the City of Regina has committed to achieve 100% renewable energy source by 2050 and has started its investments for years, its energy consumption is still highly dependent on natural gas and coal (Renewable Regina, n.d.).

"One thing that comes to mind is saving water and electricity. For example, it usually requires some time for the water to turn warm when taking a shower, and the cold water collected can be used to mop the floor or to water the plants. I believe reducing the use of plastic bags can also be considered as contributing to sustainability, because it takes a long period for plastic bags to decompose and increases environmental burden."

-Yutong Song

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

NET ZERO ENERGY BUILDING

SINGAPORE



The SDE4 building of the National University (Vargas, 2020)

What can Fort learn from Thurles?

As seen from the Lisheen Mine in Ireland, the use of multi-layered liners is effective at mitigating leakages from tailing ponds and preventing the groundwater of nearby communities from being negatively impacted. Through this, the tailing can sit in ponds longer until they have broken down and can be properly disposed of. Fort McMurray should be able to make sure the companies are using this technology to alleviate the impact of the oil extraction process on its inhabitants not only on living things but also the water, the sustainer of life.

The issue of contaminations from tailing ponds mixing with groundwater and nearby river systems is quite common worldwide. The process of diverting the leaked water into seepage is deemed not enough in resolving the ongoing leaking issue that many mines and regions of energy extraction face. One solution that many tailing ponds are starting to use is geomembrane liners that reduce the permeability for the toxins to leak out of tailing ponds (Tuomela et al., 2021). One location that has used this technology is at the Lisheen Mine in Thurles, Ireland. Thurles is known to be rich in lead/zinc mining and many mines have been established nearby of which faced issues during the planning phases from the usage of lined tailing management facility (TMF). To prevent this issue, the Lisheen Mine had implemented the use of composite liners which are made of a complex geomembrane, like low-density polyethylene (LLDPE) that is infused with a traditional clay liner. The two liners are placed on embankments and underneath the tailings of the ponds that prevent the tailing from mixing with the groundwater. Modelling has shown that the leaks in the two layers of liners would be less than 10 mm2, which is considerably low comparing to the leaks in the past (Dillion et al., 2004). The use of these geomembrane liners is used in large-scale mines like the Lisheen Mine in Thurles, which has a population of just eight thousand people (City Population, 2017). Solutions as these can be implemented by the companies doing extraction of oil and minerals. Governments should create policies and laws that force large corporations to take leakage measures. By implementing a combination of both these liners law enforcement can help to reduce the leaks from tailing ponds into groundwater and rivers.

A CITY RUNNING ON FUMES



FORT MCMURRAY, AB



Petroleum refinery from the Athabasca oil sands, Fort McMurray, Alberta (Krüg, 2012)

"To me, sustainability is the idea of trying to meet current standards, while also thinking about what affect this may have in the future. For engineers specifically, this topic can be of great importance as we are always planning to start projects that could last for years to come. Sustainability should always come up at some point along the plan of action."

-Vince Li

SUSTAINABLE INDUSTRIALIZATION

CANADIAN ENGINEERING GRAND CHALLENGES

Canada has been known to be one of the world's worst countries for greenhouse gas emissions, despite a growing use of nuclear and hydro energy. However, unbeknownst to many, Alberta is one of the main contributing factors to this ranking, producing an egregious 66.67 tonnes of greenhouse gas emissions per capita (Conference Board of Canada, 2016). To put this in perspective, it has produced 45.90 tonnes more than the province New Brunswick, ranked as the country's previous highest. Alberta also produces more than three times the national average of emissions and overall, has seen a 58% increase since 1990 (Canada Energy Regulator, 2019). These statistics are no surprise when considering Alberta's economy relies on the production of oil and gas, as well as petroleum refining based in Fort McMurray.

The mass burning of fossil fuels in Fort McMurray generates greenhouse gases that trap the sun's radiation in the atmosphere, making the climate warmer than it naturally would be otherwise. Hence, the term "Greenhouse Effect," leads to many problems down the line such as a global increase in temperature, rising coastal sea levels, and extreme climates. Fort McMurray and many parts of Alberta are geographically known to be vast and filled with open plains of nature, perfect for renewable sources of energy such as wind or solar. Yet, despite these advancements, the province is still in high demand for greener energy sources to mitigate its already huge amount of emissions.

LONG TERM INVESTMENT

MUNICH, GERMANY





Linde, a hydrogen storing and testing plant based in Munich, Germany, for optimizing industrial processes (Spekking, 2019)

What can Fort McMurray learn from Munich?

In essence, the idea of substituting green hydrogen has potential in reducing Fort McMurray's industrial footprint and regional climate. Although the Athabasca Oil Sands may not see less industrialization geographically, the city can learn from Munich to slowly reduce greenhouse gas emissions and eventually, meet the standards of CEGCs and SDGs in the coming decades.

Germany was a heavily reliant fossil fuel country a couple years ago due to the dense industrial plants that exist in the cities of Hamburg, Saxony, and Stuttgart. However, the Western European country now has a plan set in motion that others should start to follow. Although Germany is actually ranked higher in terms of emissions per capita, it has adopted many renewable energy reservoirs as a solution. Most notably, one of these methods is the eventual use of hydrogen as an energy source. In Munich, carbon-free hydrogen, also known as "green hydrogen," is produced and stored using electricity to split hydrogen molecules from water. It can also be produced through renewable processes, such as the use of electricity generated from solar and wind sources. With a proper long-term plan in motion, the investment into hydrogen storing is forecasted to fulfill 15-20% of the world's energy needs in the coming decades (Jacobo, 2020). The stored energy can then be used to power hydrogen-based transport, replace diesel in the future, or even be blended into natural gases used today to diminish emissions. Most importantly, refineries that require the use of fossil-based hydrogen as a base substance, can easily be replaced with green hydrogen to decarbonise their processes. This is possible as the already existing infrastructure in industrial plants to make chemicals can continue to do so with green hydrogen without a problem. A main focus of Germany's government is to eventually use this stored energy in Munich as an alternative to replace hard-coal coke in the future, a commonly used industrial fuel with a very high carbon content (German Federal Ministry for Economic Affairs and Energy, 2020). As such, the investment into hydrogen storing can be extremely beneficial in the long run, with potential to help meet the energy demands as a green and renewable option in the future.

OIL SANDS EXTRACTION CREATES “STICKY” SITUATION

INDIGENOUS TRIBE IN FORT MCKAY, AB



Wastewater from extraction facility (right) in Fort McKay is stored in tailing pond behind board (left). 99% of mined land remains un-reclaimed.

“”

-Mannatpal Kankwal

SAFE AND SUSTAINABLE CITIES
CANADIAN ENGINEERING GRAND CHALLENGES

Alberta’s oil sands produce over 80% of Canada’s oil, which produced 2.95 million oil barrels per day in 2019, compared to 2.2 million a day in 2014. Peace River, Cold Lake, and Athabasca are three regions covering 142,000 km2 that make up Alberta’s oil sands (Canada, 2020). Fort McKay First Nation, FMFN, is an indigenous settlement in Athabasca with a population of 745 (Government of Canada, 2019), that has had a major impact from oil extraction.

Oil production is detrimental for the environment. 2.6 barrels of fresh water, and 2 tons of sand produce one barrel (NASA, n.d.), with each barrel producing 103 kg of CO2 and toxic wastewater as by-products. More than 11.4 million litres of this wastewater are stored daily near the First Nations settlement in waterbodies known as tailing ponds, totalling 1.25 trillion litres in 2018 (The Narwhal, 2021).

The high usage of fresh water leaves no water for trees, which have largely dried out. Tailing ponds are also leaking into groundwater. FMFN residents are strictly advised short showers and bottled water for survival. Fishing, part of the First Nations’ culture, is now impractical as the consumption of fish from nearby waterbodies is linked to high rates of cervical cancer and bile duct cancer in FMFN.

There are currently 21 projects with a total capacity of 3.3 million barrels a day approved/in production, and 1.6 million barrels a day planned in the FMFN area. Since the 1960s, 210,000 acres have been mined but only 250 acres are reclaimed, the rest 99% considered disturbed (Ulmanu, Poulton, Mullin, Goldenber, Levene, Ochagavia, Holder, n.d.).

MCW ENERGY GROUP ADOPTS ECO-FRIENDLY OIL EXTRACTION

UTAH, UNITED STATES



Oil Extraction facility in Utah recovers 99% of hydrocarbon content.

MCW Energy Group, an oil extraction company, has patented an extraction method that recovers up to 99% of hydrocarbon content from oil sands in Utah, USA, leaving no toxic tailing ponds. The water and sand by-products can be safely returned to the ground once oil is extracted (Green Car Congress, 2013).

Utah contains the largest oil sands source in the USA, containing up to 15 billion barrels of measured oil over an area of over 600 km2 (Utah Geological Survey, n.d.). This makes it an ideal location for MCW Energy Group to perform tests for their extraction technology.

Upon performing tests on a sand/soil mixture of 41% water, 26% bitumen, 32% cellulose and 1% impurities, the by-products were clean sand/soil, clean water, and bitumen. The sand/soil and water can be returned, and bitumen is used for several applications (Green Car Congress, 2013).

This process of extraction is also economical. With tests done in 2016, MCW Energy were able to produce a barrel of oil for $35, at WTI price of $80. The company started with an initial capacity of 250 barrels a day and plans on scaling it up to 5000. This is projected to decrease the cost to produce the oil to $20 per barrel, which increases profits, allowing the company to invest more in this technology (Staff, 2016).

This technology allows MCW Energy Group to extract oil with no tailing ponds, ensuring safe return of sand/soil, decrease the production cost, and increase the bitumen by-product, all of which are ideal in the oil extraction process. MCW Energy Group has significantly decreased toxic by-products from oil production and aims to export this technology to markets around the world.

What can Fort McKay learn from Utah?

With the new extraction method, not only are contributions to tailing ponds reduced, but clean water as by-product can be put back for healthier trees, consumable fish, potable water, and a more sustainable and greener future for Fort McKay. Furthermore, the method is more economical, especially at Canada's significantly larger scale.

HOW OIL REFINERIES ARE HARMING FIRST NATION COMMUNITY



THE AAMJIWNAANG FIRST NATION COMMUNITY, ON



Aamjiwnaang Community Resource Centre Directly Beside "Chemical Valley"

"To me, sustainability is about making decisions and acting in a way that does not harm future generations. It is about being conscious of the consequences of our actions in the long run."

-Saranya Jeyakanthan

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

The Aamjiwnaang First Nation is an Anishinaabe First Nations band located on reserve land in the southern region of Sarnia, Ontario. In 2016, the population of this small community was estimated to be 630 people (Statistics Canada, 2018). It is located directly adjacent to several petrochemical plants in an area which is also known as "Chemical Valley". Unfortunately, the community's proximity to these plants has had a serious impact on the health of the community. Since the 1990s there has been a decline in the proportion of male births (Mackenzie et al., 2005). In fact, between 1999 and 2003 only 33% of births were male (Mackenzie et al., 2005). This is a rare phenomenon and while there could be several potential causes, the constant chemical exposure to the population is considered to be a contributing factor. A gas leak on February 7, 2014, from the Esso Imperial Oil Refinery resulted in the release of 500 kilograms of hydrocarbon gas (Sean Craig et al., 2017). The population experienced symptoms such as burning eyes, dizziness and nausea (Sean Craig et al., 2017). The very next day, Plains Midstream, a fractionation plant nearby that makes propane, also had a spill. A kilometre away, the concentration of benzene (a carcinogen) reached a dangerous level of 50.2 ppb (Sean Craig et al., 2017). There are over 500 government reports of similar industrial spills and leaks in the area over a 2 year period (Sean Craig et al., 2017). While the air quality in Sarnia was once the worst in Canada, with 21 micrograms of PM10 particles per cubic metre of air (CTVNews.ca Staff, 2011), the region has come a long way since then due to more stringent regulations. However, the production of fuels in this region still requires some major changes in order to achieve the triple bottom line of sustainability.

CITY POWERED BY ITS OWN 100% RENEWABLE ENERGY COMPANY

BASEL, SWITZERLAND



The Rhine River in Basel, Switzerland

What can Aamjiwnaang learn from Basel?

Basel's proximity to several rivers has allowed the city to depend primarily on hydropower. Similarly, the Aamjiwnaang First Nation is located by St. Clair River and Lake Huron. The potential for a similar transition towards hydropower and away from fossil fuels and nuclear energy exists. However, the Canton of Basel-Stadt's government played a key role in making this transition. Government intervention will likely be necessary for Aamjiwnaang First Nation community to follow in the same footsteps.

The city of Basel is located in the north of Switzerland. The Rhine River runs through the city, splitting it into two sections and the city is also situated by the Birs and Wiese rivers (Britannica, 2013). The city's proximity to these water bodies makes it ideal for hydropower generation. As a result, the main source of energy for the city is hydropower and the remaining 10% of energy production is sourced primarily from the wind, with some energy sourced from geothermal and biomass as well. None of the energy in the region is produced from non-renewable energy sources, making it one of the few cities in the world powered by 100% renewable energy. The supply of this energy is facilitated by a publicly owned company called Industrielle Werke Basel (IWB) and has been owned by the canton of Basel-Stadt since 2010 (IWB, 2021). Since the 1970s, the region of Basel has been opposed to the construction of more nuclear power plants and has slowly converted to renewable energy sources instead (Kanton Basel-Stadt, n.d.). The canton of Basel-Stadt has also been offering a variety of resources to aid in transitioning to renewable energy such as free-of-charge energy advisory services for residents and replacing oil/gas heaters in their homes (Kanton Basel-Stadt, n.d.). Their main source of energy, hydropower, does not have a significant impact on air quality (EIA, 2020). The air quality in the region is good, with a US AQI of 17 and only 4.1 micrograms per metre cubed of PM2.5, the main pollutant in Basel (IQAir, 2021). A report on the implementation status of climate change measures found that any air pollution in the region was mainly caused by road traffic (Cantonal Office for Environment and Energy, 2017).

CANADA'S MOST PREVALENT SOURCE OF RENEWABLE ENERGY

MUSKRAT FALLS, NL



Muskrat Falls Hydroelectric Dam During Construction

"Sustainability means consuming and using the resources available to me in a way that is going to preserve them. It means actively trying to reduce my use of certain goods and make decisions that at the end of the day will help my kids and future generations actually have access to the things they need. Sustainability to me personally means beig conscious of my consumption."

-Taylor Numan

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

Muskrat Falls is one of the many waterfalls along the Churchill River that is being harnessed for its hydroelectric potential. The Churchill River flows through Labrador. It serves as the hunting and fishing ground for the Sheshatshiu Innu First Nations who are settled a little further down the river at Happy-Valley Goose Bay. The Sheshatshiu use the river as a main source of food and the construction of the hydroelectric dam at Muskrat Falls has put their way of life in danger. (Levac, n.d)

When hydroelectric dams are created a reservoir must be constructed, and this comes with the flooding of the surrounding area. When the flooding occurs the levels of methylmercury in the water increase due to the decaying of organic matter among other reasons (Hudson, November 2017). This methylmercury is not an issue for the drinking water supply for the surrounding populations but for the Sheshatshiu it is. Since they source a large amount of their food from the river the methylmercury levels are increased, as it compounds as it moves through the food chain. Regularly this is not a cause for concern but due to the fact there is numerous dams along the river the Sheshatshiu are becoming increasingly at risk. These reservoirs and large dams also impact the wildlife in other ways. Natural migrations and movement of wildlife around the river is impacted and natural populations decrease because of the construction of the dam (Cox, May 2019).

This hydroelectric project was also approved despite the fact there were other more economical options that would have provided cheaper options for energy production. The project also was completed extremely behind schedule and cost the province twice the estimated 8.2 billion it was supposed to. Overall, the hydroelectric project has created more problems not only environmentally but also economically for the population of Muskrat Falls and the surrounding areas (Roberts, November 2020).

HYDROELECTRIC POWER, A SUSTAINABLE SOLUTION

AARE RIVER, SWITZERLAND



Aare River in Switzerland

What can Muskrat Falls learn from Aare River?

Communities directly impacted by hydroelectric power plants largely include First Nations communities. These communities rely on water systems as sources of food, and they are the ones impacted by increased levels of methylmercury. A sustainable energy source means sustainable for everyone, not just the main population. In the future hydroelectric power plants need to access their impact and choose the most equitable solution for all.

In Europe hydropower has been around for centuries. In Austria and Switzerland run-of-the-river hydroelectric power plants allow for the creation of electricity without the costly and massive dams that traditional hydropower plants use. These alternatives also eliminate the need for the massive reservoirs that increase methylmercury levels in the ecosystems. This type of hydroelectric generates a lower output but the environmental benefits of these systems allow for the construction of numerous along one river or stream. (Robinson, February 2018)

Run-of-the-river hydropower plants are implemented in regions that have existing rivers. Some of the qualities that are desirable for this type of energy production are natural topography that allows for high flow rates of water and changes in elevation that creates a current with high enough speed that its useable. These hydropower plants generate electricity by diverting the water to a small collection area and then channeling it through something called a penstock to ensure that the water has enough pressure to spin the turbines which transform the kinetic energy of the water into electricity. The water then flows back into the river and continues along its natural path (CTCN, n.d). These systems have smaller changes in elevation than traditional dams and allow for fish ladders and technologies that mitigate environmental effects of the hydropower plants. Overall, they have much smaller impacts than traditional hydroelectric power plants (Azpo, March 2019).

Run-of-the-river dams are largely used along the River Aare in Switzerland. One of the largest producing power plants is the run-of-the-river hydroelectric power plant in Gösgen, Switzerland. This power plant was built in 1917 and has been producing energy since then. It was rebuilt in 2000 and the power output was increased by twelve percent. Gösgen is Switzerland's powerhouse of electricity production as it is also home to a large nuclear power plant. (Association, February 2021)

OIL IN THE SAND, POLLUTANT IN THE PARK ENVIRONMENTAL ISSUE

WOOD BUFFALO, AB



Oil sand field (Swift et al., Stop tar sands oil expansion and infrastructure 2016)

"My understanding of sustainability: The extent of that the use of reusable, recyclable materials without the influence of performance, and the increased longevity."

-Jiatong Xu

SUSTAINABLE INDUSTRIALIZATION

CANADIAN ENGINEERING GRAND CHALLENGES

The Regional Municipality of Wood Buffalo (RMWB) is the one of the largest municipalities in North America with a 68,454 square kilometers territory. The growing rate in this municipality is impressive, 12% employment growth even in the recession, doubled population since 2000 and ranked as the one of most beneficial area for investment (Regional Municipality of Wood Buffalo 2014). Most of these developments and achievements should be attributed to the discovery of oil sand in this area. Oil sands (shown in figure 1.) are natural deposits which are rich in "bitumen"; a viscous mixture of hydrocarbons that can be widely used in many industrial purposes (Oil Sands and the Regional municipality of WOOD BUFFALO, n.d.). Due to bitumen contains hydrocarbons, it is apparently a type of fossil fuel.

When oil sand is acting like a money printer, it is also impacting the environment. Wood Buffalo National Park is one of victims. Since oil sands are mixtures of chemical compounds, they can contaminant water body and soil when they are being exposed in an oil-sand environment. Additionally, the tailing, a side product during the extraction and processing of oil sand, which contains heavy metal and residual hydrocarbon, can also compromise the integrity of the park. When a leakage of tailing pound, or a failure of tailing management occurs, this side product can infiltrate into the park (Wood Buffalo National Park, 2019).

After describing the environmental issues above, here is a question. No matter the oil sand itself, or the side product during manufacturing, why there is a chance that these pollutants can access to the park such easily? According to an ambient monthly report for air quality from Wood Buffalo Environmental Association (2021), because of the power failures in plants, air quality analyzers were offline multiple times over a month. Thus, the reliability of the equipment on site is suspicious. After all, the environmental issues originate from human activities.

ON A RENEWABLE PATH TO THE FUTURE

BURLINGTON, UNITED STATES







60 tonnes of wood chips can keep the plant operational for one day (Woodard, White, Sitrin, & Gerstein, 2016)

What can Wood Buffalo learn from Burlington?

Burlington is a perfect example that how an industrial city transfers to a sustainable green city. There exists a similarity between old Burlington and current Wood Buffalo, which is they both have pollution issues, and heavy industry is playing the majority of the role of cities. RMWB really can learn from the metamorphosis of Burlington and use it to transit Wood Buffalo to a sustainable green city. Of course, this would not be an easy task and need a firm resolute to execute it for the long term.

The city of Burlington is located on the eastern shoreline of Lake Champlain. It is a small city with a 43,063 population and 40.12 square kilometers of territory. Early 20th Century, Burlington city was thriving and populated by various kinds of petroleum transportation. However, as the time passed, in 1980's most heavy industries and petroleum shipments were shifting somewhere else, leftover a decayed and contaminated shoreline to citizens. Meanwhile The City of Burlington realized the pollution along the shoreline and decided to clean this up. The main goals of Self-sufficiency and environmental protection were determined during that period (History, n.d.).

In order to self-support energy demand and to protect the environment, a coal-powered plant was altered by a biomass generating station called "MCNEIL", which can produce electricity from the bio-energy in wood chips. When the station is fully operating, it can feed the energy for the whole city. Whereas, in usual, half of the energy output is from other infrastructures such as wind farms and hydro plants (Our energy portfolio, n.d.). As the contributions of these renewable energies, the electricity input to the grid of the city of Burlington is all from renewable energy. In theory, green energy is more costly than traditional fossil fuel, but the community perfectly solved this issue and even can earn revenue from selling surplus energy to other cities. In addition, such a combination of energy source can provide sufficient redundancy (Burlington, Vermont: A city powered by renewable energy, n.d.).

The success of the city of Burlington is not achieved in a night. The span of time from the establishment of MCNEIL power plant to now is over 30 years. Over this time, Burlington was gradually phasing out fossil fuel energy and embracing renewable energy. However, thing is not done, the government now is focusing on promoting electric vehicles, thermal energy, and other implementations of clean energy.

Landfill/SATPALDA

CHAPTER 6: SOLID WASTE MANAGEMENT



CHAPTER INTRODUCTION

When disposing our waste, it does not just cease to exist when we throw it away. Disposal is a form of treating the waste produced, however, solid waste management is the practice of managing what we have discarded. Better yet, this practice is better known as resource recovery by recovering reusable material and even recovering energy. This module introduces waste types, categorizes the objectives of waste management systems, and identifies a hierarchy for waste management. Several treatment methods are described including those that constitute waste disposal such as landfilling and incinerating; and those that consisting waste diversion such as recycling, and composting, while highlighting the impacts on air, water, and other relevant environmental impacts. Because there is an economic value to the waste when recovered, this module also considers waste management as an optimization problem using linear programming to determine the optimum mix of products to maximize profit.

Learning Outcomes

By the end of this week, you will be able to:

- Categorize solid waste
- Define waste management systems and their objectives
- Identify the solid waste management hierarchy
- Differentiate between waste disposal and waste diversion strategies
- Describe waste treatment methods including landfilling, incinerating, recycling and composting
- Identify air, water and other environmental impacts associated with waste treatment methods
- Make decisions using linear programming to optimize waste treatment options
- Formulate a linear program for optimization
- Solve a linear program graphically

MAY RECYCLE, BUT FAILS IN MANAGING ITS SOLID WASTE

VANCOUVER, BC



Burying Earth Alive with our Waste by Justin Ritchie licensed under CC BY-NC-SA 2.0 https://www.flickr.com/photos/jritch/4677848928

Excessive use of landfills in British Columbia are contributing to climate change. If they continue to fill landfills at the current rate, they will reach capacity rapidly. Then, they must find more land to use for landfill. This increases the amount of waste over a larger surface area. Landfills produce methane gas (CH4), which is a greenhouse gas (GHG) and contributes to global warming and accelerates the effects of climate change. (WB Waste Solutions, 2019)

British Columbia, specifically the southern part of the province, is very populated, so waste accumulates fast. The urban life there is typically accompanied with exponentially increasing mass use of single-use plastics, contributing to the landfill. Single-use plastics usually can't be diverted or recycled, so they all end up in landfills. Examples of single-use plastics are take-out containers, cups, plates, bowls, forks, spoons, knives, plastic straws and stirrers, plastic bags and plastic water bottles, which are ubiquitous in developed cities in British Columbia. (Ridge Meadows Recycling Society, 2021)

In British Columbia, the gross emissions of greenhouse gases increased by 3.3%. (Environmental Reporting BC, 2021) While emissions have been decreasing, the province isn't being proactive enough. The province needs to be more aggressive with their policies and regulations, and they've only recently began talks about initiating programs to solve their waste management problems.

""

-Chamena Srikanthan

SUSTAINABLE INDUSTRIALIZATION

CANADIAN ENGINEERING GRAND CHALLENGES

ROYAL WASTE DIVERSION — SUPPORTED BY HER MAJESTY

VICTORIA, CANADA



Follow the 'Diverted from Landfills' Brick Road by Richard Eriksson licensed under CC BY 2.0 https://www.flickr.com/photos/sillygwailo/3669617636

What can Vancouver learn from Victoria?

Vancouver, B.C. could learn a couple things from Victoria, B.C. Residents of Victoria have seen how much litter is in the surrounding water, and many are then motivated to separate their waste, and drop it off at the appropriate recycling depots. Vancouver is a very urban city, with its residents used to litter from its population of just over 2.6 million people. If Vancouver spent more time on education, or creating incentives, its residents may begin to partake in slowing down the waste cycle and extending life spans of materials. (Pawson, 2021)

Victoria, British Columbia has started implementing programs to help their waste management problems. One program is having corporations manage and be responsible for recycling initiatives for their products that consumers eventually contribute to the local Victoria landfill. (Government of British Columbia, 2021) Victoria encourages their residents to try to organize, collect and set aside their trash, for as long as possible. There is a relatively local recycling depot, that residents can drop of their separated waste to. This ensures that most trash is diverted from landfills, extending the landfills' life span. The diverted trash can then be recycled in their appropriate category and reused, restarting the cycle of the materials use. A report commissioned by the Ministry of Environment and Climate Change Strategy in 2016, found that the Extended Producer Responsibility program in B.C. diverted 160,000 tonnes of material from landfill and greenhouse gas emissions were reduced by over 200,000 tonnes (CO_2e) in just one year. (Pawson, 2021) (Ministry of Environment and Climate Change Strategy, 2020)

Victoria, B.C. has a population of over 92,000 people, and it is also the capital city of British Columbia. Victoria has one of the mildest climates in Canada, so its population is almost always out, and spending their money. They purchase items like take-out food, which is usually sold with single use plastic containers, cutlery, cups, straws, etc. British Columbia was found to be one of the most efficient recycling programs in Canada and North America. (Johnston, 2019)

THE NEGATIVE IMPACTS OF LANDFILLS

ARNPRIOR, ON



A common site in Ontario – a sprawling landfill

"One personal change I made at the start of the pandemic was to stop using plastic water bottles and to instead use my reusable water bottle. I had realized that I was drinking a lot of water and throwing away plastic bottles and decided that I should try to cut down on my use of plastic."

-Aly El Refai

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Canada as a country produces a vast amount of waste. So much in fact, that some waste from Ontario is even sent to the United States, as there are not enough landfills to process all that waste. The Ontario Waste Management Association estimates that in 12 years, Ontario's 805 landfill sites will be filled. Landfills in Canada are very common, but more importantly, these landfill sites have severe negative impacts on both the environment and society. Landfills are a contributor to climate change. They produce large amounts of methane and carbon dioxide. While the methane can be used as a fuel, that only serves to contribute more to climate change (Advantages and Disadvantages of Landfills - Conserve Energy Future, n.d). Landfills also produce a liquid called leachate. Leachate is toxic and can contaminate bodies of water, impacting the environment and ecosystems around it. Moreover, they are also extremely costly and ruin the landscape around it. While arguments can be made that landfills can later be converted to parks and open air recreation centers, this does not change the fact that for the large lifespan of the landfill, it is a huge eyesore and causes unpleasant smells for residents living around it, causing real estate prices to drop (What are the Negative Effects of Landfill?, n.d). Most of these issues are felt by the residents of the residents of Arnprior, a town located in the east of Ontario. Arnprior has a population of approximately 8795 residents (Census Profile, 2016 Census, 2016) and has recently opened an investigation into contaminated water discovered around the landfill site near the Ottawa River. The most likely culprit is believed to be leachate the leaked into the surrounding land, causing the water to test for levels of iron, boron, barium, and organic compounds deemed unsafe.

TURNING THE PROBLEM INTO A SOLUTION - APPROACH TO WASTE

BORÅS, SWEDEN



The head office of the Incineration as well as Powerplant for Heat and Electricity

What can Arnprior learn from Borås?

In conclusion, if the town of Arnprior was able to implement the same strategies as Borås, they would no longer have an issue with leakage from landfills harming the land around it.

The issues that come with landfills, as previously stated, are many. Leachate leaks, real estate prices going down, complaints from residence, horrible odors, etc. are just a few of those problems. However, several Scandinavian countries have seen waste that goes to landfills not as a problem to be dealt with, but as a resource to be used. Several cities in Sweden, including the City of Borås have used all their waste as a source of energy, burning all their waste, eliminating two birds with one stone – lessening the reliance of the nation on fossil fuels, while avoiding the use of landfills and the host of problems that come with it. It has reached the extent, that the entirety of the country now faces a shortage of waste and has opted to import nearly 1 million tons of waste from neighboring country to use as an energy source (Leber, 2015). The city of Borås near the south of Sweden has a population of approximately 66,273 residents. It is an essential part of the railway service across Sweden.

Borås initially started their new model of dealing with waste by using 3000 households to test their new model. After it was deemed successful, it was implemented across the whole city. The waste produced is separated in to two parts – recycling and resources used to be converted electricity, fuel or heat. This system of waste management has been determined to only work because of one key factor – the cooperation of citizens. The citizens of Borås are given detailed booklets informing them of the several different ways to dispose of their waste at home before it is collected and sent to processing plants to be recycled or converted to electricity (Rajendran et al, 2013).

A COMMUNITY SUFFERING AMID WASTE MANAGEMENT CRISIS

OHSWEKEN, ON



Garbage Piling up at Incinerator

Ohsweken, Ontario is the largest community located on the Six Nations reserve south of Hamilton with a population of 1,500 (Groat, 2020). Centralized in Southwestern Ontario this reserve has a landfill that services their whole population of 12,892 including the population of Ohsweken (Groat, 2020) that had reached capacity in 2006 and has continued to be used through piling more waste on top of the full landfill (Huang, 2014). This landfill has no lining and reached capacity at twice the expected rate leading the community to seek a new waste management solution which consisted of an incinerator that promised zero emissions and delivered the exact opposite. The incinerator was found to emit chemicals at 200 times the allowable limit that cause a multitude of health problems during its five-month long trial run (Green, 2015). The trial run was shut down due to a community lead protest that called for the incinerator to be shut down due to the emissions, odour, and concerns about the resident's health (Huang, 2014). From concerns about the landfill being unlined and overused and the water quality this could affect to the dangerous emissions plaguing the air, a community is suffering from a lack of resources and action in relation to their solid waste management. If this issue remains unchecked the future of the community's residents as well as the surrounding area will become no doubt more concerning.

"The elements of sustainability that I've incorporated into my personal life focus mainly on environmental impacts and contributing to my local economy. I tried to implement a small-scale circular economy approach involving reusing and remaking from items already in the household before they eventually get recycled or thrown away."

-Emma Moorhouse

SUSTAINABLE INDUSTRIALIZATION

CANADIAN ENGINEERING GRAND CHALLENGES

AIMS TO BE A ZERO WASTE CITY

SAN FRANCISCO, UNITED STATES



Inside San Francisco, California Recycling Facility

The city of San Francisco, California is home to 881,549 residents and is located on the west coast of the United States. The majority of the population is financially well off and the city is fairy densely populated (Census profile: San Francisco, CA,2019). San Francisco brought mandatory recycling and composting into effect in 2009 for all residences and businesses while also banning items that area a hazard to the environment. To correspond with these new regulations the city also incentivised the public by allowing much higher recycling and waste pick up than regular trash before penalty. The introduction of this improved waste management system did however come at a price, more employees, a large facility, and operations costs for a program of such a large scale for the city of San Francisco (Brigham, 2018). Diversion of waste through recycling and composting can greatly decrease the amount of waste that ends up in a landfill which can help with increasing the life span of a landfill and decrease the amount of carbon dioxide released into the atmosphere. Composting in the case of the system in San Francisco has added benefits because the compost when complete is then used for crops in the surrounding area which cycles the energy back through the system through the food production (Brigham, 2018).

What can Ohsweken learn from San Fransisco?

Though Ohsweken and San Francisco differ greatly in size the base concepts of the waste management system implemented in San Francisco could be of great benefit to Ohsweken. With the Ohsweken landfill being overwhelmed by waste a solution could be to aim for a mitigation of waste bound for the landfill by adapting a recycling and compost system to the community's needs.

TORONTO PRODUCES TOO MUCH WASTE FOR SMALL TOWNS



VARIOUS COMMUNITIES, ON



A tractor drives through the City of London W12A Landfill Site (Chopowick, 2019)

“To me, sustainability is a condition where society can meet its needs and improve upon them without compromising the ability of future generations to also meet their needs. These needs are fulfilled using natural, social, economic resources, which all must be used at a rate less than the rate they are being produced. ”

-Nancy Situ

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

Toronto accounts for a big portion of Ontario's population and its waste. As landfills reach capacity, government officials look to build landfills in smaller towns where there is land available. However, the town residents are against the idea including those in Ingersoll, a town 150 kilometers southwest of Toronto. Not only will a new landfill in Zorra Township cause odour and 150 daily visits by trash-hauling trucks, but it is also a risk to the groundwater. There is strong opposition to the proposed landfill as citizens place anti-landfill signs on lawns and roadsides as shown in Figure 1.

Locals fear that the leachate caused by waste breakdown will enter the groundwater that is used for consumption and irrigation. The project director claims there will be no issue with the landfill’s containment liner, but the opposition says the liner is likely to fail, especially after the landfill is full. As landfill proposals in small towns increase, landfill opponents see this as a trend: Big cities, unable or unwilling to deal with their own garbage, looking down Highway 401 for a convenient place to stash it (Lupton, 2019). The amount of waste being created is a big issue and according to industry research, Ontario is running out of places to store its trash. It has been estimated by the Ontario Waste Management Association (OMWA), that Ontario’s available landfill capacity is expected to be exhausted in 10 to 14 years. This number already considers the millions of tonnes of waste that are exported to the United States (Ontario Waste Management Association). Despite opposition against new landfills, the current landfill proposal process does not allow municipalities a final say. There is a struggle between small towns lobbying against local landfills and the diminishing capacity of current landfills.

CITY POWERED BY ITS OWN 100% RENEWABLE ENERGY COMPANY

BASEL, SWITZERLAND



Colourful Recycling Bins in Germany are labelled with its contents (recycling-bins-recycle-environment-waste)

What can Aamjiwnaang learn from Basel?

Basel's proximity to several rivers has allowed the city to depend primarily on hydropower. Similarly, the Aamjiwnaang First Nation is located by St. Clair River and Lake Huron. The potential for a similar transition towards hydropower and away from fossil fuels and nuclear energy exists. However, the Canton of Basel-Stadt's government played a key role in making this transition. Government intervention will likely be necessary for Aamjiwnaang First Nation community to follow in the same footsteps.

The city of Basel is located in the north of Switzerland. The Rhine River runs through the city, splitting it into two sections and the city is also situated by the Birs and Wiese rivers (Britannica, 2013). The city's proximity to these water bodies makes it ideal for hydropower generation. As a result, the main source of energy for the city is hydropower and the remaining 10% of energy production is sourced primarily from the wind, with some energy sourced from geothermal and biomass as well. None of the energy in the region is produced from non-renewable energy sources, making it one of the few cities in the world powered by 100% renewable energy. The supply of this energy is facilitated by a publicly owned company called Industrielle Werke Basel (IWB) and has been owned by the canton of Basel-Stadt since 2010 (IWB, 2021). Since the 1970s, the region of Basel has been opposed to the construction of more nuclear power plants and has slowly converted to renewable energy sources instead (Kanton Basel-Stadt, n.d.). The canton of Basel-Stadt has also been offering a variety of resources to aid in transitioning to renewable energy such as free-of-charge energy advisory services for residents and replacing oil/gas heaters in their homes (Kanton Basel-Stadt, n.d.). Their main source of energy, hydropower, does not have a significant impact on air quality (EIA, 2020). The air quality in the region is good, with a US AQI of 17 and only 4.1 micrograms per metre cubed of PM2.5, the main pollutant in Basel (IQAir, 2021). A report on the implementation status of climate change measures found that any air pollution in the region was mainly caused by road traffic (Cantonal Office for Environment and Energy, 2017).

THE CONTINUOUS WAR ON SOLID WASTE

VANCOUVER, BC



Metro Vancouver solid waste management landfill located in Delta

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-Gjergj Ndoi

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Since the dawn of time, humanity has continuously strived for progress and innovation, resulting in an exponential economic boom for many countries and their major cities. As one of these cities, Vancouver has seen its economy flourish, reaching a GDB of $138.3 billion in 2016 with a population of 2’463’431(Greater Vancouver Area).

However growth in development does not come without its struggles. For a city of this population, solid waste management has always been a problem to be taken seriously. In Metro Vancouver, the amount of waste generated in one year per person is approximately 1400kg, comparable to the weight of a mid-sized automobile. Uneaten and spoiled food makes up for about 25% of all residential garbage, which is more than any other type of waste in the region. Clothing, on the other hand is comprised of 20’000 tons of waste and represents about 2% of the region’s garbage. Most of the waste sent to incinerators and landfills consists of materials from construction and demolition sites such as wood and scrap metal.

When analyzing the data received from the Municipal waste disposal data and Statistics Canada some positive feedback can be noticed for the city of North Vancouver, where only 197 kg of waste per single family residence were sent to a landfill or to incarceration. However this cannot be said for the City of Vancouver, which by contrast sent 318 kg of waste per SFR in the same year. These disposal rates are simply unsustainable, since landfills do not have unlimited capacity.

Metro Vancouver has one designated landfill facility located in Delta; and it received 68% of all the region’s annual disposed waste in 2017 (736’000 tonnes). This made up for a 6% increase from the previous year and judging by these rhythms, the 52-year-old landfill with an area of 320 hectares will reach its maximum capacity in 2031. It is clear that progress is being made, however the battle against solid waste is still very present and tough to be

PLASTIC ROAD - MODERN PROBLEMS REQUIRE MODERN SOLUTIONS

ROTTERDAM, THE NETHERLANDS



Rotterdam cycling track, made from recycled plastic

As one of Europe's largest city ports with a population of 651'446, Rotterdam serves as a great economic center for the whole bastion of the EU. However this city has more to offer than just economic benefits of a trading hub. Its history dates back to the year 950 CE as a settlement near the Fen stream, which explains the meaning of the name Rotterdam as "Muddy water" (Rot- muddy, a- water). Throughout the years the city steadily grew to become one of the most important cities not only in the Netherlands but in Europe as well. It survived constant battles against the sea (given the geographical location of the Netherlands, a lot of areas are actually below the sea level), medieval wars and two World Wars and emerged as a modern city, home to 180 nationalities, with lively cultural life, maritime heritage and modern architecture.

