TORONTO'S PLAN FOR 100% RENEWABLE ENERGY BY 2067

Jonathan Higgins

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Foreword

By completing this final research paper, it helped me gain an understanding of how to integrate my passion for renewable energy into urban planning to ensure that I can reach my career goal of becoming a certified planner through OPPI. This paper was a collection of knowledge that I acquired throughout the program in both classroom learning and an internship. The experience of being able to combine my entire post-secondary education, both McMaster and York, into one final paper is extremely gratifying and has reignited my passion to make the world a more sustainable and healthier place.

Abstract

The purpose of this major paper is to help the City of Toronto transition to 100% renewable energy. Some of the most salient barriers to achieve that climate security goal are: the limited experience with renewables in the current electrical grid; the aging and crumbling energy infrastructure; and the limited energy conservation ethos amongst local residents, businesses, and industries. Understanding the current state of renewables in the world and Canada makes setting goals and a realistic timeline easier. By summarizing what other cities from around the world did to help their quest towards only renewable energy, lessons and policies were discovered that would benefit Toronto. Three major areas, city policies, buildings, and transportation, were identified to be areas of concentration to help the goal become a reality. The proposed timeline incorporates these areas with realistic dates in which each task should be completed by. The conclusion is that Toronto can reach the goal of becoming 100% renewable energy if the steps are taken and acted upon accordingly. My research indicates that to achieve its climate security targets Toronto needs to start planning immediately a strategy for 100% renewable energy to ensure maximum benefits at the lowest cost to all stakeholders.

Introduction

One critical aspect of energy planning is how to manage and supply the built urban landscape with a sufficient amount of energy to fuel society's ever-growing demand. A shift in consumer, commercial, and industrial views on more traditional energy sources, such as coal, has led to a larger focus on renewable energy supplies worldwide (Ellabban, Abu-Rub, & Blaabjerg, 2014). Renewable energy is when energy is gathered from a natural resource at a sustainable rate that will not exhaust the natural resource over the course of time (Government of Canada, 2016). Along with these renewable sources, an increased interest in energy efficiency and energy conservation has been adopted in international markets. As the global focus on renewable energy intensifies, both developed and developing countries are shifting their policies and approaches to energy planning. By integrating renewable energy sources, cities, regions, and even entire countries can help combat their energy issues while providing a multitude of other benefits to themselves and those around them. With the world becoming more urbanized each year and the global population continuing to rise, it would be beneficial for society to understand these changes and adapt accordingly (United States Census Bureau, 2015). While energy planning consists largely of production and management of energy sources, by reducing the consumption and demand with renewable energy supplies, cities could see positive effect. From an energy planning view, the positive effects would be due to an integration of renewable energy into the urban landscape. This matters immensely in Toronto as the current provincial energy plan is under public consultation with the current main energy sources, multiple nuclear power plants, needing an immense amount of taxpayers funds continue to be operated safely and the removal of coal plants without a plan to replace their energy production. There are worries currently about the safety of nuclear given past accidents such as Chernobyl and Fukushima and debates that argue whether the source is renewable or not. By increasing the supply of renewables in Toronto and the surrounding areas, the residents can see a safe and healthy alternative that can provide indefinite energy. To fully understand the challenges and barriers presented during this global *energiewende*[1], Toronto, a city that displays immense cultural and economic impact will be analyzed with how it can best become a sustainable city with an enormous amount of renewable energy integrated into the built environment and natural landscapes. The goal is to provide a framework and a timeline to transition Toronto to a 100% renewable energy by 2067. By grasping the issues and providing potential solutions for this goal, it will become evident that Toronto can achieve this goal while also developing into the *folkecenter*[2] for all of Canada, and potentially North America.

Current State of Renewables Worldwide

Case Studies

The goal of changing a city's electrical sources to 100% renewable energy is a feat that cities around the world have pledged. Two cases that are interesting as they draw similar comparisons to Toronto in size or climate are Frankfurt, Germany and San Francisco, United States. While these cities not the most ideal of comparison, it is the best available given the cities that have committed to 100% renewable energy worldwide.

Frankfurt am Main, Germany

Frankfurt is one of the top five largest cities in Germany and the second biggest metropolitan area with an estimated population of 5.8 million (European Union, 2016). Much like Toronto, it is also a hub for commercial, social, industrial, and technological activity while being the leader in the area (European Union, 2016). While Toronto is more dense with 4100 people per square km, Frankfurt is fairly dense at 3000 people per square km (Toronto Hydro, 2017; European Union, 2016). Given their

[1] A German term for energy transition to an energy portfolio that is consistent of a renewable energy grid that is proficient and sustainable.

[2] A *folkecenter* is a center that specializes in educating and demonstrating to the public the benefits of renewable energy. The center is also a focal point for researchers who wish to further develop, test, and innovation within the field of renewable energies.

densities and similar climates, it makes sense to be able to understand the strategies implemented in Frankfurt. Frankfurt identified three major sectors of focus in their goal towards 100% renewable energy; electricity, transportation, and heating & cooling (World Future Council, 2014). Currently, their city planning has set the goal to generate 25% of the current electrical need with renewables from within the city, 25% from outside the city core, and 50% reduction of current usage which therefore makes it feasible to have a 100% renewable energy goal (World Future Council, 2014). While this strategy may seem extreme, there are a number of key elements that are contributing this goal. Frankfurt plans to increase their energy efficiency by 50% while expanding local district energy and supplementing the energy supply with increased solar, wind, and biomass (World Future Council, 2014). Historically, Frankfurt has been efficient and effective in setting environmental standards for the city as it has become a leader in sustainability and negating climate change. Their past environmental successes speak for themselves as they saw a 15% reduction in emissions from 1990 to 2012, even though the economy almost doubled in size and value (World Future Council, 2014). This sustainability plan was heavily backed, both publicly and financially, by higher levels of government which focused on making the strategy participatory for the residents. A large target group was the local schools which provided youth with the knowledge of energy management which will pay dividends in accomplishing the 100% renewable energy target in the future (World Future Council, 2014). While this strategy is well coordinated, there were some potential barriers that could prevent the goal from being achieved. In the beginning, there was public resistance to the energy programs as many felt the goal was too ambitious and the current building structures, many decades old, were not ideal for retrofits or upgrades (World Future Council, 2014). Frankfurt was able to overcome these barriers by instituting pilot programs that helped ease residents into the ideas while proving that renewable energy could be generated effectively. Frankfurt has been successful in moving towards their goal of 100% renewable energy now that the public and residents are fully supportive of the plan (World Future Council, 2014). Furthermore, from 1990 to 2016, the programs combined with the city's plan have helped saved almost $150 million CAD (World Future Council, 2014). Of the strategies and lessons that have been displayed in Frankfurt, Toronto can adapt and implement some of the methods and apply them to their own goal of 100% renewable energy.

