Decarbonizing the GTHA's Urban Rail Transit: A Mixed Methods Analysis of Barriers and Drivers to Electrifying the Metrolinx GO Trains

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Disclaimer

This report does not represent the views of any organization and are solely the views of the author.

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Foreword

In studying a sustainable transition to renewable energy in the Greater Toronto Hamilton Area (GTHA), it is critical to examine the ways in which policy and structural changes can positively influence a sustainable transition to renewable energy sources in urban rail transit. My goal with this paper is to determine the feasibility of implementing renewable energy in the Metrolinx GO train system, as well as identify the necessary policy changes to eliminate fossil fuels from rail transportation in the GTHA in order to contribute to climate change mitigation and the Paris Agreement of keeping global temperatures at or below 1.5°C.

This paper, through extensive research on energy policy and transit systems in Ontario, has strengthened my understanding of climate policy and its interactions with the energy sector. With due consideration given to the heightening impacts of climate change, it is realized that the needs of the future energy system will largely impact the development of energy policies, energy planning and infrastructure development. It is imperative to realize these needs and act on them if we are to see a sustainable and just future for all.

The MRP fulfils the learning objectives of the Plan of Study (POS) by directly addressing all three components. The MRP's focus on renewable energy sources and energy policy addresses the POS's third component (Environmental Policy) by proposing methods on how to advance renewable energy initiatives in core sectors and how to improve environmental policy so it has a much larger impact on a broader scale. It will also be useful to examine ways to further incorporate environmental consideration into business decisions via policy.

The paper fulfills the second learning objective of the POS (Sustainable Development) by addressing the immediate and severe impacts of climate change and justifies why renewable energy is an effective tool in mitigating climate change, therefore positively contributing to sustainable development. The paper also fulfills this component by discussing the consequences of burning fossil fuels and how renewable energy is a solution to climate change and furthering sustainable development.

The first learning objective (Business Models) is fulfilled by the MRP as a secondary focus of the paper, as the paper outlines and argues the business case for renewable energy. This highlights how the incorporation of renewable energy into business models and corporate decisions are especially beneficial to all stakeholders as well as the planet. This learning objective also makes up an essential part of the MRP as it asks how renewable energy companies can influence policy, ultimately seeking to uncover how and what legislative changes are required to influence various actors' involvement in the renewable energy sector.

Abstract

Annually, transportation accounts for 35% of Ontario's total GHG emissions and 25% of Canada's total GHG emissions (Sims et al., 2014; NRCAN, 2018). Despite a growing interest in renewable energy sources, fossil fuels are still the most widely used source of fuel and energy in both Ontario and Canada. The dependence on fossil fuels has detrimental impacts on the natural environment and negatively contributes to the planet's warming temperatures. In order to slow global warming and significantly reduce GHG emissions, Ontario needs to commit to more sustainable means of transportation for one of its most dense regions, the Greater Toronto Hamilton Area (GTHA).

This research seeks to answer the question: How can policy reform and structural changes support a sustainable and long-term transition to the adoption of renewable energy in the GTHA's urban rail transit system? In answering this, the research assesses the current state of environmental policies in Ontario and the GTHA and identifies what an effective renewable energy policy is comprised of. Drawing on the experiences of other Canadian cities that have had success with renewable energy in rail transit systems such as Calgary and Vancouver, this research explores what decarbonizing the GTHA's largest transit system, the Metrolinx GO Trains, looks like from an environmental and economic standpoint. The research also evaluates the macroeconomic effects of a renewable energy implementation in the GO Trains, and outlines in detail the business case for sustainable energy in the GHTA's urban rail transit system.

The online design platform HelioScope is used to design a hypothetical solar PV system at the Oakville GO station, and RETScreen Expert is used to develop a feasibility analysis of implementing solar energy at the Oakville GO station. Both results will serve as a base case for which to model the other GO stations on. The results show that solar energy installation at the GO Train stations do, in fact, positively contribute to a sustainable future. The HelioScope and RETScreen Expert models project a substantial and steady reduction of emissions with the implementation of solar energy while still producing long-term economic benefits for Metrolinx. Fossil fuels are no longer an option for the planet— a transition to renewable energy in the GTHA's rail systems is absolutely necessary if Earth is to see a future with clean air.

Keywords: renewable energy; urban rail transit; environmental policy; sustainable business models; climate change

Acronyms

C Celsius
CAT Climate Action Tracker
CO_2 Carbon dioxide
CO_2e Carbon dioxide equivalent
COP Conference of the Parties
CH_4 Methane
GGPPA Greenhouse Gas Pollution Pricing Act
GHG Greenhouse Gases
GPO Green Party of Ontario
GSDR Global Sustainable Development Report
GTHA Greater Toronto and Hamilton Area
GWh Gigawatt-hour
IEA International Energy Agency
IPCC Intergovernmental Panel on Climate Change
IRENA International Renewable Energy Agency
NDC Nationally Determined Contribution
NRCAN Natural Resources Canada
OECD Organisation for Economic Co-Operation and Development
OBPS Output-based pricing system
PV Photovoltaics
RES Renewable Energy Sources
RTP Regional Transportation Plan
SDGs Sustainable Development Goals
STP Sustainability Transition Policy
TWh Terawatt-hour
UN United Nations
UNDESA United Nations Department of Economic and Social Affairs
UNEP United Nations Environment Programme
UNFCCC United Nations Framework Convention on Climate Change

Introduction

> *Without more determined action we will continue to impoverish our planet with less biodiversity and fewer natural resources. We will see more environmental threats and climate-related challenges…We need to adapt to the circumstances and take transformative measures…We need to immediately curb greenhouse gas emissions and achieve sustainable consumption and production patterns in line with…commitments to the Paris Agreement…and in line with the 2030 Agenda. This cannot wait.*

This is a quote from the Declaration on the Commemoration of the 75th Anniversary of the United Nations, section 8 of the Resolution adopted by the General Assembly on 21 September 2020 (UNGA, 2020). It is now more apparent than ever that there is no more time to waste in acting against climate change. Earth's resources are quickly depleting as a result of our actions. We can no longer stand by and watch this happen. The clock is ticking.

Earth's global temperature is rapidly rising. According to the Intergovernmental Panel on Climate Change (IPCC), global temperatures are increasing at a rate of 0.1-0.3° Celsius (C) per decade (IPCC, 2018). The IPCC also claims that as an estimated 1.1°C of global temperature warming has already happened, another 0.4°C of warming is likely to happen sometime in the next one to three decades, bringing the global temperature to 1.5°C and causing irreversible damage to Earth and its populations (IPCC, 2018).

Anthropogenic climate change is largely characterized by the amount of greenhouse gas (GHG) emissions humans produce from the burning of fossil fuels. Some gases have a far larger impact on the climate, such as carbon dioxide (CO_2) and methane (CH_4), which are two of the most harmful GHG's and also the two largest contributors to global warming. The levels of CO_2 being emitted into the atmosphere are exceeding the Earth's ability to absorb it through natural carbon sinks, which is thereby causing an imbalance in global atmospheric temperature (Doney, 2014).

This rapid warming is largely a result of years of burning fossil fuels combined with an accumulation of greenhouse gases, primarily carbon dioxide, in the atmosphere. Fossil fuel consumption rates have skyrocketed since the beginning of the Industrial Revolution. However, over the past few centuries fossil fuel consumption has noticeably changed in terms of what we burn and how much is burned (Ritchie, 2017). In 1970, total global fossil fuel consumption was at 53,381 terawatt-hours (TWh), with gas, oil, and coal at 9,614 TWh, 26,708TWh, and 17,059 TWh, respectively (BP, 2020). Compared to 2019, these numbers have nearly tripled. Global fossil fuel consumption in 2019 was reportedly 136,761 TWh, with gas, oil, and coal at 39,292 TWh, 53,620 TWh, and 43,849 TWh, respectively (BP, 2020). Moreover, it was reported that for the year 2019, 84% of the world's primary energy came from coal, oil, and gas (BP, 2020). Over the coming decades we need to rapidly reduce this share by replacing them with low-carbon energy sources. From these numbers, its apparent that our society has shifted from a coal-based reliance to a combination of oil, gas and coal. However, while coal consumption is decreasing in many parts of the world, oil and gas are still rapidly rising (Smil, 2016; BP, 2020).

As mentioned in the opening quote from the UNGA (2020), the Paris Agreement is a critical document in the realm of climate change mitigation and adaptation. The Paris Agreement is an international treaty that works to reduce total global greenhouse gas (GHG) emissions by holding each of the 195 signatories accountable for their emissions contributions (UNFCCC, 2016). The goal of the Agreement is to "limit global warming to well below 2°C, but preferably kept to 1.5°C" (UNFCCC, 2016, p.5(Article 2)). However, the world is not on track to meet the goals of the Paris Agreement—to limit global warming to well below 2°C and pursue 1.5°C—but is rather heading towards a global average temperature rise above 3°C this century with catastrophic impacts on our economy, society, and environment. (UNEP, 2020). The targets outlined in the Agreement are rather aspirational, and almost all countries are failing to meet the targets year after year.

According to the 2018 IPCC Special Report on Global Warming, "warming of 1.5°C is not considered 'safe' for most nations, communities, ecosystems and sectors and poses significant risks to natural and human systems as compared to the current warming of 1°C" (Roy et al., 2018). Exceeding the limit of 2°C above pre-industrial levels is dangerously irresponsible and will put hundreds of millions of people at risk of (new or worsened) climate change-related stressors like heat waves, natural disasters, and water and food scarcity.

The future of our planet and our livelihood depends entirely on the action we take now regarding the amount of fossil fuels we burn for human activities. In the Working Group I Scientific Assessment of Climate Change, the IPCC modelled four emissions scenarios, A, B, C and D, with various levels of emissions reductions to predict future global temperature increases and subsequent impacts on the environment and the oceans. In Scenario A business-as-usual GHG emissions production, the global mean temperature is predicted to rise by about 0.3°C (with variability between 0.2°C to 0.5°C) per decade over the next century (IPCC, 1992, p.13). The IPCC reported that this is the fastest rate of increase in the past 10,000 years and will likely result in an overall increase of 1°C in global mean temperature by 2025 and up to 3°C before the end of the next century (IPCC, 1992, p.11). Under this scenario, this rate of warming will result in unimaginable consequences for the planet, such as the global mean sea level rising about 6cm per decade over the next 100 years, with predictions showing a 20cm rise by 2030 and a 65cm rise by the end of the next century (IPCC, 1992, p.23).

The other three IPCC emission scenarios (B, C and D) model progressively increasing levels of control over emissions production. In Scenario B, global mean temperature would rise by about 0.2°C per decade, Scenario C would see a rise of over 0.1°C per decade, and Scenario D would see a rise of about 0.1°C per decade (IPCC, 1992, p.5). The various scenarios are compared in the graph below.

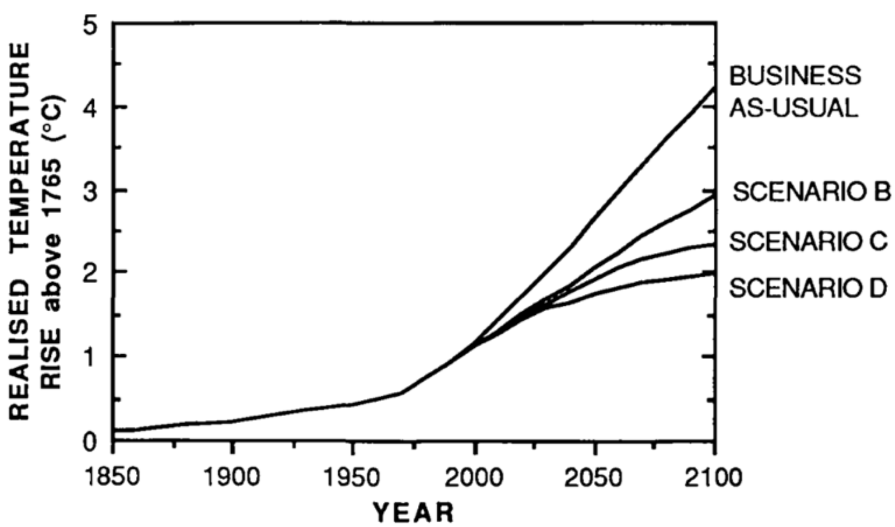


Figure 1. Comparison of the four emissions scenarios modelled by the IPCC. From Working Group I Scientific Assessment of Climate Change (1992).

Based on the original 1992 IPCC Emissions Scenarios, the IPCC 2014 Report developed associated Representative Concentration Pathways (RCPs), which are used for making projections based on these scenarios. The RCPs describe four different century pathways of GHG emissions and atmospheric concentrations for the 21st century, including air pollutant emissions and land use (IPCC, 2014). The RCPs, as correlated to the IPCC Scenarios in Figure 4, include a rigid emissions mitigation scenario (RCP 2.6 – Scenario D), two intermediate scenarios (RCP 4.5 – Scenario C and RCP 6.0 – Scenario B) and one scenario with very high GHG emissions (RCP 8.5 – Scenario A "business-as-usual"). These are depicted in the graph below. Scenarios without additional efforts to constrain emissions ('baseline scenarios') lead to pathways ranging between RCP 6.0 and RCP 8.5 (Figure 5). RCP 2.6 is representative of a scenario that aims to keep global warming likely below 2°C above pre-industrial temperatures.

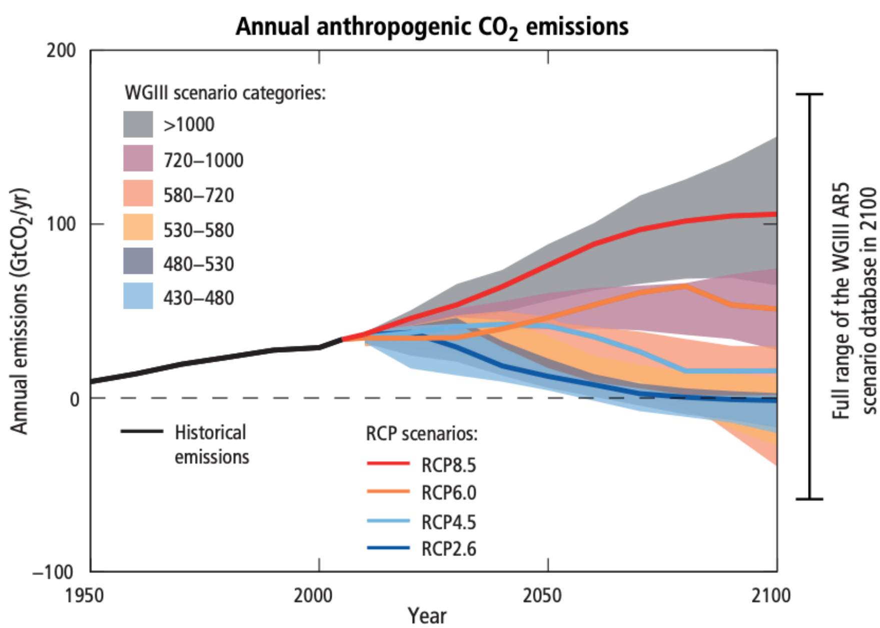


Figure 2. Emissions of carbon dioxide (CO_2) in the Representative Concentration Pathways (RCPs) (lines) and the associated scenario categories used in WGIII. From IPCC AR5 Synthesis Report: Climate Change 2014.

Each of the IPCC's emissions scenarios and RCPs in Figures 1 and 2 predict that global temperatures will rise one way or another. The important takeaway of their models, however, is that climate action and emissions controls can limit the rate of warming and spare the planet from life-threatening and irreversible consequences under the business-as-usual scenario.

Further, in a 2019 report titled *The Truth Behind the Paris Agreement Climate Pledges,* former chair of the IPCC Sir Robert Watson argues that the emissions reduction targets for 2030 made under the Agreement are not enough to keep the Earth's temperature below 2°C. Watson states that in order to see a real, impactful reduction of emissions, countries would need to double and triple the commitments outlined in the Paris Agreement, which is very ambitious considering the lack of achievement thus far (Watson et al., 2019). The report also warns that failing to reduce emissions will result in a severe blow to the economy, approximately $2 billion per day to be exact (Watson et al., 2019). This economic hit will be largely due to weather events worsened by anthropogenic climate change, and will have significant impacts on human health, biodiversity, and access to and supply of food and water in all parts of the world (Leahy, 2019).

Academics and professionals around the world argue that global emissions must be cut by at least 50% by 2030 and hit net-zero by 2050 in order to halt warming and achieve the goals of the Paris Agreement (Leahy, 2019). Watson admits that the knowledge and technology to make the necessary emissions cuts are available and achievable, but the policies and regulations to do so are not strong enough to support it (Leahy, 2019).

Past and current climate policy is insufficient, to say the least, and will not be enough to slow the rising global temperature. Two climate models produced by Climate Action Tracker (CAT) show that if current policies do not improve, our planet will warm to 1.5°C, 2°C, and 3.2°C by 2035, 2053, and 2100, respectively. In the same models, CAT predicts that continued use of fossil fuels will result in a warming to 7°C by the end of the century (CAT, 2019). This is major cause for concern and calls for rapid decarbonization.

Lowering GHG emissions and limiting warming to 1.5°C requires a systemic transition that is both fast and comprehensive (IPCC, 2018). Ideally, a transition of this sort should start with a revision of national emissions reduction targets in order to truthfully reflect the urgency of the current situation. A number of international climate agencies such as the International Renewable Energy Agency (IRENA), the International Energy Agency (IEA), as well as multiple United Nations (UN) bodies like UN Environment Programme (UNEP) and UN Department of Economic and Social Affairs (UNDESA) have repeatedly stressed the need for urgent action on anthropogenic climate change. The 2019 Emissions Gap Report advised that achieving a 1.5°C pathway would require an annual decrease in global emissions of 7.6 percent from 2020 to 2030 (UNEP, 2019). However, the recent 2020 Emissions Gap Report reflects a large amendment to the previous year's numbers. The 2020 Report states that the Paris Agreement targets would have to be tripled to achieve the 2°C goal, and at least increased fivefold for the 1.5°C goal (UNEP, 2020). The 2020 Report also notes that the present Nationally Determined Contributions (NDCs) are gravely insufficient, leaving the Earth at a temperature of 3.2°C by 2030 even with all NDCs fully implemented (UNEP, 2020).

The transport sector is imperative to the global economy as it moves people and goods around the world. However, it is one of the largest sources of emissions as it is heavily reliant on fossil fuels. The Canadian transportation sector is currently dominated by fossil fuels, which contribute an enormous amount of CO_2 emissions to the atmosphere. Research findings summarized in the Green Party of Ontario's (GPO) 2018 Climate Plan along with statistics from Natural Resources Canada (NRCAN) (2018) show that the transportation sector is the largest contributor to Canada's total GHG emissions and makes up 35% of Ontario's total GHG emissions (Sims et al., 2014, p.605). As of 2017, NRCAN reports that transportation contributed 182 Megatonnes (Mt) of CO_{2e}, surpassing the previous top contributor, the Industrial sector, which contributed 180 Mt of CO_{2e} per year in 2017 (Sims et al., 2014, p.605). Further impetus comes from the fact that there is a continuous rise in emissions from all areas of transportation due to an increased number of vehicles on the road (Sims et al., 2014, p.605).

Decreasing emissions and achieving the goal of net-zero emissions in the transport sector will require a vast deployment of renewables (IRENA, 2016). The transport sector has incredible untapped potential for the inclusion of renewable energy. For rail and light-duty road transport, electrification with renewables is a feasible and sustainable option, both economically and environmentally. With the incorporation of renewable energy into Ontario's most polluting sector, there is an opportunity to make significant progress in mitigating global warming.

This paper seeks to answer the question of how policy reform and structural investment can support a sustainable and long-term transition to adopting renewable energy in the GTHA's urban rail transit system, as well as explores the macroeconomic effects associated with a transition of this kind. The primary purpose of this research is to distil policy suggestions to the mitigation of climate change through significant reductions of greenhouse gas (GHG) emissions that come directly from the public transportation sector. The secondary purpose of this research is to show corporate incumbents in the energy sector that investing in renewable energy sources (RES) for rail transit is profitable and advantageous on multiple levels.

The first section of the paper provides an overview of past and current climate policies in Ontario, including: The Climate Change Action Plan 2016-2020; The Climate Change Mitigation and Low-Carbon Economy Act (Bill 172); the Cap and Trade Program Regulation (O. Reg. 144/16); the Cap and Trade Cancellation Act (Bill 4) and the province's new Made-in-Ontario Environment Plan. This section serves to provide context of past policy failures and highlight areas for improvement with regards to climate action in Ontario.

