Policy Recommendations for Accelerating the Charging Infrastructure of Electric Vehicle in Canada

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Abstract

Electric vehicle (EV) has great advantages in environmental, economic, and energy benefits. However, lacking of charging infrastructures is one of the most pressing challenges for developing EVs in Canada. In order to address this challenge, this thesis devises three policy options for policy makers and other stakeholders. Furthermore, by employing the Analytic Hierarchy Process (AHP) approach, this thesis sets up an assessment matrix to measure potential outcomes of policy options. Based on the results of assessment, policy recommendations are put forward to boost the development of charging infrastructures of EVs in Canada.
## Contents

Introduction ......................................................................................................................... 1

1. Status quo of Electric Vehicle (EV) and Charging Infrastructure across the World...... 2
   1.1 Main drivers of EV ................................................................................................... 2
   1.2 Overview of charging infrastructures across the world ............................................ 3

2. Development and Expected Targets of EVs and Refilling Infrastructures in Canada.... 4
   2.1 Commitment of Canadian government .................................................................. 4
   2.2 The expected target of EV in Canada ..................................................................... 5
   2.3 The current situation of EV and its charging infrastructure in Canada .................... 6

3. Problem to Be Addressed............................................................................................... 8
   3.1 Problem definition ................................................................................................. 8
   3.2 Stakeholders’ analysis ........................................................................................... 9

4. Literature review ......................................................................................................... 10

5. Objects and Approach ............................................................................................... 12
   5.1 Policy objective ..................................................................................................... 12
   5.2 Evaluation criteria ................................................................................................. 12
   5.3 Methodology ....................................................................................................... 13

6. Policy options............................................................................................................. 15
   6.1 Option 1: Government-owned agency leading model .......................................... 15
   6.2 Option 2: Private charging service company leading model ............................... 17
   6.3 Option 3: “to be a smart follower” model ......................................................... 18

7. Evaluation and Decision Analysis ............................................................................ 19
   7.1 Evaluation of efficiency ....................................................................................... 19
   7.2 Evaluation of equity ............................................................................................ 20
   7.3 Evaluation of sustainability .................................................................................. 21
   7.4 Decision analysis .................................................................................................. 22

8. Recommendations....................................................................................................... 24

9. Conclusions .................................................................................................................. 26

Reference .......................................................................................................................... 28

Acknowledgment .............................................................................................................. 30
Table List

Table 1 Levels of EV Charging infrastructures ................................................................. 3
Table 2 Incentive projects by countries ............................................................................ 4
Table 3 Electric car stock targets to 2020 based on country commitments .................... 6
Table 4 Overview of incentive programs sponsored by the governments in Canada ........ 7
Table 5 Ranked intensity of importance ....................................................................... 13
Table 6 Explanation of Sub-criteria in Assessment Matrix ............................................. 14
Table 7 Priorities of general criteria ............................................................................. 15
Table 8 Global priorities of sub-criteria ....................................................................... 15
Table 9 Federal financial incentives for charging infrastructures (budget) ..................... 19
Table 10 Range of some EV models ............................................................................. 21
Table 11 Assessment of policy options ....................................................................... 23

Figure List

Figure 1 GHGs Emissions by Sectors in Canada .......................................................... 5
Figure 2 the Structure of Assessment Matrix .............................................................. 14
Figure 3 Charging events by locations ......................................................................... 16
Figure 4 Standards of charging systems ..................................................................... 22
Figure 5 Marks of policy options .............................................................................. 24
Introduction

Mitigating the challenge of climate change is a serious issue for human society [1]. Transportation sector should be a major contributor to reduce our dependence on fossil energy and limit global warming [2]. As one of the most potential technical pathways in transportation sector, EV provides us with great advantages in economic, environmental, and energy benefits. However, lacking of sufficient charging infrastructures is an unavoidable barrier for developing EVs across the world.

In order to effectively address this issue in the context of Canada, this thesis briefly reviews achievements in the field of charging infrastructures across the world. Then, based on experience from other jurisdictions, three policy options have been formulated in terms of mainstream charging technology, organization system, and costs. They are 1) government-owned agency leading model, 2) private charging company leading model, and 3) “to be a smart follower” model. Then, in order to evaluate the potential outcomes of policy options, a sound assessment approach is built up to help stakeholders make the decision analysis. In this thesis, efficiency, equity and sustainability are selected as the main criteria. Then, according to expert opinions, each main criterion is endowed with two sub-criteria to set up a two-tier assessment system. Here it is should be emphasized that an analytical approach, called as Analysis Hierarchy Process (AHP), is embedded into this assessment matrix. It is a valuable attempt of this thesis to score outcomes of policy options by the combination of AHP and assessment matrix. Results of assessment show the government-owned agency leading model has more advantage to increase the amount of charging infrastructures in the initial stage of EVs.