San Francisco, United States

San Francisco is one of top fifteen most populated cities in the United States with around 875,000 residents (SFCED, 2017; United States Census Bureau, 2015). Much like Toronto, San Francisco is surrounded by other cities and suburbs that amount to 4.4 million residents, which is a lower population than the Greater Toronto Area at 6.8 million (United States Census Bureau, 2015; SFCED, 2017; Statistics Canada, 2017). San Francisco is smaller in land area, but has some similarities such as being located on the water, education levels, and the late start, relative to Frankfurt, for their renewable energy plan (SFCED, 2017; Statistics Canada, 2017; SFDE, 2017). Starting earlier this decade, in 2010, San Francisco first started their focus to achieve 100% renewable energy by 2020. This goal is extremely ambitious as it set out the framework to complete this task in only 10 years. The focus for San Francisco, which was similar to Frankfurt, was to improve energy efficiency. This focus will be aided by the increased generation of renewable energy within the city limits while ensuring those who can not generate on their property have the option to purchase from renewable energy providers. The influx of investment and incentives from various levels of government has allowed San Francisco to create some major projects that have them, as of 2014, on track to reach their goal (Johnson, 2017; SFDE, 2017). In 2017, the goal was reset to 2030 but had a larger focus on greenhouse gas emissions and negating global warming but still contained the goal of 100% renewable energy (US Department of Energy, 2013; IRENA, 2016). The 2030 goal is still a significant improvement on the San Francisco set a goal to reduce their greenhouse gas emissions by 25% by 2017, which was achieved in 2015 despite their economic growth and expanding population (Johnson, 2017). While the goal was pushed back from the original deadline, San Francisco still displays the desire to complete this task to their utmost ability with the largest benefits to the community and environment. Given that they have proven they can complete goals earlier than anticipated, their 2030 goal is realistic (SFCED, 2017; SFDE, 2017). Currently, a hydroelectric dam has the ability to provide over 400 MW of electricity to the city which helps cover approximately 20% of the baseline load. This is supplemented by solar-PV projects that the city owns and operates, privately owned residential and commercial solar-PV projects, and a biogas plant that works in conjunction with the wastewater treatment center (SFDE, 2017). These renewable energy source projects work hand-in-hand with the over 25 district energy plants to help provide residents environmental solutions towards the 2030 goal. These renewable sources have helped lower energy costs by a quarter which is a direct savings to the residents of San Francisco (Johnson, 2017). The major barriers that could potentially derail the plan are mostly policy related. While there is no legally binding agreement that requires residents, businesses, or the city to continue towards the path of 100% renewable energy, a public pledge has been made but that can change depending on mayor's office. As well, utilities and electricity providers are not governed by the city or town, instead they follow rules and regulations outlined by the State of California (SFCED, 2017). This could cause some providers to aim for the California goal of 100% renewable energy by 2040, instead of the city's goal of 2030. Another large issue for San Francisco revolves around the number of residents who currently rent their residences. Upwards of 6 out of 10 residents are renting their home therefore creating incentives that benefit the renter and the landlord equally could help alleviate this dilemma (SFCED, 2017). With the relatively recent start towards 100% renewable energy, Toronto can learn from the strategies and effective policies that San Francisco has utilized to reach their goals.

Policies from Other Countries

United States

In the United States, the state of California has been extremely successful in increasing energy efficiency by crafting state policies that force utility companies to offer rebates to businesses and residences. These efforts had a substantial impact on the energy consumption of the state as it decreased by 7% over a 20-year period (Geller, Harrington, Rosenfeld, Tanishima, & Unander, 2006). More impressively, California was able to reduce the peak demand during the summer by 10%, a large amount of energy given the California climate (Geller, Harrington, Rosenfeld, Tanishima, & Unander, 2006). A change mimicking California's actions could benefit Toronto by reducing the required amount of energy required and increasing the efficiency of the homes within its boundaries.

Australia

There are many countries leading in the implementation of renewable technologies, and Toronto would do well to adopt some of their strategies. The first, the Australian Renewable Energy Target (RET) scheme, which was started in 2011, consists of financial incentives for both small and large-scale projects. The Large-scale Renewable Energy Target (LRET) creates an incentive for the establishment of renewable energy power stations such as wind and solar farms or hydro-electric power stations. It does this by legislating demand for Large-scale Generation Certificates (LGCs). One LGC can be issued for each MWh of renewable electricity produced by a renewable power station. LGCs can then be sold to entities such as electricity retailers, the revenue of which is additional to that received for the sale of the electricity generated in a FIT program (Energy Matters, 2016). Australia has a similar small scale solar credit incentive (SRES) which takes advantage of the Renewable Energy Certificate, more commonly referred to as an STC, or Small-scale Technology Certificates. The solar credit incentive is available to homeowners, schools, small businesses, and community groups, where owners of a solar system can earn an upfront rebate to help cover the cost of a solar system. The subsidy is based on system size, postal code, as solar irradiance varies per location, and year of installation. Using these criteria, an average 5 kW system could result in a rebate of AUD $3340 to $4620 depending on the install location (Energy Matters, 2016).

China & Japan

In 2005, China passed the Renewable Energy Law (REL) which marked a new stage in the renewable energy development process within the country (Moosavian, Rahim, Selvaraj, & Solangi, 2013). Since the introduction of REL, many supporting regulations and guidelines have been put in place to implement it. The law was designed to promote the development and utilization of renewable energy, improve the energy structure, diversify energy supplies, safeguard energy security, protect the environment, and realize the sustainable development of the economy and society (Moosavian, Rahim, Selvaraj, & Solangi, 2013). The Golden Roofs initiative was launched in 2009 and provides a subsidy of $2.93 per watt for roof-mounted PV systems over 50 kW which could cover over half of a system's installation cost (People's Republic of China, 2017). Larger utility scale solar projects have been promoted, and in 2009, the Golden Sun program was announced, which provides up to 50% of project costs, including transmission or distribution lines to connect to the grid, and up to 70% of such costs for projects in more remote areas (People's Republic of China, 2017). This program is for projects of 300 MW capacities or greater, which will be in service for a minimum of 20 years. Financial support for renewable energy in China involves subsidies, tax policies, pricing mechanisms, and a reward scheme for green production (People's Republic of China, 2017; Moosavian, Rahim, Selvaraj, & Solangi, 2013). The country's subsidy support is also extended to overhead costs of the above-mentioned programs such as administrative fees, operational costs, and other expenses for government renewable energy agencies, as well as for renewable energy technology research and development, and provincial or local electrification projects. Tax incentives can come from the central or local governments, and can be technology specific (IRENA, 2016). There should be tax reductions or exemptions issued by local, provincial, or federal government, which will motivate the enthusiasm of entrepreneurs, and will therefore, increase the renewable market through government policy initiatives. Therefore, the City of Toronto can adopt the plan for industry that was instituted in Japan decades ago. Japan mandated that all businesses must perform an energy audit with the goal to help reduce their energy consumption. Later, the government rolled out policies that established tax incentives and reasonably priced loans for business to install energy efficient equipment and measures (Geller, Harrington, Rosenfeld, Tanishima, & Unander, 2006). Toronto could enact these measures to provide generous tax breaks and financial support given its large tax base and diverse economic earnings. With the right incentives and mindset, the city could help influence and guide industry to become more energy efficient, and in turn, reduce the amount of energy that needs to be produced.