The second section analyzes climate policy in the Greater Toronto Hamilton Area (GTHA), specifically pertaining to urban rail transit systems. It assesses the parameters of the Metrolinx Regional Transportation Plans, Metrolinx Five-Year Strategy, Metrolinx Sustainability Strategy; and the GO Rail Electrification Project. This assessment assists in creating an accurate picture of where the GTHA is currently at in terms of making rail transit more sustainable, and also allow for the identification of gaps and areas that have potential to be further developed.

The third section briefly outlines various business model innovations for a sustainable energy transition, including the business case for renewable energy and potential barriers to implementation.

The following section is an in-depth literature review discussing the key debates on fossil fuels vs. renewable energy, specifically solar energy. The literature review section provides a background for what defines a feasible and affordable renewable energy system. The review also compares examples of cities or regions that have successfully incorporated renewable energy into public transportation rail systems, such as Calgary's wind-powered Light Rail Train (LRT) or Vancouver's SkyTrain. Looking at current renewable energy policies that have succeeded help guide the research and design of a successful renewable energy system and policy for the GTHA's rail transit. The section then explores the various barriers that the GTHA is facing in terms of replacing fossil fuels with renewable energy sources for the transit sector. This section ultimately provides the foundations for policy recommendations for transitioning to renewable energy in public transit systems.

The next section provides the scope, design and methodology for the research. The methods used to gather and analyze the data for this research are based in both qualitative and quantitative approaches—using literature review, policy review, and modelling of costs and benefits using RETScreen Expert. Greenhouse Gas (GHG) Accounting will also be utilized to support the RETScreen Expert models for GHG reductions and show how funding and financing for emissions reductions can be successful. The literature and policy review highlight how research in this field has progressed over time and provide context for identifying success and failure characteristics consistent with each topic of renewable energy sources, regulatory frameworks, and energy policy in varying regions. This, alongside a critical review and comparison of clean energy policies across other Canadian provinces, allow for a comprehensive understanding, formation, and design of the best possible regulatory framework for sustainably transitioning the GO Train system to solar energy.

Following this, the results of the research are thoroughly discussed, including the RETScreen Expert and Helioscope models, GHG Accounting results, as well as recommendations for future renewable energy policy in the GTHA and Ontario will be explored deeply. The final section concludes the paper and is followed by References and Appendices.

Research Design and Methodology

Research Question

This research seeks to answer the question: How can policy reform and structural changes support a sustainable and long-term transition to the adoption of renewable energy in the GTHA's urban rail transit system? In answering this, the research will identify what an effective renewable energy policy is comprised of—which will be determined by analyzing renewable energy policy from other jurisdictions. This research will also assess the macroeconomic effects of this policy being implemented in the GO Train system, and outline in detail the business case for sustainable energy in the GHTA's urban rail transit system.

The rationale for this question hinges on the fact that fossil fuels are no longer an option for our planet— a transition to clean energy in the GTHA's rail systems is absolutely necessary if we want to see a reduction of GHG emissions. There are too many harmful environmental impacts associated with excessive GHG emissions from one of the largest emitters—the transportation sector—and it is unsustainable to continue on business-as-usual.

Research Design and Study Methodology

This research paper explores how policymakers in Ontario, specifically in the GTHA, can contribute to making the Metrolinx GO Trains less reliant on fossil fuels. Drawing on the experiences of other Canadian cities that have had success with renewable energy in rail transit systems, such as Calgary and Vancouver, this research examines what decarbonizing rail transit systems means in relation to climate change mitigation as well as the municipal, provincial, and federal goals of achieving net zero emissions by 2050. The role of policymakers, transit companies, individuals, and communities are assessed in the decarbonization of the Metrolinx GO Trains, taking into consideration the possible advantages and disadvantages this would have on society and the environment. The study results and discussion will show how renewable energy for the Metrolinx GO Trains positively contribute to supporting a more resilient and sustainable future, producing long-term economic benefits, and contributing to a significant emissions reduction.

The methods that are used to gather and analyze the data for this research will be based in both qualitative and quantitative approaches. The main methods utilized are a literature review, policy review, and modelling of costs and benefits using RETScreen Expert.

This research paper explores in detail how GO Trains in the GTHA can shift from fossil fuels to renewable energy in order to effectively and timely meet the goal of achieving net zero emissions by 2050, as laid out in provincial climate plans and the federal net zero future goal (AGO, 2019; ECCC, 2020). It investigates what climate change mitigation and decarbonization mean in relation to emissions reduction targets and strategies in transit systems, as well as the feasibility of achieving the net zero emissions goal.

The literature review relies on the York University Library databases, Canadian government documents (regulations, statistics, etc.) and other archives if appropriate (e.g. City of Calgary, City of Vancouver, GTHA's Metrolinx). To understand current initiatives and practices regarding the topic, it is necessary to reference the websites of both cities that will be used for case studies. The research weighs both the environmental and economic benefits and impacts of investing in and implementing renewable energy sources in the GO Train system. Analysis of policy and planning documents also help to illustrate both cities' past and current efforts in decreasing fossil fuel usage, decreasing carbon dioxide emissions, and mitigating climate change.

To achieve the above goals, the research identifies and reviews the information and data regarding the topic of renewable energy policies in public transit systems and establishes an overview of the topic in the context of the GO Trains in the GTHA. A review of the literature in this field is an essential part of this research paper as it provides a strong background of the research that has already been done in this field, as well as identifies gaps that are still unexplored or under-researched in this research field. The literature review also highlights how research in this field has progressed over time and will be useful in helping situate this research within existing knowledge to fill in some of the current literature gaps.

Very similarly, doing an in-depth a review of past and present policies that deal with renewable energy is highly useful for many reasons. To have a more detailed understanding of the current policies, implementation strategies and future plans, it is useful to look at proposed policies, draft plans, and other government documents to get more concrete answers. The literature on renewable energy sources, regulatory frameworks, and energy policy in varying regions makes clear the success and failure characteristics consistent with each topic. That focus, along with a critical review and comparison of clean energy policies across the nation, brings greater understanding of how to design the best possible regulatory framework for sustainably transitioning the GO Train system to solar energy.

Two important regulatory policies are examined for the case study of Calgary: the Calgary Physical Purchase Power Agreement (P-PPA) under Alberta's Renewable Electricity Act, and the City of Calgary's Climate Resilience Strategy. Both policies place special focus on establishing and maintaining a 100 percent renewable-powered train system. Similarly, Vancouver's TransLink Sustainability Policy and the City of Vancouver's Greenest City Action Plan work in harmony to sustain the city and reduce emissions with the city's 100 percent electric SkyTrain (TransLink, 2020). In acknowledging this, both Vancouver and Calgary's successes will be used as a model for the GO Trains in the GTHA, as the city's renewable projects clearly demonstrate that implementing renewable energy into mass transit is achievable and beneficial in many ways.

This research also utilizes RETScreen Expert software to model emissions reductions and feasibility of renewable energy investment in order to strengthen the arguments and further inform the answers to the research question. This research paper is most interested in identifying areas for major improvement regarding decarbonizing the GO Train system to see the feasibility and applicability for a similar process in the GTHA. For the sake of time and limited resources, this research looks at the Oakville GO Station as a focused subject. Using the Oakville GO Station as a case study will provide a real life, in-depth look at the possibility of electrifying the 24 GO stations across the GTHA's Lakeshore East and West Lines. The research then applies the data and information from RETScreen Expert and Oakville GO Station to make a 3D rendering of what the Oakville GO Station would look like and how it would function if it were fixed with a solar PV system to electrify the trains. This part of the analysis serves to evaluate arguments that renewable energy in urban rail transit can be a feasible strategy to decrease GHG emissions and air pollution in the GTHA.

All the above information is analyzed to develop policy recommendations focused on policy adjustments and structural changes that are necessary for the government and transit companies to consider in order to support a more resilient and sustainable energy system for the GTHA's GO Train system.

Literature Review

For this research paper, the literature review section provides a background for what defines a feasible and affordable renewable energy system. This section will also study and document existing examples that combine renewable energy with public transportation rail systems. Then, this section will explore the various barriers of replacing fossil fuels with renewable energy sources for the transit sector. This section will provide background as to why this topic is important to research and will provide the foundations for policy recommendations for transitioning to renewable energy in public transit systems in the major paper.

Driven by economic and demographic growth, the global demand for energy is expected to significantly increase in the coming decades (OECD, 2011). Unless current trends are reversed, this demand for energy will likely be met by excessively burning fossil fuel. This poses significant risks to the environment and to human health because of rapidly rising CO_2 emissions. In order to control these and other GHG emissions, there must be a switch to low-carbon energy technologies (OECD, 2011). The key debates in this area of research are: 1. Whether current policies, such as carbon pricing schemes (e.g. cap-and-trade or a carbon tax) are effective policy/incentive tools to finance public transportation powered by renewable energy; 2. What are the current costs of renewable energy and electric rail in Ontario; 3. What additional policies are needed to foster the adoption of such strategies in the GTHA?

As outlined by Vancouver's regional transit company, TransLink, a sustainable transportation system is one that achieves the following: allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations; is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy; limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, and reuses and recycles its components; and minimizes the impact on the use of land and the production of noise (TransLink, 2019, p.1). As will be shown in the subsequent sections, all these factors that make up a sustainable transportation system are, in fact, achievable and profitable.

Literature in this area has repeatedly highlighted the role of business models as key to promoting sustainable urban mobility, but less discussed is how sustainable innovations can actually be implemented for both economic and sustainable long-term feasibility (Ribero de Souza et al., 2019). Implementing sustainable urban mobility is a considerable challenge in some areas, with the main roadblock being the ability to provide sustainable alternatives while simultaneously reducing dependence on single occupancy vehicles (SOVs) (Banister, 2011). As outlined by Ignacio de Blas et al. (2020), changes in mobility patterns, especially those having to do with public transportation and railways, have massive energy savings potentials but require even bigger changes in behaviour among the populations. New approaches in urban mobility are greatly needed to increase the quality of transport while decreasing economic and environmental impacts to further enable opportunities to generate and implement new, sustainable business model innovations in the market (Ribero de Souza et al., 2019; Spickermann et al., 2013).

Business Models for Sustainable Energy Transitions

This section will briefly outline various business models for a sustainable energy transition, including the business case for renewable energy and potential barriers to implementation.

What is a Business Model?

Business models are widely used in literature, but their acceptance and use in context varies. Business model is typically defined as a theoretical or conceptual tool consisting of many interconnected elements that aim to express the ways in which an organization creates and sustains value or conducts business (Ribeiro de Souza et. al, 2019). Given that, it is important to note that business models are not, in themselves strategies, but rather guidelines that reflect the organization's strategy and are imperative to understanding and communicating the strategy to both internal and external stakeholders (Ribeiro de Souza et. al, 2019). At their core, business models echo a company's operational implications and strategic choices (Ribeiro de Souza et. al, 2019). As described by James Richardson (2008), there are three defined key business model aspects:

- "value proposition—what an organization intends to deliver to its customers and the reasons why they would pay for it;
- value creation—how an organization articulates resources, capabilities, processes, and networks of customers and suppliers to create and deliver the value intended; and
- value capture—how an organization generates revenue and profit from activities." (Richardson, 2008, p.12; Ribeiro de Souza et. al, 2019, p.8)

However, the traditional business model is no longer seen as widely applicable or useful given the increasing demand for sustainable innovations in the past decade. Multiple authors argue that innovations to the static business model have emerged because the traditional models were requiring continuous review and reinvention in response to new, complex, and constantly changing environments (Richardson, 2008; Ribeiro de Souza et. al, 2019; Bocken, 2021). Business models play a critical role in developing sustainable innovation beyond the organizational level, but they do not necessarily include or account for sustainability issues (Boons, 2013). It is therefore critical to understand the various aspects that should be considered in order for a business model to be sustainable (Boons, 2013).

Sustainable Business Models (SBMs)

Bocken (2021) outlines that SBMs incorporate an opportunistic and holistic lens through which to view sustainable business. Given this, SBMs can act as key drivers of innovation for sustainability in business (Bocken, 2021, p.4). For business models to be sustainable, Stubbs & Cocklin (2008), Boons (2013) and Bocken (2021) agree that sustainable business models should include the following aspects:

- draw on the social, economic, and environmental elements of sustainable development in defining the organizations purpose;
- use a triple bottom line (TBL) approach in measuring performance;
- consider the needs of all stakeholders as opposed to prioritizing shareholders' expectations;

- treat nature as a stakeholder and promote environmental stewardship;
- and encompass a systems-level and firm-level perspective.

Many authors in this field note that there is no one-size-fits-all approach to incorporating sustainability into a business model (Bocken et al., 2014; Høgevold et al., 2014; Ribero de Souza et al., 2019). However, these authors have identified and defined eight categories by which an organization can develop an SBM: "maximizing material and energy efficiency; creating value from waste; using renewable sources; delivering functionality and services, rather than ownership; adopting a management and leadership role along with stakeholders; encouraging sufficiency in consumption and production relations; re-purposing the business for society/environment; and developing scale-up solutions" (Bocken et al., 2014; Høgevold et al., 2014).

In contrast to the conventional firm-centric business model that focuses on profit generation and financial performance, Bocken (2021) notes that as SBMs take a more holistic approach to business, they ideally must involve all (or a very wide range of) stakeholders, include sustainability metrics (such as those listed above), and internalize both social and environmental concerns, as well as being economically sustainable (Bocken et al., 2013; Stubbs & Cocklin, 2008; Boons & Lüdeke-Freund, 2013). Therefore, Bocken summarizes that SBMs should place emphasis on solutions that generate and capture economic, social, and environmental value, and thus establish a strong business case for sustainability (Bocken et al., 2013; Schaltegger et al., 2012).

The Business Case for Renewable Energy and Electric Transit

Transportation, especially those with internal combustion engines such as the GO trains, produce high levels of CO_2 emissions and energy consumption, which negatively impacts the health of humanity and worsens climate change (Banister, 2011). Transitioning to sustainable energy in the transportation sector is more than just a smart move for the planet—it has the potential to make significant improvements to air quality, emissions reductions, healthier populations, and massive economic return on investments (Crawford, 2020). It is commonly thought that enhancing sustainability requires substantial financial investment with little return on investment (ROI), however a 2019 report by the Stockholm Environmental Institute for the Coalition for Urban Transitions (SEICUT) calculated that low-carbon investments and measures across multiple city sectors could yield returns worth $24 trillion over the next 30 years, with the estimated returns on low-carbon passenger transport being far higher than other sectors (SEICUT, 2019; Crawford, 2020). To break this down, as an example, the report showed that transitioning to a more efficient vehicle fleet in cities around the globe would require a total investment of $8.6 trillion, which accounts for all additional costs such as owning, operating, and fueling more efficient vehicles (SEICUT, 2019; Crawford, 2020). That is a large initial investment, but the report shows that it would pay for itself within eight years, and by 2030 annual returns would reach $320 billion, with that figure exceeding $1 trillion annually by 2050 On the environmental side, SEICUT (2019) estimates that low-carbon investments and measures have the potential to cut global urban emissions by 90% by 2050, which would vastly contribute to mitigating global warming (SEICUT, 2019; Crawford, 2020). These numbers are solely relative to fuel savings from implementing low-carbon passenger vehicles in city sectors. Regarding investment into mass urban transit would also prove beneficial for alleviating congestion, providing affordable transport for a greater number of people, and yield even larger economic returns, on top of seeing significant environmental benefits. The 2019 SEICUT report shows that a total investment of $4 trillion in public buses, trains and railway tracks would yield $1 trillion in annual benefits by 2030, with a net present value of $19.6 trillion—the largest of any investment modeled, paying for itself in just one year (SEICUT, 2019, p.94; Crawford, 2020, para. 12). The report estimates that by 2050, the creation and implementation of sustainable urban infrastructure has the potential to support 12 million jobs and reduce CO_2 emissions by 0.73 GtCO2-e (SEICUT, 2019, p.33).

Further, on the societal side of sustainability, the World Bank estimates that a lack of climate action will drive over 100 million people into poverty by 2030 (World Bank, 2015). Similarly, the World Health Organization (WHO) states that over 7 million people die annually due to air pollution, and the associated economic and environmental costs of a changing climate are rapidly increasing (Crawford, 2020; WHO, n.d.). It is reported that climate change-related natural disasters cost around $18 billion annually in lower- and middle-income countries which triggers far larger costs for households and firms of at least $390 billion (OECD, 2016). It is also estimated that healthcare costs related to pollution could rise past $155 billion by 2060 (OECD, 2016).

All the above points outline a strong and optimistic business case with evident ROI for sustainable urban infrastructure. The bottom line is that investment in low-carbon passenger transport has the potential to see substantial economic and social returns, all while making a significant, positive impact on human health and the environment (Crawford, 2020). And it is entirely feasible, as so many major cities (Shenzhen, Copenhagen, Bogotá, Vancouver, and Calgary, to name a few) have already shown.

Barriers to Implementation

Given the worsening of climate change and the growing need for innovative SBMs in the transport and energy sectors, it is necessary to identify the barriers to implementation in this field. Kariuki (2015) and the Union of Concerned Scientists (UCSUSA) (2014) outlined some of the largest and most common barriers to renewable energy adoption under the following categories: "over-reliance on fossil fuels (coal), political and regulatory barriers, technical barriers (technology and infrastructure), market-related barriers, social-cultural barriers, and financial and economic barriers" (Kariuki, 2015, para.2). These will be briefly discussed below.

<u>Over-Dependence on Fossil Fuels</u>

Heavy reliance on traditional energy sources like fossil fuels is the biggest barrier to a sustainable energy transition due to the following reasons:

- Industries require a lot of energy, and coal has a high net energy yield compared to other sources of energy
- Coal is abundant and readily available in most countries around the globe, which also means it's far lower in cost than other sources that are more limited in supply
- Technological advancements have made the burning of coal cleaner and more efficient over time, which makes it more challenging to convince industries and companies to switch to renewable energy
- The cost of developing new infrastructure and renewable energy plans is seen as an expensive burden when coal plants are already established (Kariuki, 2015; UCSUSA, 2014).

Continued use of fossil fuels is a large barrier to renewable energy development and implementation, however, these technologies are the only solution that will contribute to reducing our global dependence on fossil fuels. Aside from an over-dependence on fossil fuels, the reluctance to adopt renewable energy technologies can be attributed to the following categories of barriers.

Political and Regulatory Barriers

Another big hinderance to the adoption of renewable energy technologies in the transit sector is the lack of policies and regulations favouring the development of renewable technologies (Kariuki, 2015). The renewable energy market functions on clear and robust policies designed to increase the interest of investors, however such policies are not as common as they should be in the transit sector in the GTHA, and Ontario as a whole. This is justified by the International Renewable Energy Agency who state that "enabling policies create stable and predictable investment environments, help overcome barriers and ensure predictable project revenue streams" (IRENA, 2016, p.13).

Technical Barriers

Technical barriers to the development of renewable energy include a lack of both technology and infrastructure to support a renewable energy transition. Some major infrastructure barriers that have been seen in previous studies (cite) are insufficient grid connectivity, inadequate servicing and maintenance of equipment, and low reliability in technology, which all result in decreased confidence in renewable technologies from investors and therefore hindering advancement of the technologies (Kariuki, 2015; UCSUSA, 2014).

Social-Cultural Barriers

Social-cultural barriers include things that are outside the current paradigm, for example household or individual disinterest in renewable energy or hesitancy to implement renewable technologies due to fear of unreliability or of the unknown (Kariuki, 2015; UCSUSA, 2014). The biggest reason for most social-cultural barriers is the general public's lack of knowledge and awareness of renewable energy systems and technologies (Kariuki, 2015).

Financial and Economic Barriers

There are a number of underlying causes to the financial and economic barriers of developing renewable energy technologies, including economic status, initial capital, availability of credit facilities to purchase technologies, and availability of incentives and subsidies—all of which factor into the adoption of renewable energy technologies (Kariuki, 2015). As discussed in the above section, development and implementation of renewable energy requires a large amount of initial capital investment in comparison to traditional energy sources like fossil fuels, who typically keep initial investment costs low and maximize profits (Kariuki, 2015). Further, some countries have high levels of subsidies on fossil fuels which gives unfair disadvantage to renewable energy technologies.

Market-Related Barriers

Some factors that make renewable energy unappealing in the markets are high fluctuating prices of renewables in some countries, lack of already-established renewable energy businesses to serve as models, and an overall lack of market for renewable energy (Kariuki, 2015; UCSUSA, 2014). As mentioned above, initial investment costs are typically high for renewable energy systems, which means that market prices for these technologies and systems are also high and may be unaffordable for some. Kariuki (2015) and UCSUSA (2014) outline that market prices for renewables keeps rising because, in comparison to fossil fuels, total production cost of renewable energy remains and/or appears high, which consequently limits their marketability.