Finally, this thesis suggests that a mixed policy portfolio be a better choice for Canada. In the near term (before 2020), the government-owned agency leading model will be recommended, because it could boost the quantity of charging infrastructures more efficient and economic, which is vital for EVs in the initiative stage. In the medium term, if the technology development of batteries and charging equipment does not advance, option2 would be a better choice in the middle term (before 2030).
1. Status quo of Electric Vehicle (EV) and Charging Infrastructure across the World

1.1 Main drivers of EV

Mitigating climate change and reducing our dependence on fossil fuels are issues to which the international community has paid increasing attention. The 21st Conference of the Parties (COP21) held in Paris in December 2015 reinforced the urgent need to adopt concrete measures on an international scale to combat the threat of climate change. Emanating from COP21, the Paris Agreement, announced in December 2015, clearly laid out the objective to limit the global average temperature increase well below 2°C above pre-industrial levels [1].

The transport sector accounts for almost one quarter (23%) of global energy-related GHG emissions [2]. Thus, the ambitious GHG emissions reductions required to limit global warming to less than 2°C is unlikely to be achieved without a major contribution from the transport sector. Governments, science communities and industry have been seeking the technology solutions for several decades. As a result, a wide range of alternative fuel vehicles had been developed and deployed. This has occurred because these communities had devised the means by which to substitute conventional gasoline and diesel vehicles and in so doing match environmental necessities with environmental urgencies.

One of the most viable technology solutions developed thus far has been Electric Vehicles (EV, including Plug-in Hybrid Electric Vehicle and All-Electric Vehicle). Normally, EVs have better environmental, energy, and economic benefits than the conventional vehicles. Depending on the sources, the electricity has varied life cycle emissions. In some jurisdictions that use relatively low-carbon energy sources for electricity production, EVs usually have a life cycle emissions advantage over similar conventional vehicles running on fossil fuels [3]. Obviously, in terms of energy benefits, EVs can help us shift the transportation energy from fossil fuels to electricity derived from diverse energy sources. As for economic benefits, EVs could save the expenditures of transportation for the households by saving vehicle operation and maintenance cost [4]. Furthermore, a research by Berkeley University announced that a dollar saved at the gas pump and spent on other goods and services can generate a significant multiplier on jobs [5].

With their immense potential for conserving the energy, do so in an economically viable and environmental secure manner, EVs will play a key role in the field of transportation future [6]. By the end of 2015, 1.26 million EVs were on the road worldwide. This is a major achievement, highlighting the significant efforts deployed by governments, industry and the science community over the past ten years. By contrast, in 2014, only about half of the EVs on the road existed. As recently as 2005, EV could be measured in the hundreds [7].
1.2 Overview of charging infrastructures across the world

The development and proliferation of EVs must be accompanied with the construction of charging infrastructures. Nowadays, three kinds of charging technology models have been adopted worldwide [8]. They are AC Level 1, AC Level 2 and Direct Current Fast Charging (DCFC). (See Table 1) Depending on the charging model, the charging time can range from 20 minutes to 24 hours. This is mostly due to the cost of the equipment. Common private EV customers would generally select Level 1 or Level 2 as the most convenient charging models. Level 1 uses a standard 120V AC plug, which is commonly used in residential buildings. All EVs sold to consumers come with a Level 1 charging cord set. This allows owners to plug their EVs into common electrical outlets on the wall of their garages.

By comparison, AC Level 2 charging is also a convenient option for homes, workplaces, and other locations (such as corporate parking lots) where users wish to charge quickly during the daytime. However, Level 2 charging does require 240V or 208V electrical service, and it requires installation of specialized equipment.

Although the cost is expensive, generally several thousand dollars per unit plus additional installation and infrastructure costs, DCFC provides a significant advantage insofar as it offers the ability to charge EVs in a very short timeframe [8].

Table 1 Levels of EV Charging infrastructures

<table