Current State of Renewables in Canada

While Canada is one of the major producers of energy in the world and a large exporter, almost 75% of the total energy comes from non-renewable sources (US Department of Energy, 2015). Due to the vast supplies of fossil fuels, Canada has historically relied on these industries while also exporting an increasingly larger amount to the United States (Government of Canada, 2016; US Department of Energy, 2015; NRCan, 2017). According to a 2013 study, the potential capacity for expanding renewable energy sources in Canada is significant and is shown in Table 1 (Pembina Institute & Greenpeace Canada, 2013). With such a large potential, it was evident that a plan was needed to harvest these resources from our vast land and utilize our natural features. Given that Canada is an extremely large landmass that has access to multiple bodies of water, wind, solar, geothermal, biomass, and tidal energy, it is no surprise that Canada is a global leader in their utilization and harvesting of their renewable resources (Government of Canada, 2016). Of all the renewable energy sources in Canada, the most prominent one is hydroelectric due to the vast number of rivers, streams, bays, and lakes that are available (NRCan, 2017; Government of Canada, 2016). While some hydroelectric stations are built in naturally occurring areas that are ideal for generating electricity, other areas require a dam to maximize and generate water flow for ideal circumstances for electrical generation (Government of Canada, 2016). The development of hydroelectric stations has been aided by the favorable geographic terrain, geological sediments, and the hydrography (Government of Canada, 2016). This has been extremely evident in the Province of Quebec which has an installed capacity of 37,000 MW in 2016. The power is generated at over 60 different stations and accounts for 99% of the electrical power for the province (Hydro-Quebec, 2017). In 2014, the Canadian government reported that there were over 540 hydroelectric stations that had the installed capacity of over 78,000 MW[3], or the equivalent amount of energy produced by 130 fossil fuel power stations (Government of Canada, 2016; UCSUSA, 2017). Of the 540 stations, approximately 60% of them are small plants that produce 50 MW or less. This means that 40% of Canadian hydroelectric stations generate 95% of the hydroelectric power which accounts for almost 60% of the total electrical power generated in Canada (Government of Canada, 2016). This amounted to almost 400 TWh produced across Canada with hydroelectric power stations. The second most popular renewable energy source in Canada is bioenergy. Residents use wood to help heat their homes and water, as well as for cooking and preparing food. Almost 10% of the residential energy use comes for the use of wood equaling over 100 petajoules[4] of energy. Another form of bioenergy that is utilized is biomass which has 70 plants with an installed capacity of over 2,000 MW, or roughly 15 fossil fuel power stations. In 2014, almost 9 GWh were produced by bioenergy plants across Canada. With all these different methods of renewable energy continually increasing their production from year to year,

Energy Source	Total Capacity Additions 2015-2022 (MW)
Hydro	600
On-shore wind	1000
Off-shore wind	200
Rooftop solar	500
Ground-mount solar	500
Biomass and biogas	300

Table 1: Renewable energy by technology and capacity (Pembina Institute & Greenpeace Canada, 2013)

[3] 1 megawatt is equal to 1,000 kilowatts.

[4] Peta represents a factor of 10^15 and therefore one quadrillion joules.

it is feasible with significant investment that renewables can replace the fossil fuels as the number one provider of energy in Canada (Government of Canada, 2016).

Currently, in the Province of Ontario, the government has started a cap and trade program. The Province of Ontario would benefit from the utilization of a cap-and-trade system as it would be an incentive for all to reduce their consumption of carbon, therefore decreasing greenhouse gas emissions, and would also promote the use of carbon neutral renewable energy generation while supporting the discontinuation of conventional energies made using fossil fuels (NRCan, 2017). With the introduction of a cap-and-trade system, the government could put a firm limit on the overall amount of CO_2 emissions being produced by industries within its jurisdiction, and reduce this limit periodically until the region's target emissions levels are met. According to the David Suzuki Foundation (2014), such a step will force individual companies to lower their emissions to a quota which will be fairly determined through auction. If a polluter exceeds their particular quota, they are permitted to purchase unused quota from other companies (The David Suzuki Foundation, 2014). This type of system allows the market to determine the price of emissions, which makes the cost relatively unpredictable when compared to carbon taxation system, where a set price is paid for every tonne of emissions produced. The benefit to a market set price is that it gives monetary incentive for industries to seek cleaner energy sources, and as such, the price of cleaner energies becomes more affordable to the point where they are on par, or cheaper than fossil fuel based energy. As well, this would be extremely beneficial for companies that are environmentally friendly as it would give them an added financial incentive to maintain their high environmental awareness. The David Suzuki Foundation (2014) claims that the most important favourable outcome of a cap-and-trade system is that it ensures a reduction of total greenhouse gas emissions, where as a carbon tax solely makes the cost of business more expensive as pollution levels are estimated to the same amount. According to MaRS Discovery District (2010), these systems increase the demand for clean energy technologies by raising the cost of using fossil fuel based energy, which helps to bring these costs in line with those of clean energy options. Cap-and-trade systems also have the potential to be very successful in Ontario as the presences of natural resources which can generate energy are abundant in the province.

Current Support Systems for Renewable Energy in Toronto

While renewable energy is gaining support in Toronto, there is not a significant amount of support from the City of Toronto to incentivize residents, but some intriguing ideas are present. In 2016, one of Toronto's programs was recognized by the Federation of Canadian Municipalities for working towards the goal of a sustainable city (City of Toronto, 2016b). This program, known as HELP, Home Energy Loan Program, offers financing options to qualified homeowners who wish to reduce their energy bills and greenhouse gas emissions (City of Toronto, 2016b). The City of Toronto provides low-interest loans of up to 5% of the property value, which residents pay back via their property taxes. This incentive is marketed towards individuals by mentioning they will save on their energy bills, lower their energy usage, help resale value, and increase the comfort within their home (City of Toronto, 2016c; City of Toronto, 2016; City of Toronto, 2016b). This program has been successful thus far in Toronto, as average residents who utilize this program have noticed their energy cost decrease by approximately a quarter (City of Toronto, 2016b).