Essentially, there are a lot of factors working against the successful development and employment of renewable energy systems. However, identifying these barriers and actively working to overcome them with proper strategies, policies and marketing techniques can have immense impact on future success of renewable technologies. Global dependence on fossil fuels must be diminished and replaced with renewables if any emissions reductions and climate change mitigation is to be seen in the near future.

Carbon Pricing Mechanisms

The first key debate in this area of research discusses the efficacy of carbon pricing mechanisms on both the reduction of GHG emissions and its potential to save taxpayer money. There are two main forms of carbon pricing that have been tested out in several areas, including Ontario: a carbon tax and a cap-and-trade system. A carbon tax is a per-ton tax on the carbon dioxide emissions rooted in fuels or other products, whereas a cap-and-trade system is designed to place a limit (cap) on emissions and allows polluters to buy and trade emissions permits. Both are government regulatory programs, and both generate revenue that is supposed to go directly into green initiatives, however there is much controversy about the overall effectiveness of carbon pricing.

Proponents of carbon pricing acknowledge that a carbon tax is somewhat regressive as it generally affects the poor harder than the rich, but they show that carbon pricing generates a lot of revenue—between $740 billion and $3 trillion over 10 years, to be exact (Kaufman & Gordon, 2018; Roberts, 2019). This revenue can then be used to offset the regressivity by reinvesting the funds back into green projects like clean energy. Proponents also argue that pricing carbon emissions can “drive efficient emission reductions, spur innovation and allow businesses and households to choose how they reduce emissions” (Mountford & McGregor, 2018). This is rationalized by stating that clean technologies and practices can now compete with fossil fuels or other GHG-emitting technologies. Further, expanding carbon pricing mechanisms around the world, along with fossil fuel subsidy reform, are essential to accelerating the low-carbon transition. If designed and implemented effectively, carbon pricing can achieve sustainable development benefits and reduce economic inequalities (Mountford & McGregor, 2018).

Opponents of carbon pricing mechanisms strongly believe that it will raise costs and slow economic growth, which can be countered in saying that the macroeconomic effect of a carbon tax varies depending on what the government does with the revenue. Opponents also argue that carbon pricing has weaknesses in five critical areas: problem framing and solution orientation; policy priorities; innovation approach; contextual considerations; and politics (Rosenbloom et al., 2020; Kaufman & Gordon, 2018). This is defended by saying that climate policy responses must move beyond market failure reasoning and focus on fundamental changes in existing sociotechnical systems (such as energy, mobility, food, and industrial production) in order to address the urgency of climate change and to achieve deep decarbonization (Rosenbloom et al., 2020).

Greenhouse Gas Pollution Pricing Act (GGPPA)

An advancement in the realm of Canada's carbon pricing efforts is the Greenhouse Gas Pollution Pricing Act (GGPPA). The GGPPA was passed into law as of March 2021 and aims to disassemble the federal carbon tax by giving provinces the freedom to individually implement their own carbon pricing system—either a cap and trade program or a carbon tax, but within the means of their provincial jurisdictions (Brook et al., 2021). The GGPPA, by giving provinces autonomy to decide their pricing schemes on their own, will hopefully provide more opportunities to employ sustainable energy alternatives and therefore reducing GHG emissions.

As of March 2021, the Supreme Court of Canada found the federal Greenhouse Gas Pollution Pricing Act (GGPPA) to be constitutional in a split 6–3 decision (Brook et al., 2021). The GGPPA works to dismantle the national carbon tax and gives provinces the freedom to individually implement their own carbon pricing system (Brook et al., 2021). Many provinces, including Ontario, have long been fighting for provincial autonomy to regulate GHG emissions and adopt their own strategies for climate change mitigation within their own borders. This decision represents the end of that fight and, hopefully, the beginning of a harmonious framework to reduce GHG emissions and mitigate the impacts of climate change in Canada. It is also noted that this decision may have "significant and widespread implications for future legislation, regulation, and taxation of GHG emissions" as the GGPPA may impede previous commitments under the Pan-Canadian Framework on Clean Growth and Climate Change (PCF) (Brook et al., 2021; Osler, 2021).

The GGPPA stipulates that provinces can choose to implement either a carbon tax or a cap and trade system, so long as they meet the minimum federal pricing and emissions reduction targets. If a province refuses or fails to implement their own pricing system, they are subject to the federal pricing system committed to under the PCF (Osler, 2021). The GGPPA operates on two key components: 1. Addition of a fuel charge on 21 types of fuel, and 2. Introduction of an Output-Based Pricing System (OBPS) for large industrial emitters. The first component, the fuel charge, states that the price per tonne of carbon dioxide equivalent (CO_2eq) will increase by $10 each year on April 1. The fuel charge came into effect for Ontario in April 2019 at a price of $20 per tonne of CO_2eq. As of April 1, 2021, the price per tonne of CO_2eq is $40 (Osler, 2021).

The second component of the GGPPA is the OBPS for large industrial emitters. Under this system, facilities must pay a carbon price if their emissions exceed the set level. Facilities that emit less than the set level earn credits that can be sold (Osler, 2021). Further details about the OBPS can be found in the *Output-Based Pricing System Regulations*, SOR/2019-266.

Overall, the main issue in the realm of pricing carbon is the politics of it. Political resistance has kept carbon prices far below the reasonable social cost of carbon. Research shows that carbon prices should be around $50/ton (USD) in order to see some improvements in emissions numbers (Roberts, 2019). However, carbon pricing systems in the Regional Greenhouse Gas Initiative, the Western Climate Initiative, and even the carbon tax in BC have prices well below $50/ton, which proves the large and highly influential role of politics in climate change mitigation strategies such as carbon pricing (Kaufman & Gordon, 2018; Roberts, 2019).

Ontario Policy and Research Context

Overview of Climate Policy in Ontario

As mentioned above, climate action in Ontario is significantly absent. Excessive amounts of greenhouse gas (GHG) emissions is one of the largest issues that the province of Ontario currently faces. Ontario is accountable for less than 1% of global emissions yet remains one of the largest global emitters per capita (Government of Ontario, 2016(a)). A 2018 audit conducted by federal Environmental Commissioner Julie Gelfand and auditors general in nine provinces observed that while many governments have "high-level goals to cut emissions, very few have detailed plans to actually reach those goals" and says actions taken thus far have been "haphazard, inconsistent, and lacking in detail with no timeline for action or funding" (OAG, 2018; Rabson, 2018).

Ontario is Canada's second largest carbon polluter, not far behind the country's largest polluter, Alberta (Rabson, 2018). This puts Ontario in an important position as it has the power to either accelerate Canada's efforts to cut carbon pollution or significantly hinder the country's progress.

The 2018 turnover in provincial government brought in a new wave of climate policy for Ontario. Prior to the current Premiership of Doug Ford, Ontario was making significant progress in reducing carbon pollution and was even on track to meet its Paris Agreement targets (Government of Ontario, 2016(b)). Former Ontario Premier Kathleen Wynne had initiated and implemented multiple policies and programs aimed at carbon reduction and carbon pricing, including the Climate Change Action Plan (CCAP), the Climate Change Mitigation and Low-Carbon Economy Act (CCMLEA), and the Cap and Trade Program Regulation. The initiatives committed to under the CCAP planned to help Ontario achieve the short- and long-term emissions reduction targets that were established under the CCMLEA, and the market mechanism to support the CCAP and its carbon reduction targets is a cap and trade program (Government of Ontario, 2016(a)). These regulations were intended to be long-term frameworks for a successful reduction of GHG emissions in the province through various means: The cap and trade program would put a price on carbon and hold large polluters accountable for their actions; the CCMLEA would invest the proceeds from the cap and trade program into green projects and activities that reduce GHG pollution; and the CCAP allocated spending to be invested in green projects and initiatives in Ontario's key action areas (transportation, buildings, land-use planning, industry, Indigenous communities, research and development, government, and agriculture) (Government of Ontario, 2016(a)).

However, with the emergence of Doug Ford as the new Premier in 2018, the province's previous environmental plans were immediately dismantled. Ford campaigned on a platform that was 'For the People,' which meant that he would scrap any legislation that costed taxpayers more money, including the cap and trade program. Not long after he was sworn into office, Ford enacted the Cap and Trade Cancellation Act and began disassembling the CCMLEA and CCAP—both of which were funded by revenues from the cap and trade program. In place of these programs, the Ford government created the Made-in-Ontario Environment Plan, which, as described by Ontario's Auditor General Bonnie Lysyk, "lacks sound evidence and sufficient detail" (Sharp, 2019). Additionally, the federal government committed to the goal of net zero emissions by 2050. These ambitious regulations and climate goals will be further explored and analyzed next.

Climate Change Action Plan, 2016-2018

Unveiled in June 2016, the Climate Change Action Plan (CCAP) was intended to build upon the 2011 Climate Ready: Ontario's Adaptation Strategy and Action Plan—the Ontario governments very first public commitment to addressing climate change, and the 2015 Climate Change Strategy. Similar to the previous Plans, the 2016 Climate Change Action Plan outlined several key actions the government planned to take in combating climate change through emissions reduction targets of 2020, 2030 and 2050. The CCAP budgeted for government spending of $5.9 to $8.3 billion over the period of 2016-2020, with the primary focus on "transition assistance and incentives for households and businesses to reduce greenhouse gas (GHG) emissions, divert waste, and conserve energy" (OSPE, 2016, para.2). Ultimately, the Action Plan was designed to provide consumers and businesses with the freedom to choose if they wanted to adopt low-carbon technologies or not—the Plan was intended to offer Ontarians more reasons to reduce their carbon footprint (Government of Ontario, 2016(a)).

Essentially, the CCAP was the underlying framework to all GHG emissions reduction in the province. It was the foundation of the cap and trade program, which generated revenue to support and invest in the action areas in the CCAP, which would then support then a low-carbon Ontario (Government of Ontario, 2016(a)). In detail, the CCAP committed to the following GHG emissions reductions targets: a reduction of 15% by the end of 2020; a reduction of 37% by the end of 2030; and a reduction of 80% by the end of 2050 (MHNCC, 2018, p.4).

Critiques of the Plan noted that climate change did not seem to be acknowledged as a current issue in the Plan, illustrating that the government viewed climate change as a future issue that could be addressed and curbed by limiting emissions (OSPE, 2016). They also noted that municipalities need additional and adequate funding for these reduction initiatives, and that the government should widen its scope to view other climate change issues (such as water and wastewater systems) as being an important component of this plan. Along the same lines, critiques noted that the Action Plan failed to fund or prioritize critical efforts in the mitigation of risks to public health and the economy (OSPE, 2016).

However, proponents of the Plan saw a number of benefits resulting from the CCAP. They noted that the Action Plan brings with it the establishment of two new organizations: The Green Bank and the Global Centre for Low Carbon Mobility (OSPE, 2016). The government allocated approximately $1 billion and $120 million to the respective organizations in order to stimulate and support business and government transition to a low carbon economy via cost reductions and best practices (OSPE, 2016). Proponents also highlighted that the Action Plan helps define how the proceeds from the cap and trade program and auctioning would be spent, leaving no room for discrepancies and ensuring transparent investment in green initiatives in the province (Government of Ontario, 2016(a)).

As mentioned above, the CCAP was meant to be the framework to support the achievement of Ontario's GHG emissions reductions targets. This included the Climate Change Mitigation and Low-Carbon Economy Act and the Cap and Trade Program, both of which were strong initiatives to reduce GHG emissions.

Climate Change Mitigation and Low-carbon Economy Act, 2016-2018 (Bill 172)

The province of Ontario's commitment to fight climate change was demonstrated with the Climate Change Mitigation and Low-Carbon Economy Act (CCMLEA) in 2016. This Act called for decarbonization at the highest level in recognition of the critical environmental and economic challenges climate change imposes on the global community. The Act also included two critical regulations: Ontario Regulation 144/16: The Cap and Trade Program (and its incorporated Methodology for the Distribution of Ontario Emission Allowances Free of Charge) and Ontario Regulation 143/16: Quantification, Reporting and Verification of Greenhouse Gas Emissions Regulation (and its incorporated Guideline for Quantification, Reporting and Verification of Greenhouse Gas) (Government of Ontario, 2016(a)).

The CCMLEA was designed as the underlying framework for the Cap and Trade Program as it outlined the provinces plans to achieve the abovementioned GHG reduction targets (Olawuyi, 2016). The Act placed a cap on carbon emissions and facilitates the trading of pollution allowances. The ultimate objectives of the Act were to reduce the amount of GHG emissions while offering financial incentives to businesses (Olawuyi, 2016). See Figure 3 below for how the CCMLEA and Cap and Trade Program work in harmony under the CCAP.

Figure 3. Cycle of how the Cap and Trade Program works in harmony with the Climate Change Action Plan to transition to a low-carbon future for Ontario. (Government of Ontario, 2016(a)).

There were 3 key requirements for Ontario's Climate Change Mitigation and Low-Carbon Economy Act: renew this action plan at least every five years; establish a GHG Reduction Account to track cap and trade proceeds and ensure they are invested in green projects and programs; and provide annual public reporting on action plan progress as well as funds tracked in and out of the GHG Reduction Account (Government of Ontario, 2016(a)). Also, under the Act, the Ontario government acknowledged that any action taken to fight climate change would be fully disclosed, including the use of cap and trade proceeds (Government of Ontario, 2016(a)).

With the creation and enactment of the CCMLEA, the Government of Ontario acknowledged that collective action was required to address issues of climate change. As a result, Ontario joined a shared carbon market called the Western Climate Initiative (WCI) with Quebec and California to reduce GHGs internationally by establishing a carbon price. They noted that one key determination of this Act was to establish a broad carbon price through the cap and trade program that would alter every Ontarian's behaviour and mindset regarding carbon consumption and GHG emissions contributions (Government of Ontario, 2016(a)). It was clear that a cap and trade program in Ontario had the potential to be beneficial for emissions reductions not only in the province, but around the world too.

Cap and Trade Program, 2016-2018 (O. Reg. 144/16)

Ontario's cap and trade program was implemented in April 2016 in accordance with Ontario's CCMLEA, Bill 172 – O. Reg.144/16. The CCMLEA was the legislation that provided the legal basis for province-wide emission targets, including the cap and trade regulation and the associated green spending programs (ICAP, 2019). The implementation of a cap and trade program in Ontario meant that prominent steps were being taken towards decreasing our GHG emissions, and thus taking steps towards a greener future for the province. The cap and trade program aimed to give polluters incentive to cut emissions, functioning on the grounds that if you pollute less, you pay less.

Essentially, a cap and trade program is a market-based mechanism to reduce greenhouse gases (Olawuyi, 2016). In a cap and trade system, the government sets an emissions cap and distributes emission allowances consistent with the set cap. Emitters are responsible for holding allowances for each ton of greenhouse gas they emit. Companies can then buy and sell allowances among each other, creating a market through which emissions prices are established. Companies that can reduce their emissions at a lower cost may sell their unused allowances to companies who do not meet the emissions cap allowance. The establishment of this market and its ability to price carbon allows for emissions to be reduced in a cost-effective way, as the price of carbon drives investment decisions and stimulates market innovation (C2ES, 2018).

As stated in the Cap and Trade in Ontario report produced by the former Environmental Commissioner of Ontario (ECO) (2016), the two main objectives of a cap and trade program are to establish a cap on emissions, which decreases over time, and encourage investment in low-carbon innovations through the increase in cost of emissions—so much so that the cost of reducing emissions is comparably less expensive (ECO, 2016). More specifically, the system would create a price on carbon by placing an annual limit on overall emissions, establishing and distributing allowances up to that limit, opening up a trading market for allowances and credits, and requiring emitters to report or submit their allowances (and other compliance instruments) to the government to match GHG's emitted during a compliance period (ECO, 2016).

Additionally, as outlined in the Western Climate Initiative (WCI), Ontario's cap and trade program would have been in coordination with other jurisdictions in order to contribute to broader international emissions reduction efforts. Ontario linked agreements with Quebec and California, who already have established carbon markets, to create the WCI model cap and trade program and align with these markets (Western Climate Initiative, 2010; ICF International, 2016). The cap and trade deal was signed by Ontario, Quebec and California in September 2016 and the program officially began on January 1, 2017. The cap and trade system was formulated to be the principle instrument to help Ontario accomplish its GHG emissions reduction targets of 15% below 1990 levels by 2020, 37% by 2030, and 80% by 2050 (Georgakopoulos & Davidian, 2019).

In theory, this type of flexibility would have decreased the overall costs of compliance with emission reduction targets while the cap on carbon emissions would've incentivized investment in clean technologies. This would have then facilitated the creation of new jobs and kickstarted the transition to a low-carbon economy (Olawuyi, 2016). Also, according to the 2018 Greenhouse Gas Progress Report, Ontario's GHG emissions in 2016 were the lowest since reporting began in 1990 (ECO, 2018). This follows the same downward trend in emissions that allowed Ontario to meet its 2014 emissions-reduction target of 6% below 1990 levels (see Figure 4 below) (ECO, 2018).

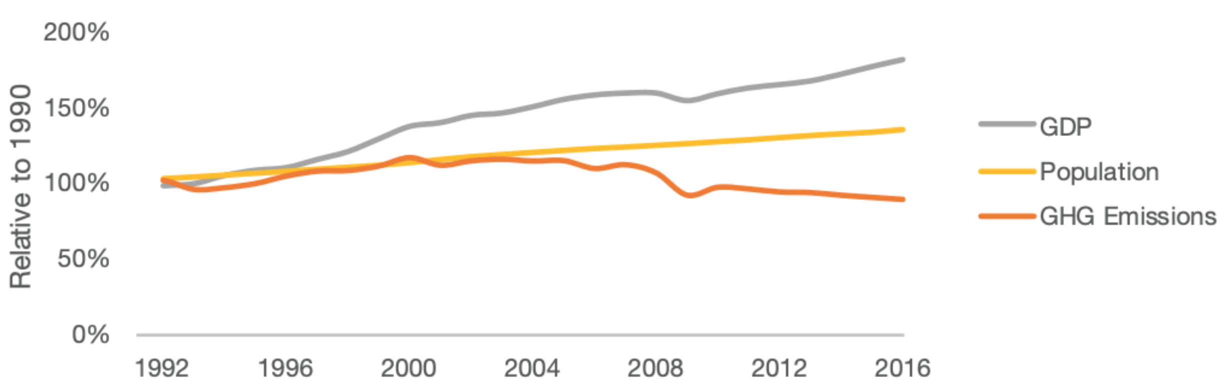


Figure 4. Ontario greenhouse gas (GHG) emissions compared to gross domestic product (GDP) and population trends by year. (ECO, 2018; Statistics Canada, 2018).

In fact, Ontario was actually considered a world climate leader after years of climate actions such as closing coal plants, slowing urban sprawl and promoting conservation, implementing the 2016 CCMLEA and its cap and trade program, joining the WCI, and joining the federal Pan-Canadian Framework on Clean Growth and Climate Change (ECO, 2018). However, with the arrival of the Progressive-Conservative Party leader and current Premier Doug Ford, the Climate Change Mitigation and Low-Carbon Economy Act was repealed on November 14, 2018, and thus the cap and trade program in Ontario was cancelled under Bill 4, The Cap and Trade Cancellation Act.

Cap and Trade Cancellation Act, 2018 (Bill 4)

With the arrival of the Progressive-Conservative party leader and current Premier Doug Ford, the Climate Change Mitigation and Low-Carbon Economy Act was repealed on November 14, 2018, and thus the cap and trade program in Ontario was cancelled under Bill 4, The Cap and Trade Cancellation Act. As outlined by the International Carbon Action Partnership (ICAP), the Cap and Trade Cancellation Act was introduced in summer of 2018 and fought to revoke the Climate Change Mitigation and Low-Carbon Economy Act of 2016 (ICAP, 2019).

As the cap and trade program was cancelled shortly after its first year in place, there is very little data that would indicate whether Ontario would have reached its 2020 targets. However, from data that is provided in reports from the International Emissions Trading Association (IETA), Ontario's cap and trade program seems to have performed relatively well in its first year in action. According to the IETA Cap and Trade Report (2018), the province added over 175,000 jobs to various sectors, offered rebates for low-income households, grew both real and nominal GDP rates, raised $2.4 billion from carbon allowance auctions (all of which is to be invested into Ontario businesses, households, and environmental initiatives), and allocated $2 billion to fund projects through the Green Ontario Fund, GreenON (IETA, 2018). These results from just one year of a cap and trade system are significant—they prove that the people and businesses of Ontario are ready and willing to make adjustments to their polluting habits if adequate structures are in place.