However the battle with the sea was not the only battle Rotterdam has fought over the years. As a city of innovation when it comes to treating problems related to sustainability, this city does not fail to surprise with its ideas for solid waste management. Their idea? Recycled roads made entirely from recycled plastic bottles.

A construction company based in this city has embraced this approach for several projects. They claim that plastic roads are more durable, lasting up to three times that of asphalt roads. These roads can also handle temperatures between 40 and 176 Fahrenheit with ease. Another advantage is the reduction in time, since segments of the roads can be prefabricated and then transported. In addition, the company argues that these projects are "virtually maintenance free", reducing the time construction crews need to block traffic and lowering emissions of operating vehicles.

Even though the war on waste is far from over, Rotterdam's innovative solutions create new hope for creating a more sustainable future when it comes to treating solid waste.

What can Vancouver learn from Rotterdam?

In addition cities can learn and improve by taking solutions from other cities as examples. As mentioned in this project, the city of Vancouver can implement the Rotterdam idea of using recycled plastic for constructing roads. This way they can create a more resilient and long lasting infrastructures, reduce emissions and reduce solid waste.

LANDFILL CLOSURE CRISIS

COLLINGWOOD, ON



A landfill filled to the brim with solid waste products (Arseneault)

Collingwood is located in Simcoe County, Ontario on the southern edge of Georgian Bay. It has a population of 20,102 and a land area of 15.69 square kilometers (Statistics Canada, 2019). It is a popular destination for tourists as it is situated right between the Blue Mountain ski resort and Wasaga Beach and hosts many events such as the Santa Claus parade, the Elvis Festival, and the Canada Day firework celebration by the grain elevators at Collingwood Harbour. There is also a museum with exhibits on the town's history of shipbuilding. In 2020, about 98,500 tonnes of solid waste were collected through curbside collection crews in Collingwood (Owen, 2021).

Staff reports from the County of Simcoe council committee estimate that the Collingwood landfill will close in 2024, with the two other Simcoe County landfill sites in Nottawasaga and Oro-Medonte closing in 2025 and 2030 respectively (Owen, 2021). The Director of Solid Waste Management, Rob McCullough, said that long-term, the county is looking at exporting solid waste once the local landfills close (Owen, 2021). This is due to the public backlash received in 2009 over the landfill site project, Site 41 (Owen, 2021). Multiple community and indigenous groups worried that since Site 41 was located on top of a large aquifer, it would contaminate the groundwater (Owen, 2021). The project was subsequently cancelled, and the council ruled that no new landfills would be built in Simcoe County (Owen, 2021). The 2021 County of Simcoe budget estimates that the county pays about $13 million annually for the export, processing, and disposal of wastes, and this number will increase as landfills close, resulting in multiple budget hits in the near future (Owen, 2021).

"Sustainability means only using as many resources as can be replenished so that the availability of the resource doesn't decrease. Since engineers are often those allocating the resources, it is an engineer's responsibility to only use as many resources as needed to not waste any."

-Jackson Davey

RESILIENT INFRASTRUCTURE

CANADIAN ENGINEERING GRAND CHALLENGES

WASTE INCINERATION LEAVES LANDFILLS NEARLY EMPTY

LINKÖPING, SWEDEN



A solid waste incineration plant (Fahey)

What can Collingwood learn from Linköping?

Collingwood can learn how to dispose of solid waste more effectively by looking at Linköping's high recycling and incineration rates. If Collingwood does this, they will see a vast decrease in the amount of garbage that needs to be landfilled or exported and their landfill closure crisis will be solved.

One solution to Collingwood's landfill problem can be found in Linköping, located in southeastern Sweden. According to Statistics Sweden, Linköping has a population of 164,616 and a land area of 1,427.81 square kilometers (Statistics Sweden). In Linköping, around 49% of household waste is recycled and 50% goes to incineration plants, leaving less than 1 percent of waste to go to landfills (Yee, 2018). The energy produced from the incineration of the waste is enough to meet the heating demand of 1.25 million apartments and provide electricity for 680,000 homes (Yee, 2018). Producing energy this way is more efficient in terms of greenhouse gas emissions. It was estimated that in 2017 the equivalent of 467,000 tons of carbon dioxide was avoided being emitted through the reduction of burnt fossil fuels and the reduction in potent greenhouse gas production from trash decomposing in landfills (Yee, 2018). If Collingwood were to implement solid waste incineration through the construction of a power plant like in Linköping, the need to export a large amount of its solid waste could be drastically reduced. Although it may be difficult for Collingwood alone to produce enough waste to make the power plant feasible since it is much smaller than Linköping, waste from towns across Simcoe County could be burned at the plant as all of Simcoe County is experiencing a landfill shortage. The only challenge would be the high cost of constructing such a power plant, however, the money Collingwood would save from not having to pay to export its garbage should make up for it in the long run.

NO TIME TO WASTE: ENDEAVOUR TO DIVERT



REGINA, SK



Trash bins used in Cities in Saskatchewan (seventwentysk, 2011)

"At home, I just try to be mindful of my own energy consumption: I turn the lights off when I'm not in the room, shutdown my computer at the end of the day and close the blinds to keep the room cooler during the summer. We also compost, recycle and try to reuse any packaging we can. My mom also started a garden so we can grow a bit of our own food too."

-Garnet Zhao

SUSTAINABLE INDUSTRIALIZATION
CANADIAN ENGINEERING GRAND CHALLENGES

At the heart of the Prairies lies Canada's largest agricultural exporter, Saskatchewan (Key Economic Sectors, n.d.). The provincial capital, Regina, is at the center of their agricultural industry and is the largest steel producer in the west of Canada (Sectors: Economic Development Regina, 2021). Although the province is known for its vast amounts of land, it also has a relatively low population of 1.2 million. As such, there is always "enough" land for landfills, and it has been easier to dump their waste - Regina is no exception (Charlton, 2019).

The city is growing and has experienced an increase in waste delivered to the municipal landfill. Between 2005 to 2008, there was an increase from 478 474 tons to 645 456 tons of waste sent to the landfill, which prompted the expansion of the landfill (Genivar, 2009). As a result, the city had investigated into methods of waste diversion as early as 2009 to tackle this impending issue as prior to their preliminary report, there was not even a publicly funded recycling program. Regina set the bar high and committed to be diverting 65% of solid waste from the landfill by 2020. In 2019, the yearly report on their progress showed improvement, but the overall diversion rate was still at about 19% (Aird & Bourland, 2019).

Regina has opted to educate its citizens on proper waste disposal, but mistakes are still made. In addition, there is no province-wide regulation on what can or cannot be recycled because it depends on the funding and resources available at a given recycling plant (Martin, 2019). Landfills decrease the utility of the land, produce leachate which can contaminate groundwater used for irrigation and release methane and carbon dioxide which contribute to the greenhouse effect. Given these adverse effects, how can Regina overcome their difficulties?

A DOT THAT HELPED CHANGE IT ALL

KARLSRUHE, GERMANY



Recycling bins at a Music Festival in Karlsruhe (File:Festival-Tonne.jpg, 2016)

What can Regina learn from Karlsruhe?

The biggest takeaway for what Regina's waste diversion program can learn from Karlsruhe, is that waste diversion begins from the start of the life cycle of any product. The policies enacted help keep companies accountable for the amount of waste they produce, effectively preventing excessive generation of the waste as a whole and fostering a "recycling culture". Hopefully, Regina's relatively new program can follow suit.

Germany has long been a forerunner in solid waste management, being a country with much less land and a higher population than all of Canada. As such, the country has undergone changes to its systems to manage solid waste, namely the implementation of the "German Packaging Ordinance" in 1991 and the formation of the Duales System Deutschland (DSD). In essence, the ordinance mandated that every company be responsible for the life cycle of the packaging which can be done by monetary contribution to the recycling of the material used and by minimizing packaging from the start (George, 1994). Companies who can prove their packaging will be accepted for recycling and pay their license fee to the DSD (based on the weight of waste produced) can mark their products with the Green Dot.

Karlsruhe, a city in the southwest of Germany and the founding city of Germany's Green Party, is but one city which has embraced these changes. As it is the norm there, they divide their waste in six main ways, recyclables, bio-waste, residual waste, papers, clear glass and coloured glass (Schwarz-Herion et al., 2008). Recyclables, which includes packaging with the Green Dot, are to be placed in bins with the red lid. Residents can therefore easily identify products where the company has pledged to ensure the proper recycling of the material. In malls, it is also very common for all stores to be required to only sell products with packaging marked with the dot (George, 1994).

As a result of these policies, companies have strived to minimize the packaging used as they will pay less in licensing fees. The funding from the licenses allows for more standardized recycling capabilities countrywide and so today, Germany boasts a waste diversion rate of 79% (Waste Management in Germany 2018 Facts, data, diagrams, 2018).

WASTE DIVERSION PROBLEM



TORONTO, ON



Toronto - Ingram Transfer Station (Iqbal, 2019)

“Some elements of sustainability that I incorporate within my personal life is: lowering my usage of gas or any sort of non-renewable resource; owning plants, such as snake plant in order to have higher quality of air; and participating in going to green spaces. I also try to reduce as much waste as possible by using reusable bottles and containers, rather than disposable ones.”

-Cyden Bian Ramos

SUSTAINABLE INDUSTRIALIZATION

CANADIAN ENGINEERING GRAND CHALLENGES

The City of Toronto, located at the northern shore of Lake Ontario, is Canada’s largest city and provides the largest GDP per capita out of any city within Canada. The city also acts as an essential harbour for the distribution of products, therefore making it an important economic hub within the Country. However, due to the recent years of quarantine from COVID-19, the population of Toronto has started to look elsewhere for entertainment and technology, and also use roundabout ways to purchase necessities. The years of quarantining have introduced poor habitual spending, which in turn increased the amount of products that Torontonians consume, according to the statistics provided by the Resource Productivity & Recovery Authority (RPRA). With an increase in general imports, Toronto is bound to have an increase in waste and will inevitably face challenges in landfill diversion. This will inevitably continue to harm the surrounding environment if not solved.

With Toronto having a noticeable increase in diversion rate between 2008-2017 from 44-53%, it was expected that this trend would continue. However, recent years have shown that the trend has stagnated at a 53% diversion rate. In 2020, a study was conducted by Ece Ikiz, et al., to provide insight into Toronto's change in consumption and waste disposal during the pandemic. It was concluded that practices that promote higher diversion rate, such as the usage of the green bin and rightful disposal, were disrupted. By preventing diversion rate from increasing, environmental harm is inevitable, as landfills will continue to disrupt and harm nearby environments, along with the use of incinerators (pollution).

CLEAN INCINERATION STRATEGY



SINGAPORE



Incineration Facility

What can Toronto learn from Singapore?

With Toronto being closely related to Singapore in terms of population and landmass, they can definitely use the same methods to help aid in increasing the amount of diversion rate and reduce the pollution involved with the increase of MSW and non recyclable waste. Toronto already has a problem of not practicing methods that increase the diversion rate, therefore it is better suited to use an alternate method, such as the one Singapore uses, to help alleviate the amount of challenges Toronto might face within the upcoming years.

Singapore, a small city-state south of Malaysia, has always been known as one of the cleanest and safest countries, due to their waste control and policies implemented. Singapore is also similar in size to Toronto, but engulfs it with a population of approximately 5.7 million. With such a small size for a large population, numerous methods of waste management were implemented to adapt for these conditions. One of these policies is to landfill only 10% of the total disposed waste, due to land restrictions. This policy reduces the amount of area needed for waste, which minimizes the amount of negative environmental impact it has, such as leachate leaking into the surroundings. Another method of their waste disposal is through incineration. Although similar to how Toronto incinerates their waste, Singapore's method differs slightly.

By incinerating MSW, we are introducing GHG and harmful chemicals into the environment. However, pollution control systems are used to reduce and minimize the pollutants. By utilizing incinerators, the size of the MSW also decreases dramatically. The size becomes small enough to be manageable within landfills and in a country with a size comparable to that of Toronto. Despite incinerating the MSW, the remaining ash is also harmful to the environment due to toxic compounds and heavy metals. This incinerator ash is mostly left deposited in landfills, however, Singapore recycles these materials back into construction material (Tan, 2006). This solves an environmental problem by reducing the amount of ash being deposited into landfills (ash is known to have high leaching values), and also provides an economical benefit through the recycling of materials. Since ash still contains heavy metals, the sorting of MSW can heavily influence in reducing the amount of heavy metal within the incinerator bottom ash, ultimately making it usable in pavements, or other construction works. Toronto can heavily benefit from this method due to the ever increasing landfills that the city has.

ONE OF CANADA'S DIRTIEST CITIES



TORONTO, ON



Green Lane Landfill in Toronto, Ontario

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-Harib Memon

Canada is one of the world's worst waste producing countries, with 720 kilos of waste produced annually by each Canadian. Over 33 million tonnes of residential and non-residential waste are disposed of every year. Two thirds of the waste produced each year is non-residential waste and only 20% of the waste is diverted, and only 33%, or one third, of the residential waste is diverted. This means that over 85% of the waste produced each year end up in landfills across the country. There are two key issues with this waste being dumped in such copious amounts. Almost any toxin, pollutants, or contaminants make it into landfills and even with the most improved landfill designs, contaminants may leak into the ground and enter natural waterways. Not only do landfills pose a threat to water quality, but they also produce a large amount of methane when organic matter breaks down in the absence of oxygen, which is a greenhouse gas 23 times more harmful than carbon dioxide. The City of Toronto, the capital of Ontario, is the most populous city in Canada. Toronto is the country's finance, business, and economic centre, as well as one of the most multicultural cities in the world. Unfortunately, this also means that Toronto is one of the biggest waste producers in Canada. Toronto produces 10,000 tonnes of waste a week, and Green Lane Landfill produces 96 cubic metres (about the volume of a two- car garage) of methane per minute. Keele Valley Landfill, which was decommissioned 16 years ago, still releases methane emissions large enough to fuel a plant that provides enough electricity to supply 20,000 homes due to buried waste. As time goes on these numbers may increase and pose even more environmental challenges than there already are, therefore, these issues must be dealt with effectively.

SUSTAINABLE INDUSTRIALIZATION

CANADIAN ENGINEERING GRAND CHALLENGES

FUTURE OF WASTE MANAGEMENT

SONGDO, SOUTH KOREA



Third Zone Automatic Waste Collection Plant, Songdo, South Korea

What can Toronto learn from Songdo?

What Toronto can learn from Songdo to reduce their waste is to use an improved incineration system like mass burn, starved air, or fluidized bed systems to drastically reduce their volume of solid waste and minimize their methane emissions which can also be used as fuel for energy. Toronto should also strive towards reusing and recycling materials before allowing it to end up in a landfill.

There are several methods of reducing the sizes of landfills and overall volume of waste. First, we must begin reducing the amount of waste generated at its source by cutting down our overall unnecessary consumption, and following the three R's: reduce, reuse, and recycle. When the other options are not possible, the next best alternative we can look to is incineration. Incineration is the process by which waste is burned to produce energy and drastically reduces the total volume of waste. Songdo, a relatively small city in South Korea with a population of over 50,000 only covering 6 square kilometres which is a hundred times smaller than Toronto's land area. Songdo is a smart city and has been called by many as "the city of the future." Songdo has one of the most impressive and innovative waste management systems in the world, the Third Zone Automated Waste Collection Plant. Waste is sucked up from waste disposal bins around the city and directly from people's apartments into underground pneumatic pipes where it is automatically sorted and recycled, incinerated for energy and heat to be used in buildings, or buried deep underground. Over 30% of the city is filled with greenery as there is no need for landfills. Since the city gets waste directly from people's apartments there is no need for garbage trucks to go around and collect waste which further reduces emissions. Overall Songdo recycles 76% of its waste which is one of the highest recycling rates in the world. Songdo is easily one of the cleanest cities in the world and its example should be followed not only in cities that struggle with its waste management like Toronto in Canada, but also globally in cities that have good waste management systems like Singapore.

FACES A GARBAGE CRISIS

MONTREAL, QC



An example of a Landfill site

“”

-Aidarus Aidarus

A landfill is a structure designed far from the surrounding environment to bury waste by compressing it and allowing the natural breakdown of materials in the waste. Historically, landfill is the oldest and it is still the most common method of waste management in the world. Although landfill harms air quality and water quality by producing landfill gases such as CO2 and emitting solids in waterways, Montreal is mainly affected by the land usage needed for Landfill.

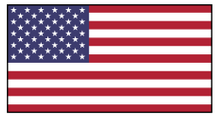
An average Montreal resident produces around 464 kilograms of waste a year, and more than 75% of the waste goes to the Landfill (Curtis, 2019). Due to a lack of enough resources to process the trash, Montreal has been shipping thousands of containers filled with discarded papers to be recycled in China (Curtis, 2019). However, China has banned the import of recycles due to its harm to their local environment, causing the waste to end up in Landfills. Furthermore, the Landfill site in the city of Terrebonne, Quebec which collects more than 40 percent of Montreal’s waste will shutter its doors to Montreal’s waste in 10 years (Curtis, 2019). With this happening, the city of Montreal is finding difficulties in handling its waste. They are looking for feasible solutions to handle their waste and reduce their waste production by 85% (Curtis, 2019).

Montreal is located in the province of Quebec, the island of Montreal, southeastern Canada with a total area of 365 km2 (Chevalier, 2020). It was founded in 1642, named after Mount Royal, the triple-peaked hill which is located in the heart of the city. The city of Montreal is the second-most populous city in Canada with a population of 1,704,694 where the majority of its population’s language is French.

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

HOW DID PANAJI END UP WITH ZERO LANDFILLS?



SAN FRANCISCO, UNITED STATES



Recyclable waste in San Francisco getting sorted by workers.



San Francisco is a cultural, commercial, and financial center in Northern California. It is located on a peninsula between the Pacific Ocean and San Francisco Bay and it is the fourth most populous in California, with 881,549 residents as of 2019 (Conrad, 2021). San Francisco was founded on June 29, 1776, with a total area of 121.4 km2. San Francisco has established itself as one of the global leaders in waste management by diverting over 80% of its waste away from landfills and incinerators which is around 1.5 million tons every year (Brigham, 2018).

The main difficulty of waste management is to find an effective system of waste segregation to ensure that waste doesn't end up in landfills, but is rather processed and recycled. The city of San Francisco has managed to do this by bringing all of the city's recyclables to a 200,000 square foot warehouse on Pier 96 that processes 40 to 45 tons of materials per hour. A team of 14 people works alongside high-tech screens, magnets, and optical sorters to separate the paper, metals, and plastics. Afterward, similar materials are arranged in a bunch together and shipped out to recycling plants both domestically and abroad (Brigham, 2018). As for the compost, all of the city's yard waste and food scraps are brought to Vacaville, about 60 miles northeast of San Francisco where compostables are weighed, crashed and blended (Brigham, 2018). Eventually, the product that is nutrient-rich is sold as fertilizer.

Furthermore, San Francisco has banned and also charge the use of environmentally hazardous items such as styrofoams and checkout bags. The waste management of the city costs about $300 million annually, which is totally financed through waste collection fees (Brigham, 2018).

What can Montreal learn from San Francisco?

Addressing the Landfill challenge is significant since it causes harm to the environment by producing Landfill Gases and also emerging microplastic into waterways. The solution to this problem is coming up with efficient solutions and systems that will efficiently segregate recyclable materials. The solution that the city of San Francisco came up with is feasible in Montreal since they are both big cities with big populations. Montreal should ban the usage of hazardous materials to the environment and also include fines/charges to residents for using these items. Furthermore, Montreal can build its own warehouses that will segregate recyclables which will lessen the amount of waste been dumped into Landfills.

IT IS NOT JUST HUMANS THAT ARE TIRED OF WEARING MASKS

ST. JOHN'S, NL



Seagull caught in blue surgical mask on coast of Quidi Vidi Lake, St. Johns, Newfoundland.

""

-Ethan Krusky

The 2019 coronavirus pandemic has taken the world by storm. One societal symptom that has developed following the nation-wide outbreak is compulsory mask mandates and PPE compliance. Canadas easternmost province, Newfoundland and Labrador, has taken full advantage of the Public Health and Protection Act, by mandating mask wearing in all indoor workplaces as of August 24th, 2020 (Smith & Samms, 2020). As a result, the usage of disposable PPE has skyrocketed in the last 12 months. It is estimated that 1.29 billion masks and 69 billion gloves are used globally each month (CBC News, 2021).

The capital of Newfoundland, St Johns, has a mere 114000 citizens (StatsCan, 2017) but is nevertheless feeling the pressures of dealing with the new challenges of synthetic PPE disposal. St. Johns beach goers and outdoorsman have been very vocal about the disappointing increase in plastic litter found outdoors since the beginning of the lockdown. Due to the lightweight, 3-ply design, common surgical masks tend to travel easily in the wind and concentrate in waterways, marshes, and beaches. (CBC News, 2020). The fossil fuel derived polypropylene and vinyl that are commonly used in mask production are notoriously resilient to degradation and can take up to 450 years to biodegrade (Yada, 2021).

The municipal authorities and solid waste management facilities are required to increase the effectiveness of the systems that bring waste from the consumers to the landfills safely and efficiently.

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

CITIZENS TO PAY UPFRONT FOR HIDDEN COSTS OF PLASTIC

OAKVILLE, CANADA



Macro/micro plastic debris collected from shore of Lake Ontario

The increased accumulation of PPE pollution is not a localized phenomenon. Cities around the world are dealing with the disturbing pandemic by-products and are being pushed harder than ever to re-assess their solid waste collection and management procedures.

Some cities have taken a legislative approach to compliance. The upper-class town of Oakville, located on the west shore of Lake Ontario in Canada, has incorporated this method in hopes of gaining a grasp on its nearly 200000 citizens. During the apex of lockdown compliance in April 2020, Oakville authorities introduced a bylaw that would see fines on improper PPE disposal increase from $100.00 to $400.00 (Yun, 2020).

Although these fines do not eliminate the accidental or ignorant polluter's, it does set a prescient that there is a cost to destroying ecosystems. The city of Oakville currently allocates 9% of tax revenue towards parks upkeep (Oakville, 2021), and can use the increased PPE fines for additional support.

What can St. John's learn from Oakville?

St. Johns could follow the framework of Oakville by introducing higher fines for those improperly disposing of covid PPE.

WASTE MANAGEMENT PROBLEM AND HOW TO SOLVE IT

TORONTO, ON



Large landfill located in Carleton Farms landfill in Wayne County, Michigan

"Sustainability is the goal of maintaining human ecological balance whilst avoiding the depletion of natural resources for future generations use. Engineers play a pivotal role in sustainability as they are responsible for designing and building systems that operate as efficiently as possible."

-Josh Ghori

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Despite Canada's environmentally friendly image, the country ranks as one of the largest producers of waste per capita. According to a 2019 study, Canada is among the bottom quartile regarding waste management. One of the largest generators of waste in Canada is Toronto. Each year, Toronto manages approximately 180,000 tonnes of recyclables through its blue bin program. Of that, about 30% goes to landfill due to contamination. The issue arises when residents clearly do not want new landfill waste sites near their cities. Additionally, there is limited space in landfills for waste in places such as China who are no longer accepting many waste items. The best current solution is shipping large amounts of waste to private landfills in Michigan, which led Toronto to sign a five- year contract with the U.S. firm Republic Services to send garbage to the Carleton Farms landfill in Wayne County. This equates to about 140 six-axle trucks driving 12–15-hour round trips, producing large amounts of carbon emissions. The majority views this solution as redundant, including the people of Michigan, where unwanted waste from Canada is one of the largest political issues in the state. The current legislation has a short-term emergency power to close borders from incoming garbage if deemed to be a threat to the health and safety of the state. If this were to happen, it would take about 48 hours for Toronto to reach an overflowing point at its seven-garbage transfer station, causing garbage to be piled up with nowhere to put it. Although this may seem like a crisis, there are several solutions being adopted across the globe that can solve this issue. But nothing will change if government leaders do not put the programs and legislations in place to promote sustainable waste management to organizations and residents of Toronto.

THE WASTE MANAGEMENT HUB OF THE WORLD

SAN FRANCISCO, UNITED STATES



Jepson Prairie Organics in Vacaville

What can Toronto learn from San Francisco?

If Toronto was to follow in San Francisco's approach to waste management by educating residents, incentivising organizations, and investing into waste management technology, they will be able to make significant increases to their diversion rates and achieve similar SDGs goals.

Unlike typical American cities. San Francisco has a much more sophisticated approach to its waste management systems. Largely influenced by the city's public policies and educational initiatives, San Francisco is able to divert about 80% of its waste from landfills, equating to about 1.5 million tons per year. In 2009, San Francisco made recycling and composting its top priority by passing the nation's first mandatory composting law. The innovation continued when the city banned environmentally hazardous items such as plastic bags and Styrofoam. To incentivise large organizations, the city provides discounts for using green and blue bins and are penalized for recyclables and compostables found in the trash bins. San Francisco has also targeted the company Recology to form an exclusive partnership around waste management. Choosing to work with one company alleviates pressure and burdens and sets up both parties for long term collaboration. Many other large cities such as New York maintain private systems comprised of hundreds of waste collection companies which provides city wide challenges in collaboration. The main element that separates San Francisco from other cities is the scale of the recycling and composting services. The city has a 200,000 square foot Recycle Center where all the city's recyclables are brought to. This equates to 40-45 tons of materials per hour being processed. 14 people work alongside high-tech screens, magnets and optical sorters to sort contaminated waste and separate papers, metals and plastics. Once all materials are sorted, they are shipped out to recycling plants. For composting, the city sends these materials to Jepson Prairie Organics in Vacaville where it is weighed, grounded up and blended to then be sold as nutrient-rich fertilizer. While this waste management system cost San Francisco $300 million annually, these programs are generally funded through waste collection fees.

POST-PANDEMIC PANDEMIC

GUELPH, ON



Just Another Piece of Nothing - One of millions of single-use face masks found across the grounds of parking lots, stores and walkways. [7]

“”

-Harjot Bhatia

The COVID-19 pandemic brought on a lot of challenges globally, from which quarantining and social distancing were the only feasible solutions. Early on, World Health Organization insisted everybody wears face masks to prevent the spread of this virus and Canada along with other countries made it mandatory to be wearing face coverings while in public. The University of Guelph completed a study highlighting the issue of inappropriate disposal of personal protective equipment (PPE) such as face masks and latex gloves. These items were predominantly being found outside grocery stores and parking lots around residential neighbourhoods. [6] This research study done for the City of Guelph was conducted by Justine Ammendolia and Jacquelyn Saturn. They found 1,300 pieces of discarded PPE widespread across an area equivalent to 50 football fields. The disposable masks may seem as if it’s made out of paper, however they are manufactured with polymers that take either decades or centuries to decompose. [8] From the total 1,300 disposed items they collected, 44% of the waste was disposable gloves. Face coverings/masks made up 31% and disinfectant wipes accounted for 25% of the total. The disposal of these PPE gears has started to be incorporated into wildlife as nests and some will probably confuse discarded PPE for food sources. Some sources have also shared numerous sightings of wildlife becoming entangled and trapped in PPE waste. Additionally, chemicals leaching off these plastics are entering into the soil and water. When plastic is left for long periods of time it breaks downs and create microplastics. As the number of microfibers exponentially grows to millions, it becomes very challenging to remove it from the environment. If PPE disposal continues to go as it currently is, then we’ll be seeing a highly detectable amount of microplastic pollution. [5]

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

HEMP TO THE RESCUE

LEZINNE, FRANCE



Be Safe Without Harm - Bio-compostable facemask made with hemp microfibers to mitigate the negative effects of single-use gear in the environment. [4]

What can Guelph learn from Lezinne?

This also can be possible from city-to-city learning where Guelph, Toronto and other Canadian cities can learn from France about integrating eco-friendly products to mitigate current environmental issues. France has been able to turn around quickly and provide hemp face coverings to 1.5 million customers and whether we need to learn the technology behind creating these products effectively, or the operational tactics to successfully implement similar products, Guelph and other Canadian cities have the chance to make a difference now.

The issue of inaccurate disposal of face masks and other personal protective equipment (PPE) is globally an uprising problem, bringing challenges to landfills, water quality and other hazardous exposures. A factory in rural France, known as Lezinne is creating the Europe's first compostable face mask. Strong motivation behind wanting to reduce plastic waste during the coronavirus pandemic from single-use protective gear as many environmentalists said it will take centuries to decompose. "This is a natural product and will go back into the soil" stated Frédéric Roure, founding president of Geochanvre. [4] Globally, approximately 129 billion disposable face masks and 65 billion gloves are used monthly, and the single-use PPE consists of plastics including polypropylene, polythene and vinyl. These biodegradable and compostable face masks are made from materials such as hemp or wood fibres, and Geochanvre was able to sell 1.5 million hemp masks to across Europe and Canada primarily. Operationally the hemp-based mask made by Geochanvre has an 89% filtration efficiency level. The mask also includes features filtering felt hemp without glue, additives or treatment, lined with a dark protective veil in compostable cornstarch. Every minor detail was taken care of as, the elastic band used to adjust the mask around your face is also recyclable. [9] The production of hemp plastic is much more environmentally friendly as it does not admit any carbon dioxide. The hemp plants used rather consume carbon dioxide and output oxygen. For every ton of hemp produced, 1.63 tons of carbon is removed from the air and the fields in which these plants are grown also enrich the soil around them. [1]

CHAPTER 7: SUSTAINABLE BUILDINGS



EV3/University of Waterloo

CHAPTER INTRODUCTION

The built environment within which we live, work and play is the human-made environment that provides for society's needs and activities – it is the cities that encompasses all the urban systems. Cities are interdisciplinary by nature because they include all the building blocks that help shape them, and one cannot discuss buildings without discussing the enabling transportation, and the energy within them, the water consumption by its occupants and the green spaces that make them healthy and liveable. This module starts with the context of the built environment, and a brief about their planning and environmentally sensitive design and development. This is then followed by a snapshot of sustainable buildings and sustainable transportation, to first define the criteria that makes them sustainable and then showcase some examples from around the world.

Learning Outcomes

By the end of this week, you will be able to:

- Recognize the built environment and relation to environmentally sensitive design
- Define the purpose of zoning in land-use planning and the shift to new urbanism
- Describe smart growth and its principles for sustainability of the built environment
- Explain with examples the three paradigms of environmentally-sensitive design (green infrastructure development, low impact development and conservation design)
- Define sustainable buildings
- List criteria for green building rating systems
- Identify factors affecting energy consumption
- Describe strategies for overall energy conservation
- Demonstrate low energy building strategies
- Define sustainable transportation
- Describe the components of a transportation system
- Classify the impacts of urban transportation modes
- Identify strategies to increase the sustainability of transportation
- Demonstrate four types of transit metropolises
- Locate innovations in public transportation

DISCONNECTED ELECTRIC SERVICES FOR NON-PAYMENT 989 TIMES

SAINT JOHN, NL



Common types of houses in St. John

“To me, sustainability means, in simple terms, it's a property that persists, or the ability to balance processes across all systems.”

-Rachel Oh

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Due to significant population growth and reckless consumption of resources, not only individuals but also companies and countries are paying great attention to sustainability. Sustainable building is one solution for this challenge; they can minimize the negative impact on our climate and natural environment by efficiency and moderation in the use of materials, and energy.

Newfoundland and Labrador were ranked as the 9th least energy efficient province among 10 provinces in Canada in 2020 (Efficiency Canada, 2020). The main criteria were broken down into sub-criteria for the scoring for energy efficiency and one of the sub-criteria is building. The most important element of sustainable building is energy efficiency. Higher levels of energy efficiency reduce greenhouse gas emissions and reduce the amount of money on energy bills.

As the title mentioned, in 2016, the city of Newfoundland and Labrador, Saint John disconnected services for non-payment 989 times (NataliaHicks & MA in Socio-LegalStudies, 2018). Lots of households in St. John have been experiencing energy poverty. However, the power rates are increasing every year in St. John. Another problem is that the province of St. John, Newfoundland and Labrador do not commit net-zero energy ready codes, while BC has committed to mandating a net-zero energy ready standard for new buildings by 2032; that is, buildings that can produce as much energy as they consume (Efficiency Canada, 2020). If this situation continues, more people will struggle with the cost of energy and will accelerate the exhaustion of resources.

THE MOST SUSTAINABLE TOWN IN EUROPE

VAUBAN, GERMANY



A cooperative housing in Vauban with solar panels on its roof

What can Saint John learn from Vauban?

St. John can learn from Vauban's solution to environmental issues. Reflecting one the climate of St. John, exploring ways to create green energy from buildings like Vauban's rooftop solar panels on the houses and buildings is one way to solve St. John's problem. Other solutions can be building cooperative buildings and low-energy houses.

Vauban is a city district in Freiburg, Germany. Vauban is a sustainable town and a "zero-emission" district in Freiburg, Germany

In Vauban, electricity for buildings is primarily sourced from rooftop solar panels on the houses and buildings. All houses in Vauban are built to a low-energy consumption standard and the installation of photovoltaic panels and solar energy is encouraged, as well as a plan to reduce household consumption (RamosAlfredo & BarcaStefania, 2010). Lots of homes are either energy-efficient buildings or plus-energy buildings; buildings produce more energy than they consume. Then, residents in plus-energy buildings sell excess energy back to the municipality so that it can be used for other buildings or communities (Europe's Greenest City District, 2021). Passive home construction refers to cutting-edge energy-efficient green building construction practices. Buildings in Vauban are almost entirely passive home or plus-energy construction which means that the buildings are primarily heated by energy gained from solar panels or photovoltaic panels. One main result of Vauban is the creation of more than 40 cooperative housing groups. Cooperative houses in Vauban are, of course, energy efficient buildings and have significant levels of social inclusion of people on low incomes (RamosAlfredo & BarcaStefania, 2010).

Low-energy housing costs only about 2% more to build than traditional housing while energy consumption falls by up to 80% and CO2 emissions are reduced by 30%. Consumption of oil for heating purposes is more than halved. The houses in Vauban save residents more than €1,000 a year per dwelling (Cutting Home Energy Consumption by 80%, 2011).

INEFFICIENCY OF GLASS BUILDINGS

VANCOUVER, BC



Glass Buildings in Vancouver

"The only examples of sustainability I have are the small ones in my daily life. I compost and recycle, try to reduce the use of plastic water bottles, etc. However, there is room for improvement."

-Isabel Lee

RESILIENT INFRASTRUCTURE
CANADIAN ENGINEERING GRAND CHALLENGES

Vancouver, the third largest city in Canada, is home to numerous glass buildings. From condominiums to hotels, the city is filled with glass high-rises. Forty percent of the global carbon emissions come from heating and cooling buildings (Migdal, 2019). Glass is a very bad insulator as it allows air to easily enter and exit. On hot days, the heat enters the building by reflection, and the cool air escapes the building. The effect is reversed with cold weather. This causes users to constantly use energy to heat or cool glass buildings, releasing greenhouse emissions and consuming a large portion of the city's energy source. Within the last decade, BC Hydro said that air conditioner use has increased by 70 percent for condominium and apartment residents (CTV News Staff, 2021).

Recently, the city had experienced heatwaves and temperatures that were close to or surpassed 40°C. This became an issue because condominium residents had difficulty cooling their homes. Most residents use portable air conditioning units. According to BC Hydro, they are "the least energy efficient models on the market" (CTV News Staff, 2021) as they can use 10 times more energy than a central air conditioning system. Although the city can produce enough clean energy while demands are high, the cooling process can get inefficient and waste a lot of energy.

Not only are glass buildings inefficient, but their production also causes a lot of harm to the environment due to melting activities. To produce glass, materials need to be burned and this releases a lot of carbon dioxide. Sulphur dioxide, nitrogen oxides, and particulate matter are also by-products of glass production that can contribute to pollution such as acidification and water pollution (AGC Glass Europe, n.d.). There are a lot of challenges to fix the city of glass.

INTERNET OF THINGS, THE FUTURE OF SUSTAINABLE SKYSCRAPERS

WEST KOWLOON, HONG KONG



International Commerce Centre in West Kowloon, Hong Kong

What can Vancouver learn from West Kowloon?

Vancouver can learn a lot from West Kowloon on how to implement the technology for sustainable glass buildings, however, it is Canada that could learn a lot more from Hong Kong than city-to-city. Canada needs to put more interest into creating sustainable solutions to glass use on large infrastructures. The lack of interest in this area makes it difficult to work on technology advancements like Hong Kong. It is not an easy task allocating resources to IoT technology, but with small steps, it is possible to attain sustainability.

Hong Kong is home to the most skyscrapers and glass high-rise buildings in the world. They consume 90 percent of each city's electricity and 60 percent of the city's greenhouse gas emissions (Keegan, 2021). The most notable is the International Commerce Centre, located in West Kowloon. The ICC is part of the top 3 percent of green buildings in the world and is BREEAM certified (BREEAM, 2021). The 118-storey building uses Internet of Things technology to analyze data and maintain the building. There are networks of wireless sensors for lighting, elevators, escalators, and air conditioning units to monitor real time energy consumption. When certain areas are not in use, they are shut off to conserve energy.

Data collection is also used to determine the priority of maintenance required in the building. The building goes under a process, called retro-commissioning, to improve the efficiency of existing equipment instead of replacing it. Air-conditioned air is conserved by smart IoT devices that monitor air temperatures and pollutants on each floor. The air distribution is controlled and distributed to different floors to optimize energy usage. Further work is being done to install solar panels and create a battery system to store renewable power. The team is hopeful that there will be mass applications of this battery storage for glass high-rises and homes.

Relating back to the energy inefficiency problems of glass buildings in Vancouver, it is obviously difficult to use IoT technology as it is costly and challenging to implement for every single glass building in the city. However, if the largest building in the city implements the technology and solutions like the ICC in West Kowloon, the energy wasted by the inefficiency and greenhouse gas emissions produced by the city can be greatly reduced. With rising technology, it is reasonable to be optimistic about the future of glass buildings with IoT devices.

A WAY TO GREEN: REDUCING EV3'S ENERGY CONSUMPTION

WATERLOO, ON



University of Waterloo Environment 3, Ontario

"Sustainability is the consumption of natural resources at a specific rate that would not deter the needs of future generations in all countries by maintaining a balance between ecological, social, and economic systems. Overall, it means the current generation is mindful of the subsequent actions that would result in the environment due to their decisions and lifestyle. Thus, they try to be conservative of the environment and contribute back to society."

-Khin Htet Htet Zaw

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

The consequences of human activities, one being the ecological footprint of buildings, influences the natural water cycle and leads to climate change. Paved surfaces decrease the amount of infiltration and increase the speed and volume of rainwater runoff. Higher speed runoffs collect more contaminants along the way, and they can compromise drinking water quality and affect aquatic life (Ibrahim, n.d.). Moreover, the highest energy consumers in Canada are the commercial and institutional buildings at 41.6% (Survey of Commercial and Institutional Energy Use, 2014). In addition, the operational phase in buildings releases more than 50% of GHG emissions (Sharma et al., 2010). The University of Waterloo considered these arising issues and constructed the Environment 3 building, which earned LEED administered by Canada Green Building Council. Environment 3 was constructed using 88% recycled steel, which reduces the energy consumption and GHG emissions in the production process compared to 100% virgin steel. It was built above the existing Environment 2 building to prevent more impervious areas that would increase water runoff and water pollution. The roof of this building collects rainwater and filters through the wetlands to operate low-flow faucets and toilets, overall reducing 87% of water consumption. It also has automatic lights that control light during dark hours and glazed panes, increasing insulation five times. These design considerations lead to 45% less energy consumption. In addition, the electrical energy is provided by rooftop solar panels supplying 67000 kWh/year (University of Waterloo's Environment 3 building earns LEED Platinum certification, 2021). Due to these modifications, Environment 3 is regarded as a green or sustainable building. It considers resource, water, and energy efficiencies, lowering its carbon footprint and impacts on water quality.