Additional support offered by Toronto can be observed through a by-law that requires newly constructed commercial, multi-resident, industrial, and institutional buildings to construct a green roof (City of Toronto, 2016). While the City of Toronto does not require a green roof for individual residential dwellings, the policy has been effective by creating over 250 green roofs since its inauguration. Green roofs have been shown to help manage storm water, reduce pollution and noise, increase biodiversity, and provide more oxygen to surrounding areas (Berardi, GhaffarianHoseini, & GhaffarianHoseini, 2014). Furthermore, green roofs have been shown to prolong the average life of a roof by reducing the effects of the elements and providing a buffer between extreme weather events. When observing the impact that green roofs have on energy, it becomes clear that the energy required to heat and cool a house is minimized (Berardi, GhaffarianHoseini, & GhaffarianHoseini, 2014; Jaffal, Ouldboukhitine, & Belarbi, 2012). The reduction in required energy to cool down a single-family residence in the hot seasons far outweighs the slight increase in heating required during cold seasons (Jaffal, Ouldboukhitine, & Belarbi, 2012). By adding solar panels to these green roofs, cities could potentially supply 20% of the daily required power from rooftop solar panels (Singh & Banerjee, 2015). While green roofs are climate dependent, it is accepted that they are an efficient method in which to increase energy efficiency and reduce the overall amount of energy required around the globe, albeit, with different levels of efficiency depending on location. Given the benefits that green roofs provide, it is understandable that in 2009, the city unveiled a grant for green and cool roofs (City of Toronto, 2016c). Applications are on a voluntary basis and can award up to $100,000 to the owner if they choose to maximize the space of their green and cool roof. This program has been successful as it has helped install over 100 green and cool roofs on residential, industrial, commercial, and institutional buildings across Toronto. Alongside programs, there are many non-profit organizations and businesses that advocate for environmentally beneficial ideas. Summerhill is a business that specializes in energy efficiency programs for residential and smaller businesses (Summerhill, 2016). The company works with utility providers, government agencies, not-for-profit organizations, and retailers to help design and implement ways to reduce their energy consumption. Tin comparison, the OSEA, Ontario Sustainable Energy Association, is a non-profit organization. This organization was instrumental in advocating for the FIT program in Ontario as well as many other projects within the city (OSEA, 2016). OSEA continually works to build connections between residents, community, industry, and the government. In Toronto, OSEA played a key role in securing funding from the Toronto District School Board for a 23KW solar system, with the potential of another 50KW solar install, should residents choose to invest in their community. OSEA also holds frequent conferences and webinars within the city to help raise awareness and promote sustainable energy growth (OSEA, 2016).

RETScreen Analysis

To understand how beneficial renewable energy can be to a Toronto homeowner, RETScreen was used to analyze an average home in the Greater Toronto Area and to generate an output of potential benefits and savings. A house was chosen in Woodbridge that is of average size and houses a middle-class family. With an initial investment of $33,000 CAD in 2009, when the microFIT rate was fixed at $0.802/kWh for 20 years, this household could have generated a decent yearly profit despite it not being in an area of maximum solar irradiance (Ministry of Energy, 2015; IESO, 2009). Due to the not ideal solar irradiance, the family was able to obtain a rate of $0.713/kWh (IESO, 2009; Ministry of Energy, 2015). During peak months, the solar roof has the potential generate up to 6 kWh/m2/day due to high radiation and extended daylight hours, whereas a low of 1 kWh/m2/day would be generated during some winter months. An average of 3.7 kWh/m2/day could thus be made over the term of a year. Using these numbers, RETScreen was able to calculate that the system should produce a total of 8,760 kWh in the first year of production, and this all could have been sold to PowerStream for $6,246. If the homeowners opted for a simple payback model, the system could have been paid off after 5.3 years, or by year 2.6 if they adopted an equity payback plan. Seeing as the average solar PV system has a lifespan of 20 years at high efficiency, for the remainder of the 14.7 years, the family could have been earning over $6,000 per year. By year 20, $105,000 in revenue could have been acquired from one solar system alone. However, regardless of the date of installation, by installing just one solar system, this family has the potential to mitigate 0.87 tonnes of CO_2 emissions per year, which is the equivalent of taking 0.16 cars off the road.

Benefits of Renewable Energy

The benefits of renewable energy have been well documented over the course of their discovery. Much like non-renewables, renewable energy resources are abundant and can deliver energy in a number of different ways as shown in Figure 1.