Since the cap and trade program was cancelled in 2018, Ontario no longer has a carbon pricing system and is thus subject to the federal government's backstop plan. As part of the Pan-Canadian Framework on Clean Growth and Climate Change, the federal government announced a $2 billion

Low Carbon Economy Fund which would provide $1.4 billion to provinces and territories who have adopted their own carbon pricing in order to assist with the transition and contribute to the goal of reducing greenhouse gas emissions (FAO, 2018, p.9). Ontario would have received approximately $420 million from the Low Carbon Economy Fund, however with the repeal of the Bill, any potential federal funding to Ontario for a carbon pricing plan is now negated. Additionally, with the enactment of Bill 4, cap and trade, the low-carbon programs that it funded, and 752 renewable energy projects have all been abandoned. The government's proposed replacements, the Cap and Trade Cancellation Act (Bill 4) and the follow-up Made-In-Ontario Environment Plan, lack most of the features of a good climate law, according to multiple experts in the field (ECO, 2018).

Made-in-Ontario Environment Plan, 2018

After ceasing the cap and trade program, the Ford government released the Made-In-Ontario Environment Plan in November 2018. The purpose of the Environment Plan is to address four key environmental challenges: protecting our air, lakes and rivers; addressing climate change; managing litter and waste; and conservation of greenspace (Bell, 2019; Government of Ontario, 2020). Included in the 2018 Made-In-Ontario Environment Plan is a commitment to reduce provincial emissions to 30% below 2005 levels by 2030, which is in alignment with Canada's 2030 target committed to under the Paris Agreement (Government of Ontario, 2018, p.21). The Plan discusses a number of policies the government intends to implement in order to achieve the target. These policies are targeted at reducing emissions in each sector, however according to the two-year progress report released by the Government of Ontario, it's unclear if any policies or programs have actually been implemented or even proposed. The Plan does, however, note that over a period of four years, the province will spend $400 million on a fund called the Ontario Carbon Trust, which aims to encourage companies to invest in initiatives that reduce GHG emissions (The Canadian Press, 2019). The Plan also proposes holding large industrial companies financially accountable for excessive emissions (The Canadian Press, 2019).

The Plan is critiqued by a number of experts in the field, including Anne Bell, Director of Conservation and Education at Ontario Nature, Dianne Saxe, former Environmental Commissioner of Ontario, and Andrea Horwath, New Democratic Party (NDP) Leader. On behalf of Ontario Nature, Anne Bell voiced many serious concerns about the new Environment Plan, mainly regarding vague and contradictory language and lack of inclusion of very key environmental challenges such as biodiversity conservation and the protection of at-risk species (Bell, 2019). Similarly, Saxe argued that Ford's new climate policy is "very inadequate and very frightening," and says that a vague plan with loose commitments will put the entire Paris Agreement at risk, which jeopardizes the entire planet's contributions to climate change mitigation (The Canadian Press, 2019). Horwath agrees that the current government is not taking climate change seriously and is not interested in hearing the necessary steps to meeting GHG emission reduction targets (The Canadian Press, 2019). It is also noted that the Plan's proposal to hold large industrial polluters financially accountable is a very similar system to the federal carbon tax, which the Ford government has fought since his campaign. This speaks further to the lack of sound plans and commitments in the new climate policy, and validates the concerns voiced by opponents, including Horwath and Saxe. However, contrary to the arguments made by these experts, Ontario climate policy, specifically carbon pricing strategies, may see significant improvement in the coming years as Canada recently passed the Greenhouse Gas Pollution Pricing Act (GGPPA) to allow provinces to individually regulate their GHG emissions on a best-fit basis (Osler, 2021).

As stated earlier, the majority of Ontario's climate policies are incoherent and ineffective for mitigating climate change. Ontario is one of the country's largest carbon polluters and one of the largest global emitters per capita, meaning significant action must be taken immediately if emissions reductions targets are to be met (Government of Ontario, 2016(a)).

Overview of Climate Policy in the Greater Toronto and Hamilton Area's Urban Rail Transit System

In coherence with some of the provincial plans, the Greater Toronto Hamilton Area (GTHA) also has a number of ambitious plans for sustainability, with some specifically geared towards the GTHA's urban rail transit systems in hopes of achieving the provincial and federal goals of net-zero emissions by 2050. This section of the literature review will focus specifically on the policies and plans put forth by the GTHA's largest transit company, Metrolinx, regarding the current and future sustainability of their GO Transit train network. As this paper seeks to outline a potential decarbonization and electrification model of the GO Trains, I will be using the Oakville GO Train station in specific to model how a decarbonization can efficiently and successfully be implemented via policy and structural reforms. As they are two key actors in this research, Metrolinx and GO Transit will subsequently be introduced, and following that will be a review and assessment of the Metrolinx Regional Transportation Plan (RTP), under which they have a Five-Year Strategy that includes a Sustainability Strategy, and the GO Rail Network Electrification.

Metrolinx is an agency of the Ontario government and is the regional transportation agency for the GTHA. Its operations include GO Transit regional bus and rail services. Metrolinx states that they are committed to "planning, building and operating transportation that supports a high quality of life, a thriving, sustainable and protected environment and a strong, prosperous and competitive economy" (Metrolinx, 2016, p.2). Metrolinx works with the provincial government, regional transit agencies, and engages with civic, academic, business and community partners in creating and implementing transportation plans like the Regional Transportation Plans (RTPs), the Metrolinx Five-Year Strategy, and the Metrolinx Sustainability Strategy (Metrolinx, 2016).

GO Transit has been around since 1967 and is the regional public transit service for the GTHA. The GO Transit network is the largest division of Metrolinx as it connects with every municipal transit system in the GTHA, and the train and bus lines span from Hamilton and Kitchener-Waterloo in the west to Newcastle and Peterborough in the east, and from Orangeville and Beaverton in the north to Niagara Falls in the south (GO Transit, n.d.). Under the 2009 Greater Toronto and Hamilton Area Transit Implementation Act, GO Transit and Metrolinx merged together to build infrastructure quicker, relieve congestion and generate jobs (Government of Ontario, 2009).

Metrolinx Regional Transportation Plans

Metrolinx's previous Regional Transportation Plan (RTP), *The Big Move: Transforming Transportation in the Greater Toronto and Hamilton Area (GTHA),* was adopted in 2008 and was the company's first RTP. The Big Move was centrally focused on expanding transportation in the GTHA region so as to help create thousands of new green jobs while saving billions of dollars in time and energy (Metrolinx, 2012). The company's newest RTP, *The 2041 Regional Transportation Plan,* builds on the previous RTP as it is focused on the needs of travellers and supports a high quality of life, a prosperous economy and a healthy environment (Metrolinx, 2018(b)). Metrolinx describes the 2041 RTP as "a blueprint for creating an integrated, multimodal regional transportation system that will serve the needs of residents, businesses and institutions. [The 2041 RTP] supports *Ontario's Growth Plan for the Greater Golden Horseshoe, 2017*, which sets out a broad vision for where and how the region will grow, and identifies policies on transportation planning in the GTHA." (Metrolinx, 2018(b)).

The 2041 RTP has three goals: to create strong connections, complete travel experiences, and ensure sustainable and healthy communities (Metrolinx, 2018(b)). The RTP outlines five strategies to achieve these goals: Complete the delivery of current regional transit projects; Connect more of the region with frequent rapid transit; Optimize the transportation system; Integrate transportation and land use; and Prepare for an uncertain future (Metrolinx, 2018(b)). Metrolinx states that full implementation of the 2041 RTP will result in an integrated and unified transportation system for the GTHA, improving passenger experience, offering improved access to reliable and frequent rapid transit, and making travel more affordable thereby reducing the need for single-occupancy vehicles (Metrolinx, 2018(b)).

The 2041 RTP Engagement Report provided an overview of public, stakeholder and municipal feedback on the RTP. It summarizes questions, comments and suggestions that have been voiced the RTP's vision, goals, strategies, and priority actions (Metrolinx, 2018(c)). Generally, feedback regarding the 2041 RTP was well received among municipal partners, stakeholders, and the public, who agreed with the vision, goals and five strategies outlined in the RTP (Metrolinx, 2018(c)).

The RTP's are the umbrella framework for various strategies and plans undertaken by Metrolinx, such as the Metrolinx Five-Year Strategy and the Metrolinx Sustainability Strategy, both of which inform and guide the successful implementation of the RTP. These will be discussed next.

Metrolinx Five-Year Strategy (2017-2022)

The Five-Year Strategy is Metrolinx's roadmap for 2017 to 2022 and was designed to shape the company's decision making and influence how their investments are prioritized. Metrolinx outlines in their 2017 Five-Year Strategy document that they will "seek to integrate sustainability into [their] policies and practices so that current and future economic, environmental and social impacts are considered when [they] make decisions about how [they] plan, build and operate." (Metrolinx, 2016, p.14). The company has identified four areas that they will focus their sustainability efforts into:

1. Develop and implement a climate resilience program to manage and mitigate risks resulting from climate change;
2. Minimize energy use and emissions by adopting technologies and programs to effectively track, monitor and reduce energy consumption;
3. Integrate sustainability into our supply chain by considering the amount of materials that should be used and their impact throughout their life cycle; and
4. Consider the ecological impact of new infrastructure and services and make best efforts to manage, preserve and protect ecosystem services (Metrolinx, 2016, p.14).

Objectively, this sounds aspirational and performative. However, Metrolinx has created action plans for each of their four Strategic Priorities, which include a tailored approach to the Priority and an action plan on how they will advance the Priority in terms of their Plan, Build, Operate, and Connect missions (Metrolinx, 2016, p.15-22). In this Strategy there is also a chart that clearly outlines key deliverables and foundational projects relative to each of the four Priorities (Metrolinx, 2016, p.22-25). As of 2021, Metrolinx has provided very little updates about their progression towards meeting the goals of their Five-Year Strategy.

Metrolinx Sustainability Strategy (2015-2020)

The Metrolinx Sustainability Strategy was designed to be a roadmap for achieving the company's vision of working together to reduce environmental impact and enhance opportunities within its communities (Metrolinx, 2017(c)). Metrolinx outlines that their plans for sustainability are directly aligned with and supportive of key policies and legislation within various levels of government and within their own company, including their original Regional Transportation Plan The Big Move (2008), the previous Ontario's Climate Change Mitigation and Low-Carbon Economy Act (2016), and the previous Climate Change Action Plan (2016).

The Sustainability Strategy addresses some aspects of sustainability through existing Metrolinx strategies and plans, as well as other areas that require additional focus and attention (Metrolinx, 2017(c)). As seen below in Figure 5, the Strategy focuses on five sustainability goals: Become climate resilient; Reduce energy use and emissions; Integrate sustainability in our supply chain; Minimize impact on ecosystems; and Enhance community responsibility (Metrolinx, 2017(c), p.13).

Figure 5. Metrolinx Sustainability Strategy Goals and Implementation. Source: Metrolinx Sustainability Strategy (2015-2020). (Metrolinx, 2017(c)).

These priority goals represent the areas of greatest need and opportunity within Metrolinx, and as such are significantly material to Metrolinx and its stakeholders (Metrolinx, 2017(c)). Metrolinx states that over years 2015-2020, these sustainability goals would be integrated into all phases of planning, building, and operating a sustainable transportation system (Metrolinx, 2017(c), p.13). Each of the goals has multiple criteria that will be used to measure action and success in each goal to hold Metrolinx accountable to their commitments. The goals and their corresponding actions and measurement criteria are outlined in the Performance Scorecard (see Appendix A).

The Metrolinx Sustainability Strategy has outlined how Metrolinx works towards transforming the way the GTHA moves. The Strategy addresses societal needs, protects the environment, delivers on community accountability, and supports the economic well-being of its surrounding regions (Metrolinx, 2021(b)).

As outlined in the Sustainability Strategy priority goals, Metrolinx created a corporate Climate Adaptation Plan and a Planning for Resiliency report at the end of 2017 (Metrolinx, 2021(b)). The report discusses the rationale for climate resiliency and adaptation in Metrolinx's operations. It documents the company's experiences with and responses to extreme weather events, and it outlines climate change projections and best practices for building resiliency to climate change and extreme weather that are applicable throughout the GTHA up to the year 2050 (Metrolinx, 2021(b)). These two documents are important additions to Metrolinx's strategies and policies for sustainability as they ensure that sustainable practices are embedded in the company's work and values. As of the first quarter of 2021, there is no additional reporting produced regarding the results of the Sustainability Strategy and whether or not the priority goals and actions were met with success.

GO Rail Network Electrification 2017

In their expansion to include the GO Transit network, Metrolinx is considering a more sustainable approach by using hydrogen powered vehicles. Metrolinx recognizes that the GTHA is a rapidly growing area which demands a larger transit network, therefore it commits to implementing the Regional Express Rail, among other improvements to the GO system (Metrolinx, 2017(a)). As part of the Regional Express Rail project, Metrolinx, in partnership with Hydro One, carried out the TPAP in accordance with Ontario Regulation 231/08 – Transit Projects and Metrolinx Undertakings (made under the Environmental Assessment Act) in order to examine the environmental impacts of converting multiple GO rail corridors to electric (Metrolinx, 2017(a)).

The plan is proposing to electrify GO-owned corridors. By 2025, Metrolinx aims to have electrified trains running every 15 minutes, all day and in both directions, within the most heavily travelled sections of the GO network (Metrolinx, 2017(a)). In the December 2017 Transit Project Assessment Process (TPAP) Statement of Completion from Metrolinx, the GO Rail Network

Electrification project aims to convert six GO-owned rail corridors—Union Station, Lakeshore West, Kitchener, Barrie, Stouffville, and Lakeshore East— from diesel to electric propulsion, including power supply and distribution infrastructure, and bridge modifications (Metrolinx, 2017(b)).

According to the Public Meeting #3 Summary Report released in January 2021, there was a wide range of feedback about the electrification project from public consultations held in February 2020. The Report outlines that general feedback about the GO Expansion program includes support for the service increases and interest in learning more about future train technology and the TPAP process and timelines, as well as the impact assessment studies results (Metrolinx, 2021(a), p.8). However, concerns were voiced about potential noise, vibration increases, traffic, lack of commuter parking, electromagnetic field/interference impacts, property and natural environment impacts of the proposed infrastructure, and potential impacts to existing businesses and employment at some of the sites (Metrolinx, 2021(a), p.9).

Metrolinx held a second round of consultations in August 2020 where new infrastructure was proposed, and potential impacts and mitigation strategies were presented to the public. The Report outlines that feedback for the electrification project was generally supportive of moving towards cleaner train technology and increased network services (Metrolinx, 2021(a), p.10). However, concerns were similar to those of the previous consultations and include concerns about property impacts, vegetation removals along GO corridors, future operational noise impacts and proposed noise wall locations, and natural environment impacts (Metrolinx, 2021(a), p.11).

A third and final round of public consultations for the TPAPs was held from November – December 2020 in which Metrolinx provided updates on study results for three TPAPs and presented a draft of the findings from the environmental and technical studies (Metrolinx, 2021(a), p.12). According to the Summary Report, two Addendum projects have one more round of public consultations to go through, and one Conservation project has two more rounds of public consultations to go through before the project can become subject for public review and the Minister's approval (Metrolinx, 2021(a), p.12).

In all, the GO Rail Network Electrification project seems relatively solid in foundation as it has adequately planned out all new site work and adjustments, it has had multiple rounds of communication and consultation with the public, and it accounts for a number of risks that may occur during the process—all of which were initiated with the GO Electrification Study Final Report in 2010 (Metrolinx, 2010). It is also apparent that the public is widely supportive of increasing train service and moving toward cleaner train technology (Metrolinx, 2021(a), p.40). More importantly though, there were questions from the public about why electric trains run faster than diesel trains and whether Metrolinx is considering hydrogen trains. Metrolinx responded to this with a Hydrogen Feasibility Strategy that explores all the issues associated with implementing trains powered by hydrogen fuel (Metrolinx, 2018(a)). Finally, its reported that there were suggestions to consult with international agencies or companies that have successfully implemented and operated electric train service in order to best implement it in the GTHA.

Case Studies

Key Debates on Fossil Fuels vs. Electric/Solar Power (in Rail Transit)

The second key debate in my research considers the economic feasibility (and subsequent impacts on business) of a total decarbonization of the transportation sector. Proponents of this debate say that there are multiple benefits for the environment, the economy, and society. Some authors in this research area have defended a transition to a 100% renewable economy as a way to achieve an ultimate and lasting solution to emissions mitigation and reduction (Jacobson & Delucci 2011; García-Olivares, 2012; IPCC, 2011; Singer, 2011; Lehmann & Nowakowski, 2014; Creutzig et al., 2014; Breyer et al., 2017). My review of the literature indicates that many authors believe that any renewable energy transition will likely be supported by more efficient uses of fossil fuels, especially natural gas (Lee et al., 2012; Sgouridis et al., 2016). In the long-term, these authors contend that our economy should become fully renewable in order to reap the full potential of economic benefits.

Additional reports suggest that there are a variety of ways renewables can impose costs on the system, including the need to backup intermittent supply and strengthen grids. Multiple studies suggest that integration costs in 2030 range from $7USD to $55USD/megawatt hour (MWh), as long as the system includes a small amount of additional flexibility (Aurora Energy Research, 2016; Leach, 2006; Evans, 2017). Similarly, Aurora Energy Research (2016) found that solar integration costs would reach no more than $8USD/MWh. This estimate assumes solar capacity increases from today's 11 gigawatts (GW) to 40GW in 2030, making solar integration a potential net benefit to the electricity system (Aurora Energy Research, 2016). It is concluded that cost estimates are typically much lower for flexible systems, therefore it is beneficial for long-term success with renewable energy alternatives, and that onshore wind and solar will remain among the cheapest ways to generate power in the coming decades (Aurora Energy Research, 2016). As part of this further research, the costs of developing renewable energy projects in the GTHA will be calculated in the subsequent sections using RETScreen expert, estimates by local RE firms, and available public data on existing projects.

Lessons Learned from Other Jurisdictions

As previously mentioned, the Greater Toronto and Hamilton Area is the primary subject for this research. However, the cities Calgary and Vancouver will be explored as a reference to a successful transition to renewable energy in a municipal public transit system. Both Canadian cities are known to be a leader in renewable energy usage thanks to their investments in electric trains and wind energy (Chan & Karim, 2017). According to the 2017 Transit Report Card of Major Canadian Regions, which evaluates transit systems based on factors like revenue kms per service hour, operating costs, passenger trips per capita, and more, Calgary and Vancouver both received A+ grades and were tied for second-best in Canada. In comparison, the GTHA received a grade of C, meaning its service performance was lower than expected in comparison with other regions of Canada (Chan & Karim, 2017).

Calgary's CTrain

Calgary's CTrain is a light-rail rapid transit (LRT) system and is powered 100% by renewable energy. The CTrain is the only LRT system in North America that uses wind-generated electricity for power (New Energy Economy, 2018). The Pembina Institute (Dodge & Kinney, 2015) outlines that Calgary went all-in on renewable energy in 2012 after their initial decision in 2001 to purchase 21,000 megawatt-hours of wind power each year for 10 years. The 2001 decision meant that 12 new wind turbines were erected, and the 2012 decision to go all-in on renewables jumpstarted the construction of two wind farms, which totalled 144 megawatts of installed wind capacity for the city (Dodge & Kinney, 2015). In addition to their wind-powered transit system, the City of Calgary's other operations use a mix of 100 percent renewable energies including hydro, biomass, and solar power (Dodge & Kinney, 2015). By purchasing wind power and transitioning the city to exclusively renewable energy, Calgary reports that it is avoiding the emission of 56,000 tonnes of carbon dioxide per year from just its transit sector (New Energy Economy, 2018).

One set of regulatory policies that is important in this analysis is Calgary's Physical Purchase Power Agreement (P-PPA) under Alberta's Renewable Electricity Act, which specifically focuses on Calgary's 100 percent renewable-powered train system, the CTrain. As wind is the most inexpensive source of electricity in Alberta, Calgary city council voted in 2001 to purchase 21,000 megawatt-hours of wind power each year for 10 years, which is how much electricity the LRT uses in one year (New Energy Economy, 2018). In 2012, Calgary fully committed to clean energy and purchased enough renewable power for all of the city's operations. By purchasing wind power, Calgary Transit reports it is avoiding the emission of 56,000 tonnes of carbon dioxide per year (New Energy Economy, 2018; Dodge & Kinney, 2015). The most important aspect of Calgary's framework is that the city's other operations use a mix of renewables including wind, hydro, biomass, and solar power. The P-PPA totals 450,000 megawatt-hours a year, or the equivalent power demand of over 65,000 Calgary homes (New Energy Economy, 2018; Dodge & Kinney, 2015). In acknowledging this, Calgary's successes can be used as a model for the Metrolinx GO Trains in the GTHA, as Calgary's renewable projects clearly demonstrate, implementing renewable energy into mass transit is doable and beneficial in many ways.