A WAY TO GREEN: INCORPORATING WIND TURBINES ON THE BUILDIN



BAHRAIN, SAUDI ARABIA



BWTC in Bahrain, Saudi Arabia

What can Waterloo learn from Bahrain?

Renewable energies such as wind, solar, biomass, and geothermal energy can be incorporated as a design element of the buildings to supply energy. Other elements such as glazed panes, gravel roofs and energy-efficient lighting should also be considered to lower fossil fuel-related GHG emissions. The location of the building is also critical since increasing accessibility decreases the need to travel long distances, subsequently reducing carbon footprint.

Fossil fuel consumption increases significantly over the years (over 64% in 2019) to accommodate human activities, and they play a significant role in supplying global energy (Ritchie & Roser). When they are burned, they produce carbon dioxide and many other greenhouse gases, leading to global climate change and air pollution. One of the causes of fossil fuels is the operational phase in buildings that release more than 50% of GHG emissions (Sharma et al., 2010). Bahrain World Trade Centre (BWTC), located in Bahrain, Saudi Arabia, is regarded as a sustainable building as it uses renewable wind energy to lower the reliance on fossil fuels. BWTC takes advantage of its location with sea breezes by integrating large-scale wind turbines in its design. The power from this wind energy provides up to 15% of the building's electricity needs. Wind electricity emits less than 1% of GHG emissions supplied by coal-fired electricity; thus, wind energy is considered renewable for its relatively low emissions (Chang et al., 2021). Since the wind turbines are installed between the building, it reduces the physical footprint and the creation of impervious areas that would have been created otherwise, which could potentially lead to water pollution and climate change. It also has shadings to reduce solar gains, deep gravel roofs supplying kinetic insulation, and energy-efficient lighting, further decreasing reliance on fossil fuels. Moreover, since it is located in "the business heart of Manama" and is within proximity with the international airport and major ministries, it decreases the need for fossil fuel as less distance is needed to travel using vehicles (Bahrain World Trade Centre, n.d.).

CONCRETE, CO2, AND CLIMATE CHANGE



CARLETON PLACE, ON



Carleton Landing North Subdivision with Concrete Foundations (Carleton Landing North Subdivision, 2021)

"As I feel many people do, I try to compost, reduce my plastic use and energy consumption, and shop secondhand in order to reduce my environmental impact. Additionally, I don't drive and choose to ride my bike or walk when possible as a means of transportation, I eat vegan in part because of the unsustainable practices often involved with animal farming and buy food locally when possible."

-Carly Zander

SUSTAINABLE INDUSTRIALIZATION
CANADIAN ENGINEERING GRAND CHALLENGES

Concrete is one of the most commonly used building materials on the planet but is also one of the largest CO2 emitters. A key agent in concrete is cement, the production of which involves calcium carbonate from limestone combining with calcium oxide and carbon dioxide, releasing carbon dioxide into the air. Additionally, this process requires the transport of materials and the heating of a mixture of limestone, clay, and iron ore or ash to extreme temperatures, which results in further CO2 emissions from fossil fuels used for these purposes. All of this contributes to concrete accounting for approximately 8% of the CO2 being emitted into the atmosphere (Warburton, 2019); these CO2 emissions contribute to global warming and the negative impacts associated with climate change, including the global average temperature rise, sea level rises, and extreme weather events (Ibrahim, 2021).

Carleton Place, Ontario is one of many towns contributing to this issue. Carleton Place is a rapidly growing town on the outskirts of Ottawa which, as of 2020, has a population of 13,153. In a 2021 review, projected growth suggests that 3124 additional homes, including 2149 active development applications, need to be built by 2038 to meet projected demands (J.L. Richards & Associates Limited, 2021). The construction of these additional homes will inevitably require the use of concrete, particularly in the foundations of the homes. One such example in Carleton Place is the Bodnar subdivision being built by Cavanagh Developments; the subdivision will have 193 single detached homes, 317 townhouse units, and 9 apartment dwellings which will involve concrete foundations through Cavanagh Concrete Ltd. (Gesner, 2021). Another example is the Carleton Landing North subdivision being constructed by Olympia homes, which includes the construction of 450 family homes (Olympia Homes, n.d.); the current construction of these homes, with concrete foundations, can be seen in the image below. As a result of these development to meet residential demands, Carleton Place is contributing to the CO2 emissions associated with the use of concrete as a building material.

CARBON REDUCED CONCRETE

ATLANTA, UNITED STATES



The Kendeda Building Constructed using CarbonCure Concrete in Atlanta, Georgia (Kendeda Building at the Georgia Institute of Technology, 2020)

What can Carleton Place learn from Atlanta?

Based on the CEGC and SDG, it is evident that developers in Carleton Place can learn from the solution used in recent Atlanta development to construct in way that works towards achieving these goals. The solution applied in Atlanta, if enacted in Carleton Place, has the potential to meet the development needs of the community while working to minimize the concrete related CO2 emissions.

Possible solution to the CO2 emissions from concrete include using alternative materials and/or a production process that will result in less emissions. Various options exist that allow for lower carbon emissions than traditional concrete production, including using supplementary cementitious materials such as fly ash and slag to replace some of the cement which significantly contributes to concrete's carbon emissions (Central Concrete Supply Company, n.d.). Another alternative is using a cement powder and sand mixture with loosely packed particles so CO2 and H2O can be added between spaces to react with the cement, preventing the CO2 emissions to the atmosphere (Solidia). One possible material solution is being produced by the brand CarbonCure; the technology developed by this company involves injecting captured CO2 emissions into concrete, where the CO2 can become chemically converted into a mineral to be used in the concrete, thereby reducing the carbon emitted into the atmosphere (CarbonCure, n.d.a).

The successful application of this technology can be seen in Atlanta, Georgia, where it has already been used in the construction of three large scale buildings: a 36,700 m2 mixed use building at 725 Ponce, the Kendeda Building on the Georgia Institute of Technology Campus, and the 2020 Georgia Aquarium expansion. It is estimated that CarbonCure concrete, in these three projects alone, prevented approximately 1.8 million pounds of CO2 from entering the atmosphere during the construction process (CarbonCure, n.d.b). The successful reduction in carbon emissions in these Atlanta projects suggests CarbonCure concrete and other similar carbon reduced concrete options can be used in global building projects to reduce carbon emissions from concrete.

HOMELESS SHELTERS FAILING

CALGARY, AB



The Drop-In Centre in Calgary

“My family tries to be more environmentally friends by composting, reusing, recycling as much as we can, rather than throwing things in the garbage. We also try to buy in bulk, so that less packaging is being used. As much as possible, we also try to buy food that is locally grown.”

-Raian Kaba

In Calgary, homeless people have struggled to be able to find a decent and safe place to live. In 2008, Calgary pledged to eradicate homelessness over a ten year frame ending in 2018 (Markusoff 2018), but this was far from met, with over 1200 people sleeping in homeless shelters each night in Calgary currently (Small 2021). During the COVID-19, pandemic, many individuals who are homeless have reported sleeping outside out of fear of contracting the virus. These individuals are at a high level of risk of suffering from the effects of air pollution, especially after the 299 wildfires in British Columbia in July of 2021 (Thom 2021) which have caused air pollution notices in Calgary and other parts of Alberta. Because of this high risk of contracting COVID, homeless shelters have become unsustainable and dangerous places for residents as they could potentially result in people having to spend time and money on healthcare to recover from the virus. The solution that many have been forced to adopt of sleeping outside, may lessen the chance of getting the virus, but it is environmentally unsustainable as the buildings that are operated for homeless people aren’t full, using a similar amount of resources and space but serving less people. Homeless shelters are thus unsustainable buildings in Calgary both because they are becoming dangerous places with the potential to cause ripple effects in the healthcare system, but even more so because the energy emissions per person increases as the number of temporary residents in the building decreases with the fear of COVID hanging.

GREEN HOMELESS SHELTER

FAIRFAX, UNITED STATES



Katherine K. Hanley Family Shelter

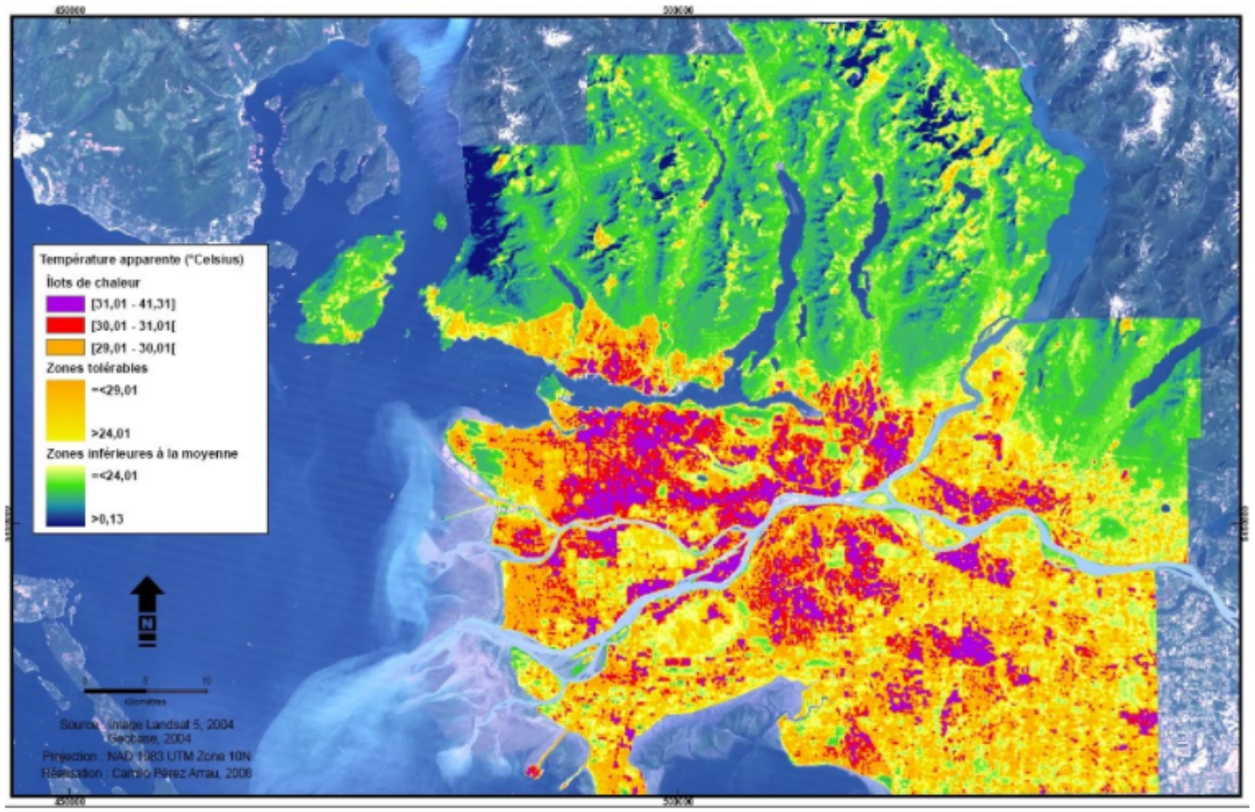
In Fairfax, Virginia, the Katherine K. Hanley family shelter recently received a Green Globes certification. This shelter is a place for families with young children to spend time in while they search for a permanent place to live (Lillard 2009). The building used greener practices and sustainable design to create an environment that is positive and hopeful for all the residents that use the facility. Throughout the lifetime of the project, from construction to completion, there was a primary focus on efficiency. The materials and appliances selected were chosen to reduce the building's environmental impact, while also keeping maintenance costs low. Examples of these include having light-coloured shingles to minimize the heat-island effect. All the materials used in the construction of the building were either from Maryland or Virginia, to limit the costs and carbon emissions related to transportation and hauling, and all of the plants used are native to the region (Lillard, 2009). Furthermore, there is a natural tree preserve area in efforts to maintain local greenery. This building aims to house people for a maximum of 45 days, by the end of which they should be on their feet with a new place to live lined up, making it environmentally and socially sustainable.

What can Calgary learn from Fairfax?

Based on the example from Fairfax, Calgary should also strive to develop more sustainable buildings, particularly homeless shelters. Fairfax uses energy efficient systems with their lighting, AC, heating and plumbing, and locally sources their materials.This also keeps the usage costs lower. Calgary's homeless shelters should strive to replicate this, especially if the number of people change drastically based on the COVID situation, as it decreases tax-payer cost and decreases the negative environmental impacts.

WILL THE URBAN HEAT ISLAND EFFECT INCREASE DEATH RATE?

VANCOUVER, BC



Temperature map of Vancouver on July 17, 2004. Heat islands are indicated in purple. (Urban Heat Islands (UHIs), 2019)

“”

-Michael Convertini

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Vancouver, located in British Columbia is the third largest Canadian city in surface area (Urban Heat Islands (UHIs), 2019). In this city, there is an abundance of concrete and cement infrastructure. The challenge caused by infrastructure made from concrete and cement is that it creates the urban heat island effect (IWBC, 2019). Buildings are one of the main culprits of heat-retaining infrastructure (IWBC, 2019).

Between 1986 and 2004, Vancouver saw the largest increase in surface heat island formations across Canada (Urban Heat Islands (UHIs), 2019). Heat islands form when infrastructure such as buildings made from concrete and/or cement naturally absorb and retain heat from the sun (IWBC, 2019). This heat absorption artificially increases the surface temperature in parts of the city. Once the temperature in a specific area is determined to have increased by at least 5˚C above normal, it becomes classified as an urban heat island (Urban Heat Islands (UHIs), 2019). As a city becomes more developed, the effect of heat-retaining buildings increases causing a rise in its average temperature. It is estimated that over 30 million Canadians live in heat island prone cities like Vancouver (Climate Atlas of Canada, n.d.), and with the increased temperatures of these cities, heat waves become more common and potent which can lead to death. In June 2021, approximately 500 people died in British Columbia due to a historic heat wave (Saric, 2021).

It is becoming more apparent that the dangers attributed to urban heat islands in metropolitan areas are escalating. Solutions and alternatives must be explored to mitigate the effects of urban heat islands.

COMBATTING THE URBAN HEAT ISLAND EFFECT

BASEL, SWITZERLAND



Project "Meadow Carpet" green roof in Basel, Switzerland (Climate Adapt, 2016)

What can Vancouver learn from Basel?

Basel can study the effectiveness of their green roof project by comparing their smaller heat island effect to that of Vancouver's. On the other hand, Vancouver can learn why and how Basel was able to successfully implement green roofs. They will also understand the benefits in the form of monetary incentives due to the energy savings of building a green roof as observed in Basel.

What began as an energy saving pilot project in the 1980s has evolved into a solution for the urban heat island effect (Climate Adapt, 2016). Today, the city of Basel, Switzerland has the most green roofs per capita in the world due to various financial incentives and new regulations created over the span of several decades (Climate Adapt, 2016).

Green roofs, also known as roof top gardens, are typically placed on the roof of tall buildings to remove heat from the air and provide shade thereby reducing air temperature around the buildings (United States Environmental Protection Agency, n.d.). A study has found that green roofs are effective in reducing roof temperatures by as much as 30-40˚F which can decrease a city's average temperature by approximately 5 ˚F, reducing the urban heat island effect (United States Environmental Protection Agency, n.d.). Green roofs are an extremely effective measure against the heat island effect in high density areas because they can be built on rooftops of existing buildings, eliminating the need to build green parks on limited and expensive land (Climate Adapt, 2016).

An investigation in 2006 found that approximately 23% of all flat roofs in Basel incorporated green roof infrastructure. Presently, it is estimated that 40% of Basel flat roofs are green (Climate Adapt, 2016). As of 2002, Basel amended a law pertaining to new buildings resulting in strict green roof specifications. A soil thickness of 12cm and vegetation native to Basel must be used. The main reason for Basel's high percentage of green roofs, however, is due to the energy savings (Climate Adapt, 2016). It was found that green roofs can reduce building energy use by 0.7% leading to annual savings of $0.23/ of the roof's total surface (United States Environmental Protection Agency, n.d.).

HIGH ENERGY CONSUMPTION ACCELERATING CLIMATE CHANGE

TORONTO, ON



Greenhouse gas air pollution in Toronto's energy manufacturing centre

"Sustainability means the ability for humans to use Earth resources appropriately without posing a threat to future generations. In addition, sustainability means that humans should adapt to more environmentally friendly practices and they should create efficient models that protect the Earth's atmosphere and natural water from pollution."

-Eddie Jamtorki

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

From the beginning of the 21st century, there has been a rapid increase in technological development. Now more than ever before, people from all around the world are using more energy in order to operate their household appliances and digital devices. The increase in population of the world's largest cities is also causing a higher demand for energy and electricity from buildings. In order for cities to meet these high energy demand, manufacturing facilities such as hydroelectric or natural gas need to accelerate their daily operation. However, by increasing manufacturing operations, the energy complexes emit more greenhouse gases to the atmosphere. The greenhouse gases can cause a world-wide temperature increase followed by more severe weather events. This problem is already affecting the City of Toronto which is the largest city in Canada with a population of 6,255,000. Toronto is the largest contributor to the Canadian economy and it is also the commercial, financial and industrial centre of Canada. It also accounts for 18.5% the Total GDP of Canada. Each year the average Ontario Household uses about 9500 KWH of electricity and 90GJ of Natural gas. This amount of energy consumption is considerably higher than the other provinces in Canada. During a 2019 study of Toronto's building energy consumption, it was found that building energy consumption in Toronto accounted for 740 million equivalent KWh with most of the energy consumption comprising of electricity and natural gas. In addition, natural gas was responsible for the most greenhouse gas emissions (59,258 tonnes of CO_2 equivalent) followed by 12,484 tonnes CO_2 equivalent of electricity. Therefore, the electricity and natural gas energy that Toronto's buildings are heavily dependant on are the catalyst for the increase in green house gases. As the city buildings continues to heavily rely on electricity and natural gas energy, it will cause an increase in annual temperature and more destructive storms throughout the year.

ENERGY EFFICIENCY KEEPS GHG EMISSIONS TO A MINIMUM IN SHANGHAI, CHINA



Wind resistant shape of Shanghai Tower in Shanghai, China

What can Toronto learn from Shanghai?

Overall, the city of Shanghai has struggled severely with air pollution and contributing to global warming. Through resilience and hard work, the city was able to direct itself toward a sustainable future that emits less Green House gas. The City of Toronto can also follow the strategy of constructing sustainable buildings by using innovative designs that reduce energy demands.

China is among the few countries in the world that has been hardest hit by air pollution. The burning of coal and fossil fuels in the past decades has created the largest volume of greenhouse gases among any other country in the world. Each year around 4,000 people in the country die every day from air pollution related causes and the green house gas emission has lead to global temperature rise in the past years. Despite past problems, many cities in China such as Shanghai are implementing sustainable practices which can reduce Carbon footprint. The city has begun a tree planting program in order to remove the air pollution already in the air. There has also been a shared bike concept that has been adapted by the people in order to travel within the city. This practice has dramatically lowered the greenhouse gas emissions from transportation vehicles. However, during recent years Shanghai city has undergone a large transformation from low-lying buildings to tall skyscrapers covering the city centre. Many of the large buildings that have been recently built in the metropolis have adapted sustainable methods to consume energy. The Shanghai tower is an example of a green building that improves energy efficiency, reduces energy consumption and uses renewable energy sources by using a combination of 43 different sustainable technologies. The building uses a geothermal heating pump in order to heat and cool the building. In addition, it uses wind turbines at top of the tower to provide 10% of the building's total electricity. This intricate design uses two layers of glass skin that are separated by sky gardens in order to provide natural cooling and ventilation to the building. The tower also uses 6700 water control valves to increase the efficiency of heating and ventilation in the building, thereby reducing energy waste. Overall, by using all the sustainable methods, the building is saving a total of 37000 tonnes of CO_2 which would otherwise be released to the atmosphere. Therefore, it is apparent how the innovative sustainable technology applied to the Shanghai tower is increasing energy efficiency while reducing carbon footprint.

REAL ESTATE BUBBLE. HOUSES BEING BUILT EXPONENTIALLY



BRAMPTON, ON



Brampton City Hall West Tower

"I love coffee so initially I bought a Keurig coffee maker that uses coffee pods made from plastic, and this wasn't sustainable, so I switched to whole coffee beans and use recycled filter papers to make coffee. We as a family grow a lot of vegetables throughout the summer and we use the coffee grounds along with the filters to fertilize the soil. We also own an electric car to save money on gas and not use gas."

-Akash Satishkumar Desai

SAFE AND SUSTAINABLE CITIES
CANADIAN ENGINEERING GRAND CHALLENGES

Water is life. It is one of the most vital substances for life to sustain and when water gets polluted, it can create a detrimental impact on small to large populations worldwide. Water's ability to be a good solvent has allowed humans to use water to transport waste and substances effectively, which includes pollutants. The release of untreated contaminants into bodies of water has raised concerns about how corporations and governments are dealing with habitat destruction and toxins being transported up the food chain. This is an ongoing issue along the Athabasca River in Fort McMurray, and it is discovered that toxic waste from nearby tailing ponds is getting into the river and groundwater. The leakage from these tailing ponds was brought to the attention of the Canadian federal government and it is confirmed the evidence of "compositions of tailing fluid and natural bitumen-influenced groundwater in recent years" (Riley, 2020). The study found that naphthenic acid concentrations were a sign of anthropogenic affected groundwater containing toxins and found levels ranging from 6-2 mg/L, where 2 mg/L NAs is normal (CEC, 2020). The indication of toxins can have detrimental impacts on the people and wildlife that use groundwater and the river for drinking water as these toxins can lead to a higher risk of disease and cause cancer. Fort McMurray, a small emerging city located in northern Alberta is famous for its oil-rich sands which brought several energy companies and employees to the population (Campbell, 2013). Though these companies have offered economic prosperity to the area, they have violated environmental laws. These laws were established to keep away chemicals from the extraction process so that they will not affect the health of the residents and wildlife. If no further action is taken against violating environmental laws and no new solutions are found, the ecology and people will find the region no longer be viable.

MILES AHEAD OF OTHERS WHEN IT COMES TO SUSTAINABILITY.

COPENHAGEN, DENMARK





Copenhagen international school

Copenhagen is the leading greenest city in the world, this capital city has planned to go carbon neutral by 2025. That is insane to think about, while some cities our still struggling with freshwater issues, Copenhagen is going to go carbon neutral in less than 5 years. They have multiple plans to achieve this, the city has a lot of infrastructure for clean transportation. The city has more bike lanes than roads and only 29 percent of the population own cars while the rest prefer biking, walking and public transportation. This is possible because the city made having a car extremely expensive to encourage its population to stay healthy and ultimately reduce its carbon footprint. In terms of buildings the capital has many buildings that are in almost all top ten lists of most sustainable buildings. For example, the Copenhagen international school has about 12000 solar panels installed, this is one of the largest in a school. Doing this not only promotes green energy but encourages students to be inspired from it. The school also has a food waste management system to grind the waste and use for biofuel, and then use the burned remains as fertilizers or fed to livestock. Most of the school's interior is made up of bamboo and wool sofas, basically materials that are sustainable to use. (Thakur, 2019)

What can Brampton learn from Copenhagen?

I think all cities can learn from Copenhagen, Denmark, they have some of the most sustainable buildings. Adding solar panels to all schools is a must because it saves energy and inspires children.

THE GAS GUZZLER OF CANADA



GREATER TORONTO AREA, ON



Ontario Natural Gas Power Plant

“Besides the obvious answer of maintaining an environmentally healthy life such as reducing waste disposed, riding a bike to your destination rather than driving or drinking paper straws instead of plastic, other changes in my life incorporates a healthy sustainable lifestyle. Before covid locked us in our house, my family used to purchase most of our fruits and vegetables from a local framer. This encourages cuts back on fossil fuel consumption needed to bring these produce to a grocery store.”

-Connor McCracken

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

As time goes on, we see the rapid expansion in the area many people deem their home in the Greater Toronto Area. What people neglect to realize or choose to ignore, is the significant consumption of energy in Toronto. In the “Annual Energy Consumption & Greenhouse Gas Emissions Report” for the City of Toronto, it is reported in 2017 that the largest greenhouse gas emitter was through the burning of natural gas (Environment & Energy Program Administration, 2018). These emissions amounted to about 179.95 grams of carbon dioxide per kWh. As well, this value has remained relatively constant since 2013. It is specifically reported that this number is not expected to be reduced in the coming years, as Toronto will continue to expand and the need for energy along with it. Of the many consumers of energy in the city, the leading sector is “administrative offices”, with an estimated 138.4 million kWh (Environment & Energy Program Administration, 2018). This in turn makes sense, as administrative buildings account for more than 4 million square feet of space in the city. As previously mentioned, this number is surely growing as Toronto remains an expanding city. With this expansion, we slowly start to see a loss in green space, which has proven to combat the produced carbon emissions through photosynthesis. As a result, we observe an increase in paved and impervious surfaces, thus increasing the temperature in the area due to the absorption and retainment factor of solar energy in paved surfaces (Loh, 2008). Toronto isn’t the only growing city in Canada, but it can be seen as a leader in this industry if the right changes are made and a more sustainable approach is taken.

PROBABLY CHILLIER WITH THEIR NEW LIVING WALLS



SANTIAGO, CHILE



Chilean Consortia Building, Santiago, Chile

What can the GTA learn from Santiago?

Although natural gas causes much less global warming emissions than coal or oil, it is still a fossil fuel, meaning there are still greenhouse gases being distributed into our atmosphere. Not only would the implementation of living walls reduce the carbon in our air through photosynthesis, but also reduce the amount of energy needed per building. Toronto is one of the most recognizable cities in all of Canada. Whether you are addressing someone from another province or from another country, they more than likely are familiar with Toronto. Having said that, Toronto's implementation of living walls can be a launching point for other cities to learn from, and try to implement effective sustainable buildings of their own. This could be used in other large urban cities such as Vancouver, but also smaller, more rural cities like Attawapiskat, who's main power supply comes from Fort Albany.

If Toronto's expansion is presumed to continue laterally, then what's stopping us from expanding sustainability vertically. Living walls can contribute to a wide variety of environmental, economic and social issues. For instance, plants and trees are considered to be effective scavengers of pollutants and gaseous elements from the atmosphere. They filter out airborne particles through their leaves and branches by absorbing gaseous pollutants through the process of photosynthesis, thus improving overall air quality (Dwyer, Schroeder, & Gobster, 1994). Living walls also provide a natural element of shade to a building. Depending on the density of the living wall, there will be a lack of solar energy leaked into buildings, thus reducing the need for air conditioners to be run to the extent as they are now (Loh, 2008). This in turn reduces the amount of energy consumed per building, and would bring down Toronto's energy consumption average. As another note, plants not only filter out impurities in our air, but also in our water. Before water enters the ground water aquifer, impurities such as nitrogen and phosphorus bond with soil particulate, thus bettering our groundwater (Johnston & Newton, 2004). One example of an effective implementation of a living wall is the Chilean Consortia Building in Santiago, Chile. Designed by Henry Browne and Borja Huidobro, this building has numerous features that make it sustainable, including the interior and exterior vegetation panels. These panels absorb the heat of the sun through a dense and lush vegetation façade on the side of the building, thus reducing the need for large amounts of energy in the building (Sheweka & Magdy, 2011). This is only one example, but living walls are more than likely the direction most architectural firms will lean, as the demand for combatting carbon emissions grows.

WATER – THE BIGGEST ASSET AND LIABILITY

SAUGEEN SHORES, ON



Saugeen Shores Breakwall with Reduced Winter Ice-Cover (Cassan, 2009)

"In my personal life, I try to avoid single-use plastics as much as possible. I like to use devices such as reusable water bottles and shopping bags. This increases my sustainability since one reusable item can replace hundreds of single-use items. Another thing I enjoy is walking or riding my bike for errands to avoid driving. This is a great way to reduce wasteful emissions while still accomplishing the task and getting the added benefit of a healthy lifestyle."

-Daniel Henstock

RESILIENT INFRASTRUCTURE

CANADIAN ENGINEERING GRAND CHALLENGES

Saugeen Shores, Ontario is a municipality of small communities next to Lake Huron. Statistics Canada (2017) reports a population of 13,715 people. The community features twelve beaches and 30km of cycling trails along the waterfront (Saugeen Shores Tourism, n.d.). Most residential buildings are detached, single-family homes (Statistics Canada, 2017). Typically, properties are built near the shoreline to take advantage of the view over the lake.

Climate change is destabilizing water cycles in the community. Precipitation has seen a significant increase, with notable escalations in intensity during the summer (The Lake Huron Centre for Coastal Conservation [TLHCCC], n.d.). Furthermore, storms are becoming stronger; wind, snowfall, and thunderstorms are predicted to increase in severity (Sargeant, H. & Sweetnam, D., 2020). Water levels in nearby Lake Huron are expected to see an average warming of several degrees Celsius in the next half-century (Georgian Bay Forever, n.d.). Water levels are expected to decrease over time due to greater evaporation caused by reductions in seasonal ice-cover (TLHCCC, n.d.). Despite this, residents should expect unpredictable variations in the water level each year (Georgian Bay Forever, n.d.). These combined fluctuations in water movement put into question the sustainability of buildings in the community. Sargeant and Sweetnam (2020) explain that many local homes were not intended to withstand these worsening conditions. Precipitation patterns will cause frequent flooding of properties and accelerate soil erosion (TLHCCC, n.d.). Low-lying buildings or those with basements will be vulnerable to water damage. Roofs can also be affected by intense storms, furthering the risk of property damage (Sargeant, H. & Sweetnam, D., 2020). Saugeen Shores benefits greatly from its local waterbodies, but due to the threats of climate change, adaptations must be put in place to keep it safe.

RISING TO THE CHALLENGE OF RESILIENT BUILDING



CASTRO, CHILE





Buildings on Stilts in Castro (Figueroa, 2019)

What can Saugeen Shores learn from Castro?

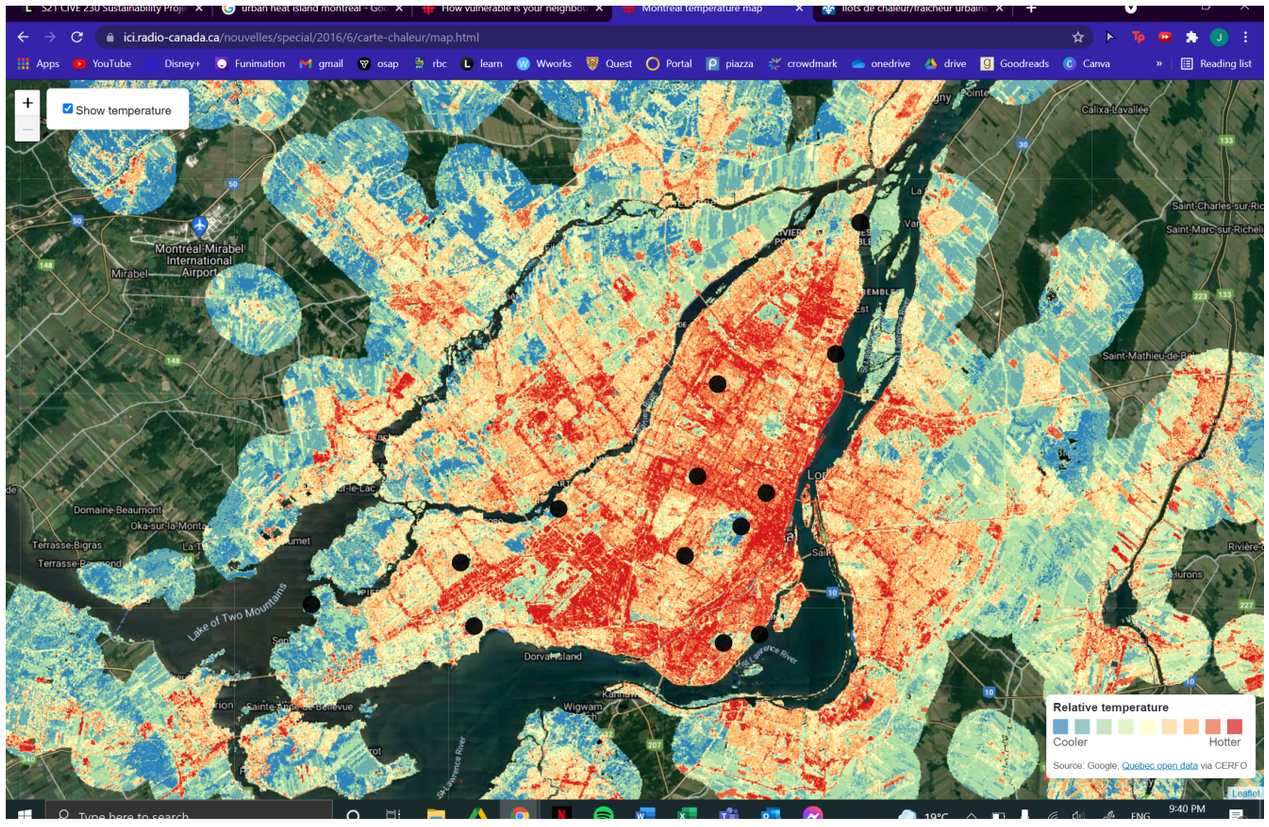
The economies and lifestyles of those living in Saugeen Shores and Castro rely heavily upon the water. It is an economic driver and contributes to the social identities of these cities. Both expect increased unpredictability in precipitation and water levels. Saugeen Shores can improve the sustainability of its buildings by taking inspiration from Chilean palifitos.

Castro is a small city on the Chilean island of Chiloé. This historic city is the third oldest in the country (Fodor's Travel, n.d.). Tourists visit this city of 8,000 for the local art, food, and architecture (GoChile, n.d.). Castro is located on the Gulf of Ancud which allows fishing to be a major economic driver in the community (World Habitat, n.d.). This location poses several challenges that have been exacerbated due to climate change. Sea level rise threatens buildings located near the coast. Castro also experiences heavy, frequent rainfall events (GoChile, n.d.). The city was last hit with a tidal wave in 1960 that damaged much of the infrastructure and faces increasing vulnerability to natural disasters due to climate change (GoChile, n.d.). The increased flood risk forced adaptations to local building practices.

This community has integrated intelligent design into their buildings to improve resilience. Homes and businesses are built on stilt foundations. The structures called palifitos are a well-known architectural feature of the island (Fodor's Travel, n.d.). Buildings on stilts can withstand high water levels and flooding while minimizing damage to the inside (World Habitat, n.d.). Deep piles can withstand soil erosion during flash flooding decreasing the likelihood of structural failure in the foundation. For small buildings in Castro, wood is typically used for the stilts. In large structures and those that must meet stringent building codes, steel reinforced concrete is a good choice for its strength under compressive loading (Walbridge, 2020). This adaptation is key since it allows residents to safely remain in their local community without moving away from the waterbody that supports their economy.

DEADLY HEAT WAVES HIT MONTREAL'S URBAN HEAT ISLAND

MONTREAL, QC



Thermal map illustrating the Urban Heat Island effect around Montréal, Canada

"To me, sustainability is people making choices, big or small that are mindful of the state of the environment and either help to improve it or at the very least, try their best to not contribute to its destruction. In addition, these choices would ideally leave the earth a better place than it is for future generations."

-Joia Mendez

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

As global warming persists, intense heat waves become more frequent and extreme, especially for those in cities. Dubbed "Urban Heat Islands" (UHIs), densely populated and constructed cities are significantly warmer than rural surroundings due to the island's efficiency in amplifying and trapping heat above the earth's surface. This is due to the high thermal capacity of buildings, loss of vegetation, heat release, and building typology. UHIs are typically 1°C to 3°C warmer than rural surroundings (Health Canada, 2020); however, parts of central Montreal have recorded temperatures up to 12°C hotter (Natural Resources Canada, 2013). The buildings which form Montreal's urban landscape have a low albedo and high thermal capacity, allowing them to absorb large amounts of solar energy and slowly release it as heat. The UHI effect is greater in central Montreal and the east end because the lack of vegetation minimizes the evaporative cooling benefits that comes from natural surfaces. In addition, buildings will release extra heat due to energy inefficiency in operations such as heating and cooling systems. Finally, high-rises in a condensed layout alters air flow, thus trapping heat in specific neighbourhoods. These effects are further amplified by large populations, and with a size of 1.7 million the UHI effect in Montreal can lead to serious heat waves (Statistics Canada, 2017). In 2018, Montreal suffered an extreme heat wave where maximum daily temperatures reached 35.5°C in parts of the city, leading to 66 deaths (Sante Montreal, 2019). Though this extreme heat event only lasted six days, Montreal is predicted to experience an average of 24 very hot days (+30°C) per year by 2050, putting many of its residents at greater a health (Health Canada, 2020).