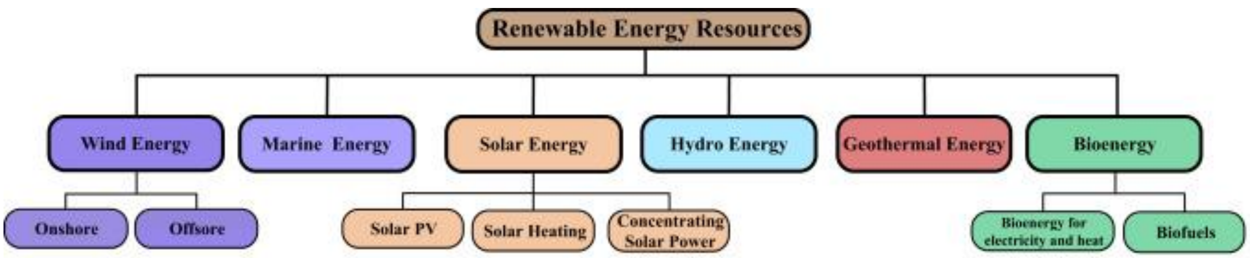

Figure 1: Renewable energy sources and harvesting method

By 2035, it is expected that the worldwide renewable energy generation will increase almost three-fold. With that being the case, the benefits of renewable energy should be documented to maximize the advantages to the residents and stakeholders. With a growing demand for renewables coupled with a decreasing demand for fossil fuels, the cost of renewables has dropped considerably in the past decade (Moosavian, Rahim, Selvaraj, & Solangi, 2013; Geller, Harrington, Rosenfeld, Tanishima, & Unander, 2006; Ellabban, Abu-Rub, & Blaabjerg, 2014). Thus, it is now cheaper and more feasible for many more individuals, cities, and countries to consider renewable energy than before. Following Figure 1, left to right, each energy source will be analyzed to determine their best strengths. Wind energy, which has the largest potential in Canada, is cheap to build and maintain compared to the energy output they provide (Pembina Institute & Greenpeace Canada, 2013; Ellabban, Abu-Rub, & Blaabjerg, 2014). While they do require a significant amount of land, the land is not unusable (Ellabban, Abu-Rub, & Blaabjerg, 2014). Many wind farms have been combined with other uses, such as food farms that were visited in Oxford County, to help minimize the impact of the potential loss of land. During the visit to Oxford County, it became evident that the wind turbines could co-exist with other land uses, as long as they were properly integrated into the natural or built environment. This helps reduce the cost of wind farm plants making them one of the cheapest renewables along with solar energy (Ellabban, Abu-Rub, & Blaabjerg, 2014). Both wind and solar produce zero carbon emission during the production of their energy, which is added benefit especially when comparing against the carbon heavy emission of fossil fuels. Solar energy has the potential to be a never-ending supply of energy, mainly due to the fact if the sun ceases to produce solar rays, energy will be the least important issue for society (Ellabban, Abu-Rub, & Blaabjerg, 2014). The ability to have solar harvesting equipment of all scales from massive solar farms spanning hectares to small installations on residential houses makes solar extremely flexible to be harvest energy as it can be installed anywhere (Energy Matters, 2016; Ellabban, Abu-Rub, & Blaabjerg, 2014; Berardi, GhaffarianHoseini, & GhaffarianHoseini, 2014; Agence France-Presse, 2015). On the contrary, hydropower can not be installed anywhere as it has specific requirements. Luckily in Canada we have an abundant supply of hydropower and future hydropower locations (NRCan, 2017). While the location for hydropower is a key aspect, the largest benefit comes from being able to create reservoirs of water. These reservoirs can be used to contain water until the supply is required or it can be used to benefit stakeholders in the form of creating a man-made body of water in which boating, fishing, boarding, and swimming can be utilized (Ellabban, Abu-Rub, & Blaabjerg, 2014). When the water is used to generate hydropower, there is no pollution or contamination passed on to the water. The last source of renewable energy that can provide benefits to Toronto is bioenergy. This source can help turn waste products into usable energy which are abundant on farms and rural areas. There is a potential to have a synergistic relationship between a wind farm that incorporates bioenergy on site and can produce energy consistently across the entire day at a lower cost than fossil fuels with considerably less pollution.

The two energy sources that were left out of the discussion above were marine and geothermal as they have very little feasibility of being incorporated into Toronto’s renewable energy plan. While marine has many of the same benefits of hydropower, it does rely on a tide and would be ideal for areas with coast line on oceans such as Nova Scotia and Newfoundland. Geothermal has some potential in Canada, but mostly in the Western provinces. Geothermal has an unlimited generation potential as it relies mainly on the working of the Earth below the surface. With future research, these two energy sources have the potential to be involved in Toronto's goal. Marine research could be conducted on the Great Lakes while further geothermal exploration could be undertaken to discover if there are any potential sites for both sources that can lead to energy generation.

Instituting Renewable Energy in Toronto

Target Setting

The first step in implementing renewable energy within the City of Toronto is to set a realistic target. While it would be pleasant to have a goal of becoming 100% renewable by 2030 such as major cities like Sydney, Australia has, it is just not feasible. Even setting a goal for 2050 like the City of Vancouver seems somewhat unrealistic given that Vancouver already has the lowest the greenhouse gas emissions per person of all the cities across Canada and the United States plus their city council has voted on a strategy of making them sustainable (City of Vancouver, 2017). Given the lack of previous planning and the dearth of future renewable energy plans, the goal for Toronto should be to become 100% renewable by July 1st, 2067 to coincide with Canada's 200th birthday.

City Policy and Services

The City of Toronto has a lot of clout with how businesses and residents operate. The city should change its view on urban planning to help make changes to current building codes and by-laws. These changes should help stimulate the growth of renewable energy. By passing a law that requires renewable energy sources to be incorporated into buildings by 2025 should help Toronto achieve the required amount of renewable energy required. The law should be effective, but a more concrete framework is required to ensure the transition happens within the timeframe. A study of cities such as

Frankfurt, San Francisco, and even other Canadian cities such as Vancouver and Victoria would beneficial in understanding the path and barriers that could be experienced. Financial incentive programs need to be created, or in this case potentially extending the micro-FIT and FIT program, to allow for larger renewable energy installations. By making a public declaration, the City of Toronto will be held responsible on a global scale and by their residents to ensure the transit happens smoothly. By having city council vote on the decision, it can become legally binding much like the process in Vancouver (City of Vancouver, 2017). To fully supply the grid, a larger FIT program should be created to help change the suppliers and utility energy sources to more renewable sources. This should be retroactively applied to projects that were online starting in 2017 to help expedite the process of installing more renewable energy sources. An increase in domestic renewable energy should be aided by a larger amount of research and development. These policies combined with a realistic timeline should help Toronto achieve the goal by 2067.

Buildings

Buildings are one of the largest consumers of energy in Toronto and need changes to help shift the transition to 100% renewable energy. The first change that is required is altering the current building standards and by-laws to include a focus on renewable energy and sustainability. In the past, most building codes and standards were focused on health and safety, which are integral aspects still, but now require an updated approach to incorporate renewable energy (Meacham, 2016). The current needs and demands of buildings are changing, which can benefit from having the LEED system incorporated to help increase building efficiency and reduce future costs (Dobias & Macek, 2014; Meacham, 2016). The LEED system also works as an incentive for the developers as green buildings that hold the LEED distinction are known to have higher resale value and the ability to charge more for monthly rent (CaGBC, 2016). The LEED process helps building managers and construction teams understand their baseline emissions and how the implement savings from the start of building construction to everyday management of the building (CaGBC, 2016). Mandating renewable energy into building construction would be an effective method to help reach the goal. Currently, it is not required in building codes in Toronto, there is however a green roof by-law that can have the criteria met using solar-PV (Government of Ontario, 2016). Mandating renewable energy into building codes is a concept that can be done as France has recently passed a law that requires newly constructed commercial buildings to have solar panels on the roof (Agence France-Presse, 2015). The Canadian Standards Group presently has an energy efficiency program in which that verify that if products meet certain standards to ensure the utmost and maximum efficiency (CSA Group, 2017). Those products can be installed in buildings to ensure they are efficient to reduce their energy requirements. Canada's energy plan was updated in 2011 and required that buildings become more efficient and allow for more flexibility when attempting to meet building codes if integrating more efficient energy solutions (NRCan, 2017). An update that can be added to the energy plan next would be to display the energy statistics of the building on a public forum that would give recognition to those who go the extra mile in energy efficiency. In British Columbia, any upgrades or installations that help a building become more environmentally friendly result in 100% property tax exemption (Shazmin, Sipan, & Sapri, 2016). This current program in British Columbia covers improvements that meet certain LEED certification levels and can be applied to a multitude of different buildings including residential, commercial, and mixed-use buildings (Shazmin, Sipan, & Sapri, 2016). Secondly, retrofitting all buildings to meet the standards of newly constructed buildings should be attainable. When observing the case study in Frankfurt, they were able to properly retrofit buildings to ensure they could be compatible with renewable energy. There are energy incentive programs that are now in operation that help homeowners identify areas of their house that need improvement. The Home Energy Conservation program allows a certified home energy auditor to offer unbiased information on different methods the homeowner can employ to lower their energy bills while offering financial incentives paid for by the utility companies (Windfall Ecology

Centre, 2017). This program can take anywhere from 6 months to a year to complete and should be expedited to help older buildings reach the standards of the newly constructed ones. The labelling of energy statistics should be completed at times when retrofits and upgrades to energy are completed. Another strategy that will help Toronto transition to 100% renewable energy is the concept of district energy. Currently, there are less than ten district energy sites in Toronto, yet there are many different areas that would be ideal for the creation of one. The district energy system at the University of Toronto is an ideal system to expand given that it is located within a dense urban area and allows for the next generation of engineers and planners to learn from the expansion. Under the Official Plan of Toronto, there have been over 20 areas that have been identified as being potential expansions for district energy. These areas should be developed to help reduce the required energy from the grid. For new developments, building codes can be altered to entice the integration of district energy. These concepts and ideas can help Toronto ensure that all new buildings will be zero-emission by 2040 and all previously constructed buildings reach the goal by 2050 while providing more energy and requiring less energy.