The other important policy behind this shift to 100 percent renewable energy in the city is the Climate Resilience Strategy. The Strategy was adopted in 2018 and operates on two functions of mitigation plans and adaptation plans. Figure 6 below illustrates the actions and initiatives of Calgary's Climate Resilience Strategy (Figure 6).

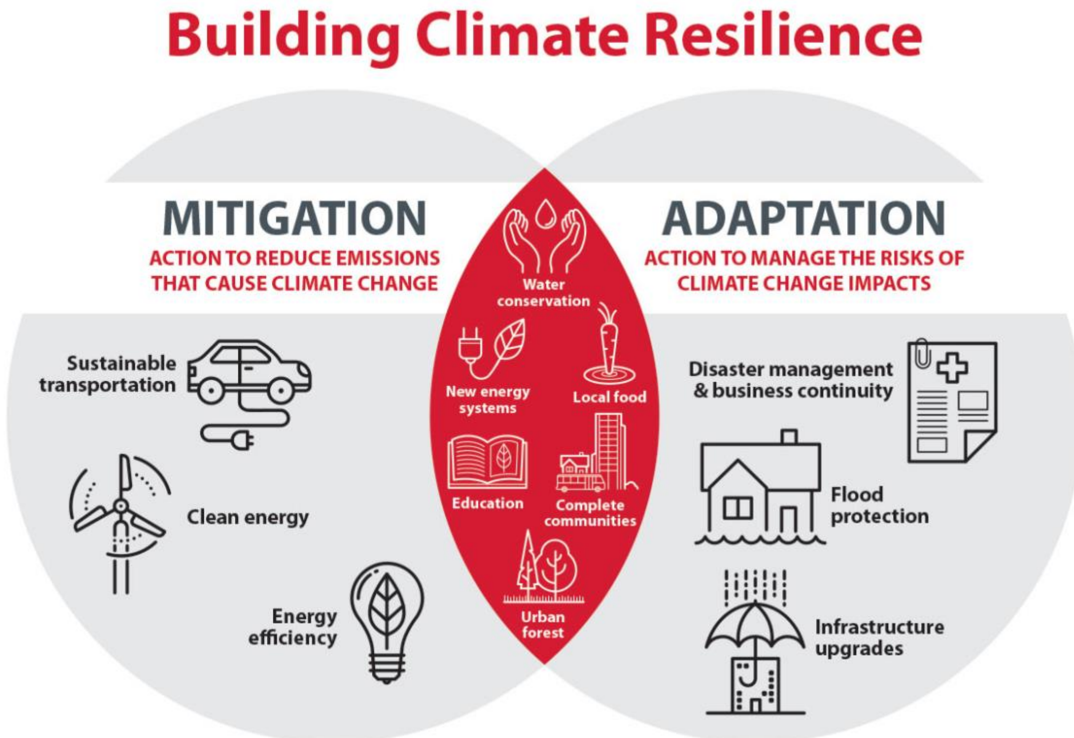


Figure 6. Actions and initiatives of Calgary's 2018 Climate Resilience Strategy. *City of Calgary (2018).*

Calgary's Climate Resilience Strategy shows a clear focus on investing in and employing clean energy and sustainable transportation to reduce emissions. The aim of the 2018 Strategy is "to maximize the resilience of Calgary in the context of a changing climate guided by local and global policy settings and specific mitigation and adaptation actions to address climate change" (City of Calgary, 2018, p.3). The goals of the Strategy are to 1. Reduce overall contributions to climate change through improved energy management and decreased GHG emissions, and 2. Respond to climate change and reduce impact of extreme weather events through implementation of risk management measures. In line with federal and provincial regulations, Calgary aims to achieve an 80 percent reduction in city-wide emissions below 2005 levels by 2050 (City of Calgary, 2018).

Overall, the Strategy is good because it advocates for a large shift away from conventional sources of energy for a large majority of city operations, which promotes a green economy, emissions reductions, improved comfort, livability, and health for citizens while reducing carbon levy costs for businesses and the city (City of Calgary, 2018). However, a 2021 report from the City of

Calgary points out that the city is not on track to meet its emission reduction targets (MacVicar, 2021). To remedy this, MacVicar highlights that Calgary is working on the development of a carbon budget so its share of emissions can be calculated, evaluated, and used appropriately in an effort to remain below reduction targets. The Calgary Climate Resilience Strategy is expected to be updated in 2022 with improvements including the potential incorporation of electric bus fleets into city operations (MacVicar, 2021).

Vancouver's SkyTrain

As mentioned above, Vancouver's largest transit system, the TransLink Skytrain, is on par with Calgary's CTrain in terms of being a top player in Canada's renewable energy and sustainable transit systems. Like the CTrain, the SkyTrain is also a light-rapid transit rail that utilizes fully renewable energy in the form of electricity through linear induction motors (TransLink, 2020). The SkyTrain lines actively reduce air pollutants due to their ability to displace road vehicle traffic and transport people around the city at a faster rate than SOVs. This superior and innovative mode of electrification for the SkyTrain is in direct alignment with both TransLink's Sustainability Policy and the City of Vancouver's Greenest City Action Plan. TransLink's Sustainability Policy is a response to the Green Transportation goals listed in the Greenest City Action Plan. The goals outlined in the Action Plan revolve around making substantial improvements to foot and bike paths as well as improvements to public transit, whilst reducing distance driven per resident (City of Vancouver, 2020). The 2040 targets of the Action Plan's goal of Green Transportation is to make at least two thirds of all trips by foot, bike, and public transit (TransLink, 2019; City of Vancouver, 2020). As shown in Figure 7 below, Vancouver is making large strides towards the success of their 2040 target.

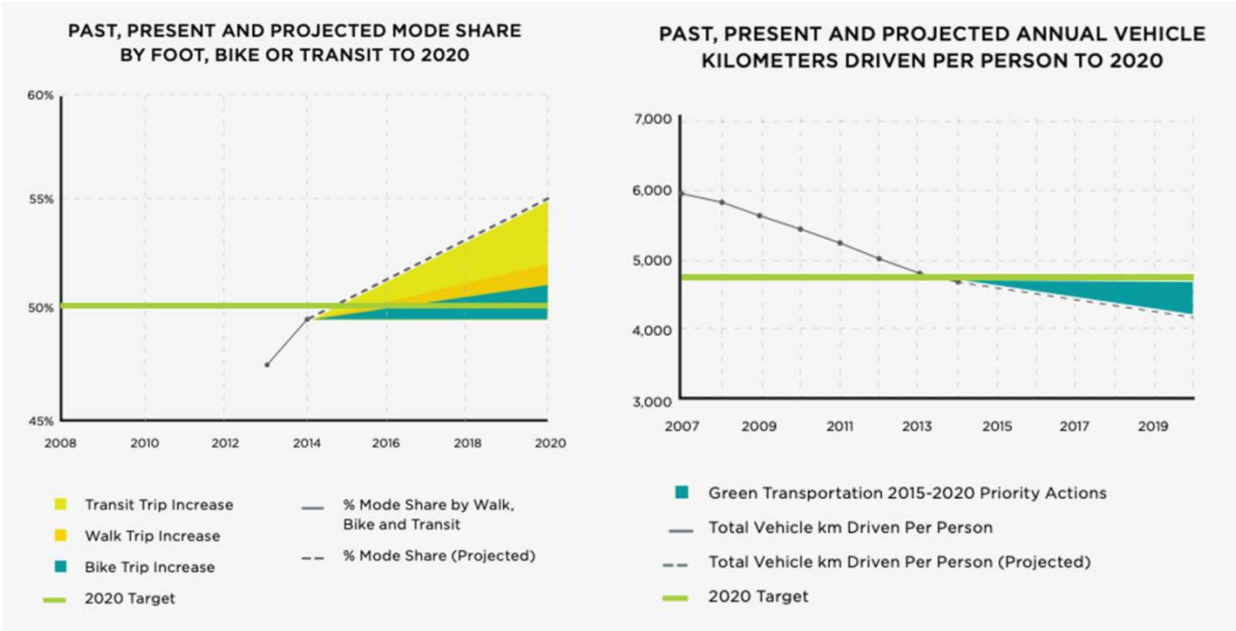


Figure 7. Past, present, and projected mode share by foot, bike or transit and past, present and projected annual vehicle kilometers driven per person to 2020. City of Vancouver's Greenest City Action Plan ().

As outlined in the City of Vancouver's Greenest City Action Plan and the TransLink Sustainability Policy, TransLink adopted three significant goals to guide their approach and operations: a 45% reduction of GHG emissions by 2030, an 80% reduction of GHG emissions by 2050, and 100% utilization of renewable energy in all operations by 2050 (TransLink, 2019). They outline that, although ambitious, these goals are highly attainable with the implementation of zero- and low-carbon fuels and technologies, such as those utilized in the SkyTrain.

Further, TransLink developed a Green Bond Program to finance their capital spending. In alignment with the International Capital Market Association (ICMA) Green Bond Principles, TransLink's Green Bond Framework "promotes integrity in the market through transparency, disclosure and reporting" (TransLink, 2020, p.4). After much success with their first green bond issuance of $400 million, TransLink issued a second green bond of $200 million, all of which were and will continue to be used to "finance or refinance existing and future sustainable capital projects…such as the Millennium Line Evergreen Extension, SkyTrain Station and rail network upgrades, new higher-capacity rail cars, Transit Centre upgrades, electric trolley fleet maintenance and new battery electric buses" (TransLink, 2020, p.4).

One major lesson that climate and transit policy in the GTHA could learn from both Vancouver and Calgary is the development of a carbon budget and/or a Green Bond Program. Accounting for the city's GHG emissions would guide operations more efficiently and allow policymakers and businesses to see which investments are proving beneficial in terms of climate change mitigation and adaptation. Additionally, a carbon budget would identify areas of largest fossil fuel consumption, which provides further opportunity for implementing energy alternatives in the respective sectors in order to contribute to greater emissions reductions for the city.

Oakville GO Train Station

Currently, the Metrolinx GO Trains are powered by diesel, which produces emissions that are highly detrimental to the environment and human health. In order to sustainably advance the GO Trains, they must be transitioned to clean energy. The following sections will model the amount of solar energy necessary to offset the electric demand of the GO Train and its MWh/year. For the purpose of scope and scale this research will focus on the Oakville GO Station as a base model that can be applied to model a solar electrification of the entire Lakeshore line.

Energy Consumption Modeling for Electric Trains

Transportation-related energy use accounts for over a quarter of global energy consumption (Wang & Rakha, 2018). As residential density and travel demand increases, there has been drastic growth in single-occupancy vehicle use and thus a worsening of traffic conditions and a continued increase of GHG emissions. Transportation systems in large metropolitan areas, such as the GTHA, have not been keeping up with this demand in efficient or environmentally conscious ways (Wang & Rakha, 2018). It is therefore critical to design effective strategies that reduce energy consumption and emissions through an incorporation of eco-friendly transportation systems for urban rail transit.

Using an oversimplified version of the modeling framework designed by Wang & Rakha (2018), the below calculations will be used to determine the approximate annual energy consumption of an electric locomotive so to compare energy and cost savings of renewable vs. current non-renewable sources in the GTHA's urban rail transit.

For the RETScreen and Helioscope models, the following data and metrics are assumed. As of the late 20th century, railway electrification systems use 25 kilovolts (kV), 60 hertz (Hz) alternating current (AC) (Wikipedia, 2021(a)). These systems are used worldwide, especially for high-speed rail; therefore this is the power demand that these models will be based on. The models will also be based on the specs of the Siemens ES64 EuroSprinter electric train, which has a power output of 6.4 MW and maximum speed of 230 km/h (Wikipedia, 2021(b)), and on the assumption that the GO station and trains run for 84 hours of service per week for 52 weeks a year (4368 hours of service annually) (GO Transit, 2020). To find the annual electricity required to operate an electric train and station, the power output (6.4 MW) is multiplied by the number of annual service hours (4368) to produce a number in MWh. Therefore, assuming that the Oakville GO station operates electric trains with a power output of 6.4 MW and runs on 4368 hours of service annually, it is estimated that the Oakville GO station, if powered by solar energy, would require 27,955.2 MWh per year to operate its trains. These numbers are the basis of my RETScreen Expert and Helioscope Design models and calculations, which will be discussed below.

Results Summary

HelioScope Solar Modelling Results

HelioScope is an online platform for solar modelling. Designing a digital solar model with HelioScope helps to better understand the feasibility of installing a solar plant. It helps to visualize the site, forecast energy generation, and estimate returns on investment as it provides a visual and graphical understanding of the site.

In modelling a solar PV system for the Oakville GO station, it was important to first take a visual assessment of the station and its surroundings. The roof of the Oakville GO Station is not very large and not well-suited for the number of solar panels needed, but there is a lot of uncovered parking lot space, so the best option in this case would be solar carports. Referencing other solar carports that have been done in the GTHA (such as the ones at York University and Mohawk College), this HelioScope model is based on solar carports produced by the racking company Kinetic Solar. Kinetic produces carports based on a modular steel construction and are sized based on the number of standard size parking spots that they cover, ranging from 2 spots to 20 spots (Kinetic, 2021). The solar panels chosen for this model will be Silfab Solar Inc.'s SIL-400 NU (400W) which is the 72-cell model of monocrystalline PV panels as they are most efficient for this project and fit the Kinetic carport. The inverters will be Sunny Tripower Core1/US (SMA) at a count of 40 or 2.00 MW (Figure 8).

Components

Component	Name	Count
Inverters	Sunny Tripower Core1/US (SMA)	40 (2.00 MW)
Strings	10 AWG (Copper)	256 (6,476.0 m)
Module	Silfab Solar Inc., SIL-400 NU (400W)	4,368 (1.75 MW)

Figure 8. HelioScope Solar PV Model for Oakville GO Station. Components.

Below is the HelioScope model image for solar carports at Oakville GO station (Figure 9). As shown, there are 20 carport installations spanning the parking lots, each with two inverters. Each wiring zone has a string size of 13-18 and an along racking stringing strategy. The solar modules are pointed alternatingly to the South West and North East to avoid shade covering nearby modules and to maximize sun time year-round.

Figure 9. HelioScope Solar PV Model for Oakville GO Station. System Model Image.

As displayed in Figure 10 below, every carport ("Field Segment") has a tilt of 10°, and intrarow spacing of 0.0m, and a frame size of 6x4. In reference to the Figure 9 model, the carports on the left and middle parking lots each have 240 modules and produce 96.0 kW of power, and the carports on the right parking lot have 168 modules and produce 67.2 kW of power.

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Carport	Landscape (Horizontal)	10°	225.53546°	0.0 m	6x4	10	240	96.0 kW
Field Segment 1 (copy)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	240	96.0 kW
Field Segment 1 (copy 1)	Carport	Landscape (Horizontal)	10°	225.53546°	0.0 m	6x4	10	240	96.0 kW
Field Segment 1 (copy 2)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	240	96.0 kW
Field Segment 1 (copy 3)	Carport	Landscape (Horizontal)	10°	225.53546°	0.0 m	6x4	10	240	96.0 kW
Field Segment 1 (copy 4)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	240	96.0 kW
Field Segment 1 (copy 5)	Carport	Landscape (Horizontal)	10°	225.53546°	0.0 m	6x4	10	240	96.0 kW
Field Segment 1 (copy 6)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	240	96.0 kW
Field Segment 1 (copy 7)	Carport	Landscape (Horizontal)	10°	225.53546°	0.0 m	6x4	10	240	96.0 kW
Field Segment 1 (copy 8)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	240	96.0 kW
Field Segment 1 (copy 9)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	240	96.0 kW
Field Segment 1 (copy 10)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	240	96.0 kW
Field Segment 1 (copy 11)	Carport	Landscape (Horizontal)	10°	225.53546°	0.0 m	6x4	7	168	67.2 kW
Field Segment 1 (copy 12)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	168	67.2 kW
Field Segment 1 (copy 13)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	168	67.2 kW
Field Segment 1 (copy 14)	Carport	Landscape (Horizontal)	10°	225.53546°	0.0 m	6x4	7	168	67.2 kW
Field Segment 1 (copy 15)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	168	67.2 kW
Field Segment 1 (copy 16)	Carport	Landscape (Horizontal)	10°	225.53546°	0.0 m	6x4	7	168	67.2 kW
Field Segment 1 (copy 17)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	240	96.0 kW
Field Segment 1 (copy 18)	Carport	Landscape (Horizontal)	10°	45.535458°	0.0 m	6x4	1	240	96.0 kW

Figure 10. HelioScope Solar PV Model for Oakville GO Station. Field Segments.

The conditions were set automatically by HelioScope (Figure 11). The weather dataset used is from the closest nearby meteonorm located 5.2km away from the Oakville GO station. The soiling stays consistent at 2 because, although at this location in Oakville there is typically heavier snowfall in December, January and February, the tilt of the panels will make it so the snow slides off and will not impact soiling. Other conditions in this set were generated automatically by HelioScope and are the standard for this type of solar PV system.

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C

Soiling (%)

J	F	M	A	M	J	J	A	S	O	N	D
2	2	2	2	2	2	2	2	2	2	2	2

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations

Module	Uploaded By	Characterization
SIL-400 NU (Silfab Solar Inc.)	Folsom Labs	Spec Sheet Characterization, PAN

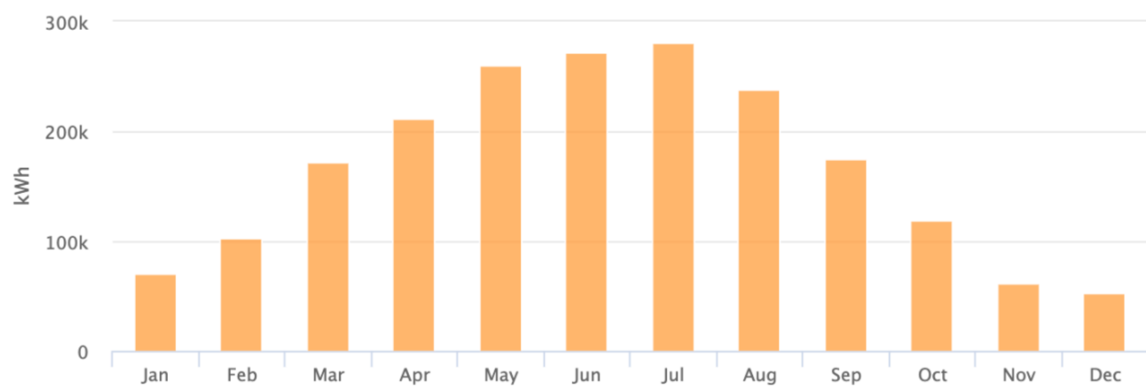
Component Characterizations

Device	Uploaded By	Characterization
Sunny Tripower Core1/US (SMA)	Folsom Labs	Spec Sheet

Figure 11. HelioScope Solar PV Model for Oakville GO Station. Condition Set.

The monthly production of solar energy from the carports (in kWh) is pictured below (Figure 12). Monthly production of energy to grid ranges from 52,389.4 kWh (minimum) to 280,328.0 kWh (maximum). Production is naturally higher in the spring and summer months (May-August) when sun time is maximized.

Monthly Production



Hide table

Month	GHI (kWh/m^2)	POA (kWh/m^2)	Shaded (kWh/m^2)	Nameplate (kWh)	Grid (kWh)
January	47.0	45.1	45.0	71,901.6	70,437.5
February	67.4	65.0	65.0	105,372.5	103,567.8
March	110.9	108.2	108.1	177,831.8	172,252.1
April	136.6	135.1	134.9	223,841.3	211,616.9
May	171.1	169.7	169.5	282,409.9	259,709.4
June	182.3	181.2	181.0	301,604.5	271,716.8
July	190.6	189.2	189.0	315,443.2	280,328.0
August	163.5	161.4	161.1	267,308.0	238,837.1
September	119.5	117.3	117.2	193,562.3	175,102.3
October	81.1	78.9	78.7	128,484.8	119,761.2
November	41.8	40.2	40.1	64,708.1	61,171.1
December	35.7	34.0	34.0	54,232.1	52,389.4

Figure 12. HelioScope Solar PV Model for Oakville GO Station. Monthly Production.

