Analyzing Ontario's Climate Change Mitigation and Transportation Planning for a Low - Carbon Economy

by

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DECLARATION

I, hereby declare this research paper entitled "**Analyzing Ontario's Climate Change Mitigation and Transportation Planning for a Low - Carbon Economy"** is the result of my writings with the exception of citations as each source is stated clearly in bibliography.

Nur Muhammed

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FOREWORD

A habitable planet is crucial for our existence. We are posing serious threats to terrestrial and aquatic ecosystems by putting tremendous pressure on biotic and abiotic environments for unprecedented economic gain. Large scale industrialization and urbanization based on fossil fuels produce tons of Greenhouse Gas (GHG) that are being piled up in the atmosphere. As a result, our planet is experiencing adverse climate change events. Following the UNFCC (The United Nations Framework Convention on Climate Change) initiatives, both federal and provincial governments have set their own targets of GHG emission reduction. The area of concentration of my Plan of Study (POS) is 'Municipal land use planning for a low-carbon economy'. Out of the vast areas of GHG emissions, three research components were elaborated in my POS which are: low carbon policy and legislation, biodiversity and ecosystem resilience, and land use planning. These components of the area of concentration of my POS have been further narrowed down to **'Analyzing Ontario's Climate Change Mitigation and Transportation Planning for a Low - Carbon Economy'** as the title of my major research paper.

This paper focuses on climate change and GHG emission reductions including rules and regulations to see whether the current implementation pattern would achieve the goals and targets set by the province of Ontario. At the same time, this study focused on a specific review and analysis of the GO Regional Express Rail electrification programs of Metrolinx. To build my understanding about this topic, I took relevant courses, including Land Use Planning Law, Environmental Economics, Regional and Urban Planning, Environmental Planning, Transportation Planning, Interdisciplinary Research in Environmental Studies, Climate Change: Science and Policy, Planning Theory, and Qualitative and Quantitative Research Methods. In addition, I took a Workshop course on Environmental Planning which solely focused on transit planning. More importantly, I did my internship with the Canadian Urban Transit Research and Innovation Consortium (CUTRIC) where I worked on an electric bus project that helped greatly to the development of this paper.

We can see that my research title, field experience with CUTRIC, workshop and the academic courses I attended are very much interconnected with my POS. As such these academic courses, workshop and the fieldwork with CUTRIC helped me develop my research area of concentration. Finally, I selected my research topic on '**Analyzing Ontario's Climate Change Mitigation and Transportation Planning for a Low - Carbon Economy'** from this broader area of research concentration highlighted in my POS.

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ABSTRACT

This study is based on review and analysis of Ontario's climate change mitigation and transportation which is eventually leading to transform into a low-carbon economy. This study is compiled into three sections. The first section provides a clear scenario of Canada's Greenhouse Gas (GHG) emission trend over the years, the federal government's role in GHG emission reduction and Canada's international commitment to climate change mitigation measures along with funding. The second section focuses on a review and analysis of Ontario's GHG emission reduction especially, in the transportation sector based on four regulatory instruments (i.e. Green Energy Act of 2009, Ontario Climate Change Strategy 2015, Ontario's Five Years Climate Change Action Plan and, Climate Change Mitigation and Low-carbon Economy Act, 2016). My analysis and arguments are focused on Ontario's GHG emission reduction target for 2014, 2020, 2030 and 2050 to examine whether Ontario's GHG emission reduction proceedings are heading in the right direction. The third section is an analytical review on Metrolinx's electrification program for the Regional Express Rail (RER) system in the Greater Toronto and Hamilton areas (GTHA). Emerging issues of the province regarding GHG emission trends, progress in emission reduction, current ways and means to reduce transport sector's GHG emissions were identified based on the results and findings of the study. Finally, a set of coherent measures have been recommended for GHG emission reduction and climate change mitigation measures applicable to Canada and Ontario. Emission reduction trend under 'Cap and trade System' suggests that Ontario's GHG emission reduction target for the year 2020, 2030 and 2050 may not be achievable in one hand, on the other hand the newly elected Ontario government's (2018) decisions on abandoning all renewable energy programs along with federal government's controversial decision on purchasing oil pipeline will further jeopardy the transformation process to a low-carbon economy.

LIST OF ACRONYMS

AV/AVs	: Autonomous Vehicle/ Autonomous Vehicles
BEB/BEBs	: Battery Electric Bus/ Battery Electric Buses
BEV/BEVs	: Battery Electric Vehicle/ Battery Electric Vehicles
BMW	: Bayerische Motoren Werke/ Bavarian Motor Works (in English)
CUTRIC	: Canadian Urban Transit Research and Innovation Consortium
CO_2	: Carbon dioxide
DB	: Diesel Bus
EPA	: Environmental Protection Agency
EU	: European Union
EUR	: Euro (European Union's currency)
EV/EVs	: Electric Vehicle/ Electric Vehicles
FCEVs	: Fuel-Cells Electric Vehicles
FES	: Faculty of Environmental Studies, York University
GM	: General Motors (manufacturer of Buick, Cadillac, GMC and Chevrolet)
gm	: Gram (weighing unit)
GDP	: Gross Domestic Product
GHG	: Greenhouse Gas
GTHA	: Greater Toronto and Hamilton Area
GHHA	: Greater Golden Horseshoe Area
HEV/HEVs	: Hybrid Electric Vehicle/ Hybrid Electric Vehicles
HOV	: High-occupancy Vehicle
IEA	: International Energy Agency
IIC	: Insurance Institute of Canada
IPCC	: Intergovernmental Panel on Climate Change
km	: Kilometre

KIA	: Kia Motors Corporation (KMC), South Korea
LRT	: Light Rail Transit
LULUCF	: Land Use, Land Use Change and Forestry
mill	: Million
mt	: Metric tons
Mt CO_2	: Metric tons of carbon dioxide
Mt CO_{2e}	: Metric tons of carbon dioxide equivalent
MoECC	: Ministry of Environment and Climate Change
MTA	: Metropolitan Transportation Authority
n.d.	: Non-dated
OCS	: Overhead Contact System
OECD	: Organization for Economic Cooperation and Development
PHEVs	: Plug-in Hybrid Electric Vehicles
POS	: Plan of Study
pkm	: Passenger kilometer
PWC	: PricewaterhouseCoopers
RER	: Regional Express Rail
RTP	: Regional Transportation Plan
RENFE	: Red Nacional de los Ferrocarriles Españoles (National Network of Spanish Railways)
TCO	: Total Cost of Ownership
UNFCC	: United Nations Framework Convention on Climate Change
USA	: United States of America
UNEP	: United Nations Environment Program
WRI	: World Resources Institute
yr./yrs.	: Year/ Years
ZeEUS	: Zero Emission Urban Bus System
ZEV	: Zero Emissions Vehicle

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

TABLE OF CONTENTS

Contents **Page**

Contents **Page**

CHAPTER 1: INTRODUCTION

1.1 Background

The unprecedented level of economic growth in recent history, which can be measured in Gross Domestic Product (GDP), has exerted tremendous pressure on nature and its natural resources. This excessive pressure on ecosystems is detrimental to the carrying capacity of the earth. Events like global warming, sea level rise, glacier melting, ozone layer depletion, tsunamis, floods, droughts, cyclones, and hurricanes are some of the resultant effects of the mass-scale human-induced problem named climate change.

Anthropogenic Greenhouse Gas (GHG) emission reduction in the context of global warming has received increased interest worldwide. The fundamental cause of climate change is truly global in scope because each country emits greenhouse gases with variable amounts of total emissions and per capita emissions [World Resources Institute (WRI, 2014)]. The transportation sector is an important contributor to global GHG emissions representing about 14% of overall emissions [Intergovernmental Panel on Climate Change (IPCC), 2014)] to 22% (Lefevre and Enriquez, 2014). The transportation sector accounts for 24% to 27% of the total GHG emission in Canada (Environment and Climate Change Canada, 2017) and the USA [United States Environmental Protection Agency (EPA), 2017] respectively. Therefore, if Canada aims to reduce its overall GHG emissions, it must reduce its transportation GHG emissions through proper transportation planning and new fossil fuel-free solutions.

To sustain life on earth, it is imperative to build an economy that ensures low emissions and less energy consumption. In this context, the Ontario government wanted to lead on climate change solutions by creating and maintaining a low-carbon economy. The previous Ontario government set a target to reduce emissions by 15%, 37% and 80% of 1990's emissions level by the end of 2020, 2030 and 2050 respectively [Ministry of Environment and Climate Change (Mock), 2016]. In addition, Ontario has recently adopted a number of policies and regulations including the Green Energy Act of 2009, Ontario Climate Change Strategy 2015, Ontario's Energy

Policy 2017, Ontario's Climate Change Action Plan (2016-2020), Climate Change Mitigation and Low-carbon Economy Act 2016 and approved Draft 2041 Regional Transportation Plan (RTP), which are the most important regulatory tools for Ontario's climate change mitigation and GHG emission reduction.

The estimated sector-wise emissions in Ontario for the year 2013 shows that three major sectors (transportation, industry, and buildings) emit about 82% of its total GHG emissions (Mock, 2016a). To reduce the transport sector's emissions (which is 35%) in Ontario, electrification of vehicles has been prioritized in the region. Metrolinx is mandated with electrifying rail transit system in the Greater Toronto and Hamilton Area (GTHA) for smart communication and emission reduction.

1.2 Justification

Emission reduction is an utmost import challenge for every nation. If we let GHG emissions to continue at the current pace, most life support system in the planet will become compromised for future generations. Therefore, conducting research on low-carbon economy is a timely and valuable effort.

1.3 Research Focus

This paper focuses on the GHG emissions caused by three key Ontario's sectors (transportation, industry, and buildings). Addressing emissions in these three sectors can help Ontario transform into a low-carbon economy. This paper analyses the key GHG emission reduction efforts of the Liberal government that ruled Ontario from 2004-2018. My analysis focuses on: Draft 2041 RTP, Ontario's Long-Term Energy Plan 2017, Ontario's Climate Change Action Plan (2016-2020) and Climate Change Mitigation and Low-carbon Economy Act 2016 as they are the most important policy documents to achieve Ontario's emission targets. Furthermore, the electrification of transportation is an important strategy to reaching emission reduction goals. Ontario's GHG emission reduction targets are 6%, 15%, 37% and 80% by the year 2014, 2020, 2030 and 2050 respectively. In this regard, my research question is whether it would be possible to achieve these emissions reduction target based on the current pace of implementation. Thus my research is guided by:

1.3.1 An analysis of Ontario's GHG emissions, emission reduction trends and the potential of achieving Ontario's emission target set for 2020, 2030 and 2050.

1.3.2 A brief review and analysis of electrification strategies for vehicles and related programs to promote public transit in GTHA from planning and implementation viewpoints.

1.4 Limitations of the Study

Environmental aspect is a wide and open field of research that is very often debated with contrasting views. Therefore, such a time-bounded single study alone cannot bring up concrete findings and solutions. Due to time constraints this paper does not analyze the consequences that the new Ontario government elected on June 07, 2018 will have on GHG emissions and mitigation strategies.

CHAPTER 2: LITERATURE REVIEW

2.1. Global Update on GHG Emissions

Although the concept of sustainable development has its original roots with 'Limits to Growth' in the 1970s, its actual meaning drew international focus since the Rio Earth Summit held in 1992. The Stern (2007) report emphasized that exponential population growth can critically destabilize planetary biophysical ecosystems. A low-carbon economy refers to an economy that designs and administers all programs and activities (housing, transportation, energy system, industry, and other built environments) in such a way that a minimum amount of GHG is released to the biosphere. Bao et. al. (2008) stated that future choices in economic development should be based on low energy consumption, low material consumption, low emission, and low pollution.

Current fossil fuel use trends lead to a projection that the average temperature increase of the planet may surpass 3°C in the 21st century. The Paris Agreement has generated a global consensus to limit global temperature rise to well below 2°C, and to reduce hydrofluorocarbons consumption (developed countries by 2019 and developing nations by 2028) [United Nations Environment Program (UNEP), 2016)].