URBAN FORESTRY VS URBAN HEAT - MANDATORY GREEN ROOFS

BASEL, SWITZERLAND



13 CLIMATE ACTION

Living Green Roof Demonstration

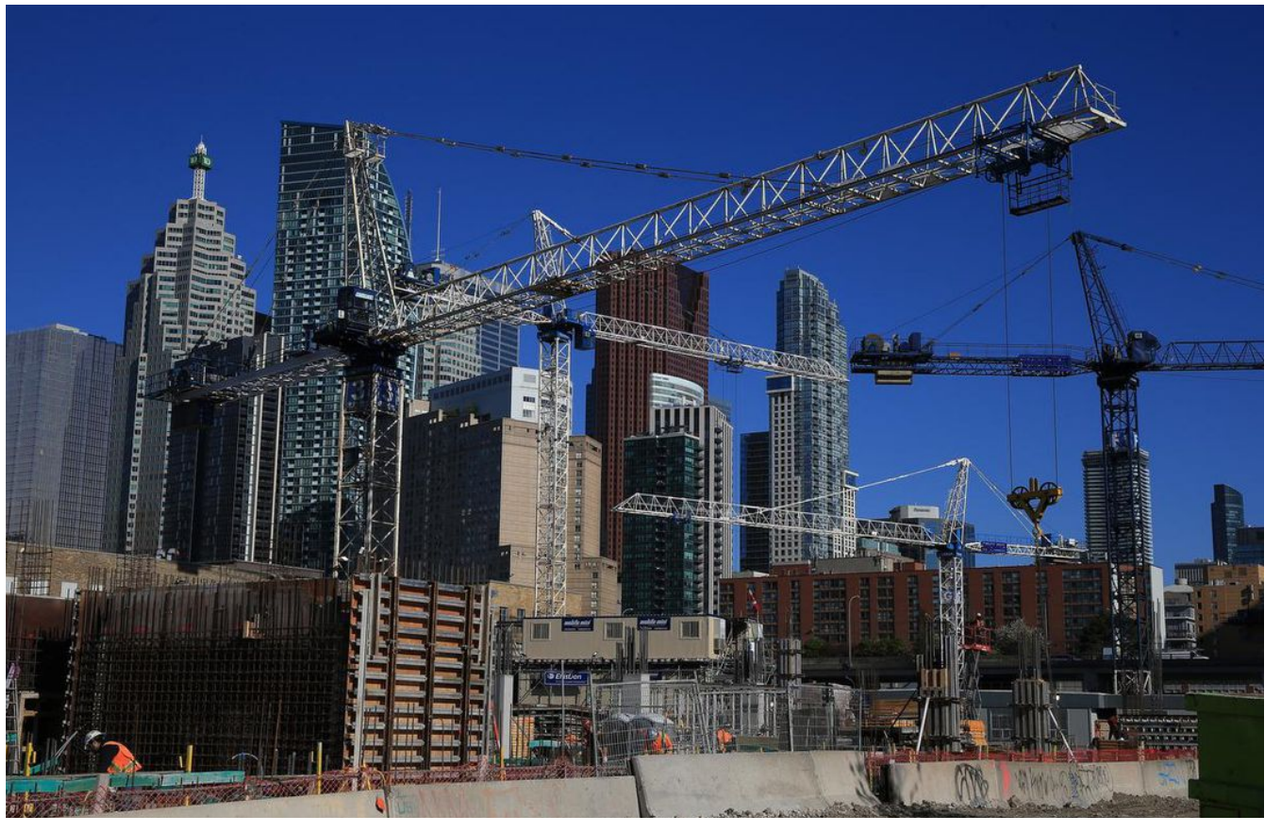
Urban heat islands are a worldwide issue as global warming progresses due to population growth and urbanization. An excellent way to mitigate heat island effects is to introduce more green spaces and natural vegetation throughout cities. Green roofs primarily keep temperatures cooler through evapotranspiration, a process in which plants can use up to 50% of the solar energy they absorb to convert the water in their leaves into vapour that is released into the atmosphere. This natural way of cooling redirects solar energy from hitting the roof, thus reducing the building's surface and ambient temperatures. In addition, urban forestry reduces the area of low albedo where sunlight is absorbed and can lower indoor temperatures by up to 5°C (Climate Adapt, 2016). Thus, reducing building energy usage in cooling processes and minimizing the amount of waste heat emitted from energy inefficiency. In 2002, Basel, Switzerland was the first city in the world to make green roofs mandatory on all new and renovated flat roofs (Climate Adapt, 2016). This was a result of a 1996-1997 initiative that provided subsidies for installing green roofs and saw huge success. As of 2019, Basel has the largest green roof area per capita with approximately 5.71 m2/resident (Climate Adapt, 2016).

What can Montreal learn from Basel?

As mentioned before, intense heat waves pose great health hazards for the vulnerable population so, as green roofs work to lower the rate at which city temperatures increase, they help the public adapt to its warming climate over time. If Montreal were to implement required green roofs, they would have to adapt Basel's law to prioritize creating green roofs on buildings being rehabilitated, as the majority of where the city's heat island exists is already densely built up.

HOW SUSTAINABLE ARE BUILDINGS?

TORONTO, ON



Toronto apartments halfway through construction

“I incorporate sustainability in my life by doing a lot of little things and trying to add those up. For example, I use a Brita filter instead of buying water bottles, I try to find things to reuse in my house and make sure I am not needlessly wasting electricity or water. I walk or bike most places rather than drive and don't spend excessively on things I don't need. All these things and many more are small individually, but add up to lead to sustainability in my life”

-Joshua Togo Saporito

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Modernization is the attempt to take a traditional subject and “update it” either through aesthetics or function. We see this in art, and it reflects in modern feats of architecture as well, such as the famous Sydney Opera house. However even though we update these things in form, what about function? Looking at this from a sustainable perspective, it’s a challenge we are still tackling today.

40% of all emissions from producing energy in Canada come from producing electricity to power buildings. This is because buildings have facilities we need to run, such as AC/heating, plumbing, and electrical appliances. This is especially true in Canada since it gets very cold during winter, so we use more much more energy on heating buildings. Water efficiency in buildings is another concern as well, since water that comes out the tap all needs to be treated, and it will go to treatment plants whether it’s wastewater or not. While all of these resources are handled through what we deem as acceptable processes, we are not at the point yet where we can call them “sustainable”.

Looking at the City of Toronto, it has a density of 1049 people per km2. Considering all of Canada only 4 people per km2, Toronto is densely packed with people relative to the rest of the country, and with that, full of offices and residential buildings. Since all these buildings are concentrated, lots of pollution come from this city as greenhouse gases, which can influence the health of the city’s residents. In fact in 2014, there were an estimated 190 premature deaths and 400 hospitalizations just due to the burden of air pollution from residential and commercial buildings from Toronto.

INTRODUCING LEED AS A GUIDELINE FOR SUSTAINABLE BUILDINGS

TORONTO, CANADA



Green Roof at Eighth Avenue Place

What can Toronto learn from Toronto?

If new buildings in Toronto were to implement some of the LEED guidelines, overall air pollution could be reduced over time, and energy that was previously used in buildings could lowered or put somewhere else.

To measure a building's environmental optimization, LEED is a system used to rate how "green" a building is. It not only considers how efficient it is in its energy consumption, but also how cost efficient it is, as well as how "healthy" it is for the environment. There are also a separate set of rules for building/interior construction, operations and maintenance, homes and even entire communities/cities, which all look at different parameters to see the magnitude of environmental impact they have. Depending on the number of points received on evaluation, buildings can be rated as Certified, Silver, Gold and Platinum (40-49, 50-59, 60-79, 80+ points respectively). Since LEED only acts as a guideline, all the benefits of acting according to the guideline come from what the building will do. For example, since reusing is a big part of sustainability, LEED buildings tend to have reduced energy and water usage, lower operating costs, and a greater resale value.

An example of a building that has implemented this solution would be Eighth Avenue Place in Calgary, Alberta. This is an office building that's been awarded a Platinum LEED Certification, the highest rating that can be received. Some implementations in the building done to achieve this were efficient plumbing fixtures (which resulted in a 40% reduction use of water), reliance on outside air to cool the building and a green roof of 25 000 sq ft, making it Calgary's largest green roof.

CONDO CRAZE



TORONTO, ON



Glossing Gleaming Glass

“In terms of sustainable development, I think that it is simply developing human living conditions in a way that is harmonious with Nature. In my opinion, I think that one of the beauties of this is that the laws of nature are broad, and they are not too constrictive. I believe that humans have a lot of space to operate within the framework of Nature, the problem is that for too many of us, preserving Nature is simply not a concern, which may be why we are in the current situation we find ourselves in.”

-Omar Karimi

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

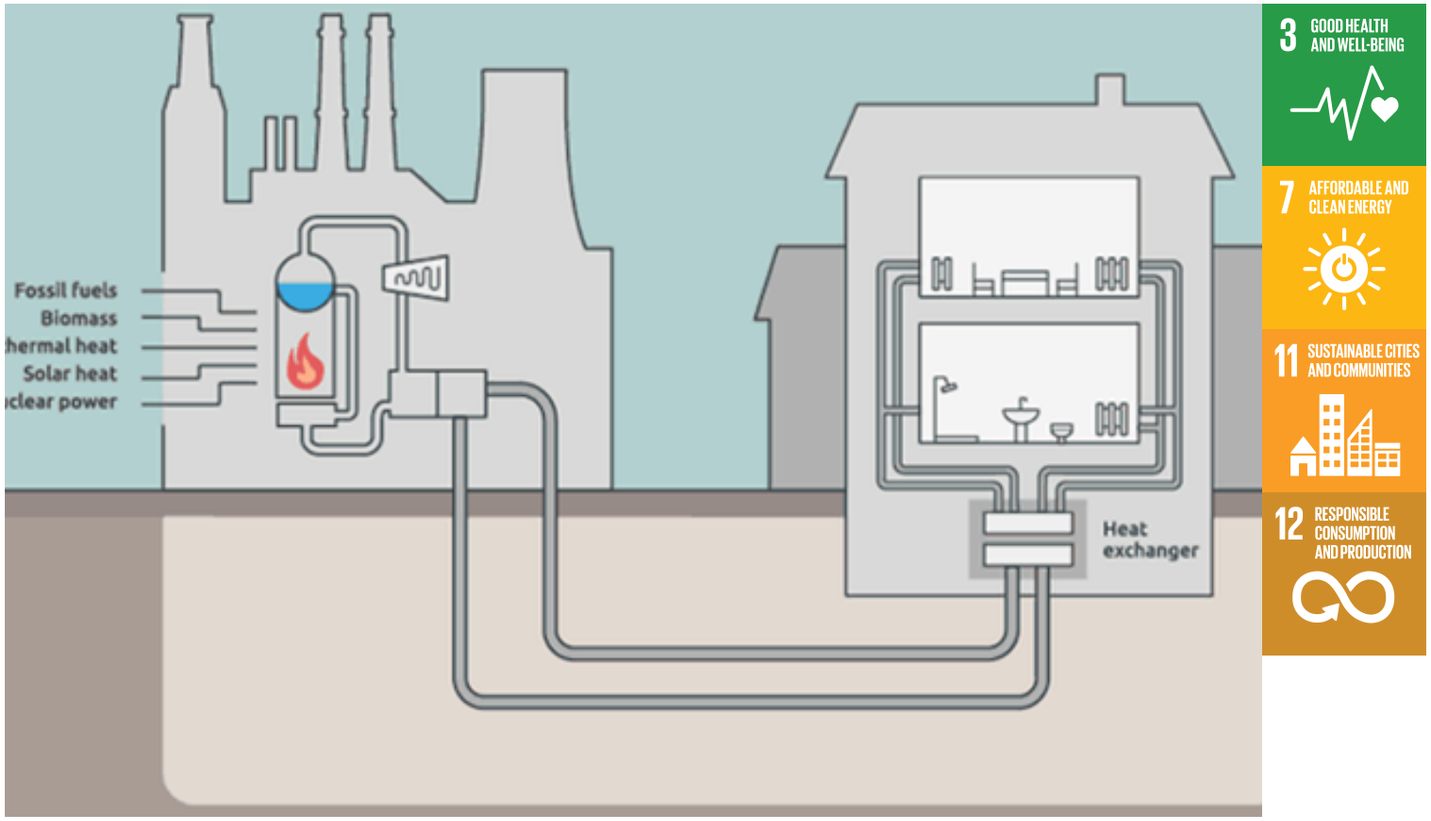
Toronto is the capital city of Ontario with a population of almost 3 million. The city has a diverse population both socioeconomically and culturally. In 2016, on average, around 4334.4 people lived per km2. It is an international hub of business, arts, culture, and finance. ("Toronto - Wikipedia", 2021)

Toronto being the densely-populated-high-standard-of-life-city that it is, has been faced with environmental challenges for the past few decades. Several defects in aspects such as: transportation, sewage, residential buildings, etc., contribute to these challenges. Regarding residential buildings, its produced environmental issues have been unique, yet seemingly simple to solve. Due to factors such as the formation of the greenbelt, and the Canadian property bubble, there has been a surge in condo-building development. In 2019, it was reported that more than 1000 condo buildings were built. (Sherman, 2021)

One major issue produced by the city’s residential buildings, is the enormous amount of resources they consume for heating and cooling themselves. It has been determined that the largest source of emissions affecting local air quality is fuels used to heat homes and businesses. The design of many new condos is not energy efficient, which is in large part caused by the abundance of windows that clad the buildings. Windows are the least insulated part of an exterior walls, and poor insulation causes a greater demand on the building’s heating and cooling systems. The method these two systems use to gain their energy is the problem. The process that generates the systems’ required energy produces emissions of undesirable gases that can pollute the surroundings. Therefore, the more energy these buildings use to cool and heat themselves, the more the emission of undesirable gases. (Sherman, 2021)

INNOVATIVE IDEA

REYKJAVÍK, ICELAND



District Heating Diagram

What can Toronto learn from Reykjavík?

Toronto should adopt some aspects of Reykjavík's method of heating its commercial and residential spaces. District heating should certainly be considered by Toronto. If Toronto were to install district heating, it can then possibly consider other more sustainable methods to derive its heat. Geothermal energy may be an option for Toronto's source of heating, but it is possible that there are more economical and practical sources of heat that are more appropriate to Toronto's geographical location.

Iceland is country that endures relatively cold temperatures, so this makes the issue of efficiently heating interior spaces of great importance. What Iceland, and especially its capital city Reykjavík has done, ought to be looked at as an example by other cities around the World.

There are two aspects to their way of efficiently heating interior spaces; the method the heat is produced, and the method the heat is distributed. Regarding how the heat is produced: Reykjavík utilizes geothermal heating, which is essentially a process of extracting geothermal energy from the ground, and using it as heat. There are several benefits to this method of heat production, such as: the energy being renewable, the high thermal efficiency (as energy conversion is not needed), along with others ("Geothermal heating - Wikipedia", 2021). It may be both uneconomical and unpractical if every individual building produces its own geothermal heat. In Iceland, geothermal heat is produced in large and central plants and is distributed to individual buildings using a system called "district heating" ("District heating - Wikipedia", 2021). District heating is a simple and old process which distributes heat that is generated in a centralized location through insulated pipes to the end user. The pipes usually deliver hot water and steam, to a maximum distance of 30 km, or even more if multiple heat sources are connected. The following are reasons why district heating is a more sustainable method of distributing heat (Hanania, Stenhouse & Donev, 2021):

A broad range of heat sources can be used at once (which increases reliability and efficiency)

Avoids unnecessary production of heat

Opportunities for using renewable energy may present themselves that would not previously be viable

A CONCRETE JUNGLE WHERE HEAT IS STORED UP

TORONTO, ON



Toronto's Skyscrapers

When you ask a non-Canadian to name a city in the Great White North most will probably come up with the same answer, Toronto. It could be the fact that it is simply Canada's largest city with a population of 2.6 million people (Statistics Canada, 2016). To accommodate for this large population and resulting workforce, more buildings, and higher buildings are needed for them to live and work in. This has resulted in Toronto having the third-highest number of skyscrapers in North America (Ricci, 2020) and a whopping 5,400 kilometres of roads (City of Toronto, 2018). Although Toronto is a beautiful city, it faces a problem due to its' dense urbanization.

Toronto, like many other cities, suffers from what is known as the Urban Heat Island effect (Allen, 2013). The effect is prevalent in a city like Toronto that has a high density of buildings and roads leading to a "higher temperature relative to outlying areas" (EPA, n.d.). This is because the city replaces natural landscapes with infrastructure made of various materials such as concrete and asphalt which "absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies" (EPA, n.d.). In extreme cases, the heat can end up being an additional 12 degrees Celsius (Allen, 2013). Heatwaves are only getting worse and almost 120 premature deaths a year in Toronto have heat as a contributing factor (Allen 2013). This urban heat, along with the overall rising temperature of the planet will result in temperatures that will cause harm to Toronto's population and especially to those in less wealthy areas that do not have access to parks and green areas nearby.

"Sustainability to me, is how efficient the use or performance of a certain task is resulting in longevity. I think Engineers today should focus on designing in a way that allows our increasing population to exist in comfort while keeping the use of raw materials, and space, as low as possible so we can use our planet's natural resources for as long as possible."

-Raphael Don Jimenez

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

SYNERGIZED WITH NATURE



SINGAPORE



Singapore School of the Arts



What can Toronto learn from Singapore?

Toronto can learn from Singapore in many ways. With Toronto's ever-increasing construction projects, it would be very beneficial to the locals if the government started encouraging projects with more natural elements. Whether that is in the form of buildings with vegetation, or more parks and recreational areas, any change will help the city of Toronto become a more comfortable and sustainable place to live.

As stated earlier, the issue of urban heat is the result of cities not having natural features which automatically cool the environment around them. Therefore, the solution to this problem is relatively simple in words, and that is to introduce more green aspects to a city. This can include having more trees, green buildings, and green spaces (EPA, n.d.) A 'green building' is a building that has considers the environment in its' design, and the quality of life of the people that are going to be in the building (World Green Building Council, n.d.). A good example of one is a building with vegetation on the roof. The vegetation helps cool the air by releasing moisture into the atmosphere (EPA, n.d.).

An example of a city that has implemented this solution and went above and beyond is Singapore. According to their Ministry of Foreign Affairs, "Singapore is a city, a nation, and a state" (Singapore Ministry of Foreign Affairs, n.d.). It has a population of 5 million people located in southeast Asia (Singapore Ministry of Foreign Affairs, n.d.), and even though it is 100% urbanized, Singapore is "the greenest city in Asia… and arguably has few competitors in the rest of the world" (Senthilingam, 2016). This is because the island consists of nearly 50% green cover mainly due to the legislation which included green building requirements (Senthilingam, 2016). A prime example of one of these green building projects is the Beach Road project, the complex has "certain floor levels lined fully with green plants" (Senthilingham, 2016). All these green buildings and areas that have been implemented will minimize the effect of urban heat along with many other environmental benefits. Singapore embodies what a green city is, and others should follow suit.

CHAPTER 8: SUSTAINABLE TRANSPORTATION



E-Bikes/The Star

CHAPTER INTRODUCTION

The built environment within which we live, work and play is the human-made environment that provides for society's needs and activities – it is the cities that encompasses all the urban systems. Cities are interdisciplinary by nature because they include all the building blocks that help shape them, and one cannot discuss buildings without discussing the enabling transportation, and the energy within them, the water consumption by its occupants and the green spaces that make them healthy and liveable. This module starts with the context of the built environment, and a brief about their planning and environmentally sensitive design and development. This is then followed by a snapshot of sustainable buildings and sustainable transportation, to first define the criteria that makes them sustainable and then showcase some examples from around the world.

Learning Outcomes

By the end of this week, you will be able to:

- Recognize the built environment and relation to environmentally sensitive design
- Define the purpose of zoning in land-use planning and the shift to new urbanism
- Describe smart growth and its principles for sustainability of the built environment
- Explain with examples the three paradigms of environmentally-sensitive design (green infrastructure development, low impact development and conservation design)
- Define sustainable buildings
- List criteria for green building rating systems
- Identify factors affecting energy consumption
- Describe strategies for overall energy conservation
- Demonstrate low energy building strategies
- Define sustainable transportation
- Describe the components of a transportation system
- Classify the impacts of urban transportation modes
- Identify strategies to increase the sustainability of transportation
- Demonstrate four types of transit metropolises
- Locate innovations in public transportation

GREAT CAR CATASTROPHE

THE GREATER TORONTO AREA, ON



The Don Valley Parkway's Ongoing Congestion Problems (Floydian, 2010)

"There are several ways I incorporate sustainability in my personal life. The first is that I do my best to use public transportation or bike places instead of driving. I was able to exercise and was not driving which would pollute the air. I also do my best to limit the number of things I purchase that are packaged, as plastic harms the environment and I personally believe it is not healthy to constantly be eating packaged goods."

-Henry Stephen Hughes

SAFE AND SUSTAINABLE CITIES

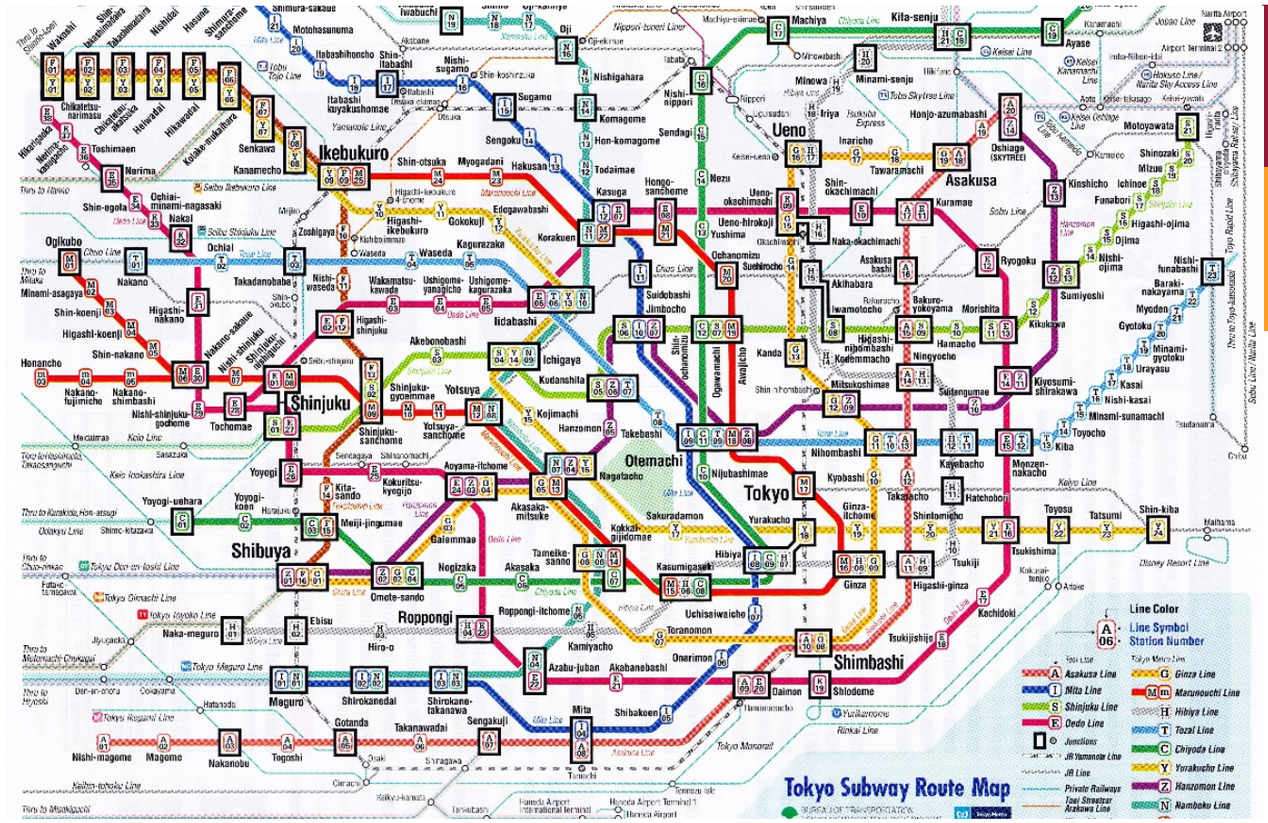
CANADIAN ENGINEERING GRAND CHALLENGES

Across Canada, urban sprawl has made many citizens dependent on the car. As cities expand horizontally, people are left with no other option than to purchase a car. Automobile and light duty truck traffic accounts for 11% of greenhouse gas emissions in all of Canada (Collie, M). As more people flock to urban areas this should be looked at as an opportunity for sustainable transportation to be implemented. Urbanization of transportation infrastructure will allow for people to eliminate the need for motor vehicles, which in turn will have a positive effect on the environment.

Toronto is an economic powerhouse that is responsible for driving the Canadian economy. In 2021, there are 6.4 million people living in the Greater Toronto Area (GTA) (Toronto Population 2021). These people own approximately 4.4 of the 11.7 million registered vehicles in Ontario at 1.3 cars per household (Bateman, C, Ambridge Law, Ontario.ca). Most people in the GTA would not be able to survive without a car given the urban sprawl that the region has undergone, as they do not have access to Toronto's limited transit network, which consists of 76.5 km of subways, significantly less than other urban hubs (The Canadian Encyclopedia). Currently the Toronto Transit Commission (TTC), is the least funded transit system in North America, leading to Torontonians having the worst commute in North America (Fox, C). As people continue to flock to urban areas, the city needs to develop a sustainable transportation plan. If the GTA continues to grow without developing a transportation plan, the GTA will become more overrun by cars and traffic, which in turn will have a negative impact on Canada's greenhouse gas emissions.

SUBWAY MASTERPIECE

TOKYO, JAPAN



Tokyo's Complete Subway Coverage, Rankin

8 DECENT WORK AND ECONOMIC GROWTH

11 SUSTAINABLE CITIES AND COMMUNITIES

Subways are an effective means of transportation. They run on their own independent system, meaning they can consistently run at high speeds, making them reliable for consumers. They are fast and can transport large numbers of people daily. Since they can be built in locations where above ground infrastructure already exists, they are the best way to urbanize transportation in cities that are rapidly expanding. Many cities have subway systems, but continual development and expansion of these systems is what will allow them to serve growing urban areas. To expand and develop subways, it is crucial that governments provide adequate funding such that these systems can deal with the increasing populations.

Tokyo is the largest city on the planet, with a population of 38.14 million people (Wikipedia). To manage the transportation of a population this size, Tokyo has implemented what many consider to be the world's best subway system. This system has been effective in combatting the ownership of cars. In Tokyo, there are only 0.54 cars per household which is 42% of that in Toronto (The B1M). Clearly people in Tokyo are not dependent on owning cars. The Tokyo subway systems spans 304 kilometers and has undergone constant expansion since its inception (Wikipedia), resulting in 13 lines and 285 stations that reach almost everyone in the city (Wikipedia). The system moves 3.9 billion passengers each year, more than any other major city (The B1M). Having this subway system will allow Tokyo to continue to grow without increasing transportation emissions. Tokyo has shown that subway systems can be developed to help combat car ownership and reduce CO2 emissions.

What can the GTA learn from Tokyo?

Cities can learn from each other by analyzing what other cities are doing well, and what they are doing badly. For example, major metropolitan hubs in the United States and Canada can learn from cities such as Tokyo on how to create a transportation system that will allow all people to have access, while at the same time limiting the number of cars on the road.

VEHICLE DEPENDENCY



WHITEHORSE, YK



Sunset at Whitehorse

“Instead of driving to places, I rather take my bike if I'm going to travel short distances. Most of the time this is when I'm going to school. Furthermore, I make sure my recycling is sorted correctly, also making sure my food goes in the green bin.”

-Nathan Leung

RESILIENT INFRASTRUCTURE

CANADIAN ENGINEERING GRAND CHALLENGES

In recent years Yukon’s capital, Whitehorse, has implemented a plan for more sustainable transportation called TDM, Transportation Demand Management Plan. This plan was initiated due to various factors; however, I will only tackle two, Public Health and Greenhouse Gas Emissions. The city has noticed an automobile dependency that encourages sedentary lifestyles and obesity. A study has shown that 91% of children/youth and 69% adults do not meet recommended levels of daily physical activity. They consider this a “conveyor belt” to cardiovascular disease, strokes, diabetes, and various cancers. Furthermore, this dependency on vehicles has led to an increased their Greenhouse Gas Emissions. In 2011, the city alone emitted an estimate of 225,000 tonnes of carbon

dioxide. They predict there will be 7.5-million tonnes of carbon dioxide emitted in the next 25 years. Currently, the city has one of the best air qualities in all of Canada, and they wish to keep it that way.

Whitehorse is the capital of Yukon, CA. The city was named after the White Horse Rapids due to the resemblance of the mane of a white horse. As of 2020, there is approximately 41,731 people living in this city, which is not a lot compared to some cities in Ontario. As one can expect, there is a large sense of community in the city as the population is so small. Living up North does present some challenges. During the summer, the days are extremely long, with approximately nineteen hours of daylight. While the shortest days are in the winter, with just over five and a half hours of daylight, which may feel as though you are living in the dark. However, the beautiful landscapes, wilderness, fresh air can make all those toils worth it.

SUSTAINABLE MOBILITY PLAN

PRAGUE, THE CZECH REPUBLIC



Prague's Beautiful Skyline

What can Whitehorse learn from Prague?

I believe Whitehorse has a lot to learn, and has huge areas to grow in. Prague is an established city and has almost 35x the population of Whitehorse. However, it is good to start early, building a foundation for sustainable transportation will be a key to a more sustainable city. I believe something Prague can learn from Whitehorse is building more methods for cycling. Currently, only 0.4% of transport in Prague is by cycling, I believe they should build more cycling friendly roads. Overall, both cities will have to continue to develop their transportation, hopefully making an impact towards a more sustainable lifestyle.

Prague, a city in Czech Republic has a unique plan to create a more sustainable transportation in the city and its suburbs. This plan does not seek to separate each transportation mode but use merits of each highlighting their connectivity. These transportation modes include automobiles, public transport, walking and cycling. Currently, the Prague Integrated Transport (PID) system plays a huge role in public transport. It is a single network which includes all public transport in Prague, metro, trams, and busses. The best thing about the network is that allows users to use only one ticket, according to one schedule. Another aspect of their plan is the "P+R", park-and-ride. These are facilities that promote public transport where people park and ride. These facilities have 3000 spots located in the suburbs and other places that promote traffic. Their transportation infrastructure allows people to travel to almost anywhere using public transport. Their plan covers many more aspects including shared mobility services, electric buses, completion of certain roads, pedestrian links, their list goes on. Due to their continual effort in this sector, Prague is now ranked 5th in the top cities worldwide

for sustainable transport according to the 2017 Sustainable Cities Mobility Index from Arcadis, a consultancy firm. This index uses 23 indicators that are grouped into the social and human implications, environmental/green factors, and economical benefits.

Prague is the capital of Czechia (a.k.a. Czech Republic). The city has approximately 1.4 million people and attracts quite a few tourists too. This means the city is quite busy, depending highly on the PID; and it shows since approximately, 52% of all trips are completed by the PID. The city is beautiful with lots of historic architecture, including many world-class museums. Furthermore, Prague has an oceanic climate, with a little humidity. Overall, Prague is one of the most beautiful and sustainable cities in Europe.

ELECTRIC CARS SWARMING



TORONTO, ON



The air quality in Toronto from cars emitting carbon monoxide (Jacobson, 2012)

“For me when I think of sustainability, I imagine using something or even building something that will be beneficial for the people/animals or the economy for long term use that can be maintained at a good rate. Engineers play a crucial part in sustainable development since they need to build something good enough to last decades, if not centuries for the use of the people and the economy.”

-Zaid Alkhatib

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

The city of Toronto, the capital of the province of Ontario, has a population of 2.93 million as of 2017, it is the largest city in Canada and the fourth largest in North America. Toronto is widely known across the world for its numerous skyscrapers, especially the CN Tower located in the Western Hemisphere. Toronto is also known for its transportation system including highways, railways, bus terminals, and roads which is important for transporting people/ products and economic growth. However, due to the high amounts of vehicles driving daily burning gasoline to function emitting pollutants such as carbon monoxide and nitrogen oxides, which are toxic pollutants that cause pollution in the city of Toronto.

As a major city for transportation in Canada, Toronto has deposited significant levels of air pollution. In 2004 it was estimated that a total of 1,700 people die yearly and 6,000 are hospitalized yearly in Toronto due to air pollution. More than half of Toronto’s air pollution is caused by car vehicles accounting for about 42% of deaths and hospitalization of 55% (Gower, 2014). In 2007, pedestrian walks were being taken into consideration to increase the number of people walking instead of always driving and was recorded to be 7.1% of Toronto’s population which started to significantly decrease the number of deaths from air pollution. Therefore, the air pollution in Toronto can be reduced by reducing vehicle dependence and promoting walking and cycling as a form of transportation.

In recent years, Toronto has made considerable improvements for a better sustainable transportation system by having more electric cars registered in the city and having a charging station for the Canadians with electric cars. This demonstrates the potential electric cars are holding in long-term effects in Toronto, to reduce the pollution in the air. People need to start using electric cars instead, for a healthier future.

ELECTRIC WEAPON AGAINST POLLUTION

OSLO, NORWAY



11 SUSTAINABLE CITIES AND COMMUNITIES

he merging of electric vehicles in Oslo, Noway

What can Toronto learn from Oslo?

Thus, Toronto can learn from Oslo's approach to eliminating the use of gasoline cars and any other forms of transportation that affect transportation sustainability. For example, this idea of promoting the use of electric vehicles, pedestrian walks, and cyclists by providing them with extra benefits to motivate the people in following the steps of climate change. To summarize in a phrase, it is a promising solution for sustainable transportation for the future.

From the few countries that are way developed and prepared for the future, they have been pushing all the boundaries for the safety of their people against the effects of air quality that are involved in a campaign led by the World Health Organization and UN Environment, making Oslo a key city for a healthier future. Oslo is the capital city of Norway, with a population of 670,000 people has the highway per capita number of electric cars globally, with 47% of its population using them as in 2018 (Vandycke, 2018).

The Norwegian government for Oslo's plan has been to promote alternative energy sources for transportation with electric vehicles while providing reduced taxes, free charging stations, free parkings, and exemptions of road tolls. Since 2012, electric vehicles have decreased the CO2 Emissions in the atmosphere by 35%, resulting in better air quality and general health (UNEP, 2020). Oslo has also been promoting the use of pedestrian walks and cyclists over vehicles as a source of transportation, in addition to giving them 1.3 km^2 of area. In 2017, 20% of the vehicles were zero-emissions. By 2025, Norway that 100% of their citizens will be using vehicles with zero emissions (Elvestuen, 2020).

As shown in Figure 2, electric vehicles are being used in Oslo as a way for the sustainability of transportation in the future. Research shows that electric cars are way better for the environment because they emit less GHGs and air pollutants into the atmosphere than gas cars(UNEP, 2020). Therefore, the use of electric cars in Oslo, Norway is seen as a key to fight air pollution in the future and sustain a safer and healthier future.

CONGESTION IS CHOKING IN MORE WAYS THAN YOU THINK



TORONTO, ON



The Don Valley Parkway in Toronto.

“I consider the impact that my choices will have on the environment. I don't vote for climate change deniers. I keep myself informed about new and existing sustainable technologies, particularly ones that have to do with buildings, transportation, and energy.”

-Thomas Ying

SAFE AND SUSTAINABLE CITIES
CANADIAN ENGINEERING GRAND CHALLENGES

Home to three million people in the city proper and more than six million regionally, it’s no surprise that Torontonians face some of the worst traffic in the country. The typical Toronto driver will spend thirty-three percent more time on the roads due to congestion—and it’s even worse if you’re a commuter (DeClerq, 2020). Travelling during the morning and evening rush hours every weekday means spending as much as six extra days out on the road. But heavy traffic is shortening lives in another way. Congestion leads to higher concentrations and lower dispersion of pollutants, contributing to increased mortality for drivers (Zhang & Batterman, 2013). Meanwhile, half of all Toronto residents live within 250 metres of a major road, which exposes even more to nitrogen dioxide, sulphur dioxides, and other pollutants, sometimes at levels beyond federal air quality standards (Chung, 2019). An estimated 7,700 Canadians die prematurely each year due to air pollution.

Local traffic creates the majority of pollution found next to major roads (Chung, 2019). This includes eighty percent of nitrogen monoxide emissions, and sixty percent of black carbon emissions, a type of particulate matter that, at levels recorded on Toronto streets, notably increases the risk of lung cancer. Tire and brake wear also produces metal-rich dust particles, a type of “non-tailpipe” emission whose health effects are not well-studied yet.

Diesel-powered vehicles are by far the worst offenders (Chung, 2019). Freight trucks, which are often poorly maintained and tested, create a disproportionate amount of emissions, and the rising popularity of same-day delivery online shopping has led to a rise of trucks on Toronto roads.

AREA C CUTS OUT CARS AND POLLUTANTS

MILAN, ITALY



An Area C gate in Milan.

11 SUSTAINABLE CITIES AND COMMUNITIES

13 CLIMATE ACTION

Milan, a city in northern Italy, and its surrounding metro area are home to over three million people. In spite of a robust public transportation system, car ownership per inhabitant in Milan was at one point among the highest in the world (Morandini & Kodukula, 2013). This, in combination with geographical and climatic characteristics, meant that Milan could not meet European pollutant limits for PM10 of 40 µg/m3. In 2008, the city created Ecopass, a traffic pollution charge applied to vehicles of certain emission classes passing through the city center during rush hour. This area covers eight square kilometres, and nearly three hundred thousand people work inside of the zone (Sevino, 2017). Although Ecopass successfully reduced emissions of particulate matter (20%), nitrous oxides (16%), carbon dioxide (15%), and ammonia (45%) within the zone, its effects on congestion were degraded as more residents switched to Ecopass-exempt vehicles. It was replaced in 2012 with Area C, a flat congestion charge applied to all vehicles passing through the same area, with some exceptions given to service vehicles, motorcycles and scooters, electric vehicles, and hybrid vehicles. In addition, Area C outright banned vehicles that failed to meet certain European emissions standards, with plans to widen this ban over time.

Within three years of its implementation, Area C reduced road traffic in the city centre by twenty-nine percent, accidents by twenty-six percent, and increased public transit speed by six percent. Compared to the levels found under Ecopass, PM10 and nitrous oxide emissions fell by an additional eighteen percent, carbon dioxide by thirty-five, ammonia by forty-two, and black carbon concentrations by thirty. The money raised by Area C congestion charges, totalling more than twenty million euros per year, has been spent on improving Milan's public transit system and promoting sustainable transportation.

What can Toronto learn from Milan?

The lesson that Toronto can take away from Milan's success is the importance of looking beyond the next election cycle. As with every congestion charge, Ecopass was initially unpopular, but Area C was created after seventy-nine percent of residents voted in favour of a system stricter than Ecopass (Sevino, 2017). After less than ten years, Ecopass and Area C improved air quality, reduced congestion, and raised millions of euros for transportation infrastructure, without affecting local business, property values, or freight deliveries.

COMMUTERS FACE OVERCROWDING DAILY IN TRANSIT SYSTEMS

TORONTO, ON



Large Crowd building up at Dufferin Station (Wyliepoon, 2018)

“Sustainability means conserving the planet's resources by recycling and being mindful of how our actions can damage the planet. Good sustainability would mean successfully maintaining a healthy amount of the specified resources.”

-Edward Yang

SAFE AND SUSTAINABLE CITIES
CANADIAN ENGINEERING GRAND CHALLENGES

Toronto is the most populous city in Canada, having a diverse population of 2,731,571 in 2016 and a population density of 4,334.4 people per square kilometre (Statistics Canada, 2017). The city has a well-known transit system, having won the award for "Transit system of the year" in 2017 (Draaisma, 2017). However, this doesn't mean the system is free of problems. Although the stations may appear spacious and maneuverable when empty, they are quickly filled by an influx of commuters. Due to high demand, Toronto's 4-line subway system often operated at much higher than its available capacity, pre-pandemic times. This leads to a problem of overcrowding, particularly during rush hours, where the rate of commuters entering the stations is greater than the rate at which buses can service them. In addition to being frustrating, history has shown that overcrowding in cities brings about many problems, namely air pollution, light pollution, and solid waste pollution. Exposure to air pollution can lead to adverse health effects or death, with air pollution causing 6.4 million deaths per year worldwide (Shi, 2019). This air pollution is linked to overcrowding and traffic congestion, where the carbon emissions from the transportation sector increased four percent from 2015 to 2017 (Kopun, 2019). Furthermore, thousands of citizens rely on the subway system for their commute. Delays in the system have significant impacts on mental health, to the point where mental health centres had to encourage people to call their hotlines (O'Neil, 2019). These impacts on mental health hinder progress in sustainable development, thus negatively affect the environment. As our population continues to grow, it can be expected that the issue of overcrowding will only worsen, and the city will continue its rate of emissions if a solution is not implemented.