Similarly, annual production of energy to grid is displayed below (Figure 13). After calculated losses, the annual production of energy to grid is 2,016,889.7 kWh, or 2016.9 MWh.

Annual Production

	Description	Output	% Delta
Irradiance (kWh/m^2)	Annual Global Horizontal Irradiance	1,347.4	
	POA Irradiance	1,325.5	-1.6%
	Shaded Irradiance	1,323.6	-0.1%
	Irradiance after Reflection	1,264.5	-4.5%
	Irradiance after Soiling	1,239.2	-2.0%
	Total Collector Irradiance	**1,239.1**	**0.0%**
Energy (kWh)	Nameplate	2,186,700.0	
	Output at Irradiance Levels	2,165,048.6	-1.0%
	Output at Cell Temperature Derate	2,150,457.9	-0.7%
	Output After Mismatch	2,072,878.5	-3.6%
	Optimal DC Output	2,068,859.6	-0.2%
	Constrained DC Output	2,068,392.7	0.0%
	Inverter Output	2,027,024.8	-2.0%
	Energy to Grid	**2,016,889.7**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		11.7 °C
	Avg. Operating Cell Temp		18.1 °C
Simulation Metrics			
		Operating Hours	4590
		Solved Hours	4590

Figure 13. HelioScope Solar PV Model for Oakville GO Station. Annual Production.

As displayed in the overall system metrics (Figure 14), the module DC nameplates (total power of all modules in the system) and inverter AC nameplates (total power capacity of all inverters in the system) are 1.75 MW and 2.00 MW, respectively. The annual production, as mentioned above, is 2.017 GWh, or 2016.9 MWh with a performance ratio of 87.1%, which represents the system efficiency in converting sunlight to grid-available AC energy. The kWh/kWp, which is the ratio of output energy to relative model (DC) nameplate power, can be used to compare this installation to any other solar installation in the world. This installation has a kWh/kWp of 1,154.4, which is a fairly average number in comparison to other electric stations that typically range from 1000 – 2000 kWh/kWp (Zhang, 2017).

System Metrics	
Design	Solar at Oakville GO Station (copy)
Module DC Nameplate	1.75 MW
Inverter AC Nameplate	2.00 MW Load Ratio: 0.87
Annual Production	2.017 GWh
Performance Ratio	87.1%
kWh/kWp	1,154.4
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	09314f8b3f-241e17f2dc-094a7f1f23-f83e07f4ab

Figure 14. HelioScope Solar PV Model for Oakville GO Station. System Metrics.

Using this HelioScope model of Oakville GO station as a base case, it can be assumed that the Metrolinx GO trains and stations can have an annual production of 48,405.6 MWh of solar energy to offset current electricity usage for all 24 lines on the Lakeshore East and West GO Lines. This is a highly oversimplified calculation using the assumed and rounded numbers from the HelioScope model above and multiplying the total annual production of the Oakville GO solar carports (2016.9 MWh) by the number of stations on the Lakeshore Line, which is 24. This is a significant amount of electricity that can be offset with renewable energy which would result in both environmental and financial savings. The details of the financial savings and emissions reductions will be discussed below with the RETScreen Expert analysis.

RETScreen Expert Feasibility Modelling Results

RETScreen Expert is one of the most widely used tools for clean energy projects and performance analysis, serving as a global standard for clean energy analysis as it is used by many key organizations including governments, private sector, and academia. RETScreen is funded primarily by Natural Resources Canada and NASA, alongside other clean energy initiatives around the world. The modelling will demonstrate the necessity of abandoning fossil fuels and transitioning to clean energy in Canada's largest emissions producer, the transportation sector. Following that, the feasibility analysis will provide insight into the viability of a clean energy transition and the financial metrics behind such a transition. Both data models can be used to influence decisionmakers and policymakers in highlighting both the environmental and economic benefits of making the switch to 100 percent clean energy in the GHTA's mass public transit.

The feasibility analysis below will determine whether renewable energy, in this case solar energy, is a viable substitute for fossil fuels and if it makes financial sense for the case of Oakville GO Station, and subsequently the other 23 stations on the GO Lakeshore Line. This analysis will help decisionmakers understand the costs, savings, emissions reductions, and overall feasibility of this project. The entire RETScreen Expert report is located in Appendix B. The following will outline the details of the feasibility analysis and discuss the results.

The RETScreen Expert feasibility analysis details stay consistent with the calculations made in the previous section by HelioScope. It models a solar PV system with a 2000 kW (2 MW) capacity at

Oakville GO Station. The closest climate database location to the Oakville GO station is Burlington Piers. This location was chosen because, like Oakville GO, it is close to the lake and the lake is east to both the Oakville GO location and Burlington Piers. This is an important factor because of the prevailing winds from the Southwest, so Burlington Piers more accurately mimics the conditions we would face at Oakville GO Station location. This is as close of an approximation of sun and weather conditions for Oakville GO station since there is no climate data for Oakville. The location climate data is below in Figure 15. Further information on the climate data can be found in the full report located in Appendix B.

	Unit	Climate data location	Facility location
Name		Canada - Ontario - Burlington Piers	Canada - ON - Oakville
Latitude	˚N	43.3	43.5
Longitude	˚E	-79.8	-79.7
Climate zone		5A - Cool - Humid	5A - Cool - Humid
Elevation	m	77	92

Figure 15. RETScreen Expert Feasibility Analysis – Location Climate Data

The summary table below displays the total electricity exported to the grid, the electricity export revenue, and the GHG emission reductions of a 2 MW solar PV system at Oakville GO. The feasibility analysis projects a total of 3,329 MWh solar energy exported to the grid, an electricity export revenue of $332,880 CAD, and an annual emissions reduction of 318 tonnes/CO_2 (Figure 16). For comparative means, it is important to note that an emissions reduction of 318 tCO2 is equivalent to 136,631.8 Litres of gasoline not consumed (this is further elaborated on in the full RETScreen Expert report in Appendix B).

Summary

	Electricity exported to grid MWh	Electricity export revenue CAD	GHG emission reduction tCO_2
Proposed case	3,329	332,880	318

Figure 16. RETScreen Expert Feasibility Analysis – Results Summary.

The financial projections are displayed below in Figure 17, detailing the costs, savings, and revenue. Most important to note of these projections is the initial investment of $3,600,000 and the total annual savings and revenue of $332,880. After the O&M costs and debt payments, the net cash flow for year 1 is $20,198. However, looking at the yearly cash flows for years 2 to 25, both the pre-tax and cumulative cash flows significantly increase year over year, with a cumulative cash flow of over $6,000,000 by year 25, which almost doubles the initial investment.

Costs | Savings | Revenue

Initial costs			
Initial cost	100%	CAD	3,600,000
Total initial costs	100%	CAD	3,600,000
Yearly cash flows - Year 1			
Annual costs and debt payments			
O&M costs (savings)		CAD	36,000
Debt payments - 15 yrs		CAD	276,682
Total annual costs		CAD	312,682
Annual savings and revenue			
Electricity export revenue		CAD	332,880
GHG reduction revenue		CAD	0
Other revenue (cost)		CAD	0
CE production revenue		CAD	0
Total annual savings and revenue		CAD	332,880
Net yearly cash flow - Year 1		CAD	20,198

Yearly cash flows

Year #	Pre-tax CAD	Cumulative CAD
0	-1,080,000	-1,080,000
1	29,464	-1,050,536
2	39,016	-1,011,521
3	48,861	-962,659
4	59,009	-903,650
5	69,470	-834,180
6	80,252	-753,929
7	91,365	-662,563
8	102,820	-559,743
9	114,627	-445,116
10	126,797	-318,319
11	139,340	-178,979
12	152,268	-26,711
13	165,593	138,882
14	179,327	318,209
15	193,482	511,692
16	484,754	996,446
17	499,791	1,496,237
18	515,289	2,011,526
19	531,262	2,542,788
20	547,724	3,090,512
21	564,691	3,655,203
22	582,177	4,237,380
23	600,199	4,837,580
24	618,773	5,456,352
25	637,915	6,094,267

Figure 17. RETScreen Expert Feasibility Analysis – Cost, Savings, Revenue and Yearly Cash Flows.

The overall financial viability can be seen below (Figure 18). These numbers are relative to profitability and quickness of return. Most noteworthy in these figures is the Benefit-Cost Ratio. The Benefit-Cost Ratio shows the relationship between the relative costs and benefits of the proposed project. This project has a BCR of 1.5, which means that the project is expected to deliver a positive net present value to a firm and its investors. With a Net Present Value (NPV) of $591,893, additional financing would be required to support the infrastructure of solar energy at the Oakville GO station.

Financial viability

Pre-tax IRR - equity	%	12.3%
Pre-tax MIRR - equity	%	10.9%
Pre-tax IRR - assets	%	4%
Pre-tax MIRR - assets	%	5.7%
Simple payback	yr	12.1
Equity payback	yr	12.2
Net Present Value (NPV)	CAD	591,893
Annual life cycle savings	CAD/yr	60,258
Benefit-Cost (B-C) ratio		1.5
Debt service coverage		1.1
GHG reduction cost	CAD/tCO_2	-189
Energy production cost	CAD/kWh	0.114

Figure 18. RETScreen Expert Feasibility Analysis – Financial Viability.

Further, the GHG reduction cost represents a savings of $189 CAD per t$CO_2$. This means that every tonne of CO_2 not emitted results in a savings of $189, therefore if the GHG reduction from solar carports at Oakville GO is 318 tCO_2 annually, that would generate a savings of $60,102 each year.

Discussion

The results from HelioScope and RETScreen Expert indicate that a transition to solar energy at the Oakville GO station is both structurally and financially feasible. The HelioScope design serves as an example of the best design fit for a 2 MW solar installation with an 87.1% performance ratio at the Oakville GO station. The key findings of the RETScreen Expert feasibility analysis are detailed above in Figures 16 and 17, with the most important findings being the initial investment costs of $3,600,000, the annual electricity generation of 3,329 MWh, the annual electricity export revenue of $332,880, and the annual emissions reduction potential of 318 tCO_2. At current, installing solar is an upfront financial investment with the expectation of a profitable return on investment, which is demonstrated in Figure 18. The projected solar PV system designed for Oakville GO shows that it will deliver on the simulated energy yield targets and will lead to technical targets being met and financial expectations being satisfied. As mentioned above, the RETScreen Expert model estimated a Net Present Value (NPV) of $591,893, which means that after accounting for all the positive and negative cashflows and the time value of money, this investment will make money in both the short and long term. Additional financing from the federal and municipal governments, bilateral credits, loans, or clean energy programs like the Toronto PACE program, would be required to support the infrastructure for solar energy at the Oakville GO station.

Additionally, looking back to the IPCC emissions modelling scenarios mentioned in the introduction of this paper, it's important to consider that emissions controls can drastically limit the rate of warming and spare the planet from life-threatening and irreversible consequences under the business-as-usual scenario. Transitioning one of Ontario's largest GHG emitting sectors (transportation) to renewable energy is an excellent measure of controlling and reducing emissions.

As the RETScreen modelling displays, installing a 2 MW solar PV system at one GO station can reduce GHG emissions up to 93%. If that were to be implemented at all 24 stations on the GO Lakeshore Line, and assuming all the metrics are the same as the RETScreen model projections (Figure 19), that would result in an emissions savings of around 7,632 tCO_2 each year. In the grand scheme of things, this amount of reduction is not massive, but it is significant enough to spark other transit companies and industries to follow in the same direction, which can lead to a substantially cleaner atmosphere for Earth—and that is the most important goal of a renewable energy transition and climate change mitigation.

The Business Case for RES in GTHA's Metrolinx GO Trains

As argued earlier in this paper, transitioning to solar energy in the transportation sector, specifically in the GO trains, would be beneficial for the planet, for society, and for business. A sustainable energy transition in the transport sector has the potential to significantly reduce emissions, improve air quality, provide citizens with more economical and sustainable transit means, which contributes overall to healthier populations and enormous economic return on investments (Crawford, 2020). One of the largest barriers to a transition of this magnitude is the initial financial investment. However, as demonstrated with the RETScreen Expert feasibility analysis, in line with arguments from the 2019 SEICUT report, there is a massive opportunity for revenue generation and cost savings in various areas of owning, operating, maintaining, and fueling solar-powered trains and train stations (SEICUT, 2019; Crawford, 2020) at the Oakville GO and other stations on the Lakeshore Line.

There are large environmental and economic issues with the current state of diesel and combination fossil fuels being used to power urban rail transit such as the Metrolinx GO trains and stations. Not only are fossil fuels disproportionately affecting the natural environment and creating problems in human health, but the resource itself is quickly being depleted and will likely run out in the next 40-50 years (Howarth, 2019). It is also important to note that, according to an IPCC report, the world will reach the 2-degree upper limit for catastrophic global warming if just 20-30% of the world's existing fossil fuel reserves are burned (Howarth, 2019). Renewable energy sources can combat this by greatly reducing emissions and eliminating the dependence on fossil fuels, thus slowing or potentially halting catastrophic warming.

The benefits of installing solar PV systems at the GO stations, in combination with the investment in electric locomotives, are threefold: people, profit, and planet. Replacing traditional fossil fuels with solar energy has several economic and environmental benefits:

- A significant reduction of carbon emissions since solar energy produces between 5 to 10 times less carbon emissions per unit of energy relative to coal or natural gas
- A full return on investment by year 20, which means a minimum of 5 years of profit generation afterwards (Figure 17)
- An increase in ridership as electric trains and solar energy appeals to an additional market of commuters and citizens and tend to have faster speeds compared to diesel trains
- An increase in number of jobs available – Clean Energy Canada and IRENA estimate roughly 320,000 solar industry jobs nationally, 2.8 million solar industry jobs worldwide, and 6.7 million jobs for all clean energy sources worldwide (Clean Energy Canada, 2017)
- An efficient use of space – with urbanization rapidly increasing, solar panels are highly beneficial to maximizing any open space, especially in the case of Oakville GO station where the parking lots serve as a prime area for solar carports and shaded parking.

The key disadvantage of an electrification project such as this one is the high initial investment costs. However, as displayed in the RETScreen Expert analysis, this project would start generating revenue from the moment it begins operations and expects to make a complete return on investment by the 21st year in operation. This means at least 5 (but up to 10) years of pure profit generation after the ROI as the panels last around 30 years before efficiency degradation begins (Berg, 2018). Other small disadvantages include a relative lack of flexibility (due to construction/addition of third rails and overhead wires), and a vulnerability to power interruptions.

The costs and risks associated with this project are as follows:

Costs

- $3.6 million for 2 MW solar installation carports (per GO station)
- Average $500,000 – $1,000,000 for each electric locomotive
- Additional costs of construction for third rails and other electric infrastructure needs
- Energy production cost of $0.114 CAD/kWh
- NPV of $591,893
- Annual life cycle savings of $60,258
- GHG reduction cost of $-189 CAD/t$CO_2$

Risks

- Financial risk – risk of insufficient access to investment and operating capital.
- Market risk – risk of rate decreases for electricity generated, or cost increases for important factors like labour or modules.
- Political and regulatory risk – risk of a change in policy or government that may affect the profitability of the project.
- Technology risk – risk of compromised efficiency and generation of less electricity over time.
- Operational risk – risk of unscheduled closures due to component failures, equipment damages, or a lack of resources.
- Weather risk – risk of lack of sunshine or snow covering solar panels for long periods of time, resulting in changes in electricity generation.

According to Worren (2012) and Renewable Energy World, most of these risks can be managed through financial instruments and insurance products. For example, technology risks can be offset through warranties and weather risks can be minimized or prepared for by using weather futures. Given that solar and electric transportation is still a relatively new industry, there is a lack of engineering studies, which means that some risk categories, especially financial risk management, are poorly replicated from other fields, therefore demanding further research into electrification of the transportation industry for more accurate and applicable factors.

To strengthen the argument for renewable energy installation for the Metrolinx GO trains, further costs regarding fuel and infrastructure investment are detailed below in Table 1. All the above points outline a strong and optimistic business case with evident ROI for sustainable urban infrastructure. The bottom line is that investment in low-carbon passenger transport has the potential to see substantial economic and social returns, all while making a significant, positive impact on human health and the environment (Crawford, 2020). And it is entirely feasible, as so many major cities like Vancouver and Calgary have already shown.

Fuel Costs and Infrastructure Investment

To calculate the total costs of solar electrification for all 24 stations on the Lakeshore line (15 on Lakeshore West and 9 on Lakeshore East), further research beyond the scope of this paper is required. However, it is roughly estimated that it could be 2 MW per station, which would be 48 MW for all stations on the Lakeshore East and West corridors. After modeling this with RETScreen Expert, infrastructure investment cost would be $3,600,000 for the 2 MW at Oakville GO Station and $86,400,000 for solar electrification of all 24 stations on the Lakeshore line. These numbers are vast oversimplifications and, again, require further research to calculate exact costs and feasibility, but for the purpose of this paper these are rough estimations to show the possibility of solar electrification of the Metrolinx GO trains and stations. My cost calculations are accurate for the photovoltaic system for Oakville GO station, so for the total cost of electrifying all 24 stations on the Lakeshore Line, it was simply assumed to be the same cost of Oakville multiplied by the number of stations (24), which is equal to the above calculation of $86,400,000.

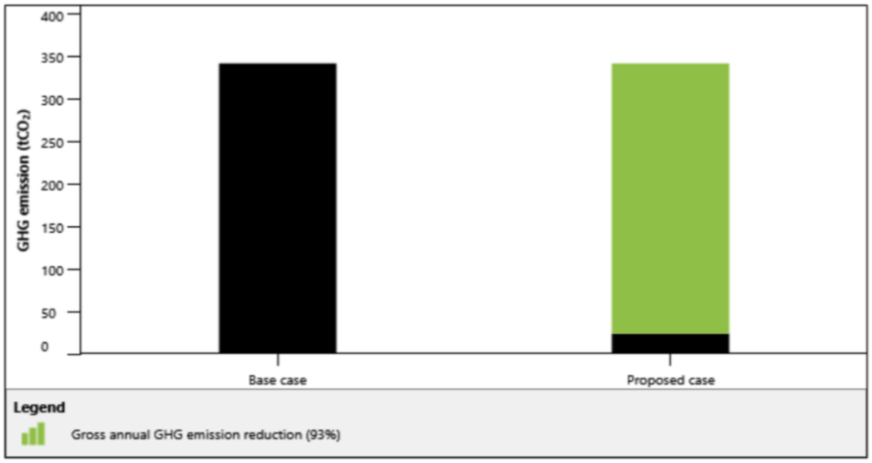
As outlined in the table below, the total annual fuel costs and annual electricity costs of the Lakeshore Lines are $30,043,860.42 and $14,750,040, respectively. These numbers tell two things: that electricity costs are significantly cheaper than fuel costs, and that with an investment of $3,600,000 for each station to be fitted with a 2 MW solar system, the annual fuel costs would substantially decrease due to a decreased need for fossil fuels.

GO Train Line	Annual Gallons of Fuel	Annual Fuel Cost ($)	Annual Ton Miles	Electricity Cost ($)
Lakeshore East	3,462,475	14,166,371.11	904,948,239	6,841,409
Lakeshore West	3,880,698	15,877,489.31	1,046,115,265	7,908,631
Total	**7,342,573**	**30,043,860.42**	**1,951,063,504**	**14,750,040**

Table 1. Fuel Costs. Table adapted from the 2010 Metrolinx GO Electrification Study.

Additionally, according to the 2010 GO Electrification Study, the cost of energy provided by diesel fuel is far greater than the cost of energy from an electrical system. The study also notes that there are major uncertainties over both electricity and diesel costs in the future, with the cost of diesel fuel expected to increase at a greater rate than electricity (Metrolinx, 2010; Metrolinx 2020). Another important factor in this feasibility analysis is that electric locomotives are comparably less expensive to maintain than diesel locomotives, therefore annual operating and maintenance costs are estimated to be lower as well. To this regard, the GO Electrification Study and the 2020 Metrolinx Business Plan estimate operating and maintenance savings at about $53 million for the electrification of the entire GO network (Metrolinx, 2010; Metrolinx 2020).

Regarding the overall GHG emissions savings, it is important to note that electric trains do not emit GHGs from the locomotives, but rather at the source of electricity generation, therefore trains propelled by electricity emit less GHGs than diesel trains (Metrolinx, 2010). By electrifying larger sections of the GO Transit rail network, greater GHG reductions can be achieved. It is estimated in the 2010 Electrification Study that electrifying the entire GO network would result in a 94% reduction in GO Transit's future GHG emissions (Metrolinx, 2010). These reductions are consistent with the RETScreen Expert emissions reductions projections as depicted below (Figure 19).