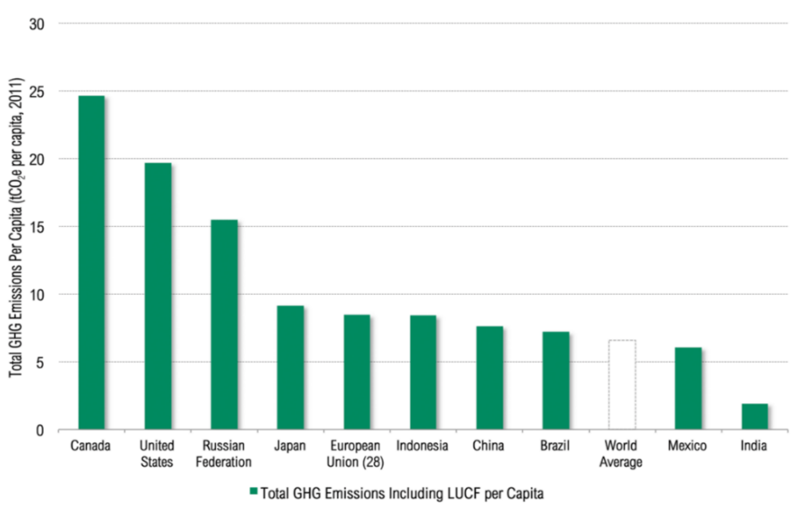
China, the USA, the EU, and India are the top four GHG emitters and are responsible for 61.5% of global carbon emissions (China - 30%, USA - 15%, EU - 28/10% and India - 6.5%) [Olivier et. al., 2015; PricewaterhouseCoopers (PWC), 2009]. In 2014, the EPA estimated that the transportation, industry, and electricity sectors emitted 77% of all GHGs in the USA (EPA, 2015). Internal combustion engine fueled-cars and trucks contribute to about 75% of the total GHGs emitted by the transport sector (EPA, 2009).

The International Energy Agency (IEA, 2017) reported that electricity (42%) and heat generation (24%) caused two-thirds of global CO_{2e} emissions from fuel combustion in 2015. However, total GHG emissions worldwide have shown a significant slowdown (49.3 GT CO_{2e} equivalent) in 2016 (excluding LULUCF) (Olivier, et. al., 2017). Table 1 and Fig.1 show the total and per capita amount of CO_{2e} emission expressed in mt CO_{2e} and percentage (%) emitted by the top ten countries. WRI (2011) shows that while China is the top CO_{2e} emitter in the world, Canada has the highest per capita emission (24.9 $tCo_{2e}.y^{-1}$) followed by the United States of America (19.9 $tCo_{2e}.y^{-1}$) and the US (19.7 $tCo_{2e}.y^{-1}$).

Table 1. Top ten CO_2 emitters in the world

Country	$C0_2$ Emission (mt $C0_{2e}$)	Percentage (%)	Population (mill)
China	10,260	22.3	1386.4
USA	6136	13.4	325.7
India	2358	5.1	1339.2
Russia	2217	4.8	144.5
Indonesia	2053	4.5	264
Brazil	1419	3.0	209.3
Japan	1170	2.5	126.8
Canada	847	1.8	36.7
Germany	806	1.8	82.7
Mexico	723	1.6	129.2

Source: WRI, 2011; World Bank, 2017



Source: WRI, 2011

Fig. 1. Top ten per capita CO_2 emitting countries

2.2 Low-Carbon Economy and Ontario's Initiatives to Reduce GHG Emissions

Canada is one of the top ten CO_2 emitters (Table 1) but when we consider per capita CO_2 emissions, Canada becomes the 2nd highest per capita CO_2 emitter in the world (Fig.1). Table 2 shows the GHG emission by each province and territory. According to this table, with few exceptions, transportation, industry and buildings are responsible for the vast majority of GHG emissions.

Ontario is the second largest GHG emitter in Canada after Alberta in Canada. Fig. 2 shows the GHG emission trends in Ontario. Ontario has set targets to reduce emissions by 6%, 15%, 37% and 80% (from 1990's emissions level) by the end of 2014, 2020, 2030 and 2050 respectively (Mock, 2016a). To fulfill these targets Ontario has passed several important rules and regulations that include; a) Green Energy Act of 2009; b) Ontario Climate Change Strategy 2015;

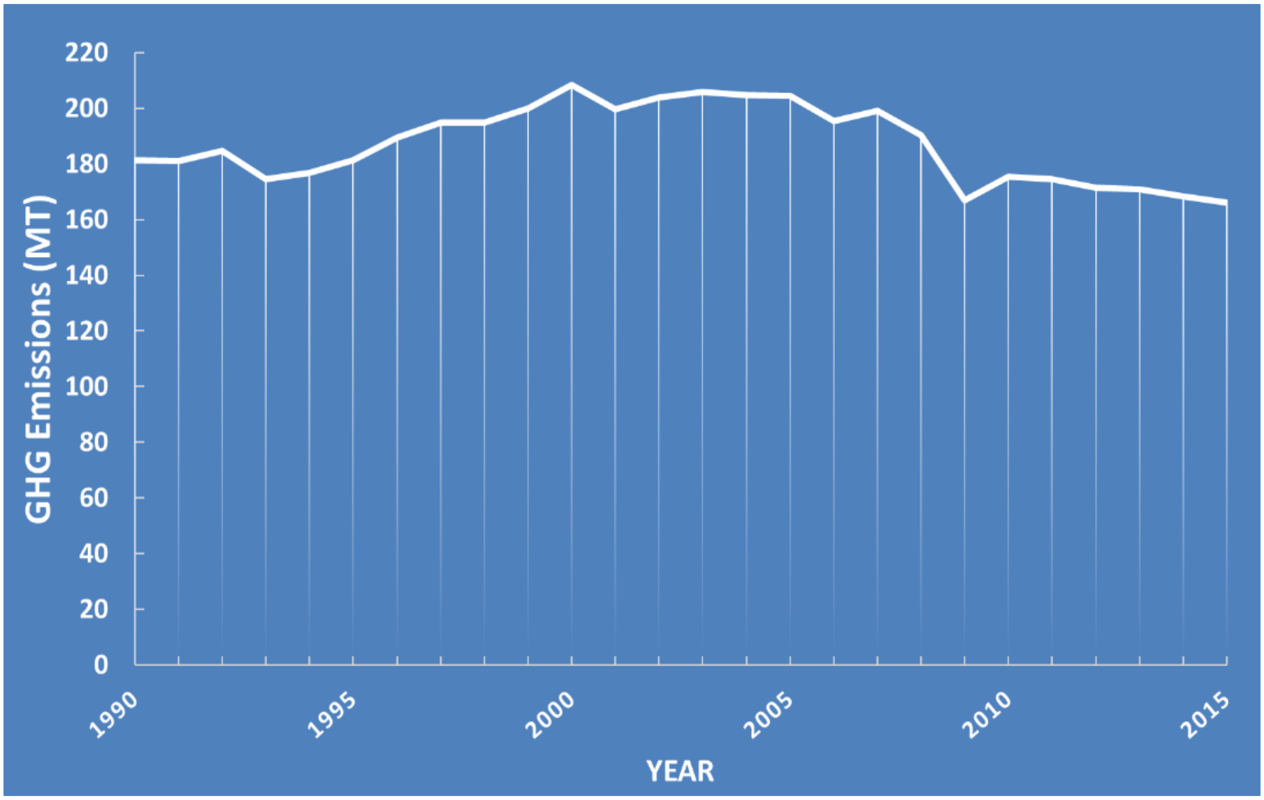
Table 2. GHG emission in percentage in all Provinces and Territories in Canada

Province	**GHG emission by sector (%)**						
	Transportation	Buildings	Industry	Electricity	Oil & Gas	Waste & others	Agriculture
Ontario	33	22	18	3	6	11	7
BC*	37	12	10	1	22	13	5
Alberta	12	7	6	17	48	2	8
Saskatchewan	14	4	4	19	32	3	24
Manitoba	33	13	6	1	3	8	36
Quebec	39	14	20	0	4	12	11
New Brunswick	28	9	6	27	19	7	4
Nova Scotia	28	14	3	42	4	6	3
NFL*	36	10	9	13	20	11	1
PEI*	47	18	1	0	0	11	23

* BC- British Columbia, NFL- Newfoundland and Labrador, PEI- Prince Edward Island

Source: Environment and Climate Change Canada, 2018

c) Ontario's Climate Change Action Plan (2016-2020) and; d) Climate Change Mitigation and Low-carbon Economy Act, 2016.



Source: Environment Canada, 2016

Fig. 2. GHG emission scenario in Ontario

The estimated sector-wise emissions in Ontario for the year 2013 are shown in Fig. 3 which illustrates that 82% of the total emissions have occurred from transportation, industry, and buildings (Mock, 2016a). Ontario Climate Change Action Plan proposed a ‘Cap-and-Trade’ system as a strategy for emission reduction in Ontario (which is a mechanism imposing a pricing system to all stakeholders based on their estimated emissions). The government suggests that about 61 mt CO_{2e} emissions can be reduced under an appropriately designed ‘Cap-and-Trade’ system that will help achieve the provincial goals of 2030 emission reduction. To provide a clean, reliable electricity system, Ontario has invested about $70 billion since 2003 (Ministry of Energy, 2017). This ‘Cap-and-Trade’ system was implemented in July 2016 and was recently cancelled by Premier Douglas Robert Ford.

2.3. Electrification of Vehicles

Research and innovation on Electric Vehicles (EVs) dates to the early 19th century. Table 3 outlines a chronological development of EVs worldwide. Until now electric vehicles in terms of market share of commercial application are insignificant except for few countries like, Norway, Netherlands, China and the USA and Canada. EVs as green logistics are evolving for its ability to control/minimize environmental externalities (Psaraftis, 2016). Electric vehicles are generally divided in to Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs) and Fuel-Cells Electric Vehicles (FCEVs). Both BEVs and HEVs have one common advantage that they can use their electric motors for regenerative breaking (Larminie and Lowry, 2012). FCEVs generate electricity from hydrogen chemical energy that either power electric motors or charges batteries (Chan, 2002). Batteries are one of the major concerns in BEVs as batteries are no longer suitable to use in BEVs if the battery capacities are reduced to 80% (McMorrin et. al., 2012).

It is reported that the global sales of passenger BEVs and PHEVs (Plug-in Hybrid Electric Vehicles) were 10,000 in 2009, 45,000 in 2011, 110,000 in 2012 and 210,000 in 2013 (Mock and Yang, 2014). However, a significant technological development has occurred to resolve battery life span, battery charging and charging stations issues. Thus, the use of BEBs is growing at an accelerated rate in China, Europe, and North America. The stock of BEBs became double in 2016 (345,000) compared to its number in 2015 (OECD/IEA, 2017). China is currently dictating the global share of BEBs (343,000) followed by Europe (1,273) and USA (200). It is expected that the global sales for BEBs will grow at a rate of 33.5% per annum during the period 2017- 2025 (ZeEUS, 2017). In this regard, European Commission's 'Roadmap to a Single European Transport Area' wants to reduce the traditionally fueled internal combustion engine operated vehicles for urban transportation system by 50% by 2030 and 100% by 2050 (Anon, 2011).

There is no known alternative besides EVs for reducing GHG emissions of the transport sector. Every country has set their own emissions reduction target according to Paris Agreement. We see that many countries including Canada have set very ambitious emission reduction targets without realistic physical modelling of their respective energy use and economic transformations. Therefore, without transforming to the electrification of most direct uses of oil and gas by clean energy sources, emission reduction targets below 1990 level will not be achievable (Williams et. al., 2012).