FLATTENING THE CURVE OF TRANSIT USAGE WITH FREE SOBA

TOKYO, JAPAN



Commuter enjoying soba at Sapporo Station (Jaako, 2008)

Tokyo, the capital of Japan, is another large and densely populated city, with a population of 13.491 million and a population density of 6.158 people per square kilometre (Tokyo Metropolitan Government). The city is known for having scenic cherry blossoms, traditional arts, and excellent food, making it a popular travel destination. Thus, a suitable transit system would be required, and Japan meets that requirement with a comprehensive and efficient train network that covers the entire city with over 280 stations. These stations carry an average of 7.6 million passengers a day with a total of 9 train lines (GoTokyo, 2021). Given such a large population, some overcrowding and congestion are to be expected and occurs frequently due to the high demand for transportation. One of the several solutions Tokyo's metro implemented was a free soba policy, where passengers would register their metro cards online and use the station before a certain morning cut-off time for ten consecutive days. This offer only applied to the Tozai line, which is the city's busiest metro route, facing a 199% congestion rate (Cheslow, 2019). The approach is similar to flattening the curve, with the idea being to deter some commuters from entering the stations during rush hour and instead board the trains at an earlier time when there is less demand. The plan was extremely successful; after only a day of the policy implementation, 8,462 people participated in the campaign to ease congestion, for the Tozai line that 76,000 passengers use daily (Cheslow, 2019). Tokyo's successful incentive shows that even small policies can create large changes, and the hope is that passengers continue to board the train at earlier times to reduce congestion.

What can Toronto learn from Tokyo?

Toronto and Tokyo are both very large cities with frequently overcrowded transit systems. Toronto could learn from Tokyo's approach of providing an incentive to reduce the overcrowding, by creating a similar incentive to spread out when commuters take the transit system.

RESIDENTS PUSH BACK OVER BIKE LANE PLANS

MONCTON, NB



Downtown Moncton, New Brunswick, Canada

"My personal experiences with sustainability shape my everyday decisions. I am a vegetarian for environmental reasons. The meat industry has a massive impact on the environment and peoples health, and I do my small part by not supporting that industry. I also drive a very old corolla, and I wear second hand clothing. Where possible, I try to support local businesses, stimulating the economy and local growth."

-Celine Vandenberg

RESILIENT INFRASTRUCTURE
CANADIAN ENGINEERING GRAND CHALLENGES

Active transport is integral to sustainable urban mobility. Replacing personal and public transit with cycling is the answer to reducing greenhouse gas (GHG) emissions; specifically, carbon dioxide emissions from fossil fuels. An average person substituting cycling for driving for one trip per day for 200 days decreases mobility lifecycle emissions by 0.5 tonnes per year (Brand, et al., 2021). Cycling also has many other benefits apart from climate change, including reducing social inequalities, and improving public health, which in turn promotes the economy (London Imperial College, 2021).

While this seems like a very simple sustainable solution, the issue is safety of riders as well as changes to already existing infrastructure. Canada alone has 74 cyclist fatalities per year, with 50% of fatalities happening in urban centers (Statistics Canada, 2019). These fatalities mostly stem from lack of safety and infrastructure.

Moncton, New Brunswick is a town in eastern Canada known for its lack of "bikeability" (Winters, Teschke, Brauer, & Fuller, 2016). Comparing other major cities in Canada, Moncton has a Bike Score of 49.3, while cities like Calgary, Alberta, and Montreal, Quebec, have scores of 74.4 and 78.8 respectively (Winters, Teschke, Brauer, & Fuller, 2016). Traffic studies were completed for the town of Moncton, and an action plan to add more bike lanes drafted. It was proposed that whole lanes be converted to bike lanes by demarcation and other signals. Locals were opposed to the plan as it was argued to be "too risky" and "local politicians hadn't consulted enough on the concept" (CBC News, 2011). It is believed that these new lanes will put cyclists at risk, and cause congestion – which directly contradicts studies on active transportation (Dalkmann & Irigoyen, 2015). Residents even asked for the process to be reversed! (CBC News, 2011).

EXTENSIVE SOLUTION TO ACTIVE TRANSPORTATION



ROTTERDAM, THE NETHERLANDS



Mapped bike paths in The Netherlands (2018)

What can Moncton learn from Rotterdam?

Moncton and Canada have a lot to learn from Rotterdam's implementation of bike lanes and accompanying infrastructure and policy, from planning to implementation, as many areas in Canada lack any support for cyclists.

The Netherlands is known for its bike lanes and high percentage (>25%) of commuters choosing active transportation as a primary mode of transportation (Pucher & Buehler, 2008). The main goal for active transport is to support environmental preservation by decoupling it with economic growth (Banerjee, et al., 2001). Most countries adopting this ideology start by transport planning from door to door, considering the trip as a whole, and trying to make the modes of transportation work cohesively with one another.

An exemplary example of bike lane implementation is at The Hague, Rotterdam. These lanes are designed to capture and treat runoff, improving water quality. The design also implements yellow brick to delineate cycling paths from pedestrian paths (Banerjee, et al., 2001). This creates a safe, efficient space for cyclists, but it does not stop there. The Netherlands, as well as Denmark and Germany, have extensive cycling right-of-way laws, integration with public transportation, and other amenities like bike parking to complement their network of bike paths (Pucher & Buehler, 2008). The Netherlands also has other supporting policies, like high taxes and restrictions on car ownership (Pucher & Buehler, 2008).

While bike lanes are a great start to promoting active transportation and lowering GHG emissions, it is in Canada's best interest to introduce new policies protecting cyclists, as well as restricting fossil fuel vehicles, and promote active, public, or other modes of green transportation. Infrastructure should be optimized for use of existing capacity. Adding more bike lanes to Monction, NB, is really just the tip of the iceberg.

TAKING A RIDE DOWN THE CARBON EMISSION CONTRIBUTIONS



WATERLOO REGION, ON



Waterloo Region Highway 7

"I currently incorporate sustainability in my life by recycling and reusing takeout boxes. I try to minimize my energy pollution by constantly turning unnecessary lights off and by unplugging technology like my laptop and phone when I am not using them, or they do not need to be charge. I take public transportation when I can to get around and I pick up litter when I can."

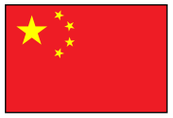
-Naomie Cecyl Seh Abomo

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

One of the largest contributors to climate change around the world is transportation and its carbon emissions. Greenhouse gases such as carbon result in large scale environmental consequences. By causing earth's heat to be trapped, sea levels rise, more incidents of extreme weather occur, heat related deaths rise and transmissions of infectious diseases increase (NDRC, 2021). At this time, over 80 percent of all CO emissions in the atmosphere are attributable to transportation, while close to 100% of CO emissions in urban areas come from motor vehicles (Dr. Nadine Ibrahim, 2021). In Canada, 53% of total emissions are attributed to passenger transportation. (NRCan, 2020). In Waterloo Region, home to two Universities and a tri-city comprised of the cities Waterloo, Kitchener, and Cambridge, with a population of 623,930 (Region of Waterloo, 2020), transportation is a large component of the region's infrastructure. Being the 10th most populous Census Metropolitan Area in Canada (Region of Waterloo, 2020), statistics indicate that in Waterloo Region, 49 percent of emissions are caused by transportation, with two thirds emitted by personal vehicles (University of Waterloo, 2021). Since transportation is a vita operation in a community, it is in the hands of engineers and scientists to innovate sustainable solutions that aid in reducing the current number of emissions. If individuals are provided with more efficient, cost effective and environmentally friendly methods of commuting, then the entire region as well as environment will benefit.

POWERED THROUGH TO AND GENERATED SUSTAINABLE SOLUTIONS



SHENZHEN, CHINA



Shenzhen, China Electrical Bus Fleet

What can Waterloo Region learn from Shenzhen?

Waterloo can learn from cities like Shenzhen by ensuring that as all new transportation infrastructure that is being created (ION, GRT, Via Rail) is sustainability at its core is as the positive environmental results are undeniable as well as aiming to achieve these goals breeds room for innovation and pushing the needle on design.

One of the methods that cities have been addressing the issue of large-scale carbon emissions from transportation is by introducing electrical buses into the communities. Not only do they reduce green house gases, but electrical buses also produce fewer emissions of other pollutants, are quieter and create a more comfortable environment for pedestrians and cyclists (CBC, 2020). They help provide cleaner air for communities and reduce noise pollutants. Many buses also charge in the nighttime, during off peak times which helps manage peak demand and supports renewable energy integration (Advanced Energy, 2020). In Chinese cities, electrical buses account for 99% of the buses on the road today. China was a pioneer in demonstrating the sustainability benefits of this solution. In the city of Shenzhen, they initially needed two electric buses to account for the service quality of one diesel bus. However, in the span of 5 years, they managed to optimize the design such that one electrical bus was identically serviceable as one diesel bus (World Resources Institute, 2019). Now, the city has over 16,000 operating electric buses. This has helped reduce carbon dioxide and other pollutants by about 48% in the city, alongside almost 15 thousand dollars in savings annually (WIRED, 2020). Many other cities have adopted these sustainable solutions with similar results, indicating that solving the issue by challenging current ways of operations can breed numerous operational, environmental, and economical benefits.

THE BATTLE OVER HIGHWAY 413



CALEDON, ON



A sign in Caledon, Ontario made by residents against highway 413 from being built

"When it comes to waste management, I want to incorporate sustainability so I buy better products for the environment and the economy. I think this is a huge issue because of global warming and also products that are unethically produces. I want to buy better products at the store so I can incorporate more sustainability into my life."

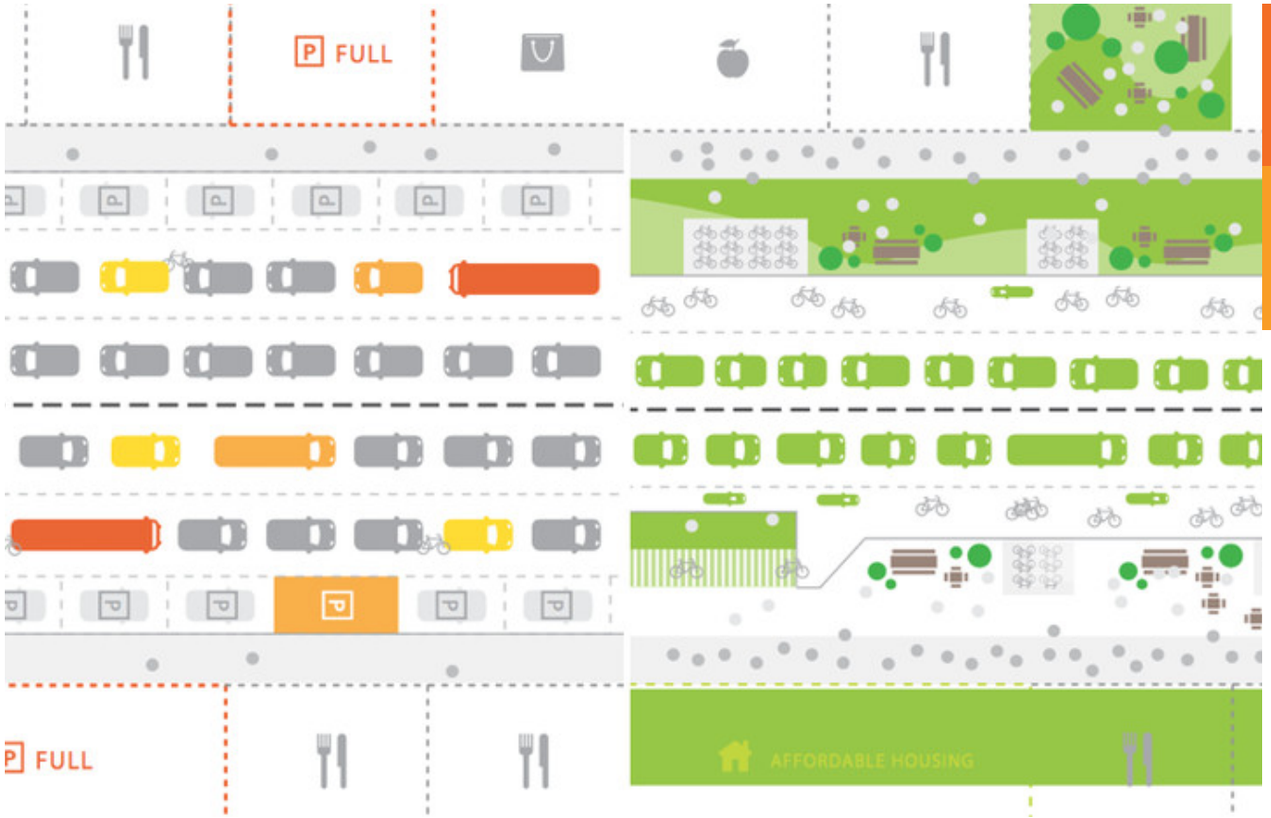
-Indusha Menaji Semba Kuttiarchchige

RESILIENT INFRASTRUCTURE
CANADIAN ENGINEERING GRAND CHALLENGES

The Ontario government has proposed highway 413, a 4-6 lane highway. It is expected to be 59km long with 11 interchanges to municipal roads and provide easier access to other 400 series highways. It would extend from Milton to Vaughan and cut through the lower part of Caledon. Some residents of Caledon are strongly against the building of highway 413. Caledon is home to 71,000 people and has great farmland, it is one of the largest municipalities in Ontario. The environmental issue at hand is that research projects that this highway would add 17.4M tonnes of greenhouse gas emissions by 2050. It also states that highway 413 may not actually improve congestion significantly instead it would just add new cars to the road. From CIVE 230 we know that over 80% of total CO (primary pollutant) emissions come from the transportation sector. Increased CO emission is dangerous for the residents of Caledon, CO interferes with the blood's ability to carry oxygen from the lungs. When analyzing it from a sustainable city perspective including ecology, economy, and equity. Building this highway may improve the economy by increasing more individuals to move to Caledon, unfortunately it will significantly impact the ecology. Emitting more GHGs from vehicles (Scope 1 emissions) into the atmosphere will create a bad ozone, this is detrimental for the farms in Caledon because it has a negative impact on the yield and quality of important crops. Another ecological impact is that it would affect 85 watercourses, 10 of these stream crossings are high priority locations because they are in deep valleys. Some politicians are also against this idea because encouraging urban sprawl is not sustainable.

IMPLEMENTING A SMART CITY PLAN TO RECLAIM LAND FROM CARS

SAN FRANCISCO, UNITED STATES



An illustration from San Francisco's Smart City proposal, to show how the land used previously by cars will be reclaimed for parks, housing and shared/autonomous vehicles.

What can Caledon learn from San Francisco?

This is relevant because San Francisco is increasing resource-use efficiency and switching to environmentally sound technologies including autonomous electric cars. Caledon can learn to adapt sustainable means of transportation instead of building a highway that would increase GHGs by 17.4M tones by 2020 and is not guaranteed to improve congestion. In order for it to be a sustainable city it needs to find a solution that meets the needs of the economy, ecology, and equity. They should consider using the strategies San Francisco has implemented including incentivizing ride sharing and utilizing autonomous electric transportation. This would help reduce existing congestion and provide benefits to the farm land around the area due to reduced GHG emissions.

One of the methods that cities have been addressing the issue of large-scale carbon emissions from transportation is by introducing electrical buses into the communities. Not only do they reduce green house gases, but electrical buses also produce fewer emissions of other pollutants, are quieter and create a more comfortable environment for pedestrians and cyclists (CBC, 2020). They help provide cleaner air for communities and reduce noise pollutants. Many buses also charge in the nighttime, during off peak times which helps manage peak demand and supports renewable energy integration (Advanced Energy, 2020). In Chinese cities, electrical buses account for 99% of the buses on the road today. China was a pioneer in demonstrating the sustainability benefits of this solution. In the city of Shenzhen, they initially needed two electric buses to account for the service quality of one diesel bus. However, in the span of 5 years, they managed to optimize the design such that one electrical bus was identically serviceable as one diesel bus (World Resources Institute, 2019). Now, the city has over 16,000 operating electric buses. This has helped reduce carbon dioxide and other pollutants by about 48% in the city, alongside almost 15 thousand dollars in savings annually (WIRED, 2020). Many other cities have adopted these sustainable solutions with similar results, indicating that solving the issue by challenging current ways of operations can breed numerous operational, environmental, and economical benefits.

IMPLICATIONS FOR THE FUTURE OF THEIR PUBLIC TRANSPORTATION



INNISFIL, ON



Future Congestion in Innisfil, ON

“Sustainability in my personal life is present by not focusing on only one aspect of my life and having a balance to minimize the effect of burning out in school and life. In first year I personally experienced it because of my lack of attention to anything outside of school, realizing that wasn't sustainable for 5 years.”

-Jaskaran Kainth

RESILIENT INFRASTRUCTURE

CANADIAN ENGINEERING GRAND CHALLENGES

Innisfil is a municipality located in Simcoe County in the greater Toronto area that has concern about its current state of development in transportation. Without the presence of a public transportation system in Innisfil, the municipality needed to come up with a solution for the demand of residents to get to places affordably without access to personal vehicles. Senior citizens and young adults will mostly benefit from public transportation, to ensure they do not face any problems with their day-to-day life. The municipality’s solution was to partner with Uber, an online rideshare service and local taxi services for certain accessibility concerns. Their solution was to price certain hubs that people would travel to regularly as a set fair and provide various discounts for different locations. The municipality says ridership was high with 85000 trips in 2018, so the local community had taken advantage of these modern public transportation incentives. This unsustainable solution was only temporary because as ridership increases, the more the city has to pay for incentives, so as the population increases their budget for public transportation will have to as well. Their concerns for bus routes to accommodate the population came from the setback of the large distances between each stop due to sparse population densities. This temporary solution brought on issues with traffic congestion, seen to be increased by 62% from 2010-2016, which comes with increased emissions problems. As they have reached budget peaks for the incentives they could provide, a monthly limit on how many rides people can do each month incurs additional fees for residents making it less affordable.

DRPT (DEMAND RESPONSIVE PUBLIC TRANSPORTATION)

DENMARK



Oresund trains at Orestad Station in Copenhagen, Denmark

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

11 SUSTAINABLE CITIES AND COMMUNITIES

The country of Denmark has implemented viable solutions for their rural population for public transportation in the form of Demand Responsive Transportation. According to an article posted by EMTA, in 2018 6.3 million passengers were transported with DRT and 1.1 million of them with DRPT, which relative to their population at the time of 6.3 million, is a significant amount of people. The DRPT method was implemented where infrastructure is already developed to save money and reduce emission into the atmosphere. It works by booking on the phone or online, so that carpooling is maximized with time saving still being considered. Copenhagen is the capital city of Denmark, and its transportation system is developed to allow for public transportation to be the fastest to move from city to city. According to VisitDenmark, the metro is the best option for transport if you are located near the center of the city. Denmark's environmental solutions have been successful, also considering Copenhagen airport has been CO2 neutral since 2019. Innisfil has implemented a version of this because uber does provide the same type of service, however, DRPT works best when planning ahead of time. Therefore when you book it can accommodate the most amount of people with the least number of vehicles which will be beneficial in keeping costs down and environmental impacts down. This way if anyone without access to a personal vehicle needs to get somewhere or to a common hub, if they book earlier larger shuttles can accommodate more residents. With future city planning for home developments, it can be made more efficient for pedestrians to walk to a bus stop or a collector's location to pick up the riders of DRPT services, therefore making it more efficient moving between stops.

What can Innisfil learn from Denmark?

Denmark has focused a great deal on environmental sustainability while still meeting the needs of their rural population. With an adaptation to Innisfil's approach to using Uber it can be significantly more sustainable in terms of saving residents money with incentives and reducing environmental impacts. If the incentive was only given when enough time for a carpool was possible, it will encourage residents to plan ahead. An investment in systems to optimize the ridesharing will make a significant impact in the goal for sustainable transportation.

TRAFFIC-RELATED AIR POLLUTION (TRAP)

WINDSOR, ON



Traffic congestion in Windsor

It is undeniable that today's transportation system brings us great convenience; however, the growing amount of car and large truck vehicle fleets and increasing traffic congestion have amplified concerns about exposure to poor quality air from traffic sources (Curran, 2014). The emission from vehicles and other transports results in traffic-related air pollution (TRAP). TRAP means air pollutants emitted from motor vehicles, including carbon monoxide (CO), carbon dioxide (CO2) … as well as mobile source air toxics. (Curran, 2014) In Canada, traffic-related emission gradients exist up to 300–500 meters from major roadways, nearly one-third of the population resides within 100 meters of a major road or 500 meters of a highway (Curran, 2014). Canadian reports show that traffic-related emissions can influence the health of people who living close to major roads, they have a mortality rate advancement of 2.5 years and a significant increase in all-cause mortality of 18%. These severe health effects might result from the higher intake fractions and subsequent doses for residents living near roadways (Jerrett et al., 2009). A report published by Rebecca Gao in 2020 shows that Windsor is the worst Canadian city for air pollution. Windsor is a city located along the Detroit River; it has an average of 8.3 micrograms of PM2.5per cubic meter (Toronto has 7 micrograms of PM2.5per cubic meter). Individuals there have the potential possibility to be attacked by lung or heart disease (Greer, 2020).

“Using less plastic is my sustainable action since plastic pollution is a very serious problem now. In my daily life, I always take my bags to the grocery store, and I avoid buying over-packaging items because it will cause more waste of plastic. Also, I usually make a shopping list before I go to a supermarket, it not only gives me a clear plan, but it also helps me avoid purchasing extra food.”

-Qianye Chu

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

VEHICLES CONTROLLING POLICY

BEIJING, CHINA



The Fourth Ring Road in Beijing in a morning rush hour

11 SUSTAINABLE CITIES AND COMMUNITIES

Beijing is a quiet busy city; it has a huge traffic capacity every day. Air pollution is used to be a major issue that affects the health of residents. To relieve the traffic pressure and better the air quality, the Beijing government instituted a combination of policy measures to control private vehicle use. During the Olympic Games in 2008, the city implemented the Odd-And-Even (OAE) policy such that vehicles can only get on the road alternately based on the odd/even of last digits on their license plates. (Sun et al., 2004) This measure is already in place in a few other cities around the world, such as Bogota and Mexico City (Sun et al., 2004). This restriction significantly reduced particulate matter and a severe air pollutant in Beijing. Based on the point estimates which indicated that the every-other-day restrictions reduced particulate matter by 18% and one-day-a-week restrictions by 21%. (Viard & Fu, 2015) In addition, according to the article (Li & Guo, 2014): "These regulations will almost pull 2.0 million vehicles off the roads across Beijing (50% private cars and 70% vehicles owned by state and city authorities). Over about 98% of vehicles complied with the policy". Clearly, this data shows that the Beijing government successfully control the air pollution-related to traffic by reducing the traffic flow.

What can Windsor learn from Beijing?

These targets are guides to mitigate the traffic issue and air pollution; more important is that these targets can accelerate the development of sustainability in Canada.

TRAFFIC CONGESTIONS ARE A PROBLEM WE CAN'T IGNORE

VANCOUVER, BC



Traffic Congestion on Cambie Street by user jdashl on pixabay is lisenced under Simplified Pixabay License

"I try not to waste any food by buying and cooking exactly how much i eat."

-Justin Jiang

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Vancouver is possibly the most beautiful city in the world. The most prominent feature of the city is the gentle embrace of nature. Down every street you glimpse an arm of the Pacific(Travel, 2017). Stanley Park, a 1000-acre urban green space (Travel, 2017), is surrounded by the English bay on three sides. Snow-capped peaks sprawl across the horizon to the north. When spring comes, cherry blossoms smudge the streets with a delicate shade of pink. However, all of these lovely sceneries come with a significant downside: Traffic. Vancouver has been ranked the most congested city in Canada and the third most congested city in North America. This means that Vancouver drivers have to face worse congestion than the people in larger cities such as Toronto, New York, or San Francisco. In fact, an average Vancouver driver wastes 149 hours sitting in traffic per year. (Kendra Mangione & Mangione, 2020) It would be bad enough if all traffic jam does is waste everybody's time. To make the situation even worse, vehicle traffic has been linked with excess morbidity and mortality rates for drivers, commuters, and individuals living near major roadways. Traffic congestion also increases vehicle emissions of various greenhouse gases and pollutants such as VOCs and NOx. (Zhang & Batterman, 2013) Even through Vancouver has made efforts towards solving the traffic issue such as adding bike lanes, expanding public transportation network, and adding one lane ways in the busiest part of the city; Vancouver still has a long way to go before it can claim that its traffic congestion problem is solved. Meanwhile, more cosmopolitan cities such as Paris have been able to control their traffic more effectively. Learning from these cities can help Vancouver in its journey towards a sustainable future.

SUSTAINABLE CITY PLANNING MADE PARISIANS WALKERS

PARIS, FRANCE



Paris, small street scene, city, travel, festival, 14 july, tourist, architecture, building exterior, group of people by pxfuel under creative commons lisence

What can Vancouver learn from Paris?

Vancouver has several problems with its urban planning. First of all, the residential zones and commercial zone are too far apart. Even completing basic grocery shopping requires a 10-minute trip by car in many areas of Vancouver. Secondly, the population density in Vancouver is too low. Lower population density means that people are spread apart, making the average trip longer. Lastly, expanding the public transportation network in Vancouver will also reduce some of the demand for driving a car.

Traffic congestion is a problem looming over every major city in the world. However, Paris solved its traffic congestion problem by having a pedestrian centric approach to urban planning. “This agility to mobilize urban space, which is by definition rarer and in higher demand in a very dense city, to serve pedestrians endures to this day among French engineers, urban planners and landscape architects” is the guiding philosophy of the urban planning in France. (de la Cité, 2018)This approach to urban planning priorities shortening the travel length of an average trip to less than 1 KM and implementing plenty of public transport options to accommodate for longer trips. To shorten average trip length, French urban planners opt for a denser population density and makes sure that each community have a complete set of supporting infrastructure such as parks, clinics, schools and business zones so that people can complete their everyday needs without taking long trips. (de la Cité, 2018)The result of this pedestrian centric approach to urban planning is that Parisians complete most trips by foot. Based on a French household survey in 2010, only 10% of all trips taken in the city of Paris are completed by car, 53% of all trips taken in the city of Paris are completed on foot, and 45% of all trips taken in the île-de-france region have a length shorter than 1 kilometer. (de la Cité, 2018) By designing the city of Paris around the idea that most trips should be within walking distance, people’s reliance on cars is greatly reduced and traffic congestion is no longer a problem. Parisian’s preference for walking is a hallmark of sustainable urban planning.

CHAPTER 9: SUSTAINABLE ENERGY



Wind Turbines/Pixabay

CHAPTER INTRODUCTION

Other sectors of the built environment that are presented in this module represent energy and water flows. This module highlights the criteria for sustainable energy use, and sustainable water systems, in addition to the urban green that is a source of ecosystem and life, and a sink for greenhouse gas emissions.

Learning Outcomes

By the end of this week, you will be able to:

- Estimate electricity generation inefficiencies and losses
- Describe design strategies for sustainable energy systems with examples
- Identify functions of urban water systems
- Describe sustainable water, wastewater and stormwater management systems with examples
- Describe benefits of urban forests with metrics
- Interpret the guidelines for urban street tree planting
- Quantify the costs and benefits of urban forests
- Recognize examples of green roofs and urban agriculture

THE EFFECT OF THE DIVERSION PROJECT ON CREE COMMUNITIES

CHURCHILL RIVER, MB



Flooding's impact in rural areas and communities

"One way I incorporate sustainability into my personal life is my choice to recycle. I do this so my trash can be remade into a new product allowing for less of those resources to be harvested from the earth. Which therefore allows for future growth and sustainability."

-Aaron Fraser

SUSTAINABLE INDUSTRIALIZATION

CANADIAN ENGINEERING GRAND CHALLENGES

The Churchill River Diversion project began operation in 1977. The projects main scope was to divert water from the Churchill River into the Nelson River, where Manitoba Hydro had large generating stations to produce approximately 75% of Manitoba's electricity. Originally operating under an interim license, Manitoba Hydro was allowed to divert water from the Churchill river into Nelson River and allow for impoundment of water in Southern Indian lake and Rat River. The interim license limits Manitoba Hydro to divert a maximum of 850 cubic metres/seconds and a maximum rise in Southern Indian lake of 3 metres. In 1986, Manitoba hydro implemented their Augmented Flow Program in the CRD project. The Augmented flow program signed annually by the Minister of Conversation of Climate allowed for Manitoba Hydro to deviate from the original levels outlined in their Interim License (Province of Manitoba). This has affected the range of lake levels on Southern Indian lake.

Although Manitoba hydro is benefiting from this diversion, Northern Manitoba Cree communities in the area are drastically affected by this project. According to locals of the community it has affected their environment in three main ways. The project has: flooded 800 square kilometers of forest, destabilized the shorelines causing for them to cave and contaminate the water with debris and sediment, and wiped out the lake's fishery (Maclean, 2019). Currently the O-Pipon-Na-Piwin Cree Nation occupy the land by Southern Indian Lake consisting of 235 families in private households and an average family size of 4.9 people (Community Economic Profile). The Chief of this community describes in a united Nations meeting how the fishing in the area has been depleted due to the flooding (Maclean, 2019).

HARVESTING HYDRO POWER WITHOUT DAMS AND IMPOUNDMENTS

SHETLAND, UNITED KINGDOM



The power behind tidal movements

What can Churchill River learn from Shetland?

As seen from the Lisheen Mine in Ireland, the use of multi-layered liners is effective at mitigating leakages from tailing ponds and preventing the groundwater of nearby communities from being negatively impacted. Through this, the tailing can sit in ponds longer until they have broken down and can be properly disposed of. Fort McMurray should be able to make sure the companies are using this technology to alleviate the impact of the oil extraction process on its inhabitants not only on living things but also the water, the sustainer of life.

Just off the islands of Shetland Scotland a new type of Hydro power was implemented back in 2016 to help provide the islands with green energy. This source of Hydro power does not require the construction of dams in order to create massive impoundments to power downstream generating stations. Therefore, not interfering greatly with the area's shoreline and environment. The islands have utilized the power of the ocean's tides to power 4, 100 kW turbines with plans to implement two more in the coming years (Nova Innovation). The turbines are connected to a tesla battery which created the world's first grid-connected tidal energy power station. With the turbines being 9 metres in size and located 20 metres below the water surface (Skinner, 2020) they have a very minimal effect on the ocean's surface and on the environment below the ocean's surface. The company, Nova Innovation, who implemented these turbines have analyzed 20 000 hours of footage and has not seen a fish struck by the blades of the turbines (Skinner, 2020).

Shetland is a group of islands located north east of Scotland and has a population of 21 880 people in 2006 (Britannica, 2020). Citizens on the islands use this energy to power some of their homes and even charge their electric cars with a new electric care charging port fully powered by the tidal energy (Renews, 2020). Multiple companies from around the world have already constructed or are working on more powerful tidal turbines. Tidal power can be very powerful, and many see it as a large part of the futures energy plan.

THIS NOT SO LITTLE LIGHT OF MINE. GREENHOUSE LIGHT POLLUTION

KINGSVILLE, ON



Greenhouse light pollution during night time hours.

“In my personal life I try to incorporate elements of sustainability by not using single waste plastics whenever possible, shopping at uptown Waterloo's Zero Waste Bulk, biking instead of driving, repurposing plastic containers, etc. I also try to make informed decisions while shopping, such as buying locally or fair trade, buying produce that is in season, and shopping in large quantities to minimize packaging.”

-Serina Ykema King

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

There are many factors to consider when investigating building sustainability. One such factor is energy usage. According to the International Energy Agency only 2% of building energy consumption can be attributed to lighting. However, despite the small fraction of energy devoted to providing lighting, the impact of lighting on the environment is quite extensive. Kingsville specifically, a town with a many greenhouses and a large agriculture sector, has struggled with light pollution which can be attributed to the extensive amount of light shining out from greenhouses 24 hours a day. The impact of light pollution has a far breadth. Animals for instance such as birds, and even see turtles along the coast, have observed changes in flight and migration patterns due to the constant light in their habitats which disorients their natural sense of direction. In addition insect populations, a primary food source for birds and amphibians, are drawn to artificial light sources at night caused by light pollution therefore having a great impact on surrounding ecosystems. Aside from local wildlife, humans have also been known to be affected by light pollution through imposing shifts in humans’ 24 internal clock more commonly referred to as the circadian rhythm. The city of Kingsville has taken action to reduce light pollution. By-Law 96-2020, effective October of 2020 requires 100 abatement of light sources used for the cultivation of plants during dark hours. This by-law while welcomed by some became highly controversial as Kingsville and its surrounding communities rely heavily on the wellbeing of the agriculture industry. Something proving more difficult during winter when lower temperatures and less day light hours make growing produce and other plants more difficult. Light pollution in Kingsville is a challenge worth shedding light on. With many stakeholders at risk, solutions to light pollution must consider the environmental, social and economic impacts of light pollution moving forward.

STREETLIGHT DIMMING TO REDUCE LIGHT POLLUTION

TUCSON, UNITED STATES



Tucson Arizona city skyline at night.

What can Kingsville learn from Tuscon?

The cities of Kingsville and Tucson have both taken action to either mitigate the impact of light pollution. Kingsville took legal action to reduce light pollution but faced resulting economic challenges. They could learn from Tucson in finding a compromise, such as reduced light (not full abatement) after midnight, to help reduce the effects of greenhouse lighting.

A major contribution to light pollution globally is the vast amount of light emanating from cities. Whether it be street lights or lights shining from buildings, the constant usage of artificial light has a larger effect on the brightness of the night sky than one might think. A 2020 study from the Society of Light and Lighting shows that street lights specifically contribute 18% of the total radiance observed from Tucson space satellites after midnight. In the study strategies including dimming streetlights from 90% to 60% of rated power for 10 days after midnight resulted in a 5% drop in total radiance. The goal of the study was to show how “smart cities” can implement small changes to decrease the overall impact of light pollution in the surrounding environment. Tucson, a city with a population density of 2,330 people per square mile is a mid sized city with less population density compared to a city like Waterloo with a population density of 3,700 people per square mile. Therefore, it can be assumed that the light pollution caused by street lights in a city like Tucson is not too far off or less even, than the average street light pollution in a Canadian city such as Waterloo as a more highly densely populated city would require more lighting infrastructure and such to accommodate the demands of its residents. The reduction of street light radiance after midnight seems like a feasible way to reduce light pollution in major cities. Especially given the need addressed in an article by Professor Paul Bogard of James Madison University, where he claims that light pollution is growing at a rate of 20% per year in some regions around the world. While just a small act, dimming street lights in Tucson Arizona has shown how impactful little changes can be to the overall health of the environment and sustainability of cities.

THE UNSUSTAINABLE TOLL OF COAL

LINGAN, NS



Lingan Generating Station (Heaton, 2006)

Burning coal is notorious for being a driving force of climate change. Like many unsustainable energy sources, coal-fired power plants are known for releasing heat-absorbing gases such as Carbon Dioxide. Thus, leading to the increasing global temperature trend seen since the Industrial Revolution. Climate change due to the high consumption of coal has been linked to an increase in intense weather events and rising sea levels. Coal consumption is also a contributor to air and water pollution due to toxins and waste released from the electricity harnessing process, some of which include Mercury, Selenium, Lead, and coal ash. Communities living near these plants are at higher risk for respiratory illnesses as well as contaminated water resources (The Canadian Encyclopedia, 2006). Although it is clear the impact coal-fired energy plants have, Canada continues to depend on this unsustainable energy source, especially in the municipality of Lingan.

Lingan, Nova Scotia is home to the Lingan Generating Station, one of Canada's largest coal-powered electrical generating stations. With a generating capacity of 620 MW, the coastal municipality contributes to 55% of coal plant generated energy in the province. A decrease in coal burning practices have been seen throughout the province, from 80% in 2007 to 55% in 2019. Yet, due to its proximity to the Generating Station, Lingan still heavily relies on this unsustainable energy source. Such decisions pose health risks for the 261 residents of Lingan, as removing all coal power plants in the province by 2030 could prevent "89 premature deaths, 8,000 asthma episodes and 58,000 days of breathing difficulty for Nova Scotians" (Gunn, 2019). Hence, although energy demands are met for the municipality, it becomes clear that steps towards the consumption of sustainable energy sources must be made to ensure the wellbeing of current and future Lingan residents.

"Whenever I go out, I try to use greener methods of transportation. Reusing old take-out containers to hold my lunches has been another way that I've been able to ensure that I'm not over-consuming resources where it isn't necessary. Finally, my family and I have tried to reduce our water consumption by collecting rainwater and using it for our plants."

-Harshini Jeevaharan

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

WINDY DAYS AND SUSTAINABLE ENERGY PRAISE IN ROCK PORT, UNITED STATES



Wind Turbine in Rock Port, Missouri (back stage, 2008)

What can Lingan learn from Rock Port?

Rock Port, Missouri and Lingan, Nova Scotia are similar in that they act as major producers of energy for surrounding neighborhoods. Although they do not share the same geographical characteristics, both experience reliable amounts of wind throughout the year. Through harnessing wind energy, the town of Lingan can ensure that current and future citizens will have access to safe, affordable, and clean energy and help meet SDG 7. By learning from Rock Port, Lingan too can hopefully become a 100% renewable city in the near future.

Communities can decrease their carbon footprints by investing in sustainable energy, one of the most effective being land-based wind energy. Wind power is generated through wind turbines that rotate due to the air pressure difference experienced on both sides of the blade. This mechanical process ensures that a built-in generator can convert kinetic energy into electrical energy. The electrical energy will then pass through a transformer, allowing for it to be consumed locally or by region through power grids. Many land-based turbines can generate approximately 6 kwh of electricity annually, which meets the energy requirements of 1500 households. Hence, making it the ideal source of energy for towns such as Lingan, Nova Scotia. Although the average wind turbine can range from being 35 - 50% efficient, such efficiency ensures that electricity can be generated instead of wind flowing directly past the turbine (Good Energy, n.d.). When adopting this energy source, it is important for municipalities to ensure that turbines are built in regions where reliable amounts of wind blow throughout the year such as in Rock Port, Missouri.

To mitigate climate change, the town of Rock Port, Missouri has become the first 100% wind-powered region in the United States of America. Located on the outskirts of town, the four wind turbines generate approximately 16 million kilowatt hours each year. As Rock Port's 1300 residents consume 13 million kilowatt hours annually, all excess generated energy is sold to neighbouring communities (University of Missouri Extension, 2008). Geographically, Missouri is near the U.S. Wind corridor, which has allowed the state to be home to over 500 turbines. The wind speed is especially high in Rock Port, which can reach around 10.0 m/s at 80 m, making wind energy a reliable energy source for the town (Missouri Department of Natural Resources, n.d.).

DIESEL DEPENDENCE

RANKIN INLET, NU



Rankin Inlet Diesel Power Station

"Most of the sustainability in my co-op jobs have been about stormwater management. In most of the sites we must maintain the pre-development storm to the post-development storm such that the contribution to the existing watersheds remains the same. We have used low impact development techniques such as soak away pits or infiltration trenches to ensure that those creek systems are maintained."