GHG emission		
Base case	341.9	tCO_2
Proposed case	23.9	tCO_2
Gross annual GHG emission reduction	318	tCO_2

Figure 19 – RETScreen Expert Feasibility Analysis – Emissions reductions projections.

Overall, there are many environmental, economic, social and community benefits to electrification. As discussed above, solar electrification of the GO trains and stations would involve significant capital investment for infrastructure but would result in some operations and maintenance cost savings and significant GHG emissions reductions.

Recommendations for Future RES Policy in Ontario

The most pressing challenge for policymakers is the need for a deep decarbonization in order to mitigate and prevent the severe consequences of climate change (Rosenbloom et al., 2020). Oftentimes, carbon pricing is presented as the primary policy option to address the issue of excessive emissions. As discussed in the above literature review, carbon pricing (like many other climate policy options) has flaws regarding its priorities, politics, and approach. Based on this paper’s policy review, case studies, the HelioScope model, and the RETScreen Expert feasibility analysis, recommendations for successful renewable energy policy in Ontario include reforming fossil fuel subsidies, implementing green fiscal policy, and considering an approach such as the Sustainability Transition Policy suggested by Rosenbloom et al. (2020).

Reforming fossil fuel subsidies has long been a top priority of the environmental movement. Fossil fuel subsidies work against local and global efforts to combat climate change as they provide the multi-billion-dollar oil, gas, and coal industries with tax breaks and handouts that further increase their profits and incentivize their pollution habits. Government subsidizing of fossil fuels also takes away spending from sectors that need it most such as environment, health, and education (MFATNZ, 2021). Reforming fossil fuel subsidies can greatly reduce pollution, improve human health, and release revenues that can be put towards implementing greener policies (UNEP, 2021). In Canada, and specifically Ontario, reforming fossil fuel subsidies involves 2 key actions: raising taxes and duties on fossil fuels and shifting support to renewable energy and energy efficiency. Subsidy and taxation reform have proven to work best when they are enforced alongside a wider push for clean energy (Sanchez et al., 2020). Further, the savings incurred from subsidy reform should be invested into alternative sources of energy in order to support a gradual phase-out of fossil fuels (Sanchez et al., 2020). The recent Greenhouse Gas Pollution Pricing Act (GGPPA) introduced into Canadian legislation takes a step towards reforming provincial fossil fuel subsidies as it places an annually increasing price on carbon for both consumer and industry. However, where the GGPPA lacks is the second key step mentioned above—the requirement for a reallocation of funds into a clean energy transition. This would be most useful in the form of a green fiscal policy (GFP). Most provinces have outlined plans for the reallocation of savings from subsidy reform, but it would be far more effective for federal legislation to mandate spending under a GFP. GFPs are key to addressing global challenges and aligning government expenditures with environmental goals and hold leaders accountable, which creates fiscal space for green investment and broader fiscal reform (UNEP, 2021).

One very useful policy reference is the Sustainability Transition Policy (STP) presented by Rosenbloom et al. (2020). In their article, they position the STP as an alternative to the typical carbon pricing policy that many governments, including the Canadian and Ontarian governments, default to. The authors identify five key problem areas within standard carbon pricing policies: 1) problem framing and solution orientation, 2) policy priorities, 3) innovation approach, 4) contextual considerations, and 5) politics. The STP works to remedy these problem areas using a mix of “contextually and politically sensitive policies that simultaneously drive low-carbon innovation and the decline of fossil fuels.” (Rosenbloom et al., 2020, para.1). Given that climate policies are typically layered on top of existing institutional frameworks, the policy design and implementation process often get complicated and does not produce the most ideal results (such as the example of Ontario's 2016 previous cap and trade program – it was unsuccessful because it was vulnerable to government turnover and was most focused on taxation instead of both taxation and policies for innovation investment). By acknowledging this, the STP approach emphasizes that to achieve a low-carbon future, two policies are needed: policies that encourage innovations (like solar photovoltaics), and policies that discourage carbon-intensive technologies (like coal). These two policies work in harmony with each other to sustainably transition to cleaner energy and dismantle prior structures.

To replicate an STP approach in Ontario and see success, it would be wise to follow the two-policy approach through a design and implementation of more innovative policies for the transportation sector. This starts with creating strong yet flexible policies that allow for more renewable energy adoption, specifically more opportunity for solar energy in large transit systems like the GTHA's Metrolinx GO Trains, in combination with policies to phase out fossil fuels such as the newly passed GGPPA or other phase-out principles, such as those outlined in the research paper by Muttitt & Kartha (2020). There are 5 principles that are suggested as the most successful path to a sustainable and just transition to renewable energy. The 5 principles are: Phase down global extraction at a pace consistent with limiting warming to 1.5°C; Enable a Just Transition for workers and communities; Curb extraction consistent with environmental justice; Reduce extraction fastest where social costs of transition are least; and Share transition costs fairly, according to ability to bear those costs (Muttit & Kartha, 2020). Following these principles ensures a fair and effective path to combatting climate change and lessening our dependence on fossil fuels.

The most significant opportunity for emissions reduction in transportation include a large-scale shift from gas and diesel-fueled vehicles to zero-emitting technologies, such as electric locomotives and solar powered operations (Yanity, 2019). While past responses to global warming have shown to be unfulfilling, it has created demands for different, more equitable approaches.

Conclusion

The climate crisis presently affecting the world has called for all sectors to step up and contribute to reducing emissions. The transport sector accounts for almost one third of Canada's annual emissions, with passenger and rail transportation accounting for over 55% of total transportation emissions (Canada Energy Regulator, 2016). This industry is an excellent starting point in this context as it has the potential to be one of the most sustainable methods on the market (Berti, 2019). There are countless transit systems around the world and within Canada that have successfully implemented renewable energy as the main power source, such as the case studies of Calgary's CTrain and Vancouver's SkyTrain. Further, due to ever-increasing air pollution and a growing demand for fossil fuel elimination, transportation electrification will surely increase in the years ahead. As discussed in this paper, one of the largest hinderances to the adoption of renewable energy technologies in the transit sector is the lack of policies and regulations favouring the development of renewable technologies (Kariuki, 2015). The renewable energy market functions on clear and robust policies designed to increase the interest of investors, however such policies are not as common as they should be in the transit sector in the GTHA, and Ontario as a whole. Pro-ecological reforms in the energy sector can be implemented quickly if the government's diversification policy for energy sources also includes as a priority the necessary development of renewable energy sources. It would be highly beneficial to further research the impact of government funding for solar technologies and programs so to better understand where federal and municipal investment priorities lay with regard to renewable alternatives. The following conclusions are gathered from the above research:

- Provincial and federal climate policy is lacking in inclusivity and effectiveness. Right now, climate policies target the consumer while still allowing industry to pollute for a fee. This does very little to actually decrease the use of fossil fuels.
- There is widespread support for emissions reduction and renewable alternatives in the transportation sector: Metrolinx has developed and published multiple studies on GO electrification and the Ontario provincial government have agreed to adopt the federal carbon tax under the GGPPA.
- As shown in the HelioScope model and RETScreen Expert analysis, implementing solar PV systems at the GO stations (in combination with electric locomotives) is feasible and

extremely beneficial for people, planet, and profit: It will cut back on commuter times as electric trains are faster and more energy efficient than diesel trains; it does not contribute any further or unnecessary carbon dioxide emissions; it requires less maintenance which saves the company money; and it will generate revenue of at least $6,000,000 over a 25-year period.

- The biggest disadvantage of electrification is the high initial investment costs and costs of infrastructure. However, investing in infrastructure development is simply that—an investment, not a finance project.
- Public policy in Canada interferes with a transition to renewable energy because of longstanding government investment in oil and gas companies. In 2020, the Canadian government dedicated $18 billion to the oil and gas sector and continues to finance the creation of new pipelines (Cox, 2021). These actions are severely misaligned with the renewable energy transition this country desperately needs, and until fossil fuel funding is eliminated, climate policies will continue to fail as they primarily work to serve government interests and priorities.
- Policy settings to support renewable alternatives in the largest emitting industries need major improvement. This needs to happen in the form of political reform and abolishment of existing institutional frameworks that are long outdated.

Policy is one of the largest influencers of change, but also one of the largest barriers to substantive action. Governments hide behind global goals far too often, leaving the leavy lifting to citizens and smaller organizations. The research done in this paper aims to show that installing solar PV systems in large transit systems like the Metrolinx GO trains is entirely feasible and beneficial to all 3 pillars of sustainable development. The recommendations made above aim to stimulate local and global action in climate change mitigation through an almost complete reform of the existing institutional and political structures in Ontario and in Canada. It is particularly apparent that wealthier countries like Canada need to take much greater action that is in favour of environmental justice, and Canada's continued actions against environmental justice (such as the recent enabling of tar sands expansion with public investment in new pipelines) combined with the lack of robust policy design and enforcement do not align with environmental goals to limit global warming to

1.5°C. Fossil fuel extraction is not a viable route to a sustainable future and a transition to renewable energy is absolutely necessary.

Areas for Further Research

This paper has detailed some of the successes and failures within current Canadian climate policies, including renewable alternative technologies for urban rail transit systems and policy recommendations to improve existing frameworks. If climate goals are to be met on time, the transportation sector must become more sustainable, and this requires more significant collective action to be taken by federal, provincial, and regional governments. In addition to the research conducted in this paper, there is a need for further studies in the field of rail transit electrification. Renewable energy alternatives are certainly the future of transportation, but design and implementation require greater research in the following areas:

a. A detailed engineering study of electrical demand versus fuel costs and emissions, among many other variables, to generate more accurate and specific numbers;
b. An in-depth financial analysis to determine investment and funding feasibility for a project of this kind.

It is apparent from this research that there needs to be much more progress with regards to innovation, research, and development for energy options in the transportation sector. It is essential to share knowledge about renewable energy technologies and the economic viability of such technologies, options, and research efforts, as well as the properly aligned policies and standards. A transformation of this sector will no doubt take some time to increase manufacturing, decrease the cost of energy alternatives, shift consumer mindsets, and implement new infrastructure, but it is imperative that the first step be taken immediately (Yanity, 2019).

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Quebec Cap and Trade Regulation

Cap and Trade Cancellation Act, 2018

Appendix A

Metrolinx Sustainability Strategy – Performance Scorecard. Source: (Metrolinx, 2017(c))

Goal 1: Become Climate Resilient

Action	Measurement
1.1 Finalize our Corporate Climate Adaptation Plan. This includes strategies to ensure that capital assets that are designed, built, and delivered by Metrolinx are resilient to the impacts of climate change.	• Complete by the end of 2017.
1.2 Develop climate resilience requirements for inclusion within technical standards, manuals, guidelines, AFP project agreements, and project specific output	• Complete by the end of 2018.

Goal 2: Reduce Energy Use and Emissions

Action	Measurement
2.1 Reduce energy consumption.	• Achieve an 18% improvement in building energy performance over the minimum specified by the *National Energy Code for Buildings* (2011) in Metrolinx operated facilities by 2020. • Develop a re-commissioning and energy systems monitoring protocol for all GO Transit maintenance facilities by 2018. • Provide energy reduction incentives within AFP request for proposals. This is to be incorporated into RFP Schedule 3, 'RFP responses regarding Technical, Financial, Affordability, Scope, and submittal format' by 2015. (Achieved) • 15% reduction in fuel consumption per revenue seat km by 2020 (from a 2012 baseline).
2.2 Reduce greenhouse gas (GHG) emissions.	• 15% reduction in mobile GHG emissions per revenue seat km by 2020 (from a 2012 baseline). • Encourage consideration of opportunities to incorporate renewable energy sources into the design of new stations and bus and rail maintenance facilities to reduce greenhouse gas emissions by the end of 2020. • Consider adding a quantitative target related to GHG emissions reduction within AFP Project Agreements by the end of 2018. • Develop consistent percentage reduction in idling time of revenue vehicles, L/km/year by 2020. • Develop an implementation plan to install Electric Vehicle charging stations at GO station sites, as per Ontario's *Climate Change Action Plan (2016-2020)* mandate with results for sustainability progress reports to be ready within this strategy reporting cycle as early as 2018 and no later than 2020.
2.3 Reduce Criteria Air Contaminants (CAC).	• Achieve 20% reduction in total CAC per revenue seat km by 2020.

Goal 3: Integrate Sustainability in Our Supply Chain

Action	Measurement
3.1 Establish a viable sustainability framework for construction materials and sustainable procurement practices.	• Adopt or develop a sustainability framework that can be applied to all transit infrastructures in the Metrolinx network. Evaluate the feasibility of adopting the ENVISION™ framework for use with categories of Metrolinx transit infrastructure by 2018 or earlier. • Include consideration of life-cycle impact in material selection by 2018.
3.2 Divert waste from landfills.	• Require vendors to produce a waste management plan with all signed construction infrastructure project agreements beginning in 2017. • Include incentives within Metrolinx construction procurements to avoid tipping fees by diverting waste by 2015. (Achieved) • Identify which construction materials, components and sub-assemblies can be recycled at the end of their useful life (for example, railway ties). RFPs for Technical Advisor Services beginning in October 2016.
3.3 Divert waste from operations.	• 80% of Metrolinx operated facilities will have a waste diversion management plan and targets by 2020.
3.4 Promote use of modular and adaptive design in our major capital projects.	• Explore opportunities for adaptive designs that facilitate recycling, deconstruction, and/or re-purposing of these infrastructures by the end of 2020. • During the design of new projects, document, and track all opportunities identified for use of modular and adaptive design. Include commentary on the pros and cons associated with each identified opportunity, as well as the rationale for acceptance or rejection. Share lessons learned and report on results as early as 2018 and no later than the end of 2020.
3.5 Incorporate sustainability requirements within procurement practices.	• Develop a *Vendor Code of Conduct, Sustainable Procurement Policy* and specific technical requirements in tenders by 2018.

Goal 4: Minimize Impact on Ecosystems

Action	Measurements
4.1 Minimize the impact of new and existing infrastructure on ecosystems and consider ways to enhance the health of ecosystems (i.e., species, habitat, biodiversity).	• Integrate requirements into Metrolinx procurement practices to manage and mitigate impacts of new and existing infrastructure on ecosystems. Report on results as early as 2018 but not later than the end of 2020. • Identify and implement opportunities to support and enhance biodiversity conservation efforts to meet or exceed applicable legislation and guidelines. Report on results by end of 2020. • Identify opportunities to enhance ecosystems to meet or exceed applicable legislation and guidelines. This includes but is not limited to consideration of native and pollinator species. Report on results by end of 2020.
4.2 Minimize and manage the use of salt and other chemicals used in operations that are dispersed in the environment.	• Implement salt management strategy, measure impact, and evaluate alternatives as necessary by 2018.

Goal 5: Enhance Community Responsibility

Action	Measurements
5.1 Minimize local impacts on communities.	• Minimize or eliminate light pollution from GO stations and maintenance facilities without compromising safety and security. Adopt this as a mandatory LEED requirement and include within applicable project tenders beginning in April 2017. • Develop and implement a comprehensive approach to address noise across the Metrolinx network. This includes a plan that would guide Metrolinx toward enhancing its ability to anticipate, manage and respond to noise issues by 2019.
5.2 Engage residents in the design and construction of new infrastructure.	• Develop a Community Charter by the end of 2017.
5.3 Support local workforce development, including partnerships to increase the supply of skills and trades.	• Develop and implement Community Benefits provisions in all Metrolinx AFP contracts with all applicable RFPs completed as early as late 2016.
5.4 Build partnerships to increase the supply of key skills and trades.	• Complete by 2020.
5.5 Develop, support and engage with educational programs to build knowledge, technology, and skills that advance sustainability and innovation, within the scope of Metrolinx's mandate.	• Develop the implementation plan and commence execution with results reportable as early as 2018 and no later than by end of 2020.
5.6 Establish an online platform for public feedback and input on projects.	• Complete by 2016.

Appendix B

RETScreen Expert Feasibility Analysis – Full Report

Feasibility report

Oakville GO Station

Taylor's MRP - Electrification of Oakville GO Station

Power plant - Photovoltaic

Prepared for:	Prepared by:
York U MRP	Taylor Sabatelli

Executive summary

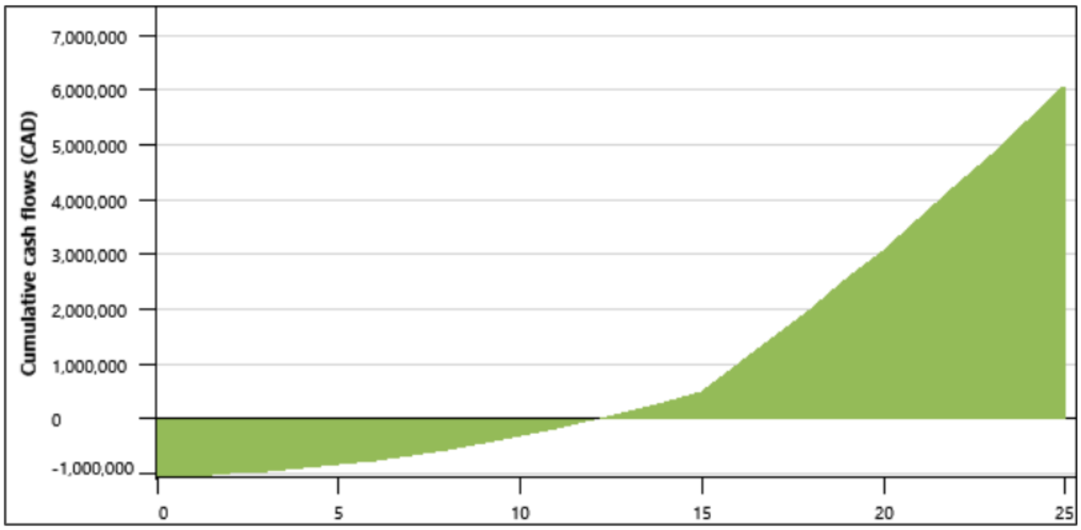
This report was prepared using the RETScreen Clean Energy Management Software. The key findings and recommendations of this analysis are presented below:

Target

	Electricity exported to grid MWh	Electricity export revenue CAD	GHG emission reduction tCO_2
Proposed case	3,329	332,880	318

The main results are as follows:

Cash flow - Cumulative



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Location | Climate data

Location

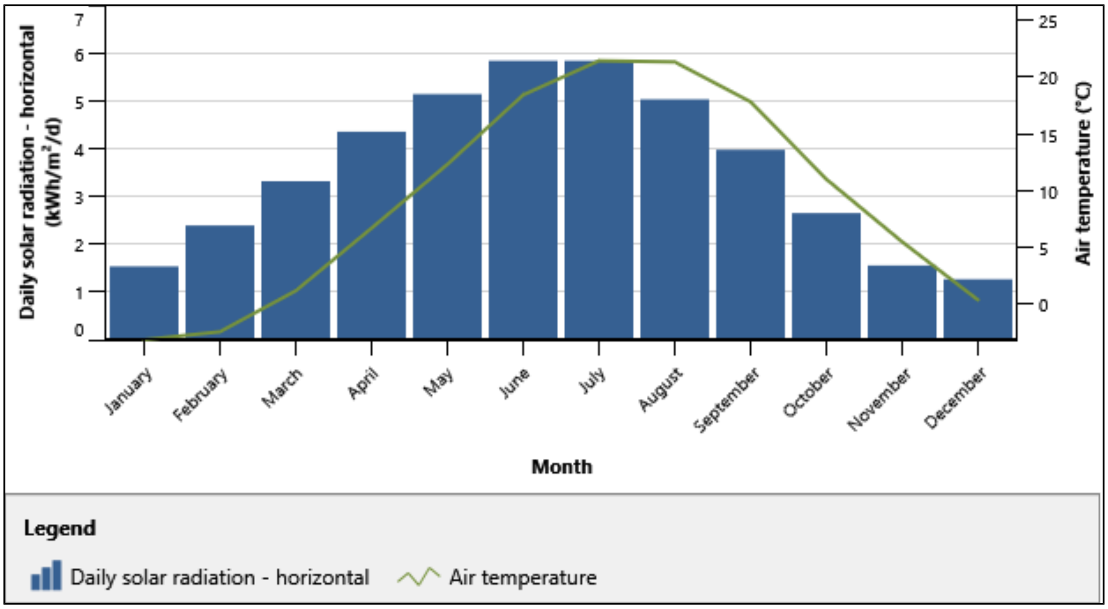
Legend

Facility location

Climate data location

	Unit	Climate data location	Facility location
Name		Canada - Ontario - Burlington Piers	Canada - ON - Oakville
Latitude	˚N	43.3	43.5
Longitude	˚E	-79.8	-79.7
Climate zone		5A - Cool - Humid	5A - Cool - Humid
Elevation	m	77	92