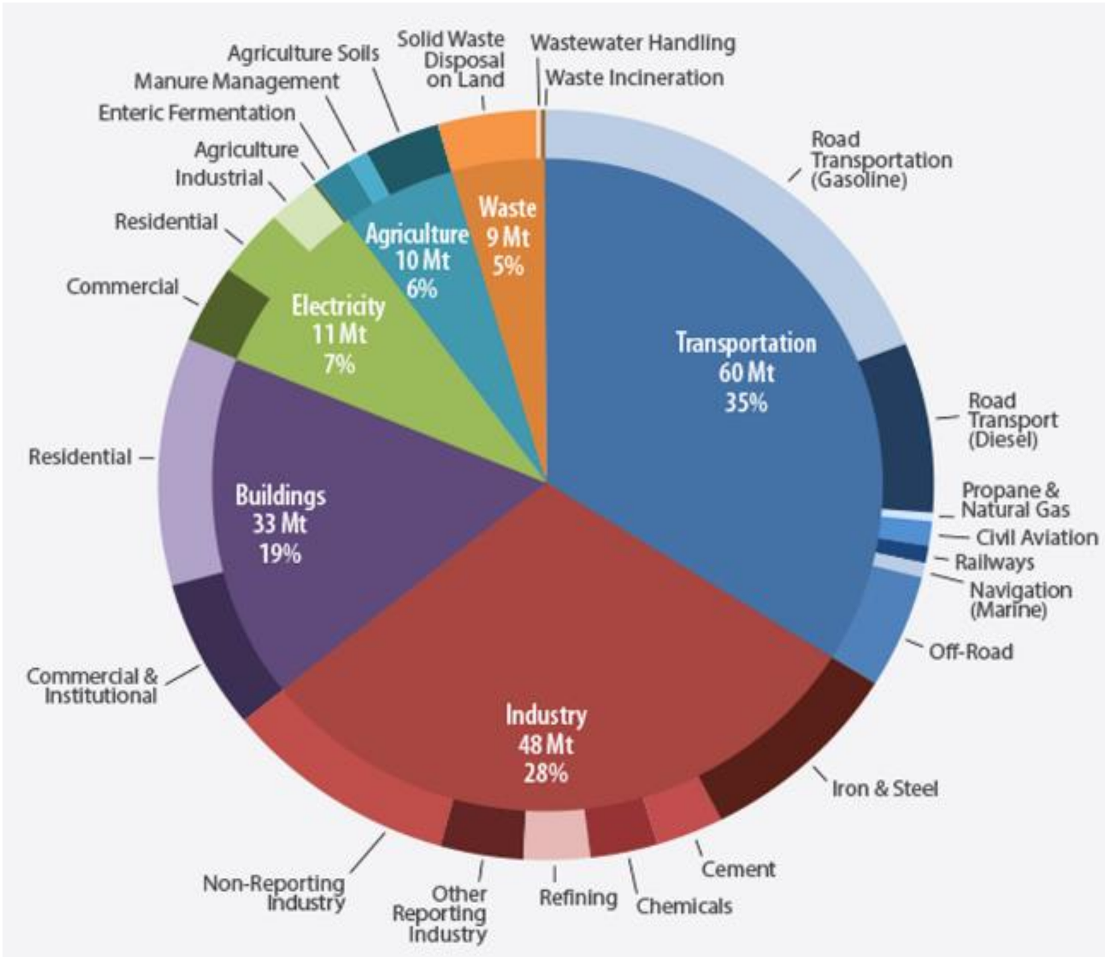


Fig. 3. Sector-wise emissions in Ontario (after Mock, 2016a)

2.4. Ontario's Transit Development

Metrolinx, Ontario's regional transportation agency, is committed to build an appropriate and cohesive transit network across the GTHA. To find the most sustainable solution for electrifying the GO Rail network, Metrolinx has been conducting a feasibility study on 'hydrogen fuel-cell rail technology (hydrail)' for its Regional Express Rail (RER) program. It is to note that Germany identified hydrogen-fuel-cell technology as a key strategy to meet its future mobility and energy demand. Furthermore, *Alstom*, a French company operating rail

Table 3. Chronological development of EVs

Period	Development
1832-1839	1st crude electric carriage, Scotland
1835	1st practical electric vehicle by Thomas Davenport, USA
1859	Rechargeable lead-acid storage battery by Gaston Planté and Camille Faure, France
1891	1st successful electric automobile by William Morrison, USA
1900	EV's huge momentum (of the 4,192 cars produced in the United States, 28% powered by electricity)
1908	Mass-produced and gasoline-powered Model by Henry Ford, USA
1966	The US Congress introduced a Bill recommending the use of EVs as a means of reducing air pollution
1990	Zero Emission Vehicle (ZEV) Mandate of California (2% of the State's vehicles must have no emissions by 1998 and 10% by 2003)
1997-2000	All-electric cars produced by big car manufacturers like Honda's, G.M. Ford, Nissan, Chevy, and Toyota
2006	Tesla Roadster is born
2010	All-electric Nissan in the USA
2012	Tesla produces its second long-range electric vehicle (Model S)
2016	GM's big push with the launch of its Chevy Bolt, an all-electric car.

Source: adapted after Berman, 2011; Bellis, 2017; Thompson, 2017

transport worldwide, has conducted the world's first fuel cell train test run (successfully) and is moving forward with a passenger test run in 2018, targeting commercial production in 2019 (Mackenzie, 2017). Metrolinx is working on the concept and designs of such vehicles. Notable progress includes, '2010 GO Transit Electrification Study' and 'Class Environmental Assessment for Minor Transmission Facilities' and 'Environmental Assessment of Electric Rail Planning' that includes major infrastructure like power stations, switching stations, transmission lines, and catenary (Hartley, 2017).

GTHA is a rapidly growing area expecting more than 10 million people by 2041. The GTHA's transportation plan the 'Big Move' by Metrolinx aims to make the largest connected transit in North America. Ontario has recently approved Draft 2041 Regional Transportation Plan to build an integrated, regional multi-modal transportation system in GTHA. One of the five strategies of the approved transportation plan are to optimize the transit system of the region (Metrolinx, 2017). Electrification of the GO Rail transit system is one such action to serve the public with frequent service and to lower GHG emissions. The Canadian Urban Transit Research and Innovation Consortium (CUTRIC) conducts research and helps commercialization of low-carbon smart mobility technologies in Canada. CUTRIC is currently engaged in research, planning and optimization of GO Rail electrification in the GTHA.

The transportation sector is one of the three major sectors for GHG emissions in Canada and the USA. Sustainable transportation has the potential to provide accessibility to everyone for basic mobility needs. Continuous research and studies are being pursued to make a proper balance between societal well-being, the quality of the environment and economic profit (Van Wee, 2012). As we know that Canada is one of the largest countries in the world, however, in terms of population, Canada ranks 38^{th} (only 0.48%) in terms of world total population (Web, n.d.). The worrisome news is that Canada is among the top ten GHG emitters in the world and ranks 2^{nd} in terms of per capita GHG emission (WRI, 2011). This means that every Canadian citizen has a very high carbon footprint. Therefore, as Canadian, we cannot deny our own responsibilities in fighting climate change battle along with government efforts.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Study Area

This study includes a review and analysis of GHG emission reduction targets set for 2014, 2020, 2030 and 2050 and the strategy, policy and regulatory means to achieve these targets in Ontario. In order to analyze the electrification of vehicles and the RER system, Metrolinx's ongoing rail electrification project in the Greater Toronto and Hamilton Areas (GTHA) was selected for this study.

3.2 Research Methods

This study made use of secondary data (e.g. Regional Transit Plan, Climate Change Action Plan, Energy Policy and Low-carbon Economy Act of Ontario) to achieve the objectives of the study. Analyzing transit policies, strategies, action along with policies on energy, climate change and low-carbon economy, I could analyze Ontario's GHG emissions, emission reduction trends and the reality of achieving Ontario's emission targets set for 2020, 2030 and 2050. The result of this analysis helped to develop a clear understanding on the effectiveness of the GTHA's transit planning initiatives and its potentials for emission reduction. In addition, the analysis identified the limitations of the policies suggesting new directives for further improvement.

Metrolinx's regional transportation planning documents and their ongoing GO Rail electrification project was also reviewed. While working with CUTRIC on its electric bus project, I discussed with CUTRIC's professionals several times through informal talks/queries on research updates on introducing electric vehicles in the GTHA. Those discussions helped me to find appropriate documents and relevant references that I used in this study. Review and analysis of secondary data and information helped me to understand many aspects (technological, financial and logistical) of electric vehicles growth in the GTHA. My analysis also identified the GTHA emission reduction potential of electric vehicle deployment.

Basically, qualitative research approach was applied to carry out this study. However, I did some quantitative assessment of the secondary data for this study as well. Personal contacts were made with several relevant offices and individuals for document collection policy and regulatory documents, journal's articles on electric vehicles, transportation planning and GHG emissions reduction, etc.

3.3 Gantt Chart

Table 4. Gantt chart of the research project

Subject	MES I & II (Sept 2016 – Dec 2017)																MES III (Jan 2018 – Aug 2018)							
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Meeting with Advisor																								
POS title selection & write up																								
Literature Review																								
MES I Submission																								
Improvement & Submission																								
Proposal writing/ & finalization																								
MES II-III Exam.																								
Data collection																								
Data analysis, report writing/revision																								
Final submission																								

CHAPTER 4: RESULTS AND DISCUSSION

4.1 GHG Emission, Current Trends and Future Actions

4.1.1 Canadian perspectives

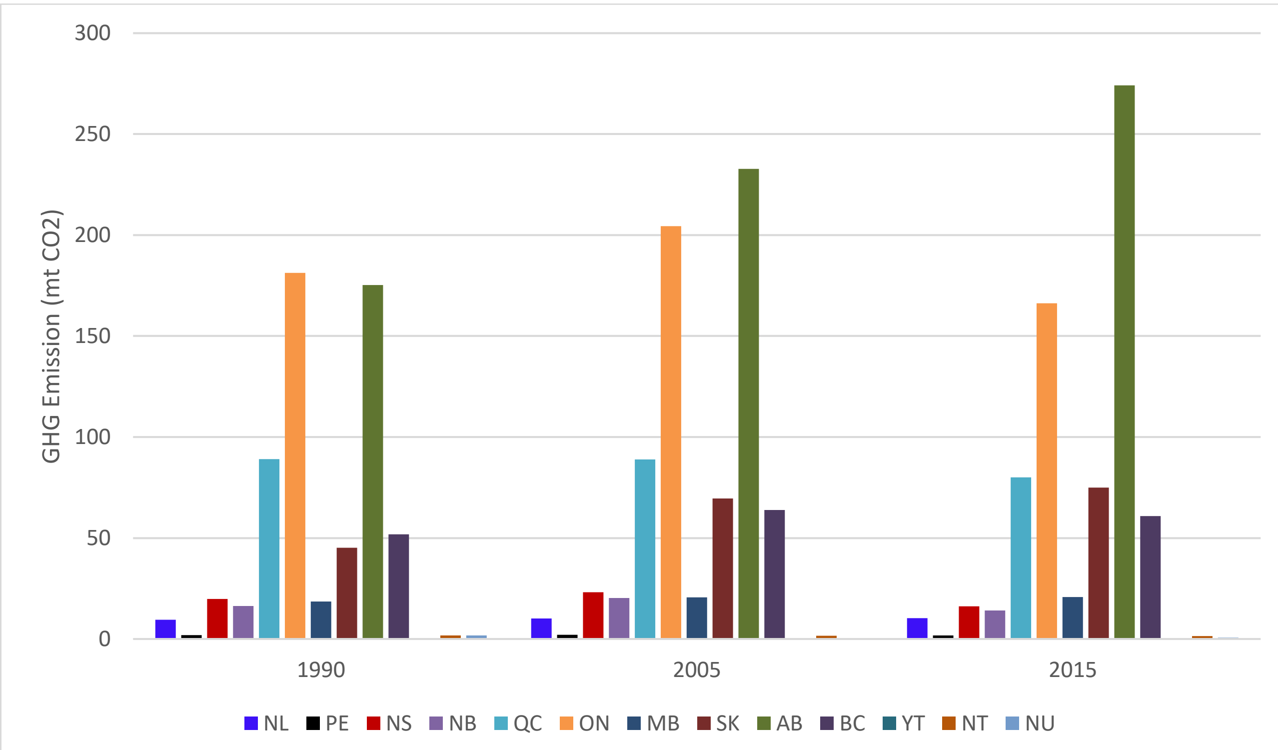
As the climate change problem continues to grow by increasing magnitude, Canada requires committed action in climate change mitigation and adaptation. We know that climate change covers a wide spectrum of issues; so precise actions and solutions are often debated and can be victimized by political hindrance. GHG emission trends in Canada are shown in Table 5 and Fig. 4 respectively. There had been significant GHG reduction in 2008 and 2009 which might have been caused by the global economic recession that stopped a lot of economic and industrial production. Although there are variations from year to year, the trend is increased emissions since 1800 until today.