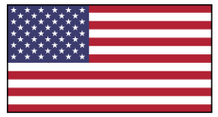
-Drew Cobean

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

In the sparsely populated Canadian territory of Nunavut, the population almost has a complete dependence on fossil fuels. Due to the distance between communities and low population density there is no centralized power grid, resulting in a reliance on predominantly diesel fuels (Fong et al., 2021). This means that each of Nunavut's twenty-five communities rely on their own individual power plant that distributes the power throughout their own micro-grid, a process significantly different than the majority of Canada, where grids between communities are interconnected (Qulliq Energy Corporation, n.d.). The dependence on imported diesel fuel threatens the sustainability of these communities with regard to not only energy, but affects the economy and environment as well. The combustion of diesel in power plants negatively impacts air pollution and releases greenhouse gases into the atmosphere accelerating climate change. Additionally, the annual purchase of diesel fuels has strained the economy of the territory. Yearly, the government spends an estimated twenty percent of its budget on energy (Pearce, 2015). Rankin Inlet is the second largest community in Nunavut with a population of 2,842 as of 2016. Like all communities it has its own diesel plant to heat and produce energy. In 2017, Rankin Inlet's five diesel generators required over fourteen million litres of diesel fuel. Based on this overall consumption of electricity, each resident averaged 24 tonnes of CO_2 equivalent per year, 60% more than the average Canadian citizen. Transportation of the fuel was not considered in this analysis, and would further increase the amount of CO_2 equivalent emitted into the atmosphere as Rankin Inlet is only accessible by air and water (Byrne, 2018). Overall, Rankin Inlet needs to curtail its diesel reliance and invest in sustainable energy sources to become more sustainable.

RENEWABLE ENERGY BEARS MAJORITY OF POWER



KODIAK, UNITED STATES



Wind Turbines on Pillar Mountain

Small isolated communities face sustainable energy issues all over the world. Without connection to a major grid system, they cannot rely on importing power from the major power plants in their respective countries. This typically increases the price of energy and often results in unsustainable energy production such as diesel. To combat this, some areas have created their own electric grid producing power from almost strictly renewable resources. Wind power from turbines, solar power from photovoltaic cells, and hydroelectric power from turbines have all been used in other remote cities (Zerehi, 2016). Kodiak, Alaska, a small town on Kodiak Island off of the southern coast of Alaska, is a prominent example of this. Although it is only accessible by air or water, and has a population of just 5,968 as of 2018 the island is 99.7% renewably powered as of 2015 (EcoWatch, 2015). The community uses their natural resources to their advantage. Kodiak, situated on the coast, experiences a great deal of wind. To exploit this, turbines on the nearby Pillar Mountain were installed to produce energy. Although they were effective the power produced was unpredictable and depended on weather conditions. In their transition away from diesel, hydroelectric turbines were then installed at Terror Lake. These turbines now produce the majority of the power in Kodiak, supplanting the previous reliance on diesel (Waldholz, 2017) The community continues to invest in renewable energy systems by upgrading its hydroelectric turbines, adding more wind turbines, and utilizing batteries to respond to changes in power production from wind fluctuations. The town is now able to produce its own off-the-grid power at cheaper prices than mainland Alaska in a sustainable and environmentally friendly manner (Roe, 2021).

What can Rankin Inlet learn from Kodiak?

Rankin Inlet can learn from Kodiak, Alaska through several different key ideas. First, Kodiak gradually transitioned towards renewable energy. Although it is an attractive idea to make a sudden switch, the progression from diesel combustion to renewable hydroelectric and wind energy took over a decade in Kodiak. Rankin Inlet could follow suit, beginning with small renewable power generation to supplement their existing diesel plants ensuring residents have a dependable source of energy during the conversion process. Secondly, Rankin Inlet can make use of its natural resources. Hydropower, tidal energy, and solar and wind resources are all potential sources of power (Byrne, 2018). Overall, Rankin Inlet should look towards Kodiak's effective model for producing economical, renewable and sustainable energy.

SUSTAINABLE WITH DEPENDING ON BLACK GOLD, OIL?

LEDUC, AB



Aerial view of Leduc on a foggy morning

“Sustainability is the ability to maintain the quality of human life at a certain rate that does not compromise the natural environment for the future generation. I think the engineers should play an important role in sustainable development. They can plan and build projects that preserve natural resources, are cost-efficient and support natural environment and human living with a responsibility.”

-Sean Cho

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

Alberta, Canada’s largest city oil-producing province, provides over 82% of total production in Canada (Canada Energy Regulator, 2021). It is hard to precisely determine the percentage of the primary electricity source in Leduc; however, if we examine the average rate of the main electricity source in Alberta, it is possible to face the main issues in Leduc. According to research from the Canadian government, in 2016, Alberta generated 47.4% of its electricity from coal, 40.3% from natural gas, and 12.3% from renewables (Canada Energy Regulator, Canada’s Renewable Power Landscape 2017 – Energy Market Analysis, 2020). As the city of Leduc is in Alberta, its economy is mainly based on the oil and gas industry with more than 1400 businesses (City of Leduc, 2017).

Therefore, the city of Leduc is one of the cities where they rely on non-sustainable energy such as crude oil and coal though it is a small city with a population of 29,993. This would likely cause significant pollution in air quality. Oil and gas production, processing and use also release massive quantities of greenhouse gases, especially methane and carbon dioxide (E.Allison & B.Mandler, 2018). A high concentration of greenhouse gases can increase the concentration of particular matter 2.5 microns (PM 2.5). According to the IQ-Air research, the historical air quality for Leduc shows that most days are over the WHO exposure recommendation. The highest PM 2.5 concertation was 132.6 on July 17th (IQ Air, 2021). If the city of Leduc continues to depend on oil and coal, the air quality will get worse, and it will have severe pollution in the city.

INCREDIBLE! 100% SUSTAINABLE ENERGY CITY,

BURLINGTON, UNITED STATES



Night View of Burlington with 100% Sustainable Energy

With a 2020 population of 43,063, Burlington is the largest city of Vermont in the United States (Review, 2021). In 2014, the City of Burlington achieved 100% of its electrical needs from renewable resources. The city's clean energy journey started back in 1984 when the McNeil Generating Station, a 50MW biomass plant that uses sustainable local wood, commenced operation (Burlington Department, 2020). Then, with the installation of the Winooski One hydro-electric facility at the Winooski River, four large wind turbines on the nearby Georgia Mountain, and rooftop solar PV on the airport, high schools, and BED, Burlington Electric Department, the City of Burlington became the first city in the US that generates its electricity entirely from renewables (CDP, 2017).

On average, most residential customers use less than 450 kWh per month and incurred $75 in monthly electric bills, which is less than most cellular telephone bills (Burlington Department, 2020). Due to the impacts of COVID-19, BED proposed a 7.5% rate increase in 2012, and it is the first-rate increase in 12 years (Burlington Electric Department, 2021). Even after the rate increase, BED's total rates remain low compared to Vermont, and New England averages and these changes will increase the average residential bill by only $4.92 per month (BED, 2021). However, BED doesn't stop there and has been on track to aim for the city to be a net-zero carbon community by 2050.

What can Leduc learn from Burlington?

The city of Leduc can learn from Burlington's approach to solving environmental problems. Switching sources relying on crude oil to sustainable energy can resolve the air pollution and decrease the PM 2.5 concentration. To sum up, it is not too late to use sustainable energy to clean up Leduc's air quality.

STRUGGLES TO SWITCH TO SUSTAINABLE ENERGY

YELLOWKNIFE, NT



Cold climate in Yellowknife requiring heating (Mike Tidd, 2017)

“Sustainability is the use/consumption of resources without it affecting the future source/source/ number of resources. For example, we can use solar energy as a resource, and it won't take away from future solar energy. Engineers play a big role in sustainable development because engineers are a key part of technological development/ advancement. Thus, when engineers are designing new technologies, they should consider the factors pertaining to sustainability.”

-Marcus Veals

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

As we progress further into the 21st century, the struggle to switch to renewable energy sources continues to be prominent throughout many communities. This is especially true when it comes to large communities in the Northern areas of Canada, as vast amounts of energy are required for heating. Small communities have been able to rely on sustainable energy sources, with the most common of those sources being hydroelectricity. However, larger communities have many more homes and businesses that require heating, resulting in a greater reliance on unstainable energy sources, since they lack enough sustainable energy to supply the necessary power.

One of these instances of a larger community that still carries a deep reliance on unsustainable energy is the city of Yellowknife. Yellowknife, located near the Northern shore of Great Slave Lake, is the capital of the Northwest Territories. With numerous different attractions, it is the most populated city in the Northwest Territories with a population of around 20,000 residents (About Yellowknife, n.d.). Yellowknife carries a cold climate that results in a great need for heat energy. In order to fulfill this need, Yellowknife has a heavy dependence on heating oil, with use of diesel and propane fuel also being prominent. Energy required to heat buildings takes up 69% of energy consumption in Yellowknife, thus resulting in a major use of these unsustainable energy sources. These energy requirements resulted in green house gas emissions of 305,000 tonnes of carbon dioxide equivalent in 2013 (Energy, n.d.). Thus, Yellowknife is facing severe problems when it comes to transitioning to sustainable energy sources, specifically for heating purposes.

PAVES THE WAY TO A SUSTAINABLE FUTURE

REYKJAVÍK, ICELAND



A geothermal energy plant in Iceland (Ásgeir Eggertsson, 2004)

What can Yellowknife learn from Reykjavík?

In summary, by following Iceland's example, sustainable heating systems and renewable geothermal energy can be used to vastly decrease the carbon footprint of Yellowknife and other cities.

As sustainable energy sources continue to be deemed the way of the future, Reykjavik leads the charge with its sustainable heating system. Reykjavik is the capital of Iceland with a population of around 123,000 people and with the northernmost capital of the world, they live in a typical cold climate area (Reykjavik: Everything you need to know, n.d.). However, even while living in a climate that requires heating often, Reykjavik has done an excellent job in finding renewable energy sources. During the oil crisis of the 1970's, the Iceland government searched for other ways to heat their homes, which led them to the use of geothermal energy (Aldred, 2008). Geothermal energy provides Iceland with a renewable energy source that is obtained through the utilisation of the heat energy generated and stored in the Earth (Geothermal Energy, n.d.). By drilling into the Earth's surface, geothermal energy is obtainable. Reykjavik has then used this energy to heat homes via district heating, which makes use of pipe systems and an energy source to heat all buildings within a community or neighbourhood. This system of district heating also reduces energy waste since excess heat energy is used to heat other buildings or to heat water as well. District heating can be applied with various energy sources, but Reykjavik uses renewable geothermal energy, thus making this entire heating system carbon free. Thus, Iceland is setting an example for all countries by making use of a renewable, carbon free source of energy to provide heating for 90% of their homes.

PETROCHEMICAL POLLUTION CAUSES HEALTH CONCERNS

SARNIA, ON



Oil Refinery in Sarnia, Ontario

Sarnia is a city located in Southwestern Ontario with a population of 74,293 (City of Sarnia. n.d.). 40% of Canadas chemical industries –62 facilities and refineries–are clustered in the area which has become known as "Chemical Valley," the central driver of Sarnia's economy (Rang & MacDonald, 2007). The residents of Sarnia, especially the Aamjiwnaang First Nations are facing serious health concerns as a result of the industrial pollution in the city's water and air. Although, the province has recently agreed to study the human health effects resulting from the petrochemical industry; residents do not believe enough action has been taken into account. An incident in August 2012 resulted in the spill of carcinogen ethylbenzene into the river; however, residents did not receive a warning from the Ontario Ministry of the Environment and Climate Change until three days after the chemical spill. The same situation occurred in 2003 after a spill of carcinogen vinyl chloride (Baxter, 2020). Benzene is another carcinogen which remains in the air as a result of petrochemical plant emissions; it is a known cause of acute myeloid leukemia (AML). Sarnia was at the top of the list in a 2019 study which found high rates of AML in Canadian industrial cities (Mowat, 2019). Another study in 2013 also revealed higher than normal levels of toxins (cadmium, mercury, and polychlorinated biphenyl) in mothers and their children. While a 2006 study of the Aamjiwnaang residents found respiratory problems, learning disabilities, and cancer (Baxter, 2020). As of January 2013, although hundreds of spills have been reported only four cases resulted with charges from the Ministry of the Environment (Craig et al., 2020). The government has a duty to protect vulnerable populations, but it is not meeting the standard. Companies need to be held accountable for their actions.

"To me, sustainability means maintaining the planet such that future generations will also be able to obtain the same quality of life as we have at the present. It also means to not consume more than the planet is able to give. Engineers play a vital role in sustainable development, especially civil and environmental engineers. There are many ways for engineers to contribute to sustainable development and it is important to do so, whether it is a small or large contribution."

-Nora Wei

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

OIL CAPITAL TO GREEN CITY

HOUSTON, UNITED STATES



Wind Farm in Texas

What can Sarnia learn from Houston?

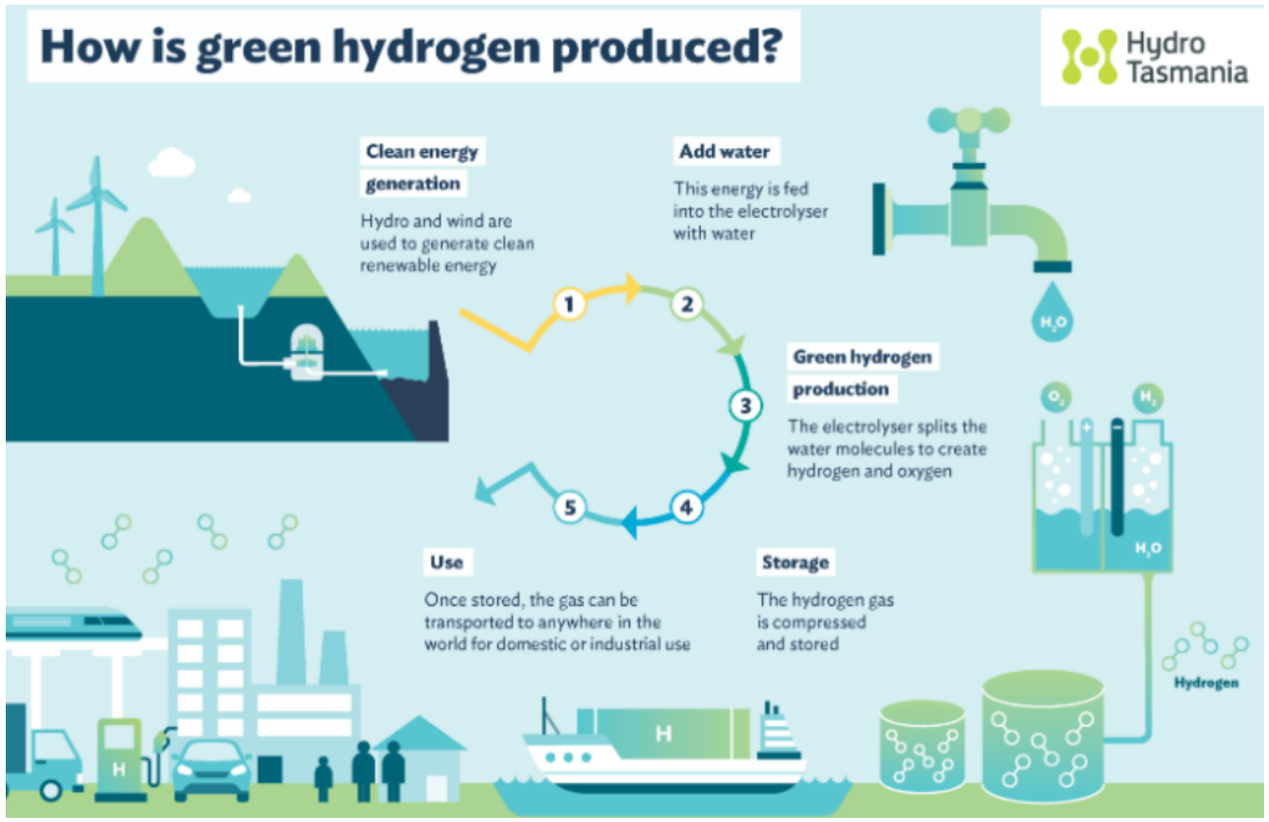
However, although the city now runs on renewable energy, it is still facing pollution issues from oil refineries which still run in the region. A report found that half of the Texas refineries emitting benzene above the federal threshold are located near Houston. Sarnia can learn from Houston that the transition from fossil fuels to sustainable energy is possible and Houston can learn from Sarnia how serious the human health impacts are from continuing its the oil industry.

The city of Houston is located in Southeast Texas with a population of 2,095,517 (United States Census Bureau, n.d.). The city's domination in the oil industry began in 1901, with the discovery of natural gas and crude oil that quickly generated the revenue to grow the city (Coburn, 2020). In a recent unexpected turn, the city has decided to remake it's image from an oil industry epicenter to a leader in renewable energy. 88% of the city's power comes from wind turbines while the other 12% is sourced from a solar farm located in Alpine, Texas (Gallay, 2019). However, Houston plans to build its own solar farm on a former landfill which will be able to generate 1,034,399 MWh of renewable electricity for 12,000 homes when completed (Ortiz, 2019). Residents have also contributed to the renewable energy movement. According to the Environment of Texas, installed solar capacity has grown from 9.5 megawatts in 2017 to 42.53 megawatts in 2019 (Watkins, 2021). The city has also increased renewable transportation by building 1,800 miles of bicycle lanes and emphasising electric vehicle and alternative fuel usage; as transportation results in 47% of the city's green house emissions (Watkins & Rice, 2020). In 2020, Houston partnered with NRG Energy Inc. in a five-year contract to power all city-owned properties with renewable energy by 2025 in hopes of becoming the renewable capital of the world. This is all part of their Climate Change Action Plan launched in 2017 as a measure to reduce greenhouse gases and become carbon neutral by 2050 (Labbe, 2020). Houston has greatly contributed to minimizing the impacts of climate change by ranking number one in renewable energy usage in America and becoming 100% green years earlier than planned.

COULD HYDROGEN BE A CLEAN ENERGY ALTERNATIVE?



EDMONTON, AB



How is Green Hydrogen Produced

"In terms of a global perspective, I realize that there isn't much that I can accomplish to be more sustainable. But on a much smaller scale I try to be aware of how my actions might affect things like plants and animals. For example, I would do simple things like not feeding ducks or avoid hurting or stepping on a plant. Another way I try to be sustainable is to purchase food that is more local. Most of the meat that me and my family buy is local."

-Eric Ranney Wiebe

AFFORDABLE AND SUSTAINABLE ENERGY
CANADIAN ENGINEERING GRAND CHALLENGES

Alberta has long been a hotspot for fossil fuel production in Canada but lately there have been plans to turn it into a large-scale producer of hydrogen-based energy. The combustion of hydrogen and oxygen produces two things: water and energy. The federal government and the Alberta provincial government has supplied funding for the purpose of turning Edmonton into a "hydrogen hub". With no carbon emissions, hydrogen technologies could contribute to net zero carbon emissions. The problem is that energy is needed in order to supply the hydrogen for the combustion with oxygen. Which means that in order to produce clean energy the hydrogen must be obtained through sustainable methods. There are three main ideas for the production of hydrogen being called green hydrogen, blue hydrogen and grey hydrogen. Green hydrogen is made through the electrolysis of water in order to separate the hydrogen and oxygen. The most sustainable way to achieve this is to produce electricity by renewable means. Blue hydrogen is hydrogen that is produced from the burning of fossil fuels but the carbon emissions are captured to prevent any carbon from entering the atmosphere. Finally grey hydrogen is made the same way as blue hydrogen accept there is no carbon capture. This is how most hydrogen is currently made which makes grey hydrogen the least sustainable of the three. Of the three methods of hydrogen production, green hydrogen is the most sustainable assuming the electricity for the electrolysis comes from a renewable source. The main issue with green hydrogen is that it is very costly. Blue hydrogen is a feasible alternative but it requires the capture and long term storage of carbon which takes up room and money.

EFFICIENT CARBON CAPTURE TECHNOLOGIES BEING TESTED

MONGSTAD, NORWAY



Carbon Capture and Storage

What can Edmonton learn from Mongstad?

The results from the research being conducted in Mongstad in Norway by the National Energy Technology Laboratory could bring about new technologies in carbon capture which could be utilized all around the world. In Edmonton, where an effort is being made to become a global hydrogen hub, the results from the research in Mongstad would be vital to their operations. It would be an opportunity for two cities in different continents being connected through research and innovation of sustainable technologies.

The National Energy Technology Laboratory (NETL) in the United States is working on testing new carbon capture technologies that will be more cost effective and more efficient at capturing carbon emissions. The NETL is using the testing facilities at the Technology Centre Mongstad in Norway in order to test these carbon capture methods. The Technology Centre Mongstad is a large testing facility in the industrial site of Mongstad, in Norway, that was designed to test various carbon capture technologies. Innovations in the carbon capture industry would open up new opportunities to make the capturing and storage of carbon emissions a more feasible method of reducing emissions. The NETL is also working on trapping captured carbon inside cement blocks for storage. The production of concrete and therefore cement results in a huge number of carbon emissions so being able to trap these emissions inside the cement itself would have a large impact. According to the NETL, carbon capture technologies will produce tens of thousands of jobs in the emerging sector as jobs in the oil and coal sector decrease due to decreasing demand. They add that many of the skills in the fossil fuel industry are transferable to the carbon capture industry. Any advances in carbon capture technology made in Mongstad could be adopted by the NETL for use in the Unites States. This could result in a partnership with Edmonton in an effort to produce blue hydrogen which could present a solution to the costly and inefficient problem of producing hydrogen sustainably.

LAND & BIODIVERSITY LOSS THREATENS COMMUNITY

HUDSON HOPE, BC



Peace River, BC. Proposed Site of Dam C at the W. A. C. Bennett Hydroelectric Dam

“From an Engineering perspective, sustainability expresses creative designs and innovative construction techniques that address environmental impacts, improve quality of life and accessibility standards, and adopt a policy to manage general economic growth against scarce resources in a long-term plan. We must be mindful that the environment is not simply an economic trade-off but one that is supportable and defendable for future generations.”

-Marc Ricciuti

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

Hudson’s Hope is a small community of 1,015 people on the shores of the Peace River in Northern British Columbia (Statistics Canada, 2017). Being one of the oldest towns in the fur-trading industry, the community is home to an abundance of natural resources (Hudson Hope , n.d.). Hudson’s Hope and its surrounding towns are home to the massive W.A.C. Bennett and Peace Canyon Hydroelectric Dams, operated and owned by B.C. Hydro (Hudson's Hope BC, n.d.). The economy of Hudson’s Hope is very resource dependent. Most residents of the community are employed with the Dam. While the Dam has led to economic prosperity and an abundance of sustainable renewable energy, its future dam (Site C) has been established to ongoing negative environmental effects. Site C is an ongoing, green-lit dam, currently under construction near W.A.C Bennett, with a revised cost of $16 billion, and a projected completion date of 2025 (Kurjata & Bains, 2021). The purpose of the project is to provide renewable energy to meet future demands. It is projected to provide 1,100 MW of power to over 400,000 homes (Clarke, 2014). In the process of Site C’s construction, flooding has taken place, which led to the loss of agricultural land, biodiversity, and the displacement of first nation’s communities. The first nation community of Hudson’s Hope relies heavily on fishing in the Peace River (Palframan, 2021). Moreover, as a result of the flooding by the construction of the dam, the presence of methylmercury forms, which poisons the fish, leading to loss of biodiversity in the area. This displaced the fish and made fishing impossible and unsafe for the first nations community (Linnitt, 2015). Moreover, almost 20 families of first nation communities are forced to move due to the flooding. According to the Crown Corporation in British Columbia, an environmental impact report found that more than 5000 hectares will be succumbed to flooding with the construction of the Site C dam (Meissner, 2013). Of that, the report suggests that 3800 hectares is deemed agricultural (Meissner, 2013). While the construction of the new Site C dam is important to serve the northern communities of British Columbia, it ultimately comes with a price for the community of Hudson’s Hope.

TIDAL POWER GENERATION



SEOUL, SOUTH KOREA



Sihwa Lake Tidal Power Generating Station in South Korea

What can Hudson Hope learn from Seoul?

While the community of Hudson Hope uses Hydropower, (a much better sustainable option to fossil fuels), it still causes severe damage to the eco system, including flooding and obstruction to the fish habitat. On the other hand, the Sihwa Lake Tidal Power Station is a great advancement to sustainable energy as it mitigates flooding and allows for fish to thrive easily.

An alternate solution to Hydro dam that mitigates flooding and biodiversity loss is Tidal Power Stations. The world's largest Tidal Power Station, Sihwa Lake Tidal Power Station is a massive 25.4 MW capacity plant built in the Gyeonggi Bay, a bay on the west coast of South Korea (iHa, 2016). The Tidal Power Station at Sihwa Lake has the power to support approximately 500,000 people (iHa, 2016). While tidal power is in the early stages of development, the design generates electricity through ocean currents. Like wind turbines, in tidal power, turbines are placed underwater, and when ocean currents are present, energy is generated because of the turbines spinning. In the Sihwa Lake Tidal Power Station, a tidal barrage, seawall, and a sluice (gate) is engineered in the design to mitigate flooding agricultural areas and allow fish to thrive (iHa, 2016). Engineers can regulate the flow of water in the barrages easily, depending on the ocean current conditions. This not only regulates flooding of farmable land, but also addresses the global issue of climate change and the threat caused by sea levels rising (Hanania, Heffernan, Jenden, Stenhouse, & Donev, n.d.). This technology can be built on a smaller scale and can be placed in rivers, like Site C being constructed in the W.A.C Bennett Dam. Since the Tidal Power Generating Station's construction, water quality began to decline because of contaminants and lack of freshwater inflow from the Gyeonggi Bay, caused by the cut-off in the seawall (iHa, 2016). Seeing that this prevented fish from thriving, the gate can be opened periodically to allow for freshwater inflow and allow for proper fish migration, thus improving water quality (iHa, 2016). The introduction of the tidal barrages and tidal power has created a profound impact on the environment and the citizens of Seoul's Capital area, in generating renewable energy for decades to come. Hudson's Hope can learn from Seoul's Tidal Waterpower Turbine innovation and experience as an alternative to the proposed Site C construction damn. The Seoul's success was predicated on the technical innovation in addressing the fundamental concerns of hydropower infrastructure in a fragile ecosystem, one that is sustainable, safe, and healthy for the citizens to continue to rely on and enjoy their use of both land

THE MOST ENERGIZED CANADIAN CITY AND THE MOST POLLUTED



TORONTO, ON



Air Pollution in Toronto, Ontario

“I incorporate sustainability in my personal life when I try to ensure that my belongings are in good condition for a long time so that I do not need to replace them frequently.”

-Jeff Kim

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

A challenge that many cities in the world faces is reducing emissions from non-sustainable energy production and Toronto is no stranger to this challenge as well. Toronto, Ontario’s capital, the most populous and largest city in Canada, is an international hub of business and culture and is one of the most recognizable cities in the world. This metropolitan city requires 72,000 eTWh annually and 63% of this energy is produced from natural gas (Toronto, 2007). Natural gas is a non-renewable energy source and is also the largest source of air pollution. Air pollution poses many health risks, and on average 280 people die due to these emissions. These emissions are also a large factor to global warming and climate change. It would not be inaccurate to say that many of the issues that the world is facing can be solved by simply switching to sustainable energy sources. Toronto has great potential for relying primarily on sustainable energy sources however, currently local renewable energy sources only account for approximately 0.6% of the city’s energy needs (Toronto, 2007). One must also recognize that Toronto faces some obstacles that hinder this change. Toronto is rapidly growing, leading to an increase in demand for energy, increase in energy costs, poor energy infrastructure, and increases the impact on the environment that all energy production has. To combat these issues, the Toronto’s Sustainable Energy Plan has been developed. This plan is designed to make Toronto a significantly more sustainable city by setting goals based on realistic projections of current and future capacity (Toronto, 2007).

THE SUSTAINABLE PARADISE AND THE GREEN NEW DEAL

SONGDO, SOUTH KOREA



Songdo's Greenbelt

South Korea is the 12th largest global economy and its reliance on renewable energy is growing however, it is still heavily dependent on coal and nuclear energy to account for 70% of its electrical upkeep (Hassan & Polito, 2020). This makes South Korea one of the most polluted countries in the world, especially around the metropolitan area of Seoul. To combat this

The Green New Deal is a $60.9 billion plan to transit South Korea from a high-carbon economy to a low- carbon economy. This plan includes investing into smart energy grids, increasing the number of electric and hydrogen powered vehicles, end the funding of overseas coal plants, introduce a carbon tax, and implement widespread green cities (Hassan & Polito, 2020). The Green New Deal has only been put into effect in 2020, in the midst of the COVID-19 pandemic, with plans to expand the solar and wind energy output to 42.7 GW by 2025 from 12.7 GW in 2019 (Kim & Thurbon & Tan & Mathews, 2020). This plan has also seen a further increase to the Greenbelt which is a large area of greenery surrounding South Korea's capital. This Greenbelt covers about 13.3% of the Seoul metropolitan area (Hosey, 2018). Further sustainable implications are being implemented. Songdo, a city just outside of the Seoul metropolitan area is perhaps South Korea's greenest and smartest city has about 40% of its area as green space and all city waste is taken directly from residential areas to a waste treatment plant through underground pipes which reduces the need for garbage trucks and limits the amount of waste on the streets (Hosey, 2018).

What can Toronto learn from Songdo?

Though Toronto and Seoul both have initiatives to become more eco-friendly, both can learn from Songdo. The use of pipes to move all waste directly from homes to a waste treatment facility has no shortage of future implications. Less landfills, more waste that is handled properly, less energy used to physically transport waste to a facility, underground pipes can also be used to warm homes leading to no need for extra energy used for the same purpose, the applications are limitless. It comes down to the imagination and the desperation to create the sustainable city.

CRUDE OIL PRODUCTION



FORT MCMURRAY, AB



Oil Sand Extraction Facilities in Fort McMurray (Willms, 2015)

"In my personal life, I use sustainability when it comes to my finances as well as my social life and the environment. In order to allow me to afford things on an ongoing basis, I work and get paid. When it comes to my social life, in order to continue to have friends, I make sure to communicate with them on an ongoing basis. Lastly, when it comes to the environment, I try not to buy plastic water bottles because they are bad for the environment and do not promote environmental sustainability."

-Anthony Valcic

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

Fort McMurray, a city in northern Alberta, is currently the largest crude oil producer in Canada (Canada, n.d.). Crude oil is a fossil fuel that is refined and used as an energy resource to power transportation vehicles, generate heat and electricity. The unfortunate truth behind crude oil and other fossil fuels is that, not only are there negative environmental implications with the extraction, production, and use of fossil fuels but there is also a finite amount of fossil fuels on Earth.

In 2019, 2.95 million barrels of oil were extracted on average per day in Canada (Government, 2020). SUNCOR, the main oil mining and production company in Fort McMurray, uses two methods of oil sand extraction:

Surface mining: large trucks and shovels are used to extract the oil sands close to the surface.

In situ: steam is injected into reservoirs heating up the bitumen allowing it to be pumped to the surface (Suncor, 2021).

Although Canada is able to generate a large amount of revenue through extracting and trading crude oil, no amount of revenue can make up for the fact that 12% of Canada's total GHG emissions are produced from these harmful activities (Government, 2020). Tailing ponds, which are ponds that are made of harmful by-products created from the extraction of the oil sands, are also a serious side effect (Doney et al., 2019). Soon these harmful effects will contribute to permanent damage of the environment in Fort McMurray and to the world as a whole unless a more environmentally sustainable energy is proposed.

Even though Fort McMurray has not reached peak oil, the oil sand supply will eventually come to an end. Fossil fuels take millions of years to create, and Alberta is extracting the oil sands at an exponentially larger rate then they are produced; hence, this form of energy is not sustainable.

FOCUSING ON SUSTAINABLE ENERGY FOR A SUSTAINABLE FUTURE

ZURICH, SWITZERLAND





Dam in Zurich (fi67, 2018)

What can Fort McMurrary learn from Zurich?

As the population grows, the need for energy will increase and as a result of this, it is important to utilize sustainable energy sources. Towns and cities should utilize natural landforms found within the town or city to create energy. For example, large waterfalls formed in nature could be used to produce energy through the use of dams and other infrastructure. Another example is to use solar panels to capture the sun's energy. It is also important that towns and cities support and advocate for the use of sustainable energy to ensure a sustainable future.

Society not only has a limited supply of non-sustainable energy sources, but these energy sources can also be very harmful to the planet. With the goal to follow a more sustainable approach, Zurich, a city in Switzerland, has set a target to become a 2000-watt society by 2050 (Energym, 2021). This means that on average, the city aims to have each person using no more that 2000 watts per hour. Energy would be consumed at a rate that would be considered sustainable. Zurich has already made significant progress when it comes to energy consumption. In fact, since 1990, average energy consumption in Switzerland per person has decreased by approximately 14.5% (Presence, 2019).

Zurich has also been in the process of switching to using more sustainable forms of energy including photovoltaics, wind, and hydro (Keystone, 2020). Switzerland has implemented a policy known as the energy strategy 2050 (ES2050) to reach its targets relating to renewable energy use. One of the main targets of this policy is to provide 37400 GWh of power per year by the year 2035 through hydro (IEA, 2019). It is estimated that hydropower is used to generate approximately 56% of Switzerland's electricity (Frangoul 2017). Large dams cause large volumes of water to fall and spin hydraulic turbines. The kinetic energy of the water is transformed into electrical energy. In addition to hydropower, Switzerland also generates a large amount of electricity from wind energy. The country has 37 wind power plants (Axpo, 2021). Due to the use of more sustainable energy, Zurich is able to reap the benefits. Switzerland has an air quality index of 37 which represents a very healthy air quality (The, 2021).

HYDROPOWER – VILLAIN OR HERO TO SUSTAINABILITY?

NIAGARA FALLS, ON



The Moses-Saunders Dam and Power Plant located in Cornwall, ON

"A couple of ways I incorporate sustainability in my life are drinking water from a reusable water bottle, cooking and eating meals at home frequently, purchasing good quality products such as more expensive clothes and technology to lengthen the time required to buy more after breaking."

-Charlene Grace Palapuz

SUSTAINABLE INDUSTRIALIZATION

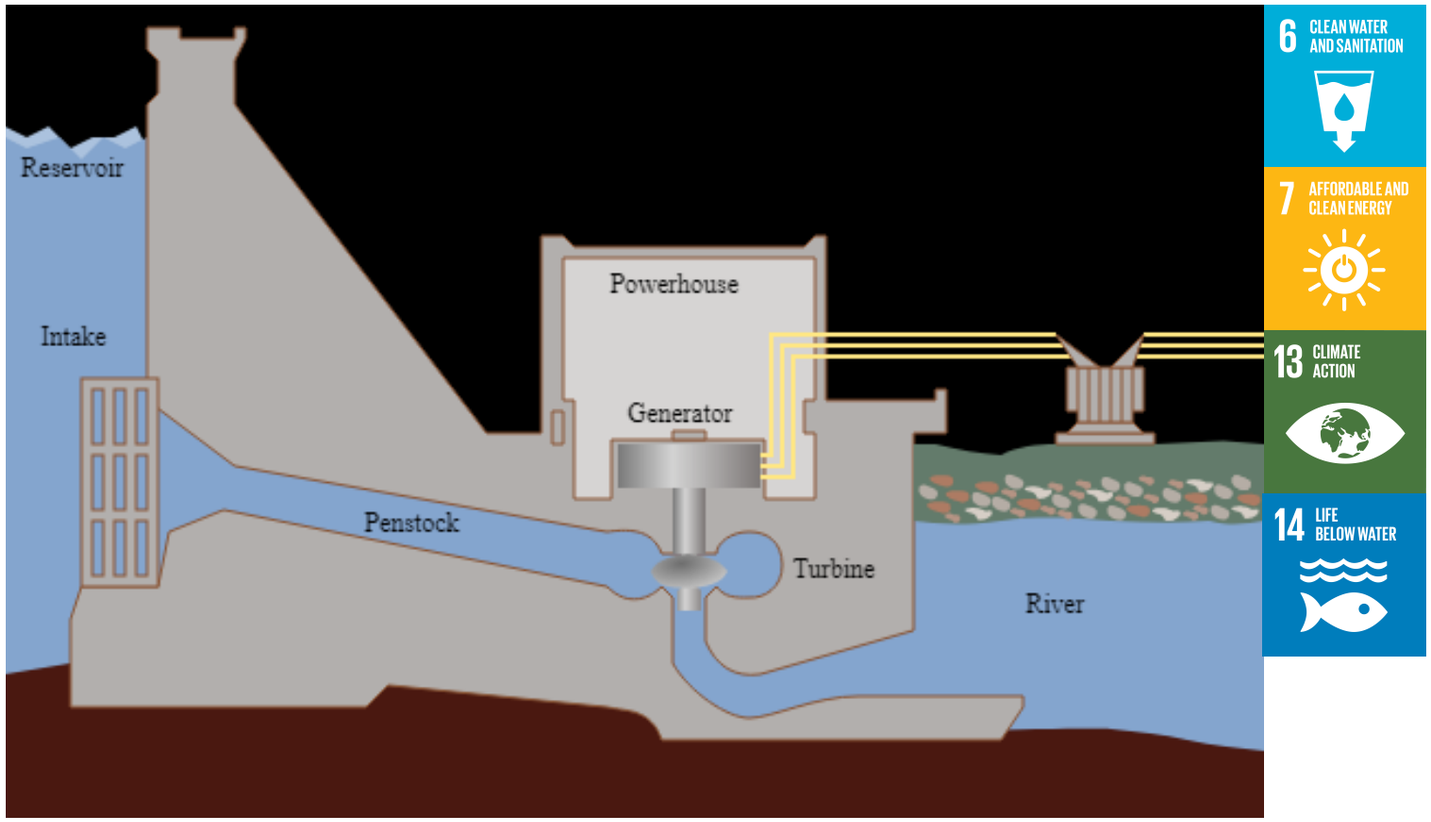
CANADIAN ENGINEERING GRAND CHALLENGES

For the longest time, mostly everyone has always assumed hydropower to be clean, renewable energy that had no harsh impacts on the Earth. However, recent engineering projects have been implemented on the falls in Niagara, Ontario to divert more water flow to the hydropower stations. After the sun goes down, the water flowing over both the American Falls and Canadian Horseshoe Falls is significantly reduced due to power generation purposes. In addition to this, even once in 1969, engineers went so far as to completely turn off the American Falls for the purpose of studying the geological aspect of the natural wonder (Macfarlane, 2019). Although these technological advances may seem very efficient, it does feel very unethical to the environment and has had a huge impact on the habitats and ecosystems that surround the falls. Furthermore, in more recent studies of the environmental effects of hydropower dams, scientists have concluded multiple impacts from wildlife to life cycle global warming emissions. To begin, hydroelectric facilities can still have a major impact on aquatic ecosystems. Since reservoir water is usually more stagnant than normal river water, it is generally more abundant in sediments and nutrients which can cultivate an excess of algae or other weeds that eventually can disrupt other animal or plant life (Union of Concerned Scientists, 2013). In addition to this, since reservoir water has lower dissolved oxygen levels, plants, and animals downstream from the plant are in danger. Finally, recent research also suggests that during a facility's operation emissions are also significant: the plants generally discovered to grow in reservoirs was discovered to emit between 0.01 and 0.03 pounds of carbon dioxide equivalent per kilowatt-hour. Although this is not a huge number compared to natural gas or coal generated electricity, we can conclude that hydropower is not 100% green.