Transportation

On June 26th, 2017, the City of Toronto was awarded North America's transit system of the year which is appropriate given their pledge to modernize the fleet and expand service areas (Spurr, TTC named best public transit agency in North America, 2017). The current subway line expansion on the University line should be completed before the school year starts in September to help minimize the number of buses required to shuttle students from Downsview station to York University. Currently, the express bus runs every four minutes during regular businesses hours which amounts to a significant number of buses that can be taken off the road by finishing the expansion. In line with the Official Plan of Toronto and the TTC's goal of reaching more customers, the subway line should be doubled to allow for more passengers. The subway is far more efficient and does not require fossil fuels, unlike the current buses. To further remove more buses, some of the more popular routes can be replaced with street cars, which are electric. This is feasible as Toronto has the largest street car network in the world and has the capacity to add and expand the lines (Spurr, TTC named best public transit agency in North America, 2017). With the integration of the PRESTO card, regional transit organizations have seen an uptick in coordination with large hubs that allow for users to transfer between different transit medians and services. To ensure that residents will continue to use these transit systems, the coordination and relationships between these organizations must continue. To improve reliability and frequency during rush hours, dedicated transit lanes should be designated for buses and other transit vehicles. A city just west of Toronto implemented dedicated bus lanes and has integrated the approach into their future transit plan (Craggs, 2015). This can effective in reducing transit congestion and increasing the timing of the buses. For those who find transit not feasible, incentives should be offered for them to use electric vehicles. By allowing green vehicles to use the HOV lanes during rush hours and offering preferred parking at public locations, the shift from the combustion engine should happen. The Ontario Government has invested heavily in the charging network with the Electric Vehicles Chargers Ontario grant that has planned for over 500 level 2 and level 3 chargers[5] to be installed in Ontario (MTO, 2017). The potential answer to those who do not find transit feasible is to increase regional transit with the expansion of the GO Transit network. Currently, the GO Transit train line that services north of Toronto towards Barrie only runs in one direction and once an hour. This can be improved to allow for service for those who do not find the transit system fits their work hours or their daily lifestyle needs. By increasing the frequency of trains by 2025, residents will have more options to allow public transit to meet their transportation needs. The Canadian Federal government decided to remove the tax break incentive for those who purchase a monthly pass which could have negative repercussions on the those who currently use the passes (Spurr, Transit users lose tax break on monthly passes in federal budget, 2017).

[5] Level 1 chargers are 120 volt AC plug such as a common standard household outlet. Level 2 is a dedicated charging station through 240 volt AC plug. Level 3 is a stand-alone 480 volt DC plug.

This incentive should be reinstituted immediately to ensure that residents are maximizing their public transit use. With the hopes of increasing ridership, the public transit fleet should be transitioned away from fossil fuel based engines by 2035 to allow for better utilization of the renewable energy. The current maintenance infrastructure will have to be upgraded to allow for charging and maintenance of the new vehicles. While replacing the entire fleet at once would be fiscally irresponsible, it is understandable that fleet units should be replaced with green vehicles once they become too old or require a major upgrade. In California, car manufacturers are required to sell a certain number of green vehicles each year which combined with the lower sales tax has helped spur the increase in green vehicle purchases (Undercoffler, 2017). By combing both of those concepts with an increase on gasoline car and gasoline sales, the uptake of green vehicles should help Toronto transit towards 100% renewable energy.

Timeline & Strategies Showing Transition to 100% Renewable Energy

While a multitude of different methods and approaches can be used to help Toronto transition to 100% renewable energy, three overarching themes should be emphasized during this timeline.

1. Reduce peak and baseload energy use
2. Increase funding and research for the use of renewable energy
3. Transition current energy sources from fossil fuel and nuclear based to renewable sources

City Policy and Services

Priority 1: Toronto shall adopt and institute a comprehensive approach to integrating renewable energy into urban planning by 2018

1.1. Adopt and implement new building standards and by-laws that promote zero-emission construction

1.2. Pass a law that requires renewable energy to be an integral part of building codes by 2025

Priority 2: To develop a policy framework to help incentivize the installation of renewable energy by 2020

2.1. Study which programs and policies would be best applied to Toronto

2.2. Create a financial incentive program that will benefit installations of renewable energy

2.3. Provide support and guidance on the best methods to use renewable energy in buildings

Priority 3: To publicly declare the goal to become powered by renewable energy by 2067

3.1. Make a public declaration to all residents and businesses that this goal is required to help alleviate climate change and provide a more sustainable province for all
3.2. Pass the declaration through city council making it legally binding

Priority 4: Develop a smart grid that is supplied with 50% renewable energy by 2040 and 100% by 2067

4.1. Introduce FIT for suppliers and utility companies by 2020 that retroactively applies to projects build since 2017
4.2. Tax incentives for research and development into renewable energy technology
4.3. Restrict the construction and retrofits while enforcing retirement plans for non-renewable energy sources

Buildings

Priority 1: New buildings to be zero-emission by 2040

1.1. Adopt and implement new building standards and by-laws that promote zero-emission construction
1.2. Incentivize and subsidize the development of zero-emission and sustainable buildings
1.3. Establish a current baseline of greenhouse gas emissions and set incremental decreases for new constructed buildings
1.4. Develop public-private partnerships to facilitate renewable energy generation
1.5. Mandate renewable energy sources into building construction
1.6. Require buildings to display their energy consumption via labelling and benchmarks
1.7. Offer tax breaks and waive development fees for groundbreaking or unique design projects that help promote sustainability or incorporate a significant amount of renewable energy

Priority 2: Retrofit all buildings to standards of newly constructed by 2050

2.1. Facilitate and expedite simple retrofits through energy incentive programs
2.2. Replicate 1.6 to extend to previously constructed buildings

Priority 3: Develop new district energy systems by 2040 while expanding current ones immediately