Table 5. GHG emission trend in Canada

Year	Emission (mt CO_{2e})	Trend (mt CO_{2e})	Year	Emission (mt CO_{2e})	Trend (mt CO_{2e})	Year	Emission (mt CO_{2e})	Trend (mt CO_{2e})
1990	611	**-**	**1999**	717	13	**2008**	729	-21
1991	604	-7	**2000**	738	21	**2009**	689	-40
1992	621	17	**2001**	728	-10	**2010**	701	12
1993	623	2	**2002**	730	2	**2011**	708	7
1994	644	21	**2003**	749	19	**2012**	716	8
1995	661	17	**2004**	751	2	**2013**	729	13
1996	682	21	**2005**	738	-13	**2014**	727	-2
1997	697	15	**2006**	729	-9	**2015**	722	-5
1998	704	7	**2007**	750	21			

Source: Adapted after Environment Canada, 2016

The GHG emissions decrease from 2014 happened mainly due to coal phase-out in Ontario. However, beside coal phase-out, Canada's efforts in global climate change mitigation, regulatory change, and public awareness might have contributed to some extend in this change. Fig. 4 clearly depicts that Alberta, Ontario, Quebec and British Columbia are the provinces causing the bulk of Canadian GHG emissions due to large population, oil and gas and other major industrial and economic concentration.



Source: Adapted after Environment Canada, 2016

Fig. 4. GHG emissions in Canada's provinces

The Federal government of Canada is committed to reducing GHG emissions by 30% from 2005 levels (Government of Canada, 2017; Government of Canada, 2017a). Furthermore, the Federal government is focusing on its emission reduction efforts to create a green economy (Morneau, 2017; Government of Canada, 2017b). To achieve that the Federal government is investing in innovation through infrastructure development, sustainable technologies and implementing plans and policies related to transforming our nation into a low-carbon economy. Beginning in 2018, Canada's Federal government has decided to impose carbon pricing with a choice for provinces between implementing a carbon tax or a 'Cap and Trade' system (Environment Canada, 2016).

Carbon pricing has been set at $10 per ton in 2018 which will rise to $50/ton by 2022; the generated revenue from carbon pricing can be spent by the provincial governments to their own climate change related programs (Government of Canada, 2017b). In 2017, the Federal government allocated budgets in various sectors that deal with climate change. For example, $11.4 million has been set aside to replace coal-fired electricity and $135.4 million to combat short-lived pollutants that contribute to climate change (Morneau, 2017). Moreover, the Federal government is highly committed to work on domestic mitigation efforts, communication and international collaboration on climate change and environmental affairs. To create an effective collaboration with provincial governments to successfully meet international carbon emission targets, the Federal government has created the Pan-Canadian Framework to confront climate change (Government of Canada, 2017c).

Table 5 shows that since 1990, Canada's emissions have increased significantly, especially in the Transportation and the Oil and Gas Exploration sectors. However, the Federal government's plan 'The Pan-Canadian Framework', regrettably doesn't address these two major contributors of emissions (Government of Canada, 2017c). Regarding oil and gas exploration, the current Federal government has proposed strict methane emission policies starting in 2018 but unfortunately has pushed it back because of industry's pressure on the government which now allows 3 more years of methane emissions (Fletcher, 2017). This contradicts the government's commitment to becoming a green economy. In addition, the Prime Minister Justin Trudeau recently bought a pipeline called 'Trans Mountain Pipeline' with a cost of $ 4.5 billion which is becoming a highly controversial fossil fuel expansion project.

Canada plays a very important role as an international stakeholder in global funding for climate change mitigation. The Paris Agreement of December 2015 reached a landmark decision to combat climate change and invest in low carbon economies. Significant efforts were pledged to support developing countries in adapting and mitigating the effects of climate change (Anon, 2017). Signatories have dedicated financial flows to lower GHG emission globally, with funds specifically dedicated to creating low carbon economies in the Global South and the Least Developed Countries (Tomlinson, 2017). The 'Road Map to $100 Billion' establishes minimum contributions in global climate financing by 2020 of which Canada's fair share is estimated at 3.9% which is amounting to $1,460 million per year by 2020 (Anon, 2017). However, instead of $1,460 million per year, current funding trend shows that Canada is contributing only $800 million per year which is insufficient, being only half of the committed share (Anon, 2017).

4.1.2 Review and analysis of Ontario's GHG emission reduction

Ontario set targets to reduce emissions by 6%, 15%, 37% and 80% of 1990's emissions level by the end of 2014, 2020, 2030 and 2050 respectively (Mock, 2016a). The main regulatory tools and instruments to achieve these emission targets are: the Green Energy Act of 2009, Ontario Climate Change Strategy 2015, Ontario's Climate Change Action Plan (2016-2020), and the Climate Change Mitigation and Low-carbon Economy Act. Ontario's Climate Change Mitigation Plan emphasizes four important strategies which are stated below (Fig. 5 highlights the Ontario's current climate change mitigation actions).

a. Emission reduction (cap and trade)
b. Assisting low-income & vulnerable communities
c. Helping businesses transition
d. Green bank & finance

Table 6 shows emission reduction trends over the past years in Ontario. Based on the trend analysis, it seems like an uphill battle to achieve Ontario's emission reduction targets in the years ahead.

Source: adapted after Mock. 2016a

Fig. 5. Ontario's actions towards climate change mitigation

Table 6. GHG emission trend and projected scenario in Ontario

Year	**Emission (mt CO_2)**	**Change**	**Change (%)**	**Year**	**Emission (mt CO_2)**	**Change**	**Change (%)**
1990	181.3	-	-	2014	168.0	-13.3	-7.3
2005	204.0	22.7	12.5	2015	166.0	-15.3	-8.4
2010	175.0	-6.3	-3.5	2016	160.6	-20.7	-11.4
2011	175.0	-6.3	-3.5	2020	154.1	-27.2	-15.0
2012	171.0	-10.3	-5.7	2030	114.2	-67.1	-37.0
2013	171.0	-10.3	-5.7	2050	36.3	-145.0	-.80.0

Source: adapted after Environment and Climate Change Canada, 2018

Ontario achieved its 2014 target of reducing by 6% its GHG emissions mainly by closing its coal plants. Ontario's Climate Change Action Plan proposed a 'Cap-and-Trade' system as a strategy for emission reduction in Ontario which is a mechanism of imposing a price system to key polluters based on their estimated emissions. It is estimated that about 61 mt CO_{2e} emissions can be reduced under an appropriately designed 'Cap-and-Trade' system that could help achieve Ontario's goal for a 2030 emissions reduction of 37% (Mock, 2016). However, the 2014 and onwards, pace of progress is rather slow due to recent political change; so, we have to see whether based on the current scenarios, those millstones are achievable or not.

Important additional steps include substitution of fossil fuels with renewable energy, incentivizing electric vehicles, electrification of public rail transport, promoting solar energy in private and public buildings, etc. Despite these positive initiatives, we have to remember that Ontario's emission increased by 1.5 mt CO_{2e}/yr from 1990 to 2005. Afterwards, Ontario's emission rate was reduced at the rate of 5.8 mt CO_{2e}/yr. and 1.8 mt CO_{2e}/yr. during the period 2006-2010 and 2011-2015 respectively (Table 7 and Table 8). To achieve its 2020 emission reduction target, Ontario needs to reduce emission by 2.4 mt CO_{2e}/yr. during 2016 to 2020 which is impossible under the current regulatory framework.

Table 7. Ontario's emission reduction trend (1990 – 2050)

Period	**Emission increase/decrease rate (mt CO_{2e}/yr)**	**Emission increase/decrease (%)**	**Amount Emitted (mt CO_{2e})**	
			From	To
1990 → 2005	↑1.5	↑ 12.5%	181.3	204
2006 → 2010	↓5.8	↓15.9%	204	175
2011 → 2015	↓1.8	↓4.9%	175	166
Projected scenario				
2016 → 2020	↓2.4	↓15%	166	154.1
2016 → 2030	↓3.5	-	166	114.2
2016 → 2050	↓3.7	-	166	36.3

Source: adapted after Environment and Climate Change Canada. 2017; Mock. 2016a

Table 8. Periodical trend analysis to comply with Ontario's Climate Change Action Plan

Period	Recorded/ to be recorded emission (mt CO_2)	Amount emitted/to be emitted (mt CO_2)	Average/year emitted/to be emitted (mt CO_2)
1990-2005	181.3-204.0	+22.7	+1.5
2006-2010	204.0-175.0	-29	-5.8
2011-2015	175.0-166.0	-9	-1.8
2016-2020	- 154.1	-11.9	-2.4
2021-2030	- 114.2	-39.9	-4.0
2031-2050	- 36.3	-77.9	-3.9

Based on the data showed in table 7 and 8, we can see that in Ontario, during 1990 to 2005 GHG emission (from 181.3 to 204 mt CO_2) was increased by 1.5 mt CO_2/yr (+12.5%). During 2006 to 2010 GHG emission was reduced by 5.8 mt CO_2/yr (-15.9%) and during 2011 to 2015 GHG emission was reduced by 1.8 mt CO_2/yr (-4.9%). If we analyze the scenario of 15% GHG reduction achievement by 2020, during 2016 to 2020 GHG emission has to be reduced by 2.4 mt CO_2/yr (-15%). A 37% GHG reduction by 2030, means that during 2016 to 2030 GHG emissions have to be reduced by 3.5 mt CO_2/yr. And finally, for an 80% GHG reduction by 2050, GHG emission during 2016 to 2050 must be reduced by 3.7 mt CO_2/yr. Now the question is, under current regulatory framework, implementation pattern and contrasting political agendas, would it be possible for Ontario to achieve its GHG emission reduction target? The most obvious answer will be 'no'. And now with the cancellation of 'Cap and Trade' we can expect more challenges.

It is apprehended that the implementation of Ontario's Long-Term Energy Plan will create different types of new demands as emissions are reduced, which are home heating, electric vehicles, water heating, and the industrial applications and development of an Ontario hydrogen industry (Brouillette, 2016). As mentioned earlier, Ontario's largest emissions sectors are transportation (35 %) and industry (28 %). However, the provincial plan for dealing with these sectors is quite vague.

An additional strategy for meeting the province's emissions reduction targets is reforestation in the City of Toronto. Increasing Toronto's tree canopy cover will reduce energy use from the heating and cooling of buildings, improve air quality through the interception of pollutants, aid in carbon sequestration, as well as enhance flood protection and erosion control (Westfall & Morin, 2012). Currently, Toronto has a 26.6-28 % tree canopy cover (sixty % of which is on private property) (Doyle, 2013). In this regard, the City of Toronto has proposed few policy implementations or financial incentives for Toronto residences to increase tree canopy cover. Moreover, the Strategic Forest Management Plan strives for a thirteen % increase in tree canopy cover over a forty to fifty year period. This long-time frame can be significantly reduced if new policies and financial incentives are developed immediately for the people of Toronto.

4.2 Electrification of Regional Express Rail and Low-Carbon Economy

GO Transit Rail is one of the most important transit development programs in the GTHA that is being upgraded for electrification. The regulatory frameworks for Ontario's transit electrification include: the 2041 RTP, Places to Grow, The Big Move and GO 2020. Feasibility studies on various aspects including land use practices, environmental impact, economic impact, noise reduction, emission reduction, investment scenarios and technical details were carried out along with public consultation. Vision, objectives and strategies of this project were developed based on the outcomes of these technical studies/evaluations.

4.2.1 Places to Grow Act

The Places to Grow Act, passed by the Ontario Government in 2005, was enacted for helping the Ontario Government to plan effectively for rapid population growth. With this law, the government can designate a specific geographic region for growth and high density urban development. A Growth Plan is a system that can help the government recognize and guide where and how development should occur within a specific area. As the GTHA is one of the most important and fast-growing areas in Canada, currently populated by 8 million people, the growth plan is crucial for developing a more progressive and advanced habitat for the additional 3.7 million people who are expected to come into the region as well (Metrolinx, 2010).