TURBINES, SOLUTION TO LOW DISSOLVED OXYGEN LEVELS IN RIVERS



WASHINGTON DC, UNITED STATES



Cross Section Diagram of a Hydropower Dam with Aerating Turbine

What can Niagara learn from Washington DC?

Due to proper rehabilitation of dissolved oxygen levels through the implementation of aeration turbines, water quality can greatly improve. In addition to having rich dissolved oxygen levels in the water, aquatic life including plants and animals are also able to thrive in oxygen abundant ecosystems. In addition to this, since plant life is directly proportional to the ability of Earth to consume greenhouse gases and produce more oxygen as an outcome, this solution provides a small impact to fight back the buildup of greenhouse gasses in our atmosphere. Finally, by lessening the environmental impact of hydropower dams, society can use this technology to improve and consider hydro more “green” and “clean”.

Many methods were proposed to increase dissolved oxygen concentrations in reservoirs and tailwaters during a summit meeting between several research groups in Washington DC on June 2-3, 2010. One of these methods included installing aerating turbines or reservoirs to increase levels of dissolved oxygen (Oak Ridge National Laboratory et al., 2010). This solution was implemented by Duke Energy on their Bridgewater Powerhouse located in Morganton, NC in the United States. In southern U.S. towns such as Morganton, low dissolved oxygen is a common issue during the warmer seasons. In summer months, lakes experience thermal stratification (when the reservoir separates into distinct layers. The top layer contains high levels of DO whereas the lower layer contains poor concentrations of DO, potentially reaching levels as low as 1 milligram per liter near the reservoir bottom at some sites. Because of this, Duke Energy has implemented the use of aerating turbines into their general schematic for the Bridgewater Powerhouse Dam. The low-quality water then gets passed through regular turbines before being released into the downstream of the facility, where poor DO levels can have significant impacts on the water quality and aquatic life (Rohland et al., 2008). There are a total of 3 main aeration methods that can be implemented towards solving this issue. The first is central aeration which is relatively inexpensive to retrofit existing turbines however, this method also tends to disrupt the flow within the draft tubes, thus causing large effects on the system’s efficiency. The second method is peripheral aeration which involves injecting atmospheric air into the draft tube cone resulting in a series of bubbles to move along the water passage. The last method is distributed aeration which include air injection slots that provide a uniform bubble distribution that is disbursed along the whole length of the draft tube.

TAILING PONDS CONTAIN TOXIC WASTE — AND THEY'RE LEAKING

ATHABASCA, AB



Oil Sands Along the Athabascan River

"I incorporate elements of sustainability in several aspects of my life. In terms of food and agriculture, I try to eat organically/sustainably farmed meats and fish, while supporting organizations that support sustainability such as Whole Foods Market whom I've worked for in the past. For waste management, I eliminated the use of plastic water bottles, and make sure to recycle products when possible."

-Yussif Salama

AFFORDABLE AND SUSTAINABLE ENERGY

CANADIAN ENGINEERING GRAND CHALLENGES

Containing the toxic waste of oil sands has proven to be a great challenge amid oil extraction, particularly, in Athabasca, Alberta.

Athabasca is a small town on the banks of the Athabaskan River, with an approximate population of one thousand two hundred fifty (Statistics Canada, 2016). It is home to one of the largest oil reserves in Canada and thus is in dangerous proximity of toxic tailing ponds.

Tailing ponds are dam and dyke facilities meant to contain the toxic biproduct of oil mines. They are surrounded by collection ditches which allow the flow of leaked water to divert into seepage ponds via drainage basins. This process was made to minimize the environmental impact of the poisonous biproduct of oil mining, however, The Commission for Environmental Corporation stated that there is scientifically valid evidence that mismanaged tailings containing the waste for Athabasca's oil sands are leaking, and may contaminate aquifers (Commission for Environmental Cooperation, 2020). The lack of full containment has allowed seepage into nearby water sources, namely, the Athabaskan River.

Crude oil is an unsustainable (although currently stable) energy source, and accounts for the majority (50.1%) of primary energy production in Canada (Statistics Canada, 2021). Despite its significance in Canada's energy production, engineers have failed to eliminate/contain toxic mining biproduct leading to numerous environmental effects.

Reported environmental effects include:

chemical poisoning (i.e., mercury poisoning, oil-soaking) of surrounding wildlife such as aquatic birds, fish, and animals.

groundwater toxification.

greenhouse gas emissions.

NEW MINE TAILINGS TREATMENT CYCLE

CANDELARIA, CHILE



Chilean Copper Mine with Cut-Off Wall System

What can Athabasca learn from Candelaria?

There have been numerous instances of oil spillage/mismanagement across the globe, and thus, many lessons to learn. Oil sand management topics such as waste management, dam integrability and design, and extraction processes have been researched and reflected upon based on several historic events. However, oil extraction companies in cities like Athabasca, Alberta have taken shortcuts in terms of research and preparation in contrast to Candelaria, Chile, and therefore, the environment is paying the price.

The Candelaria project (2008) is a leading example of safely extracting copper, an unsustainable energy source, in comparison to other developing countries. After Chilean toxic spillage events such as Berge Nice (2004) and Eider (2005), Chile made protecting its water supply a priority, and planned to achieve this through the Candelaria project. The biproduct of water being used as a binding agent to remove the mineral constituents is called 'supernatant water'. This water would increase the pH level and heavy metal content of natural water bodies and contains cyanide which is hazardous for human health. The Candelaria Copper Mine is in the Copiapó River valley near the Atacama region of Chile (Worst Polluted, 2009). Although biodiversity and human population are low in this area, its water sources are essential for its agricultural irrigation, urban residential and commercial, and industrial purposes, and thus the Candelaria project was deemed necessary.

The project planned to protect its' limited desert waters by constructing an impoundment/cut-off wall system that contains/disposes of tailings and reduces water usage. Reduced water usage was achieved through a multi-stage treatment process that treated and recirculated 80% of the water bound up in tailings (Worst Polluted, 2009). Disposal was achieved using impoundment technology, which increases the thickness of tailings for easier disposal. This twenty-year project is a world class example of a copper mining operation and is expected to extend its operation until 2040. Although generally successful, the project had two flaws. First, the remaining 20% of tailings are left untreated and are difficult to access for disposal. Secondly, the Candelaria project failed to consider smaller toxic particles which can also have an impact on the environment. Thus, although Chile leads developing countries in innovation of tailings management, new strategies for tailings management should continue to be developed.

CHAPTER 10: SUSTAINABLE WATER USE AND URBAN FORESTS



Don Valley/Ontario Nature

CHAPTER INTRODUCTION

Other sectors of the built environment that are presented in this module represent energy and water flows. This module highlights the criteria for sustainable energy use, and sustainable water systems, in addition to the urban green that is a source of ecosystem and life, and a sink for greenhouse gas emissions.

Learning Outcomes

By the end of this week, you will be able to:

- Estimate electricity generation inefficiencies and losses
- Describe design strategies for sustainable energy systems with examples
- Identify functions of urban water systems
- Describe sustainable water, wastewater and stormwater management systems with examples
- Describe benefits of urban forests with metrics
- Interpret the guidelines for urban street tree planting
- Quantify the costs and benefits of urban forests
- Recognize examples of green roofs and urban agriculture

INCREASED RUNOFF VOLUMES IN THE CITY OF RAINBOWS

PRINCE RUPERT, BC



Oily Runoff in Surrey, British Columbia

"To me, sustainability means only using/taking what you need and leaving enough resources for future generations. It also means making choices that contribute to equity for all, whether it be other people, the environment, or the economy. Sustainability is using resources at a rate that your environment can still support you, others around you, and the future."

-Cassidy Wong

RESILIENT INFRASTRUCTURE
CANADIAN ENGINEERING GRAND CHALLENGES

The city of Prince Rupert, British Columbia is known as one of Canada's rainiest cities, receiving approximately 2594 millimeters of rain per year (St. Clair, 2014). Due to the fact that it is also quite cloudy, the city is called the City of Rainbows. Its location on the west coast of Canada within the Pacific Maritime climate region is part of the reason why Prince Rupert receives so much precipitation. With climate change, the city can expect more precipitation during storms, leading to increased volumes of runoff and risks of flooding. Though Prince Rupert is a small city of about 12 000 people (Statistics Canada, 2019), it still has many impervious surfaces that do not allow for groundwater infiltration. Instead, water flows across the surface of the ground, picking up pollutants and eventually ending up in the natural waterways. The pollutants found in the runoff contaminate the water body, leading to decreased water quality and adversely impacting aquatic life.

Currently, Prince Rupert has to regularly contend with over 3000 millimeters of runoff (Statistics Canada, 2017). Though flooding isn't currently a big concern, this quantity of runoff travels at great speeds and introduces many contaminants into waterways. For example, in 2020 while a road was being resurfaced, a sudden downpour almost caused an oily substance used in paving to be swept into Prince Rupert's stormwater system (Millar, 2020). Since stormwater isn't typically treated before being discharged, any contaminant that ends up in the stormwater system will be discharged into local waterways. This can lead to increased turbidity and decreased photosynthetic activity, as well as pollution of a drinking water source (Ibrahim, 2021). It is important for Prince Rupert to minimize the quantity of runoff before contamination of drinking water becomes a large concern.

POROUS PAVEMENT

PHILADELPHIA, UNITED STATES



Pouring Water onto Porous Asphalt Demonstrating its Infiltration Capacity

What can Prince Rupert learn from Philadelphia?

Prince Rupert can look to Philadelphia to determine if it is beneficial to implement porous pavements within their city to reduce runoff volumes, as well as refer to their documentation to learn how to design for porous pavements. This will help Prince Rupert mitigate and adapt to climate change impacts that lead to increased runoff, while also providing a sustainable source of water for its citizens to use and enjoy.

Philadelphia, Pennsylvania is one of the largest cities in the United States, with a population of almost 1.6 million in 2019 (United States Census Bureau, 2019). One of the oldest cities in the country, it has a combined sewer system that is forced to "release billions of gallons of polluted water" into nearby rivers during large precipitation events (City of Philadelphia, 2017). In order to minimize the amount of stormwater entering their management system, and consequently prevent flooding and the immediate discharge of polluted water into natural waterways, Philadelphia implemented porous pavement.

When a precipitation event occurs, porous pavement mimics the reaction of the natural ground and infiltrates runoff. Porous pavement can take the form of porous asphalt, porous concrete, or interlocking pavers, and is typically used in low traffic areas such as sidewalks and parking lots. Below the surface is a layer of stones where excess water can be stored temporarily while it slowly infiltrates the soil beneath (Philadelphia Water Department, n.d.). The various forms of porous pavement infiltrate water differently. While porous asphalt and porous concrete function by allowing runoff to pass through the air voids in the compound, interlocking pavers do not have air voids within them. Instead, spaces between pavers are filled with well-graded pervious gravel, allowing water to be absorbed by the ground (Philadelphia Water Department Private Development Services, 2019). Porous pavement works well to reduce the volume of runoff that occurs – in Pennsylvania, studies have shown that porous pavement reduces runoff by up to 90% (Kwiatkowski et al., 2007, as cited by Credit Valley Conservation, 2012). With less water running across the surface of roadways and other impervious surfaces, less contaminants will be picked up and deposited in the stormwater system, reducing the concentration of contaminants and improving local water quality.

SMALL TOWN UNRECOGNIZABLE DUE TO FOREST WILDFIRE

LYTTON, BC



Raging Wildfires of Reserve Forest in British Columbia

Over the recent years climate change has had a significant effect on our ecosystem. Climate change can cause severe weather conditions like hurricanes, thunderstorms, etc. that can devastate an entire region. Wildfires are an example of a natural disaster that can occur due to climate change conditions like Thunderstorms and Heat waves and affect sustainable urban forests. The Urban forests are habitats for wildlife, improve air quality, build energy conservation and have many other benefits. When wildfires occur, the sustainable forests and wildlife are damaged, also causing benefits to be lost. Similarly, a British Columbian town, Lytton, was recently affected by a Forest wildfire caused due to extreme heat conditions (Isai, 2021). Lytton is a small town with a population of less than 300 and was engulfed in flames from the climate change caused wildfire. Due to the extreme heat temperatures, of 121 degrees Fahrenheit, the town faced this past week, it caused the wildfires to damage close to 90% of the town. The damage included residents to lose lives, homes, businesses, and food sources. But most importantly, urban forests were burned to the ground and charcoaled, causing air quality to go down, wildlife habitat to be lost, and property value and aesthetics to be destroyed (Ravindran, 2021). Therefore, the town of had to immediately evacuate and move to nearby reserves. The city and many more cities across BC are continuing to see devastating wildfires due to extreme conditions of climate change (Al Jazeera and News Agencies, 2021).

“Sustainability is the ability to keep a certain object or thing in the same condition or level. For example, when I think of sustainability, I think of our environment and resources. By keeping the environment in a good condition or using sustainable resources it means the environment isn't being damaged and the resources being used can be used often without deteriorating.”

-Vashinee Ulaganathan

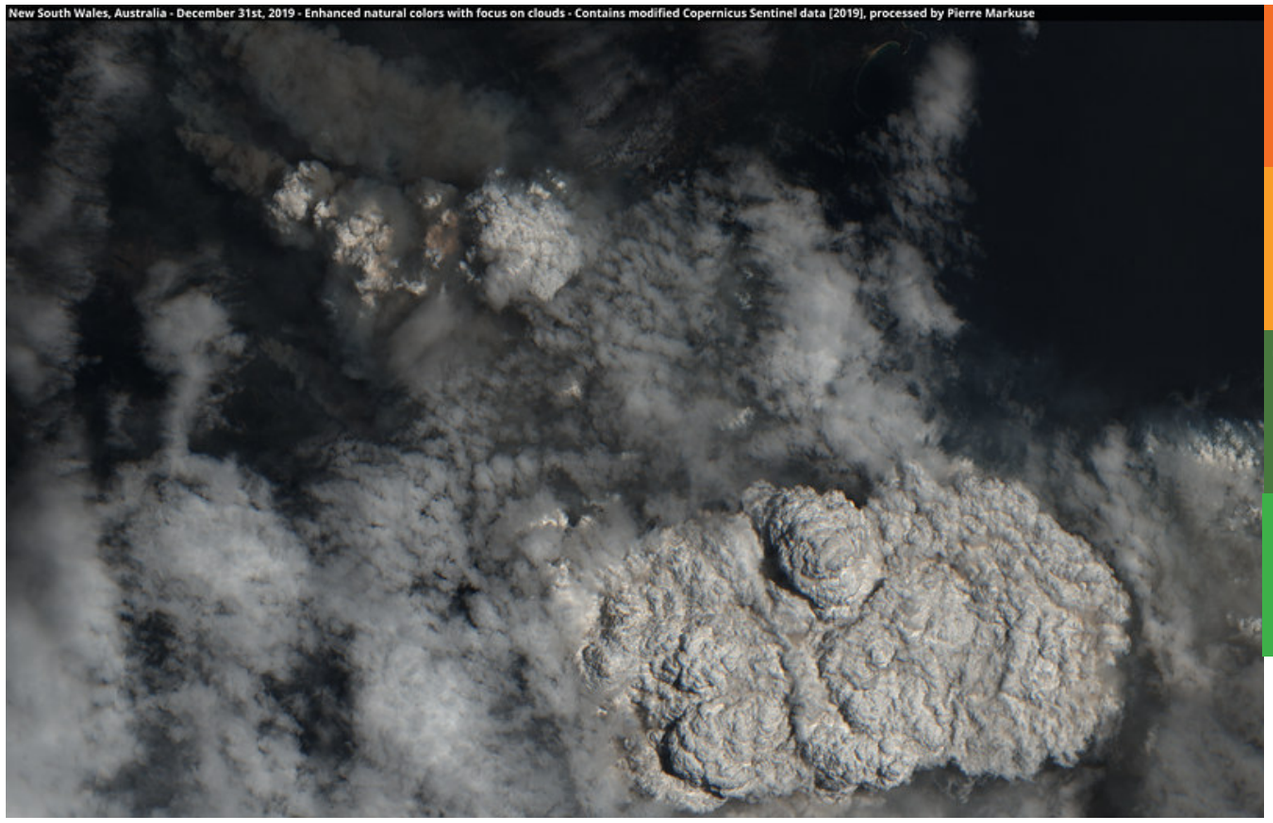
SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

FIGHTING WILDFIRES WITH THE HELP OF TECHNOLOGY



BATEMANS BAY, AUSTRALIA



Batemans Bay Bushfire Aftermath

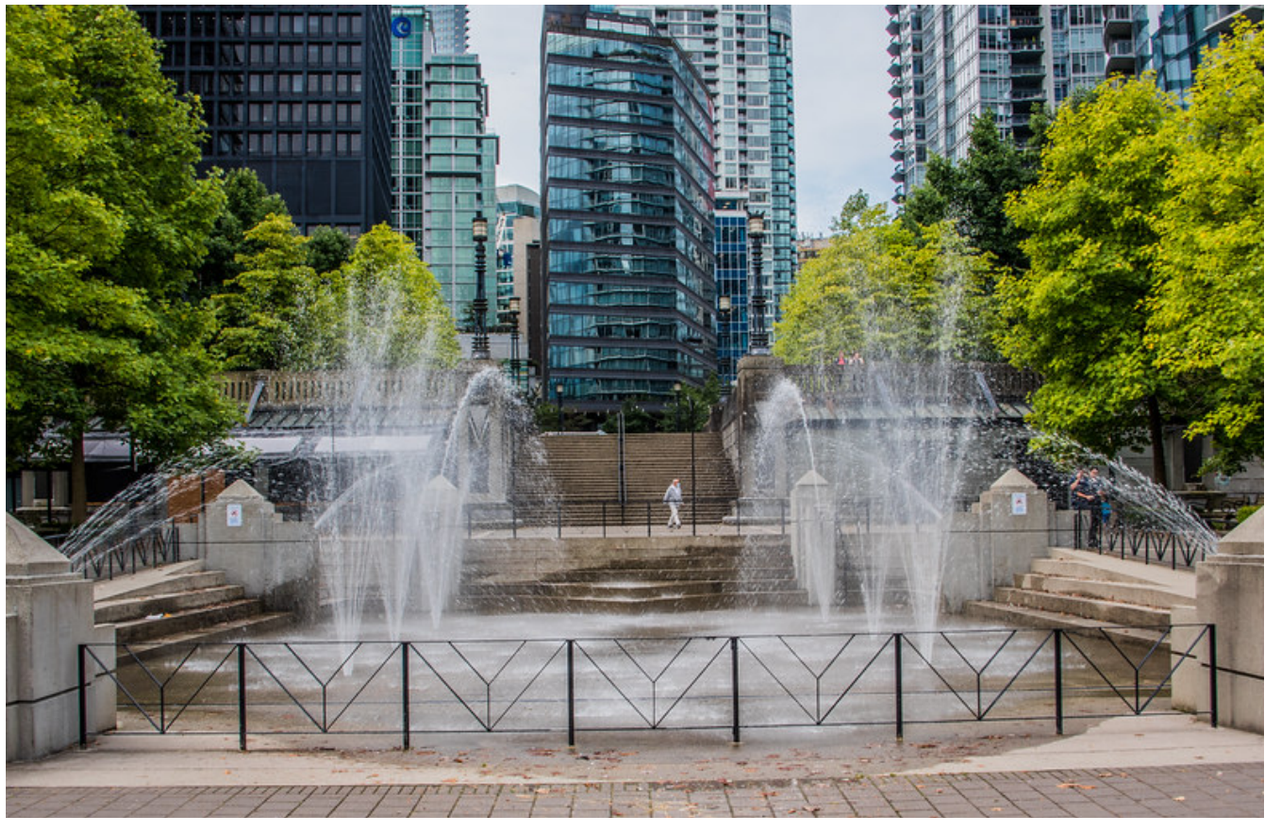
What can Lytton learn from Bateman's Bay?

Meanwhile, each city being affected by the issue can use methods used in the 2019-2020 Australian bushfire to help prevent and minimize effects of wildfires. For example, like IoT sensors, drones, and other technology used to stop the fires from getting uncontrollable (BBC News, 2020).

In the last five years, wildfires across the world have increased and have created significant damage not only to urban forests but many communities. Significant wildfires include the Fort McMurray 2016 Wildfire, 2019-2020 Australian Bushfires, and recent southern California wildfires. Most of these fires are caused by lightning and spread rapidly due to the extreme heat temperatures which is all caused by climate change. The Australian 2020 fires destroyed more than 5.4 million hectares of land and the fire needed to be stopped (Wikipedia, 2021). Therefore, in order to prevent such disasters IoT sensors are being used. These sensors allow wildfires to be detected rapidly and sometime prevented. It signals signs of fire and allows for action to possible before the disaster strikes (Foverskov, 2020). The IoT technology allowed for lowered costs and continuous surveillance of the infrastructure in the vulnerable areas (Fadia, 2020). The bushfires near Batemans Bay and other cities in the state New south Wales has significantly increased and has needed to be monitored especially with climate change increasing every year. Furthermore, with the help of Firefighters and emergency workers the fires were able to be stopped. The firefighters not only used technology like IoT sensors but also aircrafts that carry a belly tank of more than a hundred litres of water (BBC News, 2020). Despite being able to stop the bushfires, the damage caused was very significant and many homes were lost, and wildlife that lived in the forests were killed (Wikipedia, 2021).

POTENTIAL SCARCITY CRISIS DUE TO UNSUSTAINABLE USE OF WATE

VANCOUVER, BC



Water Being Used for Inessential Purposes in Vancouver

"To me, sustainability means the use of the resources we have on this earth to meet our needs without compromising or negatively affecting the ability of future generations to also use them. I feel that this does not only relate to environmental resources and being environmentally sustainable but also in terms of economically and socially."

-Hammad Ahmed

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Although Canada has some of the world's largest amounts of freshwater, parts of the country could be facing water scarcity in the future with the way residential homes have been using water for drinking, personal hygiene, and recreational purposes. One of these cities includes Vancouver, a major Canadian city located in British Colombia with a population of nearly 2,600,000 (Kenneth Chan, 2020). According to statistics, Metro Vancouver has a residential water consumption of 270 liters per capita per day which is not only greater than Toronto's 219 per day, but also Calgary's 210 (Liam Britten,2019). Vancouver citizens excessively high-water use is due to the unsustainable way they are using the resource. The data compiled from a filtration system showed that over $800 million dollars of filtered water goes to homes in the city and experts such as Nick Kerchum, head of Natural Balance, believe that majority of this drinking water ends up being used for recreational purposes such as car washes (Tyee Bridge, 2018). Additionally, due to climate change and rising temperatures, Vancouver faces heat waves and potential droughts with the region recently experiencing a record high temperature of over 40 degrees (Aubrey Clarito,2021). This resulted in an increase in air conditioning levels and various water related activities including swimming, leading to 1.79 billion liters being released from water reservoirs in the month of June 2021, reportedly the highest since 2009 (Aubrey Clarito, 2021). In essence, Vancouver's water use is unsustainable as their excessive consumption of the resource with current climate conditions for inessential purposes may impact the ability of future citizens to have access to water at the same level.

RAINWATER HARVESTING HELPING AVERT TOTAL WATER SCARCITY

CHENNAI, INDIA



Water Scarcity in Chennai

What can Vancouver learn from Chennai?

Implementing rainwater harvesting would allow citizens to continue their use of water for recreational purposes but it would involve the use of rainfall, a form of water which is not limited.

A feasible solution to Vancouver's issue is rainwater harvesting. Vancouver, although facing potential droughts in the future, currently experiences lots of rainfall annually. On average, Vancouver has been experiencing 160 days of rain per year and from 1981 to 2010, these 160 days accumulate to an average of 1457 millimeters of rainwater (Cecilia Mesquita, 2015). This makes rainwater harvesting, the practice of storing rainwater through various structures including barrels, pumps, purification systems for human use, an excellent solution (Swati Ogale, 2014). The water collected can be used for non-potable purposes including cleaning cars and watering lawns, activities which currently use large amounts of fresh water. Additionally, most rainfall water in Vancouver like other cities, falls on rooftops and roads which take it straight to storm sewers. The implementation of the rain harvesting system would promote sustainable water use as it would reduce the load on both freshwater consumptions rates as well storm water infrastructures. A city that is using this system is Chennai, located in India. Chennai, like Vancouver, experiences heavy amounts of rain with an annual rainfall of 140 cm (Lokesh Kaushik Kaushik, 2017). To combat the water scarcity they are facing, they took advantage of their large amounts of rainfall and since implementing the rain harvesting system, Chennai has reported that groundwater levels have risen by 6 to 8 meters throughout the entire city and wells which have been observed as dry for the past few decades have come back (Lokesh Kaushik Kaushik, 2017).

THE WORLD CHANGED FASTER THAN WE THINK AT



HALIFAX, NS



Where does all the snow go once it melts? (Photo taken by Rex Turgano).

Metropolitan Halifax (Halifax) in Nova Scotia is an urban concentration around the Halifax Harbour with a population of more than 300 000 (Statistics Canada, 2019). Halifax composes a third of Nova Scotia's entire population and it serves as an important "seaport with significant industrial, military and municipal infrastructure" (Government of Canada, 2015). In recent years, Halifax has experienced more frequent and severe extreme weather events and became more vulnerable to the consequences of climate change. One of the major consequences is flooding. The increasing rise of coastal water levels, more annual precipitation (rain and snow), and land subsidence are causing more frequent flooding events in Halifax ranging from minor to major floods. According to Dr. Patricia Manuel, a professor in Dalhousie's School of Planning, "[there is a] historic waterfront in Halifax. It was built when sea level was about a metre lower. The buildings are now closer to the tideline and are at sea level" (Auld, 2019); the tideline is pushing toward the land closer and closer every year. The sea level around Halifax rises at a rate of 3.3 mm per year, one of the highest rising sea level rates in Canada (Auld, 2019). On top of this, Halifax receives an average of more than 1400 mm of precipitation every year (W. Richards Climate Consulting, 2011). Depending on the severity of flooding, flooding damages the infrastructures, affects transportation services, and increases the potential of water contamination. Hence, as global temperature continues to rise with more frequent and intense climate shifts, Halifax will need to adapt and become a more sustainable and resilient city.

"Sustainability means being more concise of the resources that we are using and limits the rate that we are consuming the resources in which should not significantly exceed the rate that the resource is being produced, whether that is individually, or for business groups, factories, cities, and countries as a whole."

-Ying Hui Li

RESILIENT INFRASTRUCTURE

CANADIAN ENGINEERING GRAND CHALLENGES

A SPONGE CITY



ROTTERDAM, THE NETHERLANDS



Benthemplein Water Square used as a playground, and a water management site (Photo taken from Sustainable Technologies Evaluation Program)

What can Halifax learn from Rotterdam?

As of August 2020, heatwaves in Western Canada and flooding in Europe are evidence suggesting more frequent and intense extreme events in the future (Migdal, 2021). Although the future is uncertain, cities need to be prepared for their potential weather events as we continue to add greenhouse gases to the atmosphere. Halifax can learn from Rotterdam as they have similar geographic features and implement suitable adaptation strategies that are in line with their city planning.

Many coastal cities around the world are facing the same problem as Halifax. One that stands out of many is Rotterdam in the Netherlands. Rotterdam receives an average of 780 mm of rain annually, which proposes a great problem to the city's drainage system (Larnard, 2020). Moreover, Rotterdam is located at the intersection of two rivers and is situated at sea level (Larnard, 2020). Nonetheless, Rotterdam is ranked as a top sustainable city and a global leader in water management. In addition to the development of dams, dikes, and channels to withstand the risk of flooding, water squares are important structure measures that Rotterdam has adopted. Water square is a water storage facility but also an example of multifunctional land use and sustainable water use. The first Water square is Benthemsquare consisted of "two undeep basins for the immediate surroundings [and] one deeper basin receives water" only when the water is arriving at a continuous rate (De Urbanisten, n.d.). Surrounding stormwater is collected by the basins through stainless steel gutters and goes through an underground infiltration device to the groundwater (De Urbanisten, n.d.). This helps to water the surrounding trees and plants; and to reduce the heat island effect (De Urbanisten, n.d.). The water in the deep basin flows into the city's open water system and not the sewage system, thus removing pressure on the city's sewage system (De Urbanisten, n.d.). When the water square is dry, the square acts as a plaza for residents to play and rest. The first and second undeep basins were designed for people on the wheels to play and "an island with a smooth "so you think you can dance" floor", respectively (De Urbanisten, n.d.). The deep basin allows people to play football, volleyball, and basketball (De Urbanisten, n.d.).

A HOT TOPIC: EXTREME HEAT & URBAN HEAT ISLANDS IN VANCOUVER, BC



A bright orange sky in Vancouver amidst the June 2021 heat wave. (Plana, V)

"By the definition of sustainable methods as methods that "that do not harm people, planet or profit while also leaving a positive impact", I would argue that the adoption of a new sleep schedule supports my physical & mental health, while also ensuring I am in my top form to be able to fulfill my civic duties, reducing trash, littering, reducing reliance on packaged goods, etc., while supporting my top productivity levels."

-Peter Raja Dorkhom Bondi

In 9 days of June in 2021, 569 people died in Vancouver. (Griffiths, N.) Their deaths had a common cause: a dangerous long duration heat wave. (Crawford, T)

Heat waves especially affect urban dwellers. Roughly half of the world's population lives in urban areas, and this number is expected to rise to roughly 70% by 2030. Urbanization negatively impacts the environment mainly by the production of pollution, the modification of the physical and chemical properties of the atmosphere, and the covering of the soil surface. Considered to be a cumulative effect of all these impacts is the UHI, defined as the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island" among the "cool sea" represented by the lower temperature of the area's nearby natural landscape. (Urban heat islands) In common parlance around the GTA, residents speak of the "GTA heat island", a phenomena that largely prevents snowfall from occurring and accumulating in the GTA at rates similar to adjacent rural areas.

Vancouverites, Torontonians and Montrealers live in "urban heat islands," formed when concrete and asphalt replace grass and dirt. Buildings and concrete absorb radiation and release it as heat, making cities up to 12 degrees hotter than their rural counterparts. (Logan, C)

As the most populous city in the province, the 2016 census recorded 631,486 people in the city. The Greater Vancouver area had a population of 2,463,431 in 2016, making it the third-largest metropolitan area in Canada. Vancouver has the highest population density in Canada, with over 5,400 people per square kilometre. (Wikimedia Foundation)

WALK THE WALK, URBAN HEAT ISLANDS AND GREEN CORRIDORS

MEDELLÍN, COLOMBIA



Medellin Green Corridor during Spring (Free Image)

What can Vancouver learn from Medellín?

There are differences between the cities. Medellin is not as well planned as Vancouver, there is a considerable population discrepancy, and the climate is different. However, they are also the same in ways. There is a portion of the population that is very poor and are not able to finance a sustainable and healthy lifestyle on their own. Both cities are adjacent to mountains. Green Corridors and Urban Forests present an opportunity to improve living conditions and reduce the harmful effects of urban heat islands in both cities.

Urban Forests contribute to quality of life and quality of the environment in the city by providing shade. Shade in turn provides affects heating and cooling loads by reducing solar gains. In addition, integrating vegetation with the urban landscape provides opportunities for many potential combinations of building characteristics and arrangements of trees, such as size, and distance from home.

The Green Corridors of Medellín is a project which includes the planting of trees, shrubs, palms, and covers in an environmental network that connects streams, hills, parks, and roads. It is part of the strategy A Greener Medellín for You, which consolidates an ecological system consisting of 18 road axes, 12 stream basins and the Nutibara, El Volador, and La Asomadera hills. This project estimates to reduce up to two degrees Celsius the ambient temperature, also to decrease the effect of heat islands, to capture particulate material and improve the air quality, among others. (Medellín's green CORRIDORS)

Medellín is the second-largest city in Colombia, after Bogotá. It is located in the Aburrá Valley, a central region of the Andes Mountains in South America. According to the National Administrative Department of Statistics, the city had an estimated population of 2,508,452 according to the 2018 census. With its surrounding area that includes nine other cities, the metropolitan area of Medellín is the second-largest urban agglomeration in Colombia in terms of population and economy, with more than 3.7 million people. (Wikimedia Foundation)

MASSIVE HOUSING GROWTH LEAVING INFRASTRUCTURE IN ITS DUST

VANCOUVER, BC



New Buildings being constructed in Downtown Vancouver

As large corridors of Vancouver are starting to gain their beautiful makeovers, experts say that the infrastructure in place cannot keep up with the demand. In the most recent 30 years in the city of Vancouver massive construction and mobilization of resources have begun with the revamp of the Cambie Corridor, including the newly planned Oakridge Mall complex, and the new SkyTrain station being built along Broadway. These developments have revealed that the city has reached and is exceeding the limit in terms of the plumbing infrastructure in place. The sewer capacity has been exceeded with neighbourhoods affected experiencing regular flooding. This steady rise in newer developments with their inadequate plumbing meant that the budget for these projects has increased and their effects on the local environment has been affected as well. The insufficient upkeep and improvements made to the infrastructure has left old 1960s plumbing in some areas of the city that mix both sewage and rainwater to dump into the near by Fraser River. This is also highly problematic because of the increase of chaotic weather conditions and harder rainfalls that overloads the whole system. Vancouver engineers has reported that the rate of the replacement of sewer mains of the city has been decreasing ever since 2016, of 7.5km replaced for $37.9 million, to 2019, of 4.1km replaced for $26.7 million. The province has mandated that the separation of the sewage and rainwater be completed by 2050 and with the declining rate it seems that Vancouver will not meet this target.

""

-Ohyeok Kwon

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

IMPLEMENTING GREEN SOLUTIONS TO COMBAT FLOODING.

DETROIT, UNITED STATES



Bioretention site built by local community in Detroit

In the span of 7 years Detroit has experienced two 500-year storm events due and heavy rain flooding. To combat this $10 million of the $100 million budget for infrastructure upgrades has been put to good use and financed the installation of multiple storm water bioretention solutions such as rain gardens, bioswales, and detention ponds. Between June 25-26 15cm of rain ended of clogging and leaving drivers stranded when the Interstate Highway 94 was flooded, highlighting the growing and alarming issue. The recently installed bioretention gardens has helped manage over 140 million L of storm water every year. This was the result of the culmination of the soil and chambers built under the gardens that helped store and lessen the flow of rainwater and snowmelt. More developments in storm water bioretention in Detriot's Stellantis Assembly Complex has help alleviate around 45.4 million L of water. This was via the stormwater parks installed in a near by area. Although, these metrics and the construction of these solution has given rise to safer neighbourhoods during flooding there are flaws and inadequacies found as well. Namely, another retention pond close by to the Stellantis Assembly Complex was affected by a near by power loss at a plumping station that resulting in the water not being released that damaged 25 vehicles in its wake.

What can Vancouver learn from Detroit?

These solutions being implemented in places such as Vancouver BC where the existing infrastructure has become outdated and inadequate, can "provide for the needs of communities and the economy". This will be done through the implementation of bioretention site because the load on the existing and updated plumbing infrastructure that is built to separate storm water, will be offset by bioretention sites.

FLOODING DUE TO POOR STORM WATER MANAGEMENT



TORONTO, ON



Flooding in the streets of Toronto (WikiMedia Commons, 2013)

Toronto is one of the most populated cities in Canada, home to over 6000000 people. The infamous city attracts everyone worldwide. Climate change in the world today has run rampant, leading to increased frequency in freak weather occurrences such as storms, hurricanes and even droughts. With the increased frequency of these storms, the need for a comprehensive storm water management system has become apparent. In cities like Toronto, the presence of hard and rough surfaces such as buildings, roadways and so on have interrupted the water cycle, preventing infiltration. Consequently, a lot of the rainfall becomes storm water runoff. This leads to excess storm water flowing into the drainage systems which are unable to handle this load, leading to flooding. Previous floods have caused property damage totaling over $850 million (Windfall Centre, 2015). Moreover, the water picks up sediments and pollutants along the way which flow into rivers, lakes and streams, directly impacting the water quality and endangering aquatic life. (O'Neill, 2016) It is clear that additional methods need to be implemented in order further mitigate the impacts of flood water on the city, less the continued development lead to further strain on the storm water management system.

“Sustainability to me, deals with the use of our current resources to improve our environment but also to consider the future generation as well. An example would be not exhausting all of our raw materials.”

-Adrian Sampson

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

GREEN INFRASTRUCTURE IS THE ANSWER!

MILWAUKEE, UNITED STATES



Green Infrastructure showcased on the Streets of Milwaukee. (Volkening, 2010)

What can Toronto learn from Milwaukee?

Toronto can learn from Milwaukee with regards to its drive and support of Green Infrastructure programs, Milwaukee has created and funded programs that span from 2013-2030 thus far. Toronto can take this initiative, launching programs that support the use of green infrastructure in various parts of the city and urban areas. While there is no promise that the programs will be as beneficial for Toronto as it was for Milwaukee, it certainly can be seen as a step in the right direction in comparison to the current grey systems present.

The main reason flooding occurs is due to the increased load on current storm water management systems. These systems are commonly referred to as “grey” systems. These systems tend to fail in a plethora of areas from poor treatment, increased pressure on streams and also possess a high maintenance cost. Green systems or infrastructure may be described as the use of plant and soil systems, permeable pavements and even landscapes as a means to store, infiltrate or even evapotranspirate storm water whereby reducing the influx of water to storm sewer systems. (What is Green Infrastructure?, 2021) One city that has decided to switch to the green solution is Milwaukee. Milwaukee has a population of over 590000 and experiences 34.8 inches of rainfall per year. The city has implemented a program known as ReFresh Milwaukee. (Alliance for the Great lakes, 2020) The program has since implemented a green infrastructure policy plan and increased the amount of storm water absorbed by 10%. The city aims to reach a goal of 740 million gallons captured through green infrastructure in the year 2030. Further, according to Green Stormwater Infrastructure, Milwaukee has experienced several benefits in economy, urban vitality, ecology and public health. (Alliance for the Great lakes, 2020) Milwaukee’s successful implementation in green infrastructure and their further plans to support the program in the future clearly illustrate why it is a necessity. If most cities follow suit and stray from these conventional grey systems, flooding can be significantly reduced.

WATER NEEDS IN A CHANGING CLIMATE

OKANAGAN VALLEY, BC



Kelowna BC on the Shores of Lake Okanagan (Tourism Kelowna, 2021)

“I am very passionate about sustainable energy and innovation which has pushed me to invest my money in several renewable energy companies around North America that aim to increase renewable energy's role in the North American Energy breakdown.”

-Adam Rosenblum

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

The Okanagan Valley is a beautiful region in the British Columbia interior, stretching roughly 200 km in the North-South direction, sandwiched between the Cascade and Columbia Mountain ranges (Marsh, 2006). The region is home to several medium-sized cities including Vernon, Kelowna, and Penticton, as well as a plethora of orchards and wineries. Below is an image of Kelowna, the region’s largest city, on the shores of Lake Okanagan.