3.1. Expand existing district energy systems starting with University of Toronto
3.2. Accelerate the opportunities for district energy that are in current growth areas of the Official Plan of Toronto
3.3. Identify new locations that could potentially install district energy such as low-impact developments, mixed use areas, and other institutional areas
3.4. Update building codes to support the development of district energy that integrate renewable energy sources

Transportation

Priority 1: Improve transit service by expanding subway lines and street car lines

1.1. Finish the current University Line expansion to reduce amount of buses required to shuttle between Downsview Station and York University
1.2. Expand the subway lines from 4 lines to 8 to reach more residents by 2050
1.3. Replace certain bus routes with electrified street cars to increase the number of lines from 11 to 25 by 2050
1.4. Continue relationship with surrounding transit organizations such as YRT, Brampton ZUM, GO Transit, and Viva
1.5. Improve on reliability and frequency during rush hours
1.6. Advocate for regional pricing

Priority 2: Implement high-occupancy vehicle and transit only lanes along major transit corridors and highways

2.1. HOV lanes to be installed on major highways by 2019
2.2. Dedicate a specific lane for transit during rush hours by 2018
2.3. Preferred parking for carpool vehicles and for electric vehicles
2.4. Extending current Electric Vehicles Chargers Ontario (EVCO) grant program

Priority 3: Continue to develop regional transit with a partnership with GO Transit

3.1. Continue regional express rail and make improvements to current GO Transit system
3.2. Add a second line to the Barrie corridor by 2020 which will allow for service all day in both directions and more frequent service
3.3. By 2025 have trains running every 15 minutes both directions all day
3.4. Reintroduce the tax credit effective immediately on monthly transit passes that were removed in 2017

Priority 4: Transition public transit fleet away from fossil fuel based engines by 2035

4.1. Replace aged out units with renewable energy based units
4.2. Upgrade current transit centers to ensure maintenance and charging on electric vehicles is possible

Priority 5: Promote personal use vehicles to become hybrid, or ideally electric, by 2040

5.1. Offer insurance discounts for those using electric cars
5.2. Increase taxes on gasoline sales and combustion engine car sales
5.3. Require car companies to sell hybrid options by 2020 and fully electric by 2030

By combing the timeline with a report detailing how to make Canada 100% shows that Toronto has an obtainable and realistic goal. The breakdown displays each method of harvesting renewable energy and the breakdown possible for Toronto. Some categories scored zero due to the inability to access them financially or geographically.

	100% Canada Report	Suggested 100% for Toronto
Residential rooftop solar	1.5	5
Solar plant	17.7	15
Concentrated solar planet	0	0
Onshore wind	37.5	30
Offshore wind	21	25
Commercial/government rooftop solar	1.7	10
Wave energy	2	0
Geothermal energy	1.9	0
Hydroelectric	16.5	15
Tidal turbine	0.2	0
Totals	100	100

Table 2: Breakdown of each energy source's contribution to Canada and Toronto's 100% RE goal (The Solutions Project, 2015)

Renewable Energy Source Requirements for 100% RE

To further understand how much renewable energy sources Toronto would need, we first need to understand how much energy it currently uses. It has to be assumed that there would be enough energy to cover Toronto at its highest peak load, which according to Toronto Hydro was approximately 4,700 MW which was achieved on August 12, 2016 (Toronto Hydro, 2017). Toronto currently has 36% of energy provided by renewables and 64% provided by nuclear and gas (Statistics Canada, 2017; Toronto Hydro, 2017). This requires another 3,000 MW of renewable generation a day to eliminate the need for nuclear and gas. Currently, there are roughly 12 million vehicles registered in Ontario, of those 5.25 million are in the Greater Toronto Area[6] (Statistics Canada, 2017). To have all those vehicles switch to

[6] The population of Ontario is 13,448,494 and Toronto is 5,928,040 according to the latest census. This means Toronto accounts for 44% of Ontario's population (Statistics Canada, 2017). We assume that they account for 44% of vehicle registration as well (Statistics Canada, 2017).

electric, the City of Toronto would require an additional 0.048 MW per day to charge vehicles[7]. The TTC operates 225 million kilometers a year with its transportation service (TTC, 2013). Converting the fleet over to electric would require an additional 13.9 MW a day[8]. To be conservative, it would require 3,200 MW of electrical production to meet our current electrical needs, another 14 MW for transportation needs, and a factor of 12% more overall to account for the growing demand. This means that renewable energy sources need to be able to produce 3,600 MW of energy a day.

To meet this demand, more renewable energy generation is going to be required. According to RETScreen, each rooftop solar installation can generate 0.024 MW a day. To meet the goal of 180 MW, Toronto would need to install 7,500 rooftop solar installations. The meet the demand of 540 MW from solar farms, the government needs to just continue their projects with the Green Energy Investment Agreement that calls for close to 1,400 MW of solar farm powers in partnership with towns and First Nations (CBC News, 2015). The investment is not limited to public sectors, as there is a partnership with Samsung to develop solar farms in the GTA (CBC News, 2015). By constructing 10 solar farms with an average size of 55 MW, Toronto can meet their requirement. For wind power generation, Toronto needs to increase the number of projects that it constructs. In 2016, 21 projects were installed across Canada that amounted for 702 MW (Canadian Wind Energy Association, 2017). If Toronto can install a smaller amount of projects for a larger MW utilizing the farm land and the proximity to Lake Ontario, it can reach the potential MW requirement. By installing 35 projects onshore and 30 offshore, it should be able to fulfil the requirements and given that the funding is already in place from the government. Commercial and government rooftops will be contributing more than their fair share of solar energy.

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[7] Assuming the average person drives 15,000km/year, which would amount to 3,375 KW to charge per vehicle per year. 3,375 KW per car multiplied by the amount of cars is 17.7 MW a year. 17.7 MW divided by 365 days amounts to .048 MW a day (Tchir, 2015).

[8] 225,000,000 km/year would require 5,062,500 KW to charge over the year. This would amount to 5,062.5 MW. When divided by 365 days, it amounts to 13.86 MW a day (Tchir, 2015; TTC, 2013).

Combined with the City of Toronto's green roof by-law, this goal is more than achievable. With commercial buildings sporting rooftops much bigger than residential rooftops, it allows for a smaller number of installations providing a larger amount of MW (City of Toronto, 2016c; City of Toronto, 2016). While these goals for installations are ambitious, it does not take into account that the required MW per day from hydro is currently less than what is produced now. Toronto received over 1,000 MW per day from hydro, and the plan outlined below only requires 540 MW. In the case of emergency or a significant increase in demand in a short span, hydro can be used to provide extra power or potentially sell to neighboring provinces and states. Overall, this plan will allow for a balanced approach to harvesting renewable energy from various sources that will provide benefits to the stakeholders and residents of Toronto. By creating a diversified energy portfolio, residents will see their energy costs lower in the long term while decreasing healthcare costs and improving the environment.