The 25-year Growth Plan will help the government manage urban development while providing a proper infrastructure for the region. The Places to Grow Act also recognizes that the more people commuting to work by private car, the greater will be gridlock, delays in movement of goods and greater pollution levels. For future growth, the plan demands further concentration of urban development in already built-up areas which will justify a focus on public transit and infrastructure investment. The highest priority stated on the 'Places to Grow' plan is to focus on public transit for better transportation infrastructure.

4.2.2 The Big Move

Metrolinx is an organization created by the Government of Ontario to develop an intricate transportation plan for the GTHA. This organization has developed a RTP also called "The Big Move" whose purpose is to guide larger transportation developments in the GTHA. This plan includes the construction of over 1,200 km of transit which will provide 80% of the inhabitants in this area with public transit within 2 km of their homes (Metrolinx, 2010). This goal will allow residents to have greater access to jobs that had been situated too far from their homes which in turn will make the economy grow. This high investment project estimates about 2 billion dollars in annual investment over the next 25 years making it the largest public transit expansion in Canada (Metrolinx, 2010). The benefits of the Big Move include creating thousands of jobs, saving billions of dollars over time, saving energy and reducing pollution. Furthermore, this project will provide sustainable travel options that will reduce one-third of the greenhouse emissions emitted in Ontario making the province a much healthier place to live.

4.2.3 GO 2020

A huge public transit system of the GTHA area is GO Transit. Each day around, 200,000 passengers travel using either one of the 180 GO train trips or the 2000 GO bus trips (Metrolinx, 2010). GO Transit has created a new plan called GO 2020, which will help provide access to public transit all throughout the GTHA, consistent with the Growth Plan for the Greater Golden Horseshoe Areas (GGHA) and Metrolinx's RTP.

4.2.4 The 2041 Regional Transportation Plan (RTP)

A sound public transit system is a prerequisite for the fast-growing GTHA of Ontario. The 2041 RTP aims to develop a sustainable transportation system in the GTHA that will be aligned together with land use and will support healthy and complete communities. Keeping the affluent population in the GTHA by 2041, it envisions that achievement of three major goals which are strong connections, complete travel experience and viable healthy communities. This plan has set five strategies to achieve these goals (RTP, 2018) which are as follows:

i. Complete the delivery of current regional transit projects
ii. Connect more of the region with frequent rapid transit
iii. Optimize the transportation system
iv. Integrate transportation and land use
v. Prepare for an uncertain future

4.2.5 Metrolinx's Regional Express Rail (RER)

Metrolinx (established in 2006) is a regional transportation agency of Ontario which works with federal, provincial, municipal partners and other relevant stakeholders to build faster, easier and safer transit systems across the province through large-scale investment. They operate GO Transit, UP Express and PRESTO with a prime focus to develop transit connectivity in the GTHA. Metrolinx envisions for a quality lifestyle, an affluent economy and a healthy environment through an integrated, multimodal regional transportation system (Metrolinx, 2017a). To achieve the stated goals and targets of Ontario's first transportation plan (i.e., The Big Move-2008), Metrolinx's brief achievement can be summarized in Fig. 6.

Keeping the future population (>10 mill. people by 2041) and economic growth of Ontario in mind, Metrolinx is implementing the 'Expansion of Transit in the GTHA' which is one of the largest infrastructure projects in North America. A 'Plan to connect communities and cities' is the central theme of the 2041 RTP of the region. Based on the huge success of the BIG MOVE, Metrolinx came up with 'RTP 2041' whose aim is to create complete travel experiences, and sustainable and healthy communities in the region. This plan emphasizes developing an integrated and seamless transportation system for the GTHA. Electrification of the RER is an ambitious project that will not only ensure fast and frequent transit, but it will also fulfill Ontario's long-cherished goal of reducing GHG emissions.

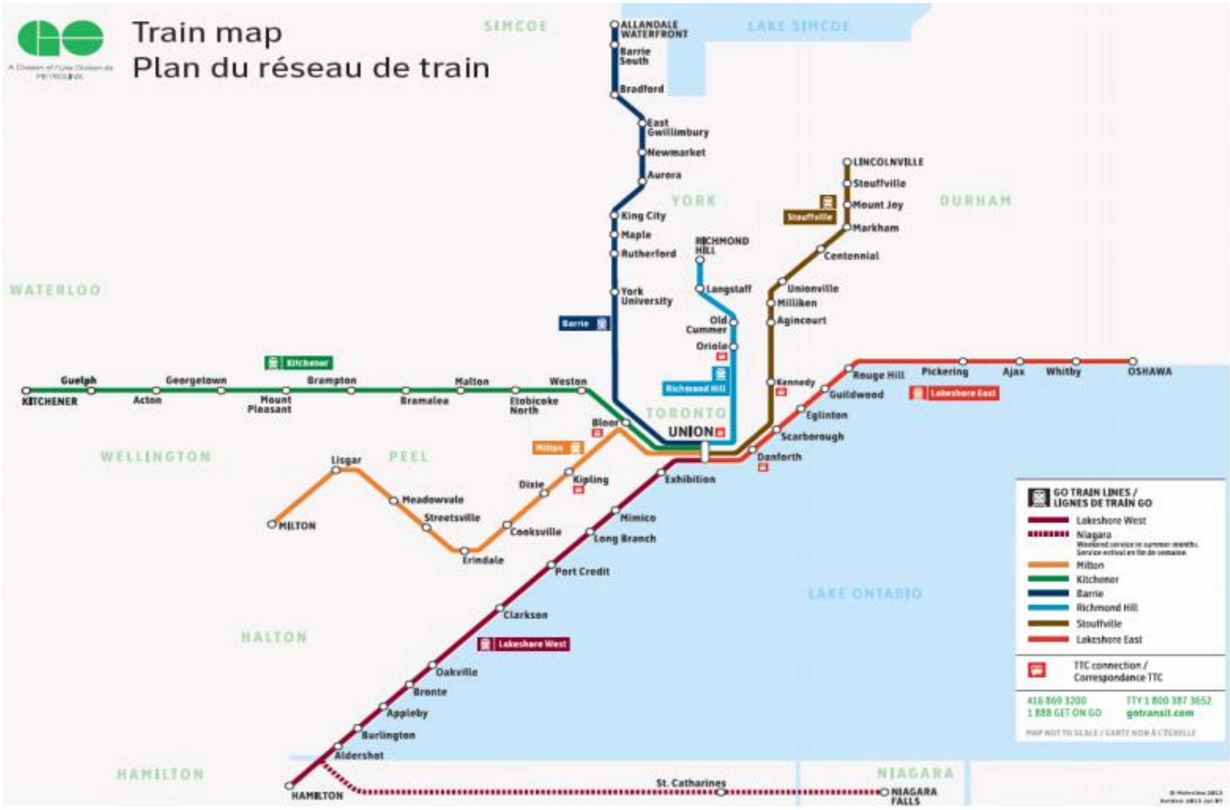
- ✓ Weekly GO train trips increased by 500%
- ✓ Eight new stations
- ✓ Expansion of network by 70 km
- ✓ Added >13 mill. passenger trips/year
- ✓ Renovated 29 stations
- ✓ Addition of about 22,000 parking spaces
- ✓ Introduced PRESTO card (adoption tripled in last five years)
- ✓ UP Express offers 3.5 mill. passenger trips/year

Source: Metrolinx, n.d.

Fig. 6. Brief summary of Metrolinx achievement in transit development

RER is a 10 year transit plan of Metrolinx which was started in 2016 for the GTHA (Fig. 7). Electrification is one of the major components of the RER plan. With a view to convert several rail corridors from diesel to electric propulsion, this project includes the design and implementation of traction power supply with associated components through an overhead contact system (OCS). Infrastructure for the required number of electrical power supply/distribution facilities will also be developed along the rail corridors. The current state of the transit network in the GTHA is shown in Table 9. The RER electrification project aims to accrue the following benefits:

i. Time savings.
ii. Easier and faster access to education, employment and other activities.
iii. Individuals switching from cars to train, which can save money and increase productivity.
iv. Congestion relief that will save time, reduce stress and improve mental health. It is reported that current congestion costs about $ 11 billion per annum in the GTHA (Metrolinx, n.d.).
v. Better connectivity between all nodes, corridors for mass mobility and economic dynamics.
vi. Improve air quality
vii. Reduce GHG emissions
viii. Reduce noise pollution from trains



Source: Metrolinx, n.d.

Fig. 7. Proposed RER networks in the GTHA

Table 9. Current facts and facilities in seven corridors under RER networks

Corridors	**Total track (km)**	**Total Ridership/weekday**	**Total trips/weekday**	**Stations**
Lakeshore West Corridor	177	60,000	90	11
Milton Corridor	106	30,000	16	8
Kitchener Corridor	166	18,000	16	11
Barrie Corridor	103	17,000	14	10
Richmond Hill Corridor	47	10,000	11	4
Stouffville Corridor	37	15,000	15	9
Lakeshore East Corridor	115	52,000	88	9
Total	751	202,000	250	62

Source: Metrolinx, 2014

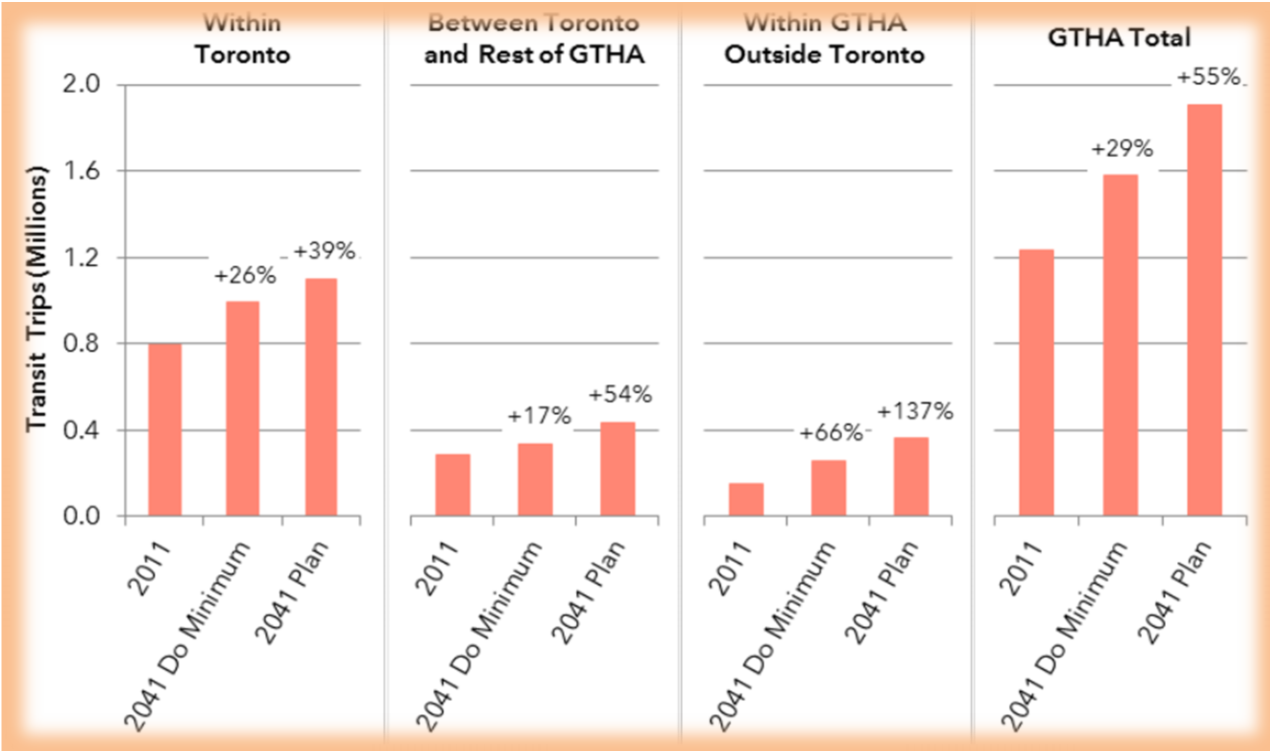
This project hoped to create a 1,623 km Rapid Transit Network (net increase 1,555 km), 1,995 km Regional Cycling Network (net increase 1,005 km), and 1,130 km HOV Lanes Network (net increase 1,020 km) all aimed at enhancing rapid connectivity within seven major nodes and corridors of this region. On the other hand, when we look at the proposed development activities (Table 10), it definitely shows a sign of significant development which can enhance economic development by creating more employment opportunities. A 300% increase in trips/week will help increase public transit use in this region. Metrolinx's Study (2017) shows that the proposed electrification of Regional Express Rail (RER) will increase trips with a trickledown effect on different travel markets (Fig. 8).