Having been described by Statistics Canada as having the smallest per-capita freshwater availability in the country (Okanagan Water Stewardship Council, 2008), the Okanagan has, and will continue to face challenges in meeting the water needs of its growing population and agricultural industry. It is estimated that 70% of the Okanagan’s freshwater demand can be directly attributed to agriculture, while over half of the remaining 30% is used for the irrigation of parks, golf courses, etc. In fact, the growing season water demands can often be 10 times higher the off season demands (Okanagan Water Stewardship Council, 2008). These statistics clearly point to the unsustainable water use seen in the Okanagan Valley over the past decades. With the looming threat of climate change now in sight, the Okanagan will likely see less rainfall along with a warmer and an even drier climate than the already semi-arid conditions. These conditions will only exacerbate the regions already scarce water supply and will require radical changes in behaviour to achieve a more sustainable water future. Making up most of the region’s water demand, the opportunity to innovate in the irrigation industry would be extremely beneficial and could dramatically reduce the area’s water consumption in the years to come.

CAN AG-TECH IMPROVE WATER EFFICIENCY



ISRAEL



Agricultural Land in the Hula Valley of Northern Israel (Wikipedia, n.d.)

What can Okanagan Valley learn from Israel?

In most cases, cities are not in competition with one another, thus, inter-city cooperation has in the past, and will continue in the future, to allow for the progression of humanity and urban spaces. While Israel has made significant headway in the race to sustainable water use, the Okanagan is likely ahead of Israel in other areas. Therefore, it is important for cities to collaborate with other cities around the globe and continue to share ideas.

Israel is a tiny Middle Eastern nation, bordering Jordan, Egypt, Syria, Lebanon, and a nearly 300 km long coastline on the Mediterranean Sea. With much of the country being classified as desert, the small nation has struggled with water scarcity issues since its founding. Thus, Israel has been forced to innovate and deploy cutting edge water conservation technologies. The country has developed excellent desalination technology for drinking water and recycles 80 percent of their water, a number that far exceeds the 5 percent seen in the USA (Regev, 2020). Originally home to a lake called the Hula Lake before being drained, the Hula Valley of Northern Israel is the narrow valley sandwiched between the Upper Galilea to the West and the Golan Heights to the East. In addition to being a stop for millions of birds on their annual migration South, the valley is also home to most of the Israeli Agriculture industry. Below is an image of the mentioned Hula Valley in Northern Israel.

Water conservation has been a pillar of Israeli water management for decades, and the irrigation of the Hula Valley is no exception. Using drip irrigation technologies, watering of the Hula Valley is 90% efficient, a significant improvement over traditional irrigation methods like furrow irrigation that achieves only a 64% efficiency (Israel Ministry of Foreign Affairs, 2013). In addition to many other Israeli built water technologies, Israel's success in drip irrigation has been a major source of pride for the nation, and they have lent their expertise to countries around the globe.

CONTINUOUS BATTLE FOR SAFE WATER



THE FIRST NATIONS COMMUNITY, ON



First Nations boy drinking from tap

“Since sustainability is generally a sizable part of all humans and societies lives, there are many ways in which I incorporate elements of sustainability into my personal life. One way in which my family and I have incorporated sustainability into our lives is switching all the lights in our house from incandescent lights to fluorescent lights.”

-Jovelle Lock

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

With more than 630 First Nations communities being scattered throughout rural Canada, the First Nations make up over 977,000 people, representing more than 50 Nations and over 50 Indegienous languages. Existing for what's speculated by scientists to be roughly 12,000 years, the First Nations make up a large part of Canada’s history and cultures. However, although they were the first community in Canada, it has not prevented them from facing inequalities and a worse quality of life in recent years when compared with the rest of the country.

One of these areas of inequality lies in the First Nations communities' access to safe and clean water. This has not just been a recent issue, as between the years 2004 and 2014, 400 of the 630 First Nations were under at least one drinking water advisory. In which a DWA(drinking water advisory), is a preventative measure issued by the Medical Officer of Health to warn the public that the water is unsafe or contaminated. This commonly occurs in a community when there are problems in the water system such as: a breakage in the water lines, equipment failure and/or poor filtration or disinfection when the water is being treated. Unfortunately, with approximately 73% of First Nations water systems possessing a medium or high risk of contamination, a lack of access to clean and safe-drinking water has been very common amongst them.

As an answer to this crisis, after being elected in 2015, Justin Trudeau promised to allocate $2 billion over the next 5 years to resolve the water crisis. However, it has been further investigated to conclude that $2 billion is not enough and is at least 30% less than what's needed for capital expenditures and on top of that, less than half of the needed $360 million annually for operations and maintenance is being provided. Though there have been improvements, with currently only 33 First Nations communities with outstanding DWA’s, 1 DWA can mean up to 5000 people can be lacking access to safe water, making this still a significant problem that needs to be addressed as soon as possible.

FROM RATIONING OUT WATER TO LEADING A WATER REVOLUTION

SINGAPORE



Singapore's NEWater building

Singapore is a city-state in Southeast Asia being home to close to 6 million residents. Singapore is the largest port in Southeast Asia and one of the busiest in the world. Once just a colony of the British, it became a member of the Commonwealth and became its own independent state on August 9th, 1965. However, being one the more densely populated cities in the world, Singapore has been battling with a water crisis since the city-state came into existence. Around 50 years ago, Singapore struggled with providing clean water and additionally suffered from a water scarcity crisis. The result of this was being forced to ration water, toilets emptied directly into streams and rivers were devoid of fish.

As a response to this issue, in Singapore, PUB manages the entire water loop, in which their goal is to capture every drop of rain it can and recycle as much used water as possible. Singapore is now recognized as a global leader in water technology, as it currently collects rainwater through a 8,000-km draining network that empties into 17 reservoirs and reclaims used water from a deep tunnel underground sewerage system deep underground. Now, Singapore's 4 main national taps supply the population with 400 million gallons of water each day.

In addition, Singapore has two projects that greatly contribute to providing safe and clean water. One being the NEWater system, introduced in 2003. Which takes used water from the sewerage system and treats and filters it through microfiltration, reverse osmosis and ultraviolet disinfection. The NEWater system accounts for 30% of the water demand, with the second main system, the desalination plant accounting for 25%. In which the city-states first desalination plant opened up in 2005. Both of these projects even being fairly independent of the weather and rain percentages.

What can First Nations Communities learn from Singapore?

In conclusion, it is important for cities to improve their sustainable water use habits by taking solutions from other cities/countries and translating them to suit their own needs. As mentioned previously in the project, the First Nations communities implement the ideas made by places like Singapore, with the ideas of capturing rain and recycling it as much water as possible by treating and filtering it so it is safe to drink. This way they can create more access to clean water, while also improving the public's health and wellbeing.

A BRICK FOR STICK



QUÉBEC CITY, QC



Forestry Covering Québec City

Québec City is the capital city of the province of Québec. Today, the Greater Québec City area is home to 717000 inhabitants and spans 9000 square kilometers. It is located on the banks of the St. Lawrence River and is the second largest city in the province of Québec. Urbanization within Québec City has had a drastic impact on the health of the urban forestry located within the city. Activities such as the construction of residential sites as well as renovating existing infrastructure is known to reduce the forestry located within the city due to the space requirements needed by the new or renovated structure. These projects also tend to damage trees in many ways some of which include, creating impermeable surfaces which restrict water absorption by the soil, damage to the root system of the trees which may lead to the death of the tree, as well as a reduction in the growth of the trees. The loss of urban forestry could result in consequences as urban forestry is known to improve to water supply as well as quality, air quality, it can contribute to flood reductions as well as temperature regulation. A study has found that the "natural canopy in the areas covering Québec City, Beaupré, l'Île d'Orléans, Lévis and other communities along the St. Lawrence River found it generates more than $1.1 billion in annual benefits." (Ruel, 2021). Benefits which will be lost if the continued reduction of urban forestry continues.

"Sustainability to me is the act of consuming and utilizing the world around us without causing harm to our surroundings as well as ensuring that world can continue to exist and function at an acceptable standard that not only enables human activities to continue but allows those who we share the world with to thrive as well. As engineers, it is our job to make sure that the world we build around us is one that is sustainable as it is habitable."

-Jayson Rex Maningding

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

GREENER DAYS



BARCELONA, SPAIN



Edifici Banca Catalana building in Barcelona

What can Québec City learn from Barcelona?

Overall, both cities can further improve their efforts in creating a greener city. The reduction of urban forestry in Québec City could be combatted by efforts such as the projects seen in Barcelona. The importance and benefits of urban forestry are great and should be valued rather than taken away and it is crucial that we see the greenery in our cities as an asset rather than an obstacle as we continue to develop as a society.

Barcelona is known as a major commercial center as well as a port city. The city is located on a plain in northeastern Spain. The region has an annual average temperature of 16 °C and experiences 600 mm of precipitation per year. Barcelona is home to 1.62 million inhabitants with the metropolitan area spanning 3235 square kilometers. Despite the area being a large metropolitan and commercial area, efforts have been made to increase the amount of greenery and biodiversity within the city through the implementation of projects such as the "Barcelona Green Infrastructure and Biodiversity Plan 2020" as well as the "Tree Master Plan". According to the Barcelona Green Infrastructure and Biodiversity Plan 2020 (2013), the goal of this project is to create green infrastructure within the city in hopes of achieving the maximum amount of green infrastructure and ensuring its connectivity, obtaining the maximum number of social and environmental services from green infrastructure and biodiversity as well as making the city more resilient in the face of future challenges such as climate change. Some of the actions this plan aims to take are increasing the volume of green space through the introduction of green roofs and walls, to provide greater areas of permeable ground, as well as increasing the presence of trees in pre-existing green areas to increase density. Correspondingly, the Tree Master Plan (2017) has similar goals in which it aims to increase Barcelona's tree cover by 5%, in addition to not only having a tree population that forms a real green infrastructure but also a tree population that provides maximum environmental, social, and economic services to the city. As of today, a budget of €9.6 million annually has been set aside for the Tree Master Plan which plans to run from 2017 to 2037.

DECADES OF UNSAFE WATER FOR RESIDENTS



NESKANTAGA FIRST NATION, ON



A local resident runs water for a bath in the community of Neskantaga First Nation.

"Sustainability to me is the development and innovation of technologies that allow for human activities to have a net zero impact on their surroundings and environment. It is also the ability for our activities to be able to be managed and held for a long-term time horizon."

-Lucas Scott

SAFE WATER IN OUR COMMUNITIES

CANADIAN ENGINEERING GRAND CHALLENGES

Access to clean drinking water has been an issue in many Canadian First Nation Reserves for a long time. Despite Canada's abundant supply of clean freshwater, many of those living on First Nation Reserves have had to rely on boiling tap water for years. This lack of clean water has been largely due to the high number of contaminants found in the water around these communities, as well as old and failing water treatment plants that have often been ignored by government bodies. Lack of funding and policies has forced these communities to rely on bottled water as their treatment plants sit unfinished or non-operational. It has been estimated that roughly 73% of the water systems in Indigenous communities in Canada are at risk of contamination.

In Neskantaga First Nation, around 450km North of Thunder Bay, this has been the reality for over 25 years. Water contamination has run so badly that many of the residents in the area have had to evacuate on several occasions, the latest being last October 2020 when 300 members were forced to live in a hotel after an oil contamination in the community's reservoir (Stefanovich, Dec 2020). The community itself has a registered population of around 414 people and encompasses an area of roughly 2000 acres. This includes a long history of moving and headaches for many community members in Neskantaga First Nation. In 1993 a natural sand, low-filter water treatment plant was constructed but had failed to properly treat the water since it's inception, causing the residents to be under a boil-water advisory since 1995 (Ketelaars, Apr 2021).

LEGISLATION AND INVESTING IN CLEAN WATER

ZHIIBAAHAASING AND WASHAGAMIS BAY FIRST NATIONS



Children play in the ditch of a small First Nation community that has been turmoiled by unclean water for decades.

What can Neskantaga learn from Zhiibaahaasing?

As progress is made in constructing new facilities and water lines for these communities, lessons can be made from past mistakes and the experience gained from each new project can help influence the next. These lessons can include: what are the best and most economical ways to treat water for a small community, where to install water lines, what methods to use for treating waste water, and more.

The solution to providing clean and safe drinking water to communities across Canada is through the introduction of protective legislation and investments into infrastructure to support these provisions. Investments into the improvement of existing water treatment facilities and training more staff to help operate these facilities could help reduce these issues. Lack of funding and government overlook is the main reason for many of these issues in these communities, something that proper policies and legislation could help solve.

In March of 2021, the Ontario and Canadian Government announced an investment of nearly $70 million in a wide range of projects across the province to provide safe drinking water to 37 First Nation communities (Infrastructure Canada, Mar 2021). These projects will include the repair of existing water lines throughout many of these communities, the repair and reoperation of water treatment plants, and the construction of new water treatment systems. In Zhiibaahaasing First Nation, the current distribution and storage systems will be revamped to ensure reliable access to drinking water. In Washagamis Bay, around 2km of water mains and service lines will be fixed and replaced, as well as many upgrades to local septic fields to ensure better filtration of the groundwater. Other actions under these plans have been to send certified trainers to many communities in need to train local staff/ operators on properly assessing their equipment and providing the correct tools to maintain water treatment systems in their communities (The Canadian Press, Nov 2020).

CLIMATE CHANGE BURNS – URBAN FORESTS FUEL WILDFIRES

LYTTON, BC



Firefighter surrendering to the wildfire

Global warming has increased temperatures in Canadian cities to record highs this summer and many Canadians are suffering from the consequences. Specifically in the town of Lytton, British Columbia, heatwaves with a high of 49.6°C set off a series of wildfires in the area causing a record of 486 deaths in the province, almost 200% more than what was typically expected (BBC, 2021). Wildfires occur as a result of increased temperatures and dry forests which act as tinder for the fire. Due to the urban forests' proximity to cities and towns with high levels of greenhouse gas emissions, heatwaves are a typical source of climate-related stress on the environment (Safford, 2013). The deforestation and additional carbon dioxide emissions as a result of annual wildfires contribute to furthering the climate problem.

The town of Lytton is home to approximately 250 residents and based roughly 260 kilometres from Vancouver, BC (BBC, 2021). Lytton is known for being the hottest spot in Canada as well as their shorter Winters. Although it is not the driest town in BC, its limited 430.6 mm of annual precipitation sets Lytton up for wildfires every summer (Climate, 2021). As the wildfires spread within minutes, residents were forced to grab minimal belongings and flee their homes as the entire town burned behind them. Kanaka Bar is a First Nations community near Lytton that was also affected by the wildfires and had to leave their homes.

"To me, sustainability is the understanding that as humans we have a responsibility to nurture the Earth so that it can continue to provide for us and many more generations to come."

-Nayab Butt

SAFE AND SUSTAINABLE CITIES

CANADIAN ENGINEERING GRAND CHALLENGES

YOU CAN FIGHT FIRE WITH FIRE — BENEFITS OF PRESCRIBED FIRES

GRANGEVILLE, UNITED STATES



A peek into the impact on air quality as a result of a prescribed fire

What can Lytton learn from Grangeville?

I believe that city to city learning should definitely be implemented to begin resolving this problem in Western North America. There's a lot of hesitancy around Prescribed Fires but the entire state of Idaho has benefited from this approach and has been able to maintain less risky and lower amounts of wildfires while the rest of the West has struggled. I believe that other cities can learn from their solution and adopt it according to the resources available to them.

The solution identified that addresses the wildfire problem that many cities experience globally is Controlled Burning also known as Prescribed Fire. Controlled burning is when a fire is initiated under controlled situations in which it is ensured that people and residential areas will remain safe in order to reduce the amount of combustible vegetation that acts as fuel in the forest (The Nature Conservancy, 2019). This method is utilized to prevent future uncontrollable fires and due to the understanding that fires are beneficial in restoring healthy forests and promoting sustainability in the urban forest ecosystem.

A city that has successfully and actively implemented Controlled Burning as a solution to their wildfire problem is Grangeville, Idaho, home to the Nez Perce – Clearwater National Forests (USDA Forest Service, n.d.). Each summer, they plan to pursue Controlled Burning at a time when weather is optimal and the impact of smoke on nearby communities can be minimized, burning an estimated amount of 5000 acres (USDA Forest Service, n.d.). The state has recently formed the Idaho Prescribed Fire Council in order to further their efforts in using Prescribed Fires as a proactive solution. However, due to the hesitancy surrounding the act of willingly starting a fire, the potential for it to become uncontrollable, and the large amounts of carbon dioxide being released on purpose, state governments outside of Idaho have tight restrictions on the use of Prescribed Fires (Kasler et al., 2021). Prescribed Fires have been greatly beneficial for Idaho; While the wildfires in the West get increasingly more fierce, Idaho's approach has resulted in just roughly 500,000 acres of land being burned, resulting in the state only experiencing smaller fires since 2012 (Kasler et al., 2021).

APPENDIX A: COURSE SYLLABUS

CIVE 230 Engineering and Sustainable Development
Spring 2021

1. TEACHING TEAM

INSTRUCTOR: Dr. Nadine Ibrahim nadine.ibrahim@uwaterloo.ca

TA/CAs: Ezgi Demircan Ozelcaglayan edemircan@uwaterloo.ca
Aida Mollaei aida.mollaei@uwaterloo.ca
Mahmoud Badawy mbadawy@uwaterloo.ca
Shreenita Chhetri schhetri@uwaterloo.ca

When sending emails, please start with "CIVE230" in the subject.

2. SCHEDULED COURSE TIMES

SYNCHRONOUS LECTURES:	Tuesdays/Thursdays 10-11:20am EST
PROFESSOR OFFICE HOURS:	Tuesdays 11:30am-12:30pm EST, or by appointment
ONLINE SOCIAL MEETS:	Thursdays 4-4:30pm EST (OPTIONAL)
SYNCHRONOUS TUTORIALS:	Thursdays 4:30-5:20pm EST

3. COURSE DESCRIPTION

This course introduces the concept of sustainability and how it applies to decision-making in Civil Engineering. The course begins by defining sustainability, both practically and technically, and describing the concepts of systems and systems interactions. Quantitative methods and measures of effectiveness are derived and applied to components of sustainability: air quality, water quality, energy and solid waste. Attention is given to sustainable urban systems and alternatives, as they apply to both developed and developing countries. Sustainability concepts covering the triple bottom line are presented, and their applicability to sustainability are described. The course deals with sustainability on two levels. First, the qualitative concepts and background information is presented. Next, specific, quantitative models which emphasize core engineering methods (such as probability and statistics, operations research, or simulation) are presented and applied to sustainability problems.

4. LEARNING OUTCOMES

Upon the successful completion of this course, students should be able to:

- Define sustainability concepts in terms of air quality, water quality, electricity/energy intensity, and solid waste management;
- Measure sustainability indicators using appropriate units, time scales, and mathematical models;
- Present life-cycle based analyses of activities' and products' impacts on sustainability;
- Apply environmental, social and economic concepts to assess the sustainability of urban systems in developed and developing country contexts;
- Evaluate strategies to mitigate threats to sustainability including the prevention of threats through passive or natural treatments, engineered solutions, and economic and policy incentives and government interventions; and
- Communicate technical information to various audiences.

5. TEACHING APPROACH

I'll be teaching sustainable development and its connection to engineering using both a qualitative and quantitative understanding of sustainability. Qualitatively, this involves describing sustainability objectives, trends, current conditions and future projections, and to have a technical and public understanding of sustainability challenges. Quantitatively, this involves modeling environmental parameters using linear programming, differential equations, regression and extrapolation, and understanding the metrics used for sustainability assessments.

I use a diversity of coursework to test your knowledge and understanding. This will be in the form of surveys, projects and visual submissions, in addition to more traditional assignments and quizzes. I believe students have different strengths, where the diversity of coursework will leverage individual strengths and give everybody a chance to shine!

Communication is key! I'll be communicating with the class more frequently than I typically would because of the nature of this term being fully online. This includes hosting a social hour because it's important to build a sense of community among the class. I'll be using the Announcements widget on LEARN during the term to communicate new or changing information regarding due dates, as needed. I encourage you to read the announcements on a regular basis and stay up to date.

The course modules are structured so that you will be busy during the week, and I want you to take a break on the weekend, every weekend, at least in my course! Try to not postpone your homework till the weekend, and use this time to recharge.

6. EVALUATION

Assignments (6 in total):	35% (Crowdmark)
Sustainability Survey:	5% (LEARN Survey)
Sustainability Project:	15% (LEARN Dropbox)
Quizzes (3 in total):	45% (LEARN Online Quiz)

Although we do our best to avoid them, mistakes can be made in grading. If you wish to query the mark you receive on coursework, then you should send an email to the instructor indicating the basis of your appeal and attaching your work for review. You must do so **within one week** of receiving your grade.

Awards: We all appreciate incentives and a pat on the back for doing a good job. To do this remotely, I'll be using the digital awards/badges on LEARN, so keep an eye out when you receive them.

Late Penalties: Late submissions will be accepted one day after the submission deadline, but a late penalty will be applied (20% off for within 24 hrs after due date). Some situations can warrant exceptions - speak to the instructor about these, and I'll do my best to accommodate extenuating circumstances.

Slip Day: A fully online term means you may encounter technology mishaps. You have one slip day to use on assignments and course activities (not quizzes). A slip day allows students the ability to submit one assignment or other coursework one day after the due date without penalty. Students choose which assignment or coursework they would like to apply the slip day to.

7. COURSE SCHEDULE

The course is structured in weekly modules where one topic is covered per week (typical format for online courses). Mark your calendars.

Week	Date	Module Topic	Activities/ Assignments	Due Dates	Quizzes
0	May 3-9	• Welcome and online working plan[a]			
1	May 10-16	• Course overview • Introduction to sustainability	• Assignment 1 posted • Sustainability Survey posted	• Sustainability Survey: May 16	
2	May 17-23	• Fundamentals of energy, environmental chemistry and growth	• Sustainability project posted[b]	• Assignment 1: May 25	
3	May 24-30	• Global atmospheric change including climate change	• Assignment 2 posted		
4	May 31-June 6	• Air pollution and models of air quality		• Assignment 2: June 7	
5	June 7-13	• Water resources and water scarcity issues	• Assignment 3 posted		Quiz 1: June 10
6	June 14-20	• Water pollution and methods to improve water quality		• Assignment 3: June 21	
7	June 21-27	• Energy – fossil fuels and renewables	• Assignment 4 posted		
8	June 28-July 4	• Solid waste management and treatment methods		• Assignment 4: July 5	
9	July 5-11	• Life Cycle Assessment	• Assignment 5 posted		Quiz 2: July 8
10	July 12-18	• Sustainable cities and sustainability assessments		• Assignment 5: July 19	
11	July 19-25	• Sustainable buildings and transportation	• Assignment 6 posted		
12	July 26-Aug 1	• Sustainable energy, water use, and urban green		• Assignment 6: Aug 3	
13	Aug 2-5	• Review			Quiz 3: Aug 5
Final Assessment Period Aug 7-16		NO EXAM FOR THIS COURSE			

Notes:

a. Completing the online work plan is optional.
b. Various due dates based on the last digit of your student number.

8. MODULES (aka LECTURES)

Module topics will be presented in multiple formats to provide flexibility for different users and learning preferences. It is expected that students will learn by viewing the recorded material, and attend the synchronous sessions. Lecture slides will be posted periodically on LEARN, along with reading references and resources, and other supporting material, if and when required. This is the lecture flow that will take place for each module on a weekly basis:

- **Monday:** Lecture slides will be posted in advance of the synchronous lectures. Pre-recorded material will be posted to LEARN. Please send in questions you may have as you go through the posted and recorded material.
- **Tuesday:** Synchronous lectures are scheduled 10-11:20am EST on Teams, which will be recorded via MS Stream for those who cannot or are unable to attend. No student should be disadvantaged by being unable to attend synchronous sessions. Recordings of the synchronous sessions will be made available on Teams.
- **Thursday:** Synchronous lectures are scheduled 10-11:20am EST on Teams. The objective of the Thursday session is to go through worked examples or dive deeper into certain topics and answer student questions. Recordings of the synchronous sessions will be made available on Teams. Thursday synchronous times will also be used to schedule the quizzes.

9. TUTORIALS

Tutorials will be structured to work through practice questions that are similar in nature to the ones that are in assignments, in addition to create a learning environment where students can seek the support of the teaching team for help with the assignment questions. TA/CAs will post pre-recorded worked examples on LEARN, and hold synchronous tutorials which are scheduled 4:30-5:20pm EST on Teams. Piazza will be available for Q&A throughout the term.

10. ASSIGNMENTS

There will be six (6) assignments scheduled throughout the term which are to be handed in for marking on Crowdmark. Assignments are due by 10am on Monday on the weeks that they are due. I strongly encourage that you take the weekend to rest. The deadline for each assignment will also be stated on the assignment hand out as a reminder. The teaching team will be running the tutorials to help students with their work, in addition to grading the assignments.

Coursework handed in for credit must be completed as an individual. Any exceptions to individual work must be acknowledged. If you are in doubt, contact your TA/CAs or instructor. Except for quizzes, you are encouraged to seek/give help from/to peers, but this help must stop short of using another peer's or group's work as your own. The best practice is to receive/give help without exchanging copies of the work, then redoing the work on your own.

11. QUIZZES

This course has three (3) quizzes that are scheduled on: Thursday, June 10, Thursday July 8, and Thursday August 5. These are individual assessments, and an equation sheet will be provided.

Synchronous quizzes will be scheduled using LEARN Quiz, and will have 90-minutes timed duration. Students who require adjustments as identified by AccessAbility Services will be accommodated by changes to quiz durations and start and end times. Also, students who have time zone differences that make quiz times unreasonable can be accommodated.

12. SUSTAINABILITY SURVEY

A knowledge survey on your thoughts and experiences with sustainability concepts and practices will be scheduled as a broad reflection on sustainability. This will be open in the first week of term and is due by Sunday, May 16 at 11:59pm EST.

13. SUSTAINABILITY PROJECT

An individual project is assigned to apply course concepts for a city of your choice and explore sustainability concepts. Every student will get a chance to contribute sustainability knowledge in cities, which could go beyond course content. This project is to encourage you to explore sustainable infrastructure, solutions and technologies globally to generate an enriched learning experience and to map your ideas to the Sustainability Development Goals (SDG) and the Canadian Engineering Grand Challenges (CEGC). Your project submissions will be compiled together to form an e-book by the class for online publishing. More information on the Sustainability Project instructions will be provided later when posted.

The topic is assigned based on the last digit of your student number, as follows:

Last digit of student ID	Topic	Module Week and Due date
0	Global atmospheric change including climate change	Week 3: due May 30
1	Air pollution and models of air quality	Week 4: due June 6
2	Water resources and water scarcity issues	Week 5: due June 13
3	Water pollution and methods to improve water quality	Week 6: due June 20
4	Energy – fossil fuels and renewables	Week 7: due June 27
5	Solid waste management	Week 8: due July 4
6	Sustainable buildings	Week 9: due July 11
7	Sustainable transportation	Week 10: due July 18
8	Sustainable energy	Week 11: due July 25
9	Sustainable water use and urban forests	Week 12: due August 1

14. Q&A

This term we will be using Piazza for class discussion. The system is highly catered to getting you help fast and efficiently from classmates, the TAs, and myself. I encourage you to post your questions on Piazza. Find our class signup link at: https://piazza.com/uwaterloo.ca/summer2021/cive230

15. ONLINE SOCIAL MEETS

Did you notice on the first page that there was a scheduled social time every Thursday 4-4:30pm EST? Social presence throughout the course is very important to students' learning, particularly in this fully online term. It's also a chance for me to get to know you as well, so that you are not just a name and a grade on a spreadsheet. **This is optional.** If you can, I encourage you to join to discuss topics that are not necessarily related to the course, eg. work space, morning routine, study habits, or the city that you currently live in. This is how we will try to remain connected even when distant.

16. RESOURCES AND REFERENCES

Portions of two texts will be used for developing supporting material for this course:

Edward S. Rubin and Cliff I. Davidson, 2000. Introduction to Engineering and the Environment. McGraw Hill. [ISBN 0-07-235467-4]

Gilbert Masters and Ela Wendell, 2008. Introduction to Environmental Engineering and Science 3rd Edition, Prentice Hall. [ISBN 0-13-148193-2]

Additional material will be sourced from Knovel and OER (Open Education Resources) Commons.

17. REMOTE TEACHING AND LEARNING TOOLS

Online learning means lots of online tools. The following is a list of the online tools that will be used:

- LEARN (https://learn.uwaterloo.ca/) will be used for posting lecture material, readings, weekly checklists and other online links, pre-recorded videos, conducing online quizzes and surveys, and project submissions on the Dropbox.
- Crowdmark (https://app.crowdmark.com): Assignment submissions
- Teams (https://uwaterloo.ca/office-365/about/apps-you-have-access/teams):
- Piazza (https://piazza.com): Q&A and discussions

18. GRADUATE ATTRIBUTES

Graduate attributes that are applicable to this course and assessed, are as follows:

GA1 - Knowledge Base
- 1b. Demonstrate understanding of concepts in natural science
- 1d. Demonstrate understanding of specialized engineering knowledge

GA2 - Problem Analysis
- 2a. Formulate a problem statement
- 2b. Develop models to solve engineering problems including identifying approximations, assumptions and constraints
- 2c. Critically evaluate solutions of engineering problems

GA3 - Investigation
- 3a. Design experiments to investigate complex engineering problems

GA4 - Design
- 4b. Critically evaluate and compare design choices

GA5 - Use of Engineering Tools
- 5a. Select appropriate engineering tools, considering their limitations

GA7 - Communication Skills
- 7a. Orally present information within the profession and to society at large
- 7b. Communicate in a written format within the profession and to society at large

GA9 - Impact of Engineering
- 9a. Identify the relevance of and uncertainty associated with the different aspects (social, cultural, economic, health, safety, legal, environmental), of an engineering project.
- 9b. Analyze the social, health, safety, and environmental aspects of an engineering project, incorporating sustainability considerations in making decisions.

19. ONLINE ETIQUETTE

Professional online communication is expected always. Refer to Student Guidelines for Communicating in Online, Professional Contexts. Simply put, if you wouldn't share it in public, don't share it online, and if you wouldn't say it to someone's face, don't say it online.

20. ACADEMIC INTEGRITY
In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. The Office of Academic Integrity provides relevant information for students, faculty and staff.

21. DISCIPLINE. Students are expected to know what constitutes academic integrity, to avoid committing academic offences, and to take responsibility for their actions. Completion of the Orientation to Academic Integrity Tutorial is encouraged and familiarity with Policy #71, (Student Discipline) is expected. Students who are unsure whether an action constitutes an offence, or need help in learning how to avoid offences (e.g., plagiarism, cheating) or understand 'rules' for group work/collaboration should seek guidance from their course instructor, academic advisor, or the Associate Dean of Science for Undergraduate Studies. For information on typical Policy 71 penalties, students should check Guidelines for the Assessment of Penalties.

22. GRIEVANCE
Students, who believe that a decision affecting some aspect of their university life has been unfair or unreasonable, may have grounds for initiating a grievance. Students should read Policy #70, Student Petitions and Grievances, Section 4. When in doubt, students must contact the departmental/school administrative assistant who will provide further assistance.

23. APPEALS
A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (other than a petition) or Policy 71, Student Discipline may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72, Student Appeals.

24. STUDENT ACCOMMODATIONS
AccessAbility Services, located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If students require academic accommodations to lessen the impact of their disability, they should register with AccessAbility Services at the beginning of each academic term.

25. CORONAVIRUS INFORMATION
Coronavirus Information for Students This resource provides updated information on COVID-19 and guidance for accommodations due to COVID-19.

26. MENTAL WELLNESS
All of us need a support system. We encourage you to seek out mental health supports when they are needed. If you find yourself suffering during this or any other term from anxiety, stress, or issues related to mental health, this is nothing to be ashamed of, and it is recommended you seek help; refer to Engineering Counselling and Campus Wellness and Counselling Services.

We understand that these circumstances can be troubling, and you may need to speak with someone for emotional support. Good2Talk is a post-secondary student helpline based in Ontario, Canada that is available to all students.

27. RESOURCES FOR ONLINE LEARNING

Thanks to the Faculty of Engineering of sharing these links that will help prepare students to be successful online learners:

- Common mistakes to avoid as a new online student
- Getting Ready to Learn on Line
- What makes a successful online learner
- 8 strategies for getting the most out of an online class
- Tips for taking online exams
- Online exam tips you'll be thankful for

28. TERRITORIAL ACKNOWLEDGEMENT

We acknowledge that we live and work on the traditional territory of the Attawandaron (Neutral), Anishinaabeg, and Haudenosaunee peoples. The University of Waterloo is situated on the Haldimand Tract, the land promised to the Six Nations that includes ten kilometres on each side of the Grand River.

As we are likely located across the world throughout this fully online Spring 2021 term, indigenous communities globally have lived sustainably with nature. Specifically for this course on engineering and sustainable development, I wish to recognize the innovations that came before us, and appreciate the sustainability principles that indigenous communities have lived by.

29. COMMITMENT TO CLIMATE ACTION

The Intergovernmental Panel on Climate Change (IPCC) calls for drastic reductions in greenhouse gas emissions to limit global warming to 1.5 C above pre-industrial levels. Climate change has several adverse implications for life on Earth, including the extinction of animal species and impacts on the livelihoods of all peoples. The effects of climate change are not evenly distributed and exacerbate existing inequalities, especially for Indigenous Peoples, People of Colour, and other peoples who are socially and economically disadvantaged. Consequently, it is essential to take prompt action to address climate change at all levels, from local to international. It is imperative to understand our individual, as well as collective, contributions to climate change and take meaningful action to reduce those impacts.

If you would like to become involved with climate change related initiatives on campus and internationally, please see the following links.

- Climate Change Student Group: https://uwaterloo.ca/climate-centre/training-and-education/climate-students
- Interdisciplinary Centre on Climate Change (IC3): https://uwaterloo.ca/climate-centre/
- Sustainability Office: https://uwaterloo.ca/sustainability/
- Project Drawdown: https://www.drawdown.org/solutions

If you have read this syllabus to the end, well done and thank you. Let me know that you have read the syllabus by sending me a picture of your favourite city to my email!

WELCOME TO CIVE 230

APPENDIX B: PROJECT INSTRUCTIONS

CIVE 230 Engineering and Sustainable Development

Sustainability Project

(due on various Sundays at 11:59pm EST on LEARN Dropbox)

The sustainability project is an individual project worth 15% of your final course grade. You have an opportunity to apply course concepts to cities of your choice and explore sustainability challenges and innovations, which could go beyond course content. This project is to encourage you to explore sustainable infrastructure, solutions and technologies in Canada and globally to generate an enriched learning experience and to tie your ideas to the Sustainability Development Goals (SDG) and the Canadian Engineering Grand Challenges (CEGC). **This project has 3 parts.**
Your project submissions will be compiled together to form an e-book by the class for online publishing.
The topic is assigned based on the last digit of your student number, as follows:

Last digit of student ID	Topic	Module Week and Due date
0	Global atmospheric change including climate change	Week 3: due May 30
1	Air pollution and models of air quality	Week 4: due June 6
2	Water resources and water scarcity issues	Week 5: due June 13
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4	Energy – fossil fuels and renewables	Week 7: due June 27
5	Solid waste management	Week 8: due July 4
6	Sustainable buildings	Week 9: due July 11
7	Sustainable transportation	Week 10: due July 18
8	Sustainable energy	Week 11: due July 25
9	Sustainable water use and urban forests	Week 12: due August 1

PART A. Canadian City Challenge
Select an environmental problem based on your weekly topic of focus that is observed in Canadian city (do not limit yourselves to major Canadian cities, and explore towns and communities across Canada from coast to coast to coast). In 300 words:

- Provide a creative title for this part (the title should at least name the problem and Canadian city).
- Describe the environmental challenge based on your topic of focus.
- Describe the Canadian city, town, community of your choice.
- Include only one representative image of the problem in your city of choice.
- Provide a title for the image

PART B. Global City Solution
Select a technological or infrastructure solution/innovation, or policy, or sustainability strategy to address the problem you have identified and its application in a city around the world. Again, do not limit yourself to large capital cities in the world, and explore towns and communities as well. In 300 words:

- Provide a creative title for this part (the title should at least name the solution and global city).
- Describe the technological, infrastructure solution, policy, strategy to address the problem.
- Describe the global city that has successfully implemented this solution.
- Include only one image of the solution in the city around the world that you selected.
- Provide a title for the image.

PART C. Connecting to CEGC and SDG

The problem you have identified relates closely to the Canadian Engineering Grand Challenges (CEGC), and the solution you have researched relates to one or more of the Sustainable Development Goals. In 300 words:

- Identify the Canadian Engineering Grand Challenge (CEGC) that this problem relates to in the Canadian city you have selected, and reflect on why it is important to address this challenge.
- Identify which SDGs this solution helps address. It is likely there will be one main SDG and other related SDGs that it relates to. Reflect on specific targets of the SDGs that are relevant.
- Reflect on the city-to-city learning by addressing what one city can learn from the other.

Important considerations for project submission

Written communication: When describing cities, problems, and solutions, aim to be both qualitative and quantitative in your descriptions. For example, depending on your topic of focus include city population, amount of waste, magnitude of pollution in the waters, amount of air pollution on highways, or how much greenhouse gas emissions can be reduced by solar panels, or how much water can indigenous communities have access to as a way to be quantitative. To be qualitative, provide descriptions using concise language (do not use flowery language in engineering communication).

Referencing information: Use the American Psychological Association (APA) style for referencing of information and use in text citation eg. (Author, Date). An example of a report reference:
UNDP (2015). Bus Rapid Transport Development in Greater Jakarta (Jabodetabek): Finance-Ready Proposal. Retrieved on May 21, 2021, from:
https://www.undp.org/content/dam/LECB/docs/pubs-namas/undp-lecb-Indonesia-Bus-Rapid-Transport-Report-201512.pdf

Referencing images: Make sure you use only images that have Creative Commons licenses (which means you are allowed to use re-use the images). You can do an image search on
Google>Images>Tools>Creative Commons licenses
An example of an image reference:
Harmoni Central Busway Transjakarta 1 by Gunawan Kartapranata is licensed under CC BY-SA 4.0
https://commons.wikimedia.org/wiki/File:Harmoni_Central_Busway_Transjakarta_1.JPG

Font: Arial or Times New Roman font size 11.

Submission: Submit your Sustainability Project as a single document in word (.doc) not PDF to LEARN Dropbox.

Resources to help you get started:

Engineering Deans Canada (2019). Canadian Engineering Grand Challenges (2020-2030): Inspiring action to improve life for Canadian and the world. Retrieved on May 21, 2021, from: https://engineeringdeans.ca/en/project/cegc/

United Nations (n.d.), Sustainable Development Goals, Department of Economic and Social Affairs, Sustainable Development. Retrieved on May 21, 2021, from: https://sdgs.un.org/goals

Best of luck authors!!

If in doubt about the choice of topic, city, problem, solution for your project, feel free to ask on Piazza (Project tab) or by email nadine.ibrahim@uwaterloo.ca

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Chapter 2: Air Pollution and Models of Air Quality

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Chapter 3: Water Resources and Water Scarcity Issues

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A helicopter drops a bucket of water on the Chuckegg Creek wildfire west of High Level, Alberta on Saturday evening, May 25, 2019 by Chris Schwarz/Government of Alberta is licensed under CC BY-NC-ND 2.0 https://www.flickr.com/photos/governmentofalberta/47936527263

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Chapter 4: Water Pollution and Methods to Improve Water Quality

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Chapter 5: Energy - Fossil Fuels and Renewables

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Chapter 10: Sustainable Water Use and Urban Forests

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