	Suggested 100% for Toronto	Required MW per day	# of new installations required
Residential rooftop solar	5	180	7500
Solar plant	15	540	10
Concentrated solar planet	0	0	0
Onshore wind	30	1080	35
Offshore wind	25	900	30
Commercial/government rooftop solar	10	360	3000
Wave energy	0	0	0
Geothermal energy	0	0	0
Hydroelectric	15	540	0
Tidal turbine	0	0	0
Totals	100	3600	100

Table 3: Breakdown of the amount of energy sources required for Toronto's 100% RE goal

Future Work

To further help Toronto reach their goal, it would be beneficial to understand how to better integrate these renewable sources into the built environment. Specially, it would helpful to better utilize the massive body of water, Lake Ontario, which Toronto currently sits on. Developing a solar map for

Toronto would be an ideal tool to help resident's uptake the solar plan as they would see their solar potential on a map and their potential earnings. If the plan can be implemented in Toronto, it should be mimicked in cities across the country to help Canada achieve the goal of becoming 100% renewable while becoming a leader in the industry of renewable energy.

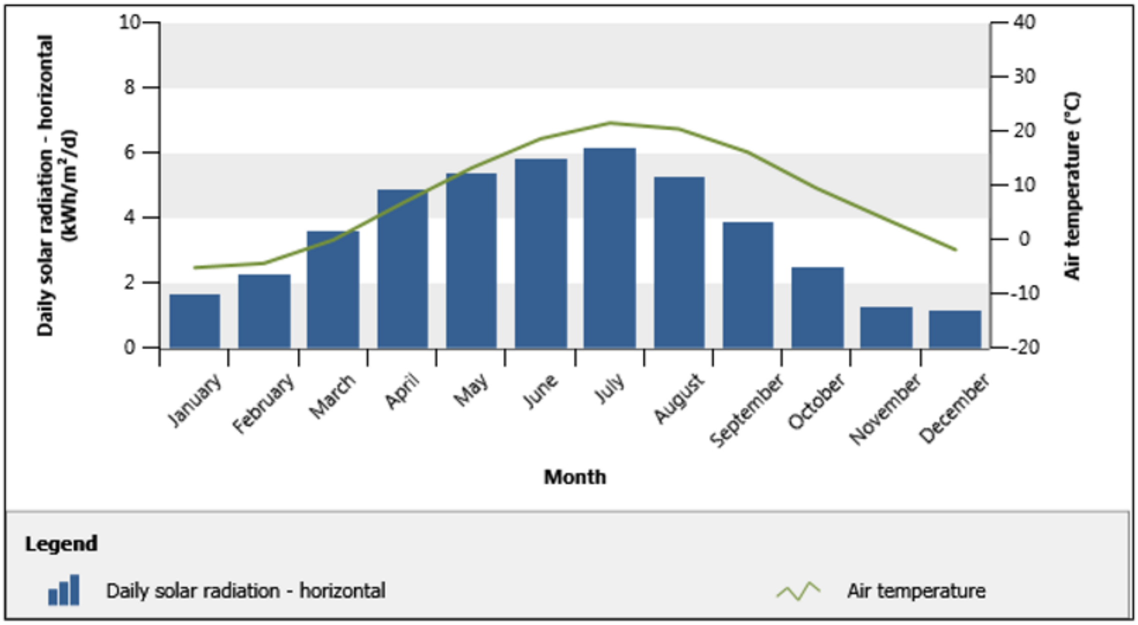
Conclusion

In conclusion, climate security goals, lower overall pollution levels, increased energy reliability, greater resilience, and local employment creation opportunities are all valid reasons that explain why Toronto needs to transition to 100% renewable energy. The growing local population and an expanding economy will continue to put a strain on the aging energy infrastructure that currently provides energy services to Toronto. With climate change occurring at an exponential rate and oil at record low prices, now is the most favourable time to invest in an energy transition to reduce GHG emissions and pollution levels by harvesting endless renewable energy sources. While the path for Toronto may seem long and daunting, and at times impossible, it is a must to start as soon as possible to reap and maximize the multiple benefits that renewables provide. As proof, other larger international cities have made the pledge to achieve 100% renewable energy and have begun their journey towards providing their residents with only renewable energy. Renewable energy sources are safer, produce less pollution, and can be produced at a cheaper rate than older nuclear and fossil fuels. The City of Toronto should become an international hub and global city for renewable energy. By leading the way, Toronto can encourage other Canadian, and international, cities to set a goal to produce all their energy with 100% renewable sources. Conducting energy planning for future generations will pay off dividends for all those involved. To complete the goal by 2067, the framework and timeline provided should be implemented immediately. With proper and efficient implementation, the goal of 100% renewable energy can be achieved and will position Toronto as a living laboratory for other cities and the rest of the world.

Appendices

RetScreen 1

Climate data



Heating design temperature	-16.1 °C
Cooling design temperature	29.4 °C
Earth temperature amplitude	21.4 °C

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	-5.1	75.9%	88.1	1.7	98.7	5	-7.7	716	0
February	-4.3	73.2%	70.9	2.3	98.8	4.7	-5.9	624	0
March	0	69.5%	73.2	3.6	98.7	4.8	-0.28	558	0
April	6.8	64.8%	80.8	4.9	98.5	4.7	7.4	336	0
May	13.3	65.3%	95.3	5.4	98.6	4.1	13.8	146	102
June	18.7	66.9%	84.6	5.8	98.6	3.7	18.8	0	261
July	21.6	66.8%	93.8	6.2	98.6	3.6	20.9	0	360
August	20.5	70.6%	86.6	5.3	98.8	3.4	19.5	0	326
September	16.2	73.6%	98.3	3.9	98.8	3.6	15.1	54	186
October	9.5	75.1%	80.1	2.5	98.8	3.9	8.8	264	0
November	3.8	77.2%	90.8	1.3	98.7	4.5	2.6	426	0
December	-1.8	77.2%	90.1	1.2	98.7	4.7	-4.2	614	0
Annual	**8.3**	**71.3%**	**1,033**	**3.7**	**98.7**	**4.2**	**7.5**	**3,738**	**1,234**

RetScreen 2

Financial viability

Financial parameters

Inflation rate	%	2%
Project life	yr	20
Debt ratio	%	70%
Debt interest rate	%	7%
Debt term	yr	15

Costs | Savings | Revenue

Initial costs			
Initial cost	100%	$	33,000
Total initial costs	**100%**	**$**	**33,000**
Annual costs and debt payments			
O&M costs (savings)		$	56
Debt payments - 15 yrs		$	2,536
Total annual costs		**$**	**2,592**
Annual savings and revenue			
Electricity export revenue		$	6,246
Total annual savings and revenue		**$**	**6,246**

Financial viability

Pre-tax IRR - equity	%	41.4%
Pre-tax IRR - assets	%	13.3%
Simple payback	yr	5.3
Equity payback	yr	2.6

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