Table 10. Proposed development tasks for RER and LRT

Sl.	Tasks	Descriptions	Remarks
1	Train sets	52	
2	New GO Tracks	150 km	
3	New GO stations	22	
4	Existing GO stations upgrade	32	
5	Bridge upgrades	>45	
6	Trips	6000/week	300% increase
7	Service	15 minutes service or better	
8	Grade separations	10 rail/road grade separations	1 rail/rail grade separation
9	Extension	Kitchener, Niagara & Bowmanville	
10	LRT stations/stops	16 stations and 65 stops	
11	New LRT Tracks	64 km	

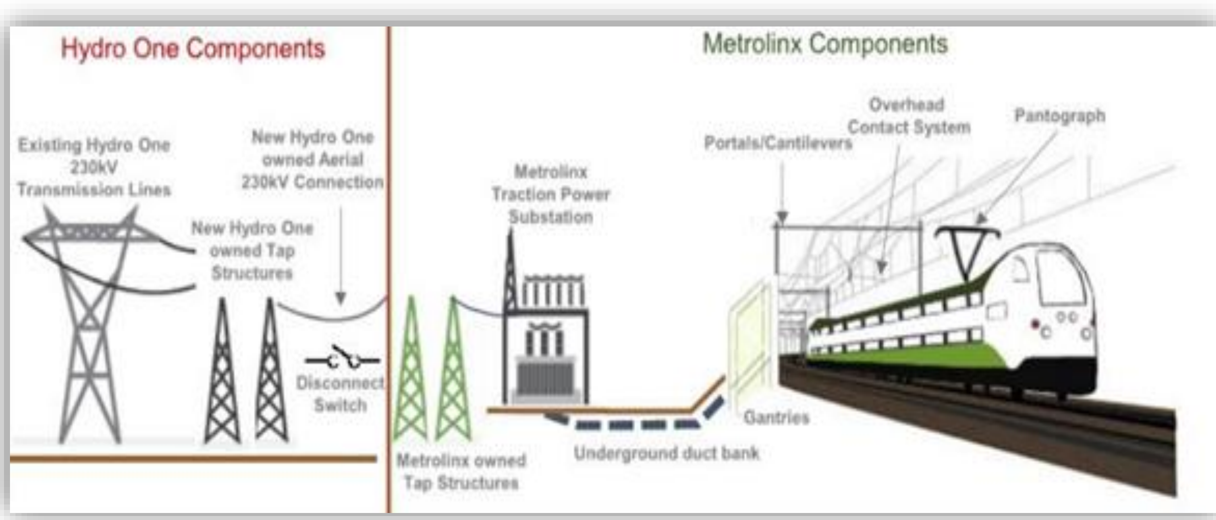
Source: Metrolinx, 2017

This analysis shows that in both projected minimum and expected scenario trips will be increased by 29% and 55% respectively in the GTHA by 2041. Similarly, this project will accelerate transit trips within Toronto, and between Toronto and the rest of the GTHA. Thus, it is expected that this public transit increase will positively enhance economic development, educational activities and industrial development within this region. The functioning of the proposed electrified rail system is shown in Fig. 9 below.



Source: Metrolinx, 2017

Fig. 8. Effect of increased travel trips on different areas of the region



Source: Metrolinx, 2017a

Fig. 9. How the proposed electric rail system will work

4.2.6 Electrification and GHG emission reduction

It is common knowledge that combustion engines emit a huge amount of GHG in the atmosphere. According to the U.S. Environmental Protection Agency (EPA) (2018), a passenger vehicle can emit 4.6 mt CO_2/yr. That EPA study indicates that the CO_2 emission/liter of gasoline is about 7,631 gm, CO_2 emission/liter of diesel is about 55,523 gm and CO_2 emission/km is about 251 gm (EPA, 2018). Electric trains can reduce GHG emissions, although it is not a zero-carbon technology as the emission reduction depends on the source of the electricity used. Table 11 presents a scenario of emission avoidance by different electric rail networks.

Table 11. Emissions avoided by passenger rail systems.

Rail System	Avoided Emissions (t CO_2/year)
MTA-New York	15,000,000
Los Angeles Metro	12,997,000
RENFE-Spain	2,460,488
Lisbon Metro-Portugal	130,275
Porto Metro-Portugal	46,996
Sao Paulo Metro-Brazil	820,000
California High Speed Rail Project	1,150,000
LGV Mediterranean Project	237,000
HSR-4500 km-France Project	1,000,000
Bangalore Metro-India Project	2200

Source: Andrade and D'Agosto, 2016

Andrade and D'Agosto (2016) show that in Rio de Janeiro, a new electric rail system has been able to avoid 866 TJ of non-renewable energy/yr and 55,449 t CO_2 /yr. With regards to passenger kilometer (pkm) avoidance, it is about 0.70 MJ/pkm non-renewable energy and 44.53 gCO2/pkm.

Electric trains do not emit GHG from their locomotives, but GHG emission can occur at the electricity generation sources. By electrifying larger sections of the GO Transit rail network, greater GHG reductions can be achieved. Electrifying the entire network would deliver a 94%

reduction in GO Transit's future GHG emissions, although this reduction would only be a small fraction (0.32%) of the overall region's emissions (Metrolinx, 2010).

4.3 Electric Vehicles as a Strategy to Decarbonize

4.3.1 A brief review on electric vehicle (EV)

Ontario needs serious steps to cut-off GHG emissions of its transportation sector because we know that this sector is the largest contributor of GHG emissions of the province. Therefore, electrification of the transport sector (i.e., rail, bus and cars) has immense roles in reducing GHG emissions in Ontario. Battery Electric Buses (BEBs) can be a viable transit option that if properly designated, can be environmentally sound, socially desirable and economically feasible. BEBs and its technological progression have been an increasing development in the context of climate change mitigation, GHG emission reduction, and air pollution caused by traditional transportation modes (internal combustion engine operated vehicles). BEBs can be defined as an 'environmentally competitive resource and energy efficient urban transportation means' that uses an electric motor powered by energy stored in rechargeable batteries (Laizāns et. al., 2016; Kontou & Miles, 2015). BEBs produce low noise and are very powerful during start up and acceleration (Kühne, 2010). In recent years, BEBs with zero emission or clean technology are getting global attention as sustainable transportation systems for better environment and human health.

Research and demonstration trials on EVS are gaining an increasing momentum worldwide. Six of the ten major car companies that show commitment to electrification of their vehicle lines are Chinese (Barnard, 2017), which includes BYD, SAIC, FAW Group, Geely, BAIC and Dongfeng. In 2016, BYD became the largest manufacturer of electric vehicles in the world. *ZeEUS* (Zero Emission Urban Bus System) and *Electricity* lead by the European Commission, *Electricity*- a Swedish initiative is advancing EVs technological development in Europe (Appendix A shows a detailed list of European cities that have electric buses running for demonstration and trials with the bus and route information). In the USA, Foothill Transit, King County Metro, StarMetro, Chicago Transit Authority and the Port Authority of Allegheny County, Pennsylvania are leading EV technological advancement through field trials. In Canada, Winnipeg Transit, Societe de Transport de Montreal, Edmonton Tran*sit*, Alberta Transit and CUTRIC (Canadian

Urban Transit Research and Innovation Consortium) are devoted to the technological progression of EVs by conducting research and demonstration trials.

I already discussed that the use of BEBs is growing at an accelerated rate in China, Europe, and North America. The stock of BEBs doubled in 2016 (345,000) compared to its number in 2015 (OECD/IEA, 2017). China is the lone developing country currently leading the global share of BEBs (343,000) followed by Europe (1,273) and USA (200). It is expected that the global sales for BEBs will grow at a rate of 33.5 % per annum during the period 2017- 2025 (ZeEUS, 2017).

4.3.2 Economic viability and sensitivity of BEB interventions

Apart from the technological development, it is important to highlight BEB's economic efficiency, especially the financial parameters which are sensitive or critical in BEB's total cost before its large-scale commercial application. Buyers have two contrasting considerations for choosing electric cars and battery electric buses; still today electric cars are being purchased by the early adopters mainly for environmental considerations and investments are required by the transit agencies for introducing BEBs in commercial applications. There have been a substantial number of studies conducted so far to compare the economic feasibility of electric vehicles (EV)s as opposed to internal combustion engine (ICE) vehicles (Inderbitzin, and Bening, 2015; Tseng et. al., 2013). Laizāns et. al. (2016) through their research on the economic viability of electric public buses (Table 12) concluded that with current technologies and benefits from electric buses do not cover the additional costs due to battery replacement costs. However, electric public bus operation expenses are substantially less than the ones for a diesel bus. With the proper choice of electric energy supply tariff plans and GHG emission control considerations, BEBs are economically much superior to diesel buses.

Nurhadi et.al. (2014) conducted interesting research to see which factors are most sensitive to the total cost of ownership (TCO) comparing two BEBs with different specifications, bus A (with 1 extra battery and 2 normal chargers) and bus B (with 1 extra battery and 2 fast chargers) and found that line distance (km/yr) is the most sensitive factor to the TCO followed by operational year, investment costs including battery, maintenance costs and helping maintenance/yr, energy costs/yr, extra battery costs, normal chargers costs and carbon taxes/yr. Percentage changes (either

Table 12. Cost comparison between Diesel Bus (DB) and Battery Electric Bus (BEB)

Costs	Investment (EUR)		Annuity (EUR)		Per km (EUR)		Remarks
	DB	BEB	DB	BEB	DB	BEB	-Life span of 12 yrs -Driving range 100000 km/yr. -Discount rate 1.16 %
Initial investment	33,2493	550,000	49,726	82,256	0.50	0.82	
Battery replacement	×	369,208	×	55,217	0.00	0.55	
Energy costs	×	×	60,000	8,648	0.60	0.09	
External costs	×	×	×	×	0.00	-0.04	
Total					1.10	1.42	

Source: Laizāns et. al., 2016

increase or decrease) of the factor costs and how these changes are sensitive to each factor for bus A and bus B are shown in Table 13. This study concludes that the percentage change of line distance (km/yr), operational years, and investment cost would be the most sensitive and significant factors on total cost of ownership (TCO) of bus ‘A’ or ‘B’.