Climate data

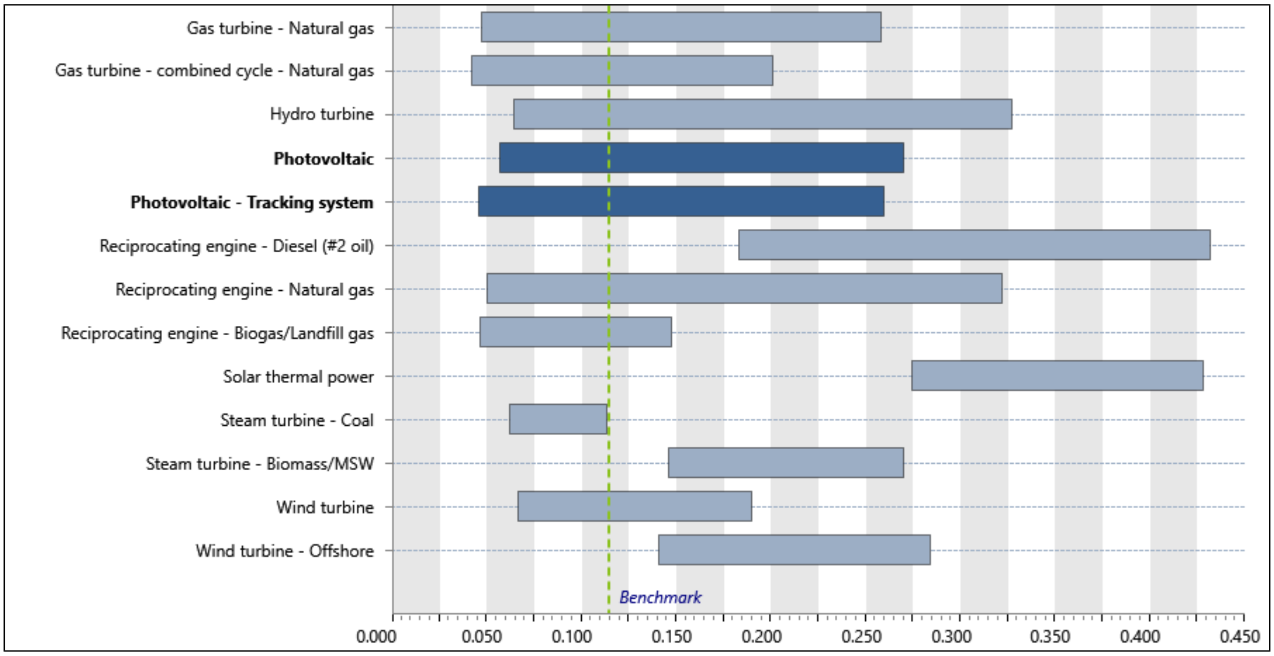


Heating design temperature	-12.9
Cooling design temperature	28.6
Earth temperature amplitude	21.4

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	-3.1	70.2%	42.78	1.54	99.3	4.5	-4.1	654	0
February	-2.4	66.2%	37.52	2.40	99.3	4.2	-3.8	571	0
March	1.2	66.0%	44.33	3.33	99.3	4.2	0.2	521	0
April	6.7	66.3%	58.50	4.37	99.1	4.0	5.9	339	0
May	12.3	68.6%	69.44	5.16	99.2	3.5	12.0	177	71
June	18.4	70.7%	71.70	5.86	99.1	3.0	17.9	0	252
July	21.4	68.2%	74.40	5.86	99.2	3.1	21.3	0	353
August	21.3	70.6%	64.79	5.05	99.3	3.2	20.7	0	350
September	17.8	70.4%	74.70	3.99	99.4	3.6	16.5	6	234
October	11.0	71.4%	70.68	2.66	99.4	3.9	9.7	217	31
November	5.5	71.5%	59.70	1.56	99.4	4.1	3.8	375	0
December	0.4	71.1%	51.15	1.27	99.3	4.3	-1.4	546	0
Annual	9.3	69.3%	719.69	3.59	99.3	3.8	8.3	3,405	1,292

Benchmark

Energy production cost - Central-grid - Range (CAD/kWh)



Benchmark: 0.11 CAD/kWh

Power plant

Photovoltaic
Taylor's MRP - Electrification of Oakville GO Station

Photovoltaic - 1000 kW		
Capacity	2,000	kW
Electricity	3,329	MWh

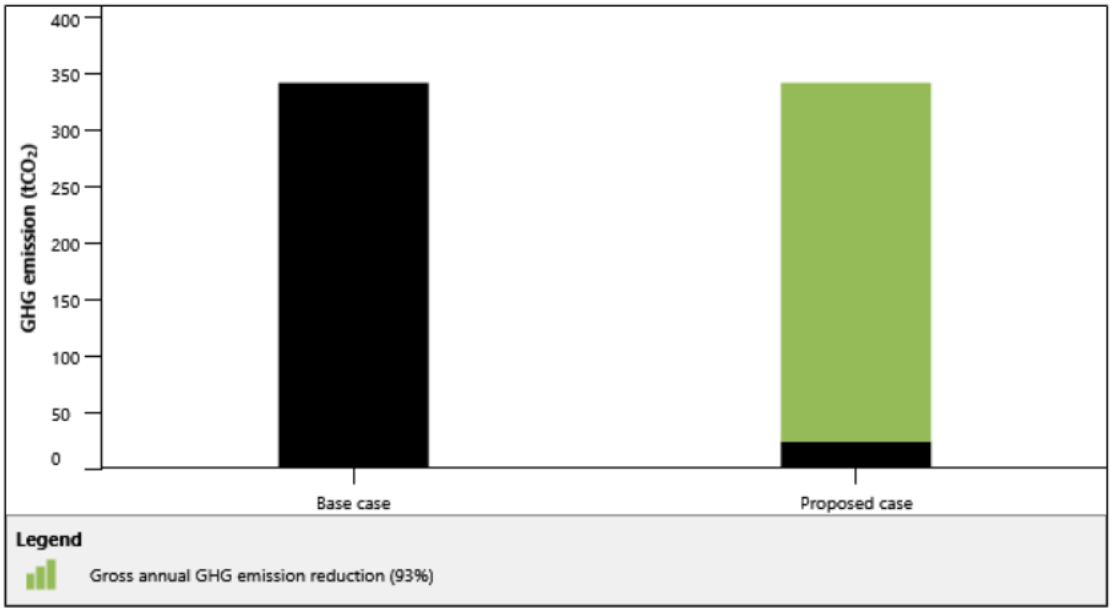
Target

Summary

	Electricity exported to grid MWh	Electricity export revenue CAD	GHG emission reduction tCO_2
Proposed case	3,329	332,880	318

GHG emission

GHG emission



GHG equivalence

318 tCO_2 is equivalent to 136,631.8

Litres of gasoline not consumed

GHG emission		
Base case	341.9	tCO_2
Proposed case	23.9	tCO_2
Gross annual GHG emission reduction	318	tCO_2

Financial viability

Financial parameters

General		
Inflation rate	%	2%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	25
Finance		
Debt ratio	%	70%
Debt	CAD	2,520,000
Equity	CAD	1,080,000
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	CAD/yr	276,682

Annual revenue

Electricity export revenue		
Electricity exported to grid	MWh	3,329
Electricity export rate	CAD/kWh	0.10
Electricity export revenue	CAD	332,880
Electricity export escalation rate	%	3%

Costs | Savings | Revenue

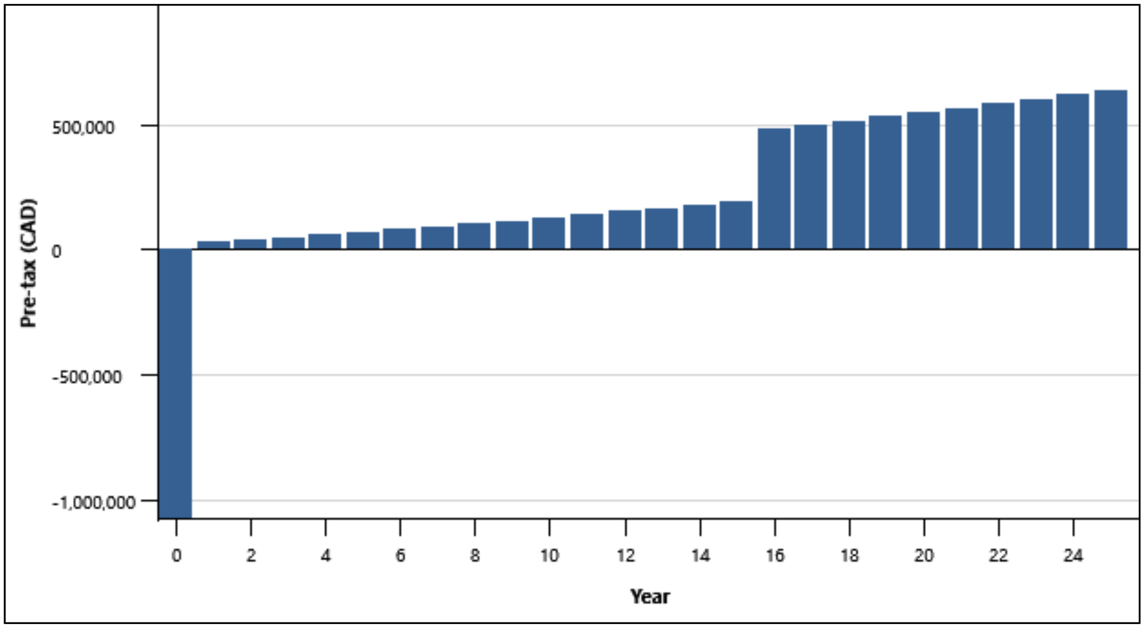
Initial costs			
Initial cost	100%	CAD	3,600,000
Total initial costs	100%	CAD	3,600,000
Yearly cash flows - Year 1			
Annual costs and debt payments			
O&M costs (savings)		CAD	36,000
Debt payments - 15 yrs		CAD	276,682
Total annual costs		CAD	312,682
Annual savings and revenue			
Electricity export revenue		CAD	332,880
GHG reduction revenue		CAD	0
Other revenue (cost)		CAD	0
CE production revenue		CAD	0
Total annual savings and revenue		CAD	332,880
Net yearly cash flow - Year 1		CAD	20,198

Financial viability

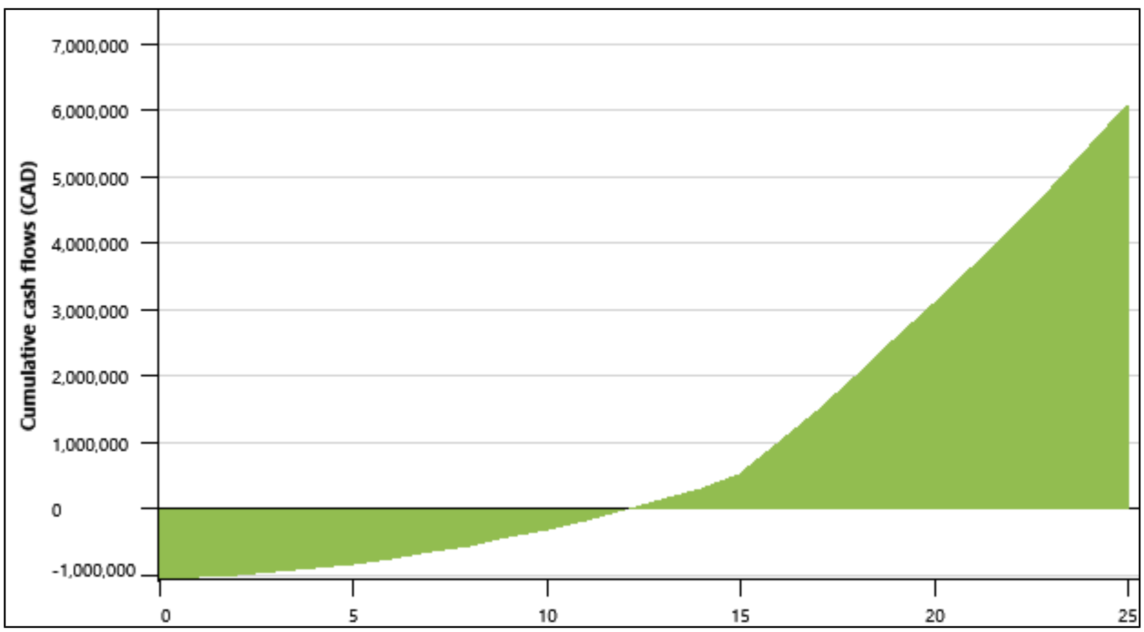
Pre-tax IRR - equity	%	12.3%
Pre-tax MIRR - equity	%	10.9%
Pre-tax IRR - assets	%	4%
Pre-tax MIRR - assets	%	5.7%
Simple payback	yr	12.1
Equity payback	yr	12.2
Net Present Value (NPV)	CAD	591,893
Annual life cycle savings	CAD/yr	60,258
Benefit-Cost (B-C) ratio		1.5
Debt service coverage		1.1
GHG reduction cost	CAD/tCO_2	-189
Energy production cost	CAD/kWh	0.114

Cash flow

Annual



Cumulative

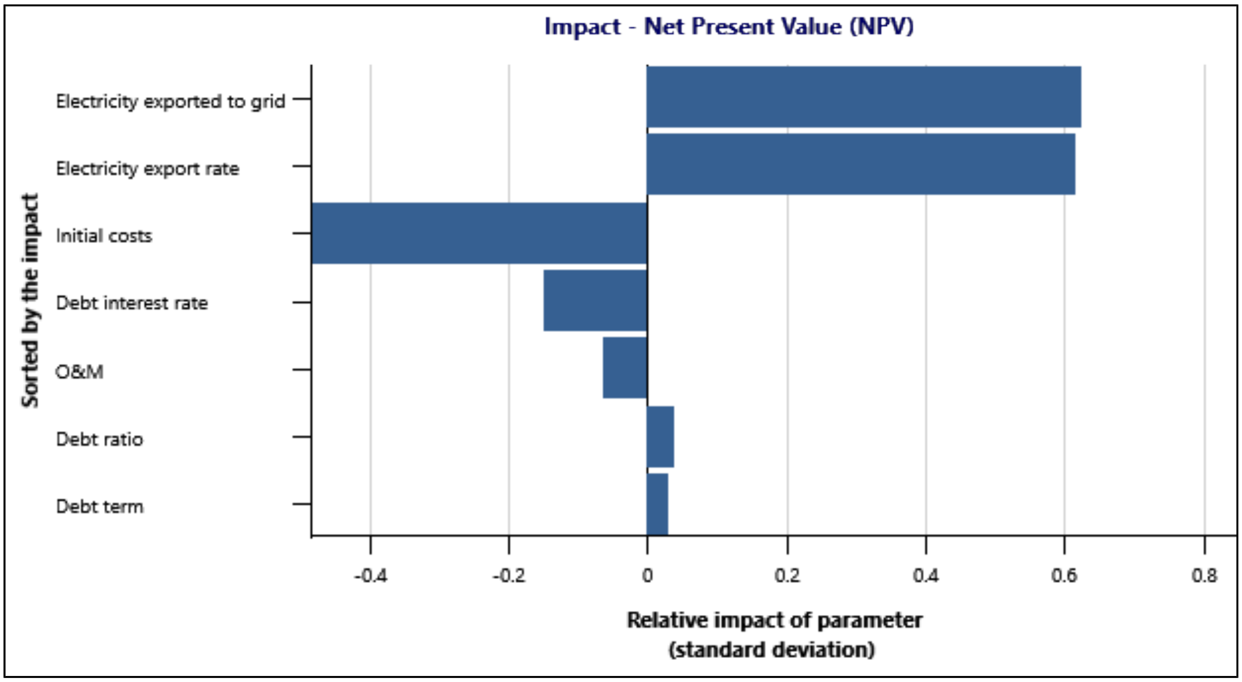


Yearly cash flows

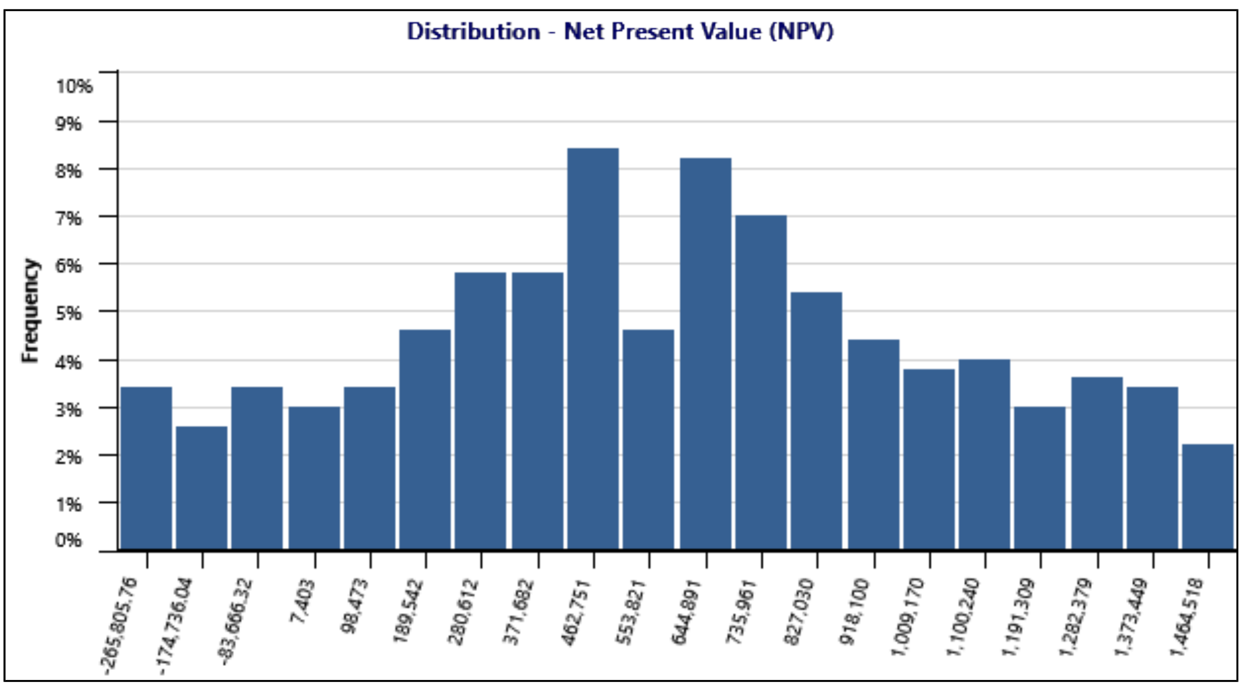
Year #	Pre-tax CAD	Cumulative CAD
0	-1,080,000	-1,080,000
1	29,464	-1,050,536
2	39,016	-1,011,521
3	48,861	-962,659
4	59,009	-903,650
5	69,470	-834,180
6	80,252	-753,929
7	91,365	-662,563
8	102,820	-559,743
9	114,627	-445,116
10	126,797	-318,319
11	139,340	-178,979
12	152,268	-26,711
13	165,593	138,882
14	179,327	318,209
15	193,482	511,692
16	484,754	996,446
17	499,791	1,496,237
18	515,289	2,011,526
19	531,262	2,542,788
20	547,724	3,090,512
21	564,691	3,655,203
22	582,177	4,237,380
23	600,199	4,837,580
24	618,773	5,456,352
25	637,915	6,094,267

Risk

Impact



Distribution



Perform analysis on	Net Present Value (NPV)				
Number of combinations	500				
Random seed	No				
Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	CAD	3,600,000	25%	2,700,000	4,500,000
O&M	CAD	36,000	25%	27,000	45,000
Electricity exported to grid	MWh	3,328.80	25%	2,496.60	4,161.00
Electricity export rate	CAD/MWh	100.00	25%	75.00	125.00
Debt ratio	%	70.0%	25%	52.5%	87.5%
Debt interest rate	%	7.00%	25%	5.25%	8.75%
Debt term	yr	15	25%	11	19
Median				CAD	598,245
Level of risk				%	10%
Minimum within level of confidence				CAD	-311,460
Maximum within level of confidence				CAD	1,510,412