4.3.3 Battery Electric Buses (BEBs) promotion

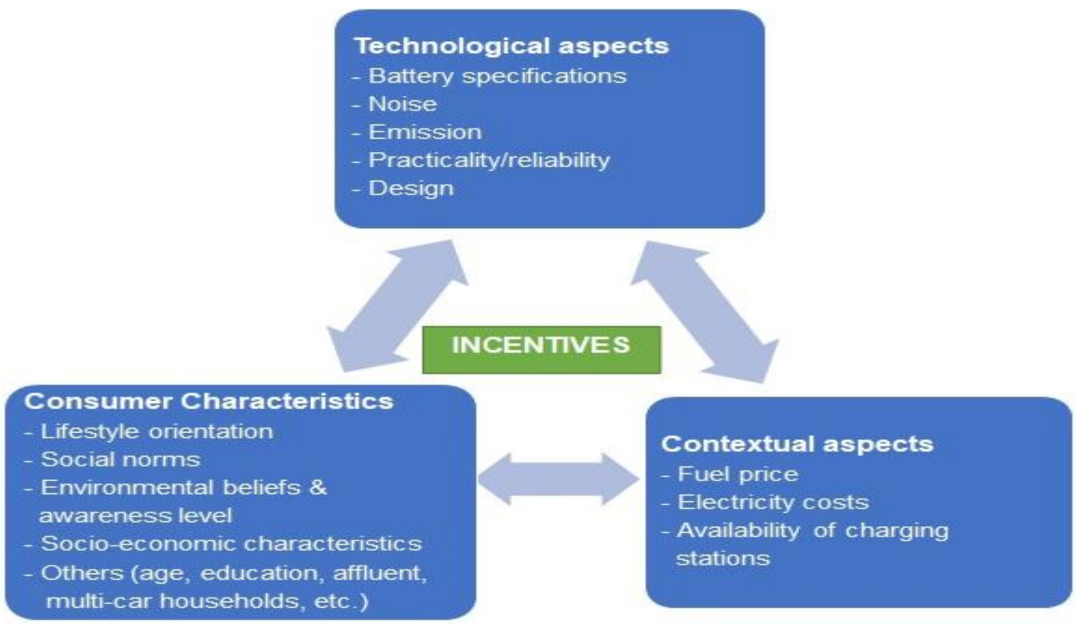
Widespread adoption of any technological innovation is the most challenging part faced by innovators. Because of socio-economic and cultural differences, every person develops an independent identity. Acceptance of BEBs by transit agencies involve huge political, cultural and economic decisions. Technological adoption largely depends on the attributes of the technology and its proponents. Sierzuchula et.al. (2014) identified three major aspects i.e., technological aspects, consumer characteristics and contextual aspects for adopting a technology. Further elaboration of these aspects is shown in Fig 10 below. In addition to these basic attributes mentioned in Fig. 10, incentives and promotion play significant roles in adoption and diffusion of a technological innovation. There are narratives for different kind of incentives applicable to different situations and subjects. For example, incentives can be regulatory, economic, persuasive and organizational (Kley et. al., 2012); it can be direct, indirect, disincentives and other (Jin et.al.,

2014) and it can also be command and control, economic, procurement, collaborative, communication, and diffusion incentives (Leurent and Windisch, 2011).

Table 13. Total Cost of Ownership (TCO) of two electric bus configurations

Most influential factor	Percent (%) change	Percent (%) change in TCO of bus A	Percent (%) change in TCO of bus B
Future Investment	+(10-30)	5–14	5–13
Travel line distance	-(10-30)	13–30	12–30
Operational year	+(10-30)	8–34	7 –33
Energy cost	+(10-30)	2–4	0–3
Maintenance	-(10-30)	2 –5	2 –5

Source: Nurhadi et.al., 2014



Source: after Sierzuchula et.al., 2014

Fig. 10. Typology of adoption of technology

As EVs are not traditional vehicles, it requires innovative production and good marketing strategy so that the producer, financer and customers can all participate in a win-win situation (Chan, 2002). Electronic and print media can play a big role on creating mass awareness about BEBs by highlighting their role in climate change mitigation and public health safety. Federal and provincial subsidies to the public and transit agencies for electric vehicles will play a catalytic role in promoting this eco-friendly electro-transit technology.

4.3.4 Development of Autonomous Vehicles (AVs)

Electric car manufacturers are leading the development of AVs. We need to find alternative energy sources preferably renewable energies and other clean energies. Self-driving automobiles are no longer a myth. With the advent of technological advancement, AVs run by 100% renewable energies can help reduce vehicular GHG emissions. Most of the car producing companies are investing in research, development, testing and promotion of autonomous cars. Honda Motor Co., Delphi Automotive PLC and Nvidia Corp. are actively involved in promoting automated vehicles in the North American Market. Table 14 shows the estimated timeline of major automobile industries to release various levels of autonomous vehicles in upcoming markets. Table 15 indicates that by 2050s autonomous technologies will be available in 80-100% of the cars and the market saturation point will be reached by the 2060s.

Zon and Ditta (2016) believe that the arrival of automated vehicles has potentially transformative implications for a wide range of policy areas in Canada. Despite this promise of development, there is a lot of uncertainty among the public about AVs too. The Insurance Institute of Canada (IIC)'s study (2016) reveals that more than 73% of respondents believe that the introduction of self-driving vehicles will be difficult for the insurance industry. 46% of respondents believe that the industry is not prepared for the expected change in the frequency and severity of collisions. A survey conducted on AVs by the insurance industry shows that 25% of the respondents are ready to adopt AVs technology, 23% are against AVs and the rest 52% have not decided yet about AVs (IIC, 2016).

Table 14. Timeline for various levels of AVs production

Sl	Cars	Timeline				Remarks
		Level 2	Level 3	Level 3 Plus	Level 4	
1	Audi	2016-17	2018	2020-1	Late 2020s	-
2	BMW	2016	-	-	2021	-
3	Ford	2019	-	-	2012	Level 2 will be the same as Level 3 of Audi
4	Honda	2016	2020	-	Late 2020s	By 2040 Honda aims no crash in Honda or Acura vehicles
5	KIA	-	2020	-	2030	-
6	Mercedes-Benz	2016	-	-	2020-21	-
7	Nissan	2016	2018	-	2020	-
8	Tesla	2015	-	-	2018	-
9	Volvo	2016	-	-	2017-20	-

Source: Web. N.d$_{a.}$ http://mashable.com/2016/08/26/autonomous-car-timeline-and-tech/#G76rBbruDEqD

Table 15. Fully self-driving vehicles implementation plan

Time line	New Car Sales (%)	All Vehicles (%)	**Remarks**
2020s	2 - 5	1 - 4	Available, expensive option
2030s	20 - 40	10 - 30	Available, moderate cost
2040s	40 - 60	30 - 50	Available, minimal cost
2050s	80 - 100	50 - 80	Standard on most cars
2060s	80 - 100	80 - 100	Saturation

Source: Insurance Institute of Canada (IIC), 2016

4.3.5 Challenges of BEB technology and optimization of charging

The case studies presented in the following section indicate that BEBs should be adopted by different transit organizations. However, mass-scale commercial application of BEB technology requires optimum solutions to the following challenges:

a. Range anxiety (fear of being stranded)
b. En route recharging time and recharging stations
c. The reliability of BEBs in field operation
d. Huge initial investment for BEBs

A good and comprehensive network of charging stations is crucial for electric vehicle operation. The transition process from conventional diesel to electric buses faces major hurdles caused by range limitations and required charging times of battery buses. These issues are associated with problems like scheduling of battery buses, fleet composition, and the optimization of charging infrastructure along with investment and operational cost optimization. Studies like Li (2016) and Nykvist & Nilsson (2015) show that the higher up-front investment costs of the BEBs can be compensated by reduced operational costs as with decreasing battery system costs. Hence, BEBs can become comparable with diesel operated buses. Lithium-ion batteries of certain capacities along with the fleet mix in electric vehicle scheduling (EVS), fleet size, and the optimization of charging infrastructure will be the main determinants for minimizing TCO of the BEBs, which is crucial to ensure their widespread adoption

4.4 Emerging Issues

Based on the above review and analysis on GHG emissions reduction and electrification of GTHA RER system, this study identifies the following issues for further development and actions:

a. It is found that the Federal government of Canada is very much lacking behind (currently paying only at the rate of $800 million/yr instead of $1460 million/yr which is just the half of the committed amount) in international funding for the global climate change mitigation program known as ‘Road Map to $100 Billion’ fund. Canada being a global environmental leader should honour its international commitments.

b. The Federal government has very little control over the provincial governments in climate change affairs, which results in widely different climate change mitigation standards and programs across all the provinces/territories. Both better administrative and financial coordination between the Federal government and the provinces/territories are essential for effective climate change mitigation strategies.

c. It was discussed earlier that Canada's emissions have increased significantly, especially in the Transportation and the Oil and Gas exploration sectors. However, the Federal government's plan, which is known as 'The Pan-Canadian Framework', regrettably does not focus on these two major contributors of emissions. Although regarding oil and gas exploration, the current Federal government has proposed strict methane emission policies starting in 2018, unfortunately has pushed it back for three years as a result of pressure from the industries. Furthermore, the Federal government has recently purchased an expensive oil pipeline. This controversial fossil-fuel expansion program is going against Ontario's climate change mitigation planning.

d. Regarding Ontario's GHG emissions reduction and efforts for transforming to a low-carbon economy, it was found that under existing regulatory mechanisms, it would be nearly impossible to achieve 2020, 2030 and 2050 emission reduction targets.

e. Recent political changes in Ontario and the Premier's anti-climate political agenda are most likely to increase GHG emissions and stop the transformation process to a low-carbon economy in Ontario. The newly elected Progressive Conservative (PC) government has already abandoned the current energy policy favouring renewable energy and energy efficiency, which will adversely affect decarbonisation of the Province. The government has also proved their strong apathy towards climate change at the very first instance by abolishing 'Climate Change' from the name of the *Ministry* of the *Environment* and Climate Change and by pledging to eliminate the 'Carbon Cap and Trade' market. In short, it is already evident that the newly elected government does not support climate action. If it continues like this, Ontario's Climate Change Action or Ontario's Climate Change Mitigation and Low-carbon Economy Act will probably become eliminated from Ontario.

f. 100% renewable energy is the ultimate goal for transforming into a low-carbon economy. Cancellation of all wind and solar contracts by the newly elected government nullify that goal and signal that the Ontario Climate Change Mitigation and Low-carbon Economy Act is at severe risk.

g. Metrolinx's intervention in electric vehicles and electrification of the rail system in the GTHA are great initiatives, although the progress is rather slow. Although such changes are very capital intensive, in the long run, they will be appreciated by all transit users. We have seen huge technological development on EVs, at the same time, various technical aspects are yet to be examined for road safety. Charging stations and the source of the electricity are key issues for EVs and BEBs that need to be understood widely. The economic efficiency of BEBs are satisfactory considering emission and noise reduction benefits, and overall comfort for users and citizens. Large initial investment for infrastructure development of BEB and electrification of rail is also a major concern that requires optimum solutions. It is also found that the proposed electrified RER can enhance wider, faster and safer connectivity among the nodes and corridors of the GTHA, which result in an economic development in this region. This development will encourage new housing and working locations to be built closer to public transportation nodes.

CHAPTER 5: CONCLUSION & RECOMMENDATIONS

Canada has manifested a strong international commitment in climate change mitigation. Each Province/Territory has set their own GHG emission reduction targets. Ontario, until today, was proactive in GHG emissions reduction and enacted laws and rules expressing strong interest to lead in climate change mitigation nationally and globally. Based on the review and analysis of Ontario's GHG emission targets and transportation strategies as a remedy for emissions reduction, this study has identified some crucial issues. Below I conclude with key suggestions for concerned professionals, academia and policymakers.

5.1 Canada

a. As Canada aims to meet the Paris Agreement, it requires to cut out emissions from the oil/gas and transportation sectors. The transportation sector should adopt and follow an integrated procedure to reduce emissions. In this regard, the Federal government should follow the footsteps of leading European countries that are advancing electric vehicles technologies. A complete ban on internal combustion engines and introducing low/zero carbon technology in transportation and the oil sector would be an ideal option.

b. All emission reduction targets across Canada should be based on 1990 levels instead of 2005. Without considering this 1990 emission level, Canada will be out of step with other countries. To keep global warming well below 2^0C, the Federal government should introduce legal instruments introducing uniform standards for climate change mitigation programs and policies across Canada.

c. Every province in Canada is rich with environmental opportunity for renewables, whether they be photovoltaics, wind power or hydroelectric. A transition to renewables such as wind and solar as opposed to oil or nuclear will lead to emission reduction and they will ensure that our communities are environmentally safe. Fully agreed commitments should be made for transformation to 100% renewable energy by every Province and Territory to create new jobs and economic activity.

d. Although the Federal government emphasizes to work with provincial governments, it lacks of specific targets, control and coordination. Solely relying on the provincial governments may cause a failure to fulfill the national emission reduction target. Therefore, clear and legitimate climate change mitigation programs should be implemented jointly by the Federal government, the provinces and territories. This can be enhanced through the carbon pricing systems imposed by the Federal government that should be followed by all the provinces and territories.

e. Canada is now paying only half of the committed funding for global level climate change mitigation measures. Therefore, the Canadian government must adjust its climate financing to reach its fair share of commitment to the 'Road Map to $100 billion' fund by 2020.

5.2 Ontario

a. Under current regulatory mechanisms, it is nearly impossible to fulfill Ontario's GHG emission reduction target for 2020, 2030 and 2050. Transportation, buildings and industries are the major contributors of GHG emissions. And without 100% renewable energy targets, GHG emission reduction is not achievable. The Ontario government should adopt new policies that favour community-based projects for renewable energy using solar, wind, hydro, bio-fuel, biogas and hydrogen fuel cell technologies to transform Ontario into a zero carbon/low carbon economy.

b. Political change is now a major obstacle to put forward climate change mitigation programs. A systemized change should be brought up among the political parties and leaders through mass campaign, environmental activism, community awareness and peoples' voices. Socio-cultural change towards climate change mitigation and environmentally friendly interests should be developed through formal, informal and non-formal education.

c. Electric vehicles, autonomous vehicles and the electric rail system are indispensable to reduce GHG emissions of the transportation sector. Although electrification of public transit system requires huge investment, considering long-term economic, social and environmental gains and low operation and maintenance cost, Metrolinx's programs should be expedited through federal and provincial funding.

d. Private car use should be discouraged by introducing fast, frequent, and safe transit technologies. At the same time, installation of solar energy in home and offices and purchasing electric cars for individual uses should be incentivised to reduce GHG emissions. Integrated long-term eco-friendly approaches in the public transit sector, industrial sector and real estate sector will eventually lead us to transform into a low-carbon society; a place that is better for all; thanks to the multiple benefits that will result from addressing climate change.

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APPENDIX

Appendix A. List of European cities with electric buses and detailed information about these buses and route

Country	City	Vehicles		No	Energy (kWh)	Charging at Terminal		Charging at Selected Stops		Charging at Depot		Max Passengers	Operation Hours /Day	Route Length (km)	Total km/day
		Brand	Model			Method	Time (min)	Method	Time (min)	Method	Time (h)				
Austria	Graz	Chariot Motors	Ebus	2	32	Pantograph	0.5 - 2	Pantograph	0.5-2min	Plug	0 - 2	90	15	3.5	203
		CRRC	Articulated bus	2	49	Pantograph	0.5 - 2	Pantograph	0.5-2min	Plug	0 - 2	135	13	3.5	188
	Klagenfurt	Solaris	Urbino 8.9 LE electric	1	120	N/A		N/A		Plug	4	51	4 - 4.8	7.5	110
Belgium	Bruges	Van Hool	A308 citybus	3	36.4	Induction	12	N/A		Plug	2.5	55	10	5.5	50 - 60
Bulgaria	Sofia	Higer	Chariot e-bus	1	21 - 32	Pantograph	5 - 6	N/A		Pantograph	0.1	91	8.5	11.2	88
Czech Republic	Plzen	Škoda	PERUN HP	2	75	Articulated Arm	7	N/A		Plug	5	82	7.5 - 18.5	6	80 - 200
	Prague	SOR	EBN	1	172	Pantograph	10 - 30	N/A		Plug	1 - 6	93	18	22 - 35	265 - 340
Denmark	Copenhagen	BYD	K9	2	324	N/A		N/A		Plug	5	61	7 - 12	9.1 - 10.8	210 - 260
Germany	Berlin	Solaris	Urbino 12 electric	4	230	Induction	5	Induction	5	Plug	4	87	22	6	168
	Bad Langensalza	Bozankaya	Sileo S10	1	230	N/A		N/A		Plug	8	66	12	4.6	200
	Bonn	Bozankaya	Sileo S12	6	230	N/A		N/A		Plug	5.5	80	13	17.2	200
	Braunschweig	Solaris	Urbino 12 electric	4	200	Induction	6 - 8	Induction	6 - 8	Plug	4 - 6	78	18	12	250

		Solaris	Urbino 18 electric	2	200							123			
	Bremen	Bozankaya	Sileo S12	1	230	N/A		N/A		Plug	2	79	10.5	30	300
	Colongne	VDL	Citea SLF-180 Electric	8	123	Pantograph	8 - 15	Pantograph	8 - 15	Pantograph	5 - 7	139	18	6.7 - 7.0	120
	Eberswalde	Solaris	Trollino 18	1	120	Articulated Arm	22	Overhead wires		N/A		146	18	18	250
	Hamberg	Volvo	7900 Electric	4	100	Pantograph	8	Pantograph	8	Plug	3 - 6	73	20	13.4	40 - 250
	Mannheim	Hess	Swisstrolley	2	60	Induction	0.5 - 4	Induction	0.5 - 4	Induction	0.25	80	15	4.5	190
	Münster	VDL	Citea SLF-120 Electric	4	62.5	Pantograph	5	N/A		Plug	3	80	14	10	200
	Oberhausen	Solaris	Urbino 12 electric	2	200	Pantograph	10	Pantograph	10	Plug	5	70	11.5 - 18.25	13.3 - 15.6	170 - 300
	Stuttgart Airport	Cobus Industries	eCobus 3000	6	85	N/A		N/A		Plug	1.5	120	17		90
Estonia	Tallinn	Volvo	7900 Electric Hybrid	24	1.2	N/A		N/A		Plug	6.5	84	1.1 - 1.2	18.1 - 19.7	221 - 249
Finland	Turku	Linkker	13 LE-D	6	55	Pantograph	3	N/A		Plug	3	68	18	12.6	350
France	Gaillac	Safra	Businova Midibus	1	135	N/A		N/A		Plug	5 - 6	53	6	10	100
	Marseille	Irizar	i2e	6	339	N/A		N/A		Plug	5 - 7	64	14 - 16	5.5	141
	Nice Airport	Heuliez	GX 337 ELEC	1	N/A	N/A		Articulated Arm	0.3	Plug	2	107	9	3.9	200
	Paris	Bollore	Bluebus 12m	23	240	N/A		N/A		Plug	5	90	14	10	180
Hungary	Budapest	evopro	Modulo C68e	20	141	N/A		N/A		Plug	1.5 - 5	53	12.3	1.5 - 6.1	128
	Szeged	Ikarus-Skoda	Tr187.2	13	81	N/A		Overhead wires		Plug	not used	125	18 - 19	9.2 - 15.8	117 - 237
Italy	Cagliari	Solaris	T12	2	37	Pantograph	8 - 10	Overhead wires		N/A		82	2 - 3 winter, 7 - 9 summer	17.1 winter, 25.6 summer	180 - 220
		Kiepe Van Hool	A330T	4	23					N/A		86			

Israel	Tel Aviv	BYD	K9A	1	324	N/A		N/A		Plug	5	58	14	18	160
Netherlands	Rotterdam	VDL/e-Traction	Citea	2	100	N/A		N/A		Plug	8	59	2.8	12	200
	Schiermonnikoog	BYD	K9	6	220	N/A		N/A		Plug	5	70	Not available		
	Schiphol Airport	BYD		35	216	N/A		N/A		Plug	3.5	65	19	0.9	120
	s-Hertogenbosch	Volvo	7700	1	120	N/A		Induction	2	Plug	6	86	12	5.3	280
		VDL	Citea SLF-120 Electric	10	120	N/A						79		5	100 - 150
	Utrecht	Optare	Solo EV	3	86	N/A		Induction	3 - 5	Plug	2	55	18	5	140
Poland	Inowroclaw	Solaris	Urbino 12 electric	2	201	N/A		N/A		Plug	2 - 5	70	23	7 - 14.2	84 - 168
	Jaworzno	Solaris	Urbino 12 electric	1	160	Pantograph	60	N/A		Plug	1.5	80	18	16	250
	Krakow	Solaris	Urbino 12 electric	1	210	N/A		N/A		Plug	4	71	13	12.4	192
			Urbino 8.9 LE electric	4	80	N/A		Pantograph	20			49	11	11.8	146
	Lodz	Solaris	Urbino 12 electric	1	120	Plug	2	N/A		Plug	4	70	6.5	7.3 - 9.9	100
	Lublin	Ursus Ekovolt	E70110	1	120	N/A		N/A		Plug + Pantograph	1 - 6	80	7	12	110
		Ursus	T70116	38	13.6	N/A		Overhead wires		N/A		75	18	12	223
		Solaris	Trollino 18	12	38	N/A		Overhead wires		N/A		125	18	11 - 15	188 - 280
	Rzeszow	Ursus Ekovolt	E70110	1	170	N/A		N/A		Plug	3	80	8 - 9	9.5	120
		Solaris	E12 Solaris Ubino-Medcom	1	210	N/A		N/A			5				
	Warsaw	Solaris	Urbino 12 electric	10	208	Pantograph		N/A		Plug	2 - 5	70	16	10	160
		BYD	K9	6	324	N/A		N/A				60	15 - 17		170 - 200

Romania	Bucharest	SOR	EBN 10.5	1	172	N/A		N/A		Plug	7	85	7 - 12	22.4	114 - 187
		BYD	K9	2	324	N/A		N/A			6			23.5	
Serbia	Belgrade	Higer	KLQ6125 GEV3	5	20	Pantograph	5 - 10	N/A		Pantograph	0.5 - 0.7	81	18	8	185
Slovakia	Kosice	SOR	EBN 10.5	9	120	Plug	180	N/A		Plug	3	80	8	30 - 35	120
Spain	Barcelona	Irizar	i2e	2	352	N/A		N/A		Plug	5 - 6	75	12 - 15	6.4 - 12.5	130 - 180
		BYD	K9	1	324	N/A		N/A			5 - 6	75			
		Solaris	Urbino 18 electric	2	125	Pantograph	6 - 8	N/A			2.5	115			
	San Sebastián	Irizar	i2e	3	340	N/A		N/A		Plug	7	75	15	13.2	150 - 200
	Madrid	Castrosua	Tempus	13	72	N/A		N/A		Plug	4	64	4.8 - 6.4	6	210
	Valladolid	Vectia	Veris 12 Hubrid+	5	24	Pantograph	3 - 5	N/A		N/A		85	5.3	6	160
Sweden	Ale Municipality	Optare	Solo EV	1	150	Plug	180	N/A		Plug	6	49	10	5	80
	Angelholm	BYD	K9-13C	5	292	N/A		N/A		Plug	4.5	70	13	7.1 - 14.2	250
	Eskilstuna	BYD		2	280 - 330	N/A		N/A		Plug	3	72	11		250
	Gothenburg	Volvo	10m prototype	3	76	Pantograph	3 - 6	Pantograph	3 - 6	Plug	4	76	10	8	156
			7900 Electric Hybrid	7	76							70	13		
	Orust	Optare	Solo SR EV	1	92	N/A		N/A		N/A		49	9	50	150
		Ebusco	2.0	1	311	N/A		N/A		N/A		90			400
		BYD		1	220	N/A		N/A		Plug	8	87			250
	Stochholm	Volvo	7900 Electric Hybrid	8	19	N/A		Pantograph	6	Plug	2	71	10.9 - 12.5	7	100
	Umea	Hybricon Artic	HAW 12 LE	6	80	N/A		Pantograph	3 - 5	Plug	4	65	18	14 - 16	250 - 260
			HAW 18 LE 4WD	3	80	N/A						100			

		Whisper													
	Vasteras	Solaris	Urbino 12 electric	1	160	Plug	60	N/A		Plug	2	65	9	12.3	100
Switzerland	Geneva	TOSA	Articulated bus	1	40	Articulated Arm	5	Articulated Arm	0.3	Articulated Arm	0.5 - 0.7	133	8	1	30
		Van Hool	Exqui.City 18T	33	28	N/A		Overhead wires		battery cells balancing	0.25 - 0.5	131	6	10	10
UK	Inverness	Optare	Solo EV	6	150	Plug	60	N/A		Plug	6	49	10 - 12	39	160
	London	BYD	K9A	2	324 - 350	N/A		N/A		Plug	6	60	11.2 - 12.8	9 - 11	150 - 250
		BYD/ ADL	Enviro200 EV	51	324	N/A		N/A			6	86			
		BYD	K8SR	5	324	N/A		N/A			6	87			
		Optare	Metrocity EV	13	92	N/A		N/A			8	60			
		Irizar	i2e	2	282	N/A		N/A			6	60			
		ADL	Enviro200 EV	3	60	Induction	10	N/A			8	83			
	Manchester	Optare	Versa EV	3	95	Plug	120	N/A		Plug	6	57	12	6	150
	Nottingham	Optare	Solo EV	35	95	Plug	120	N/A		Plug	6	43	15	24	100
			Versa EV	10	95		420	N/A				57	8.2	19.7	

Source: European Automobile Manufactures Association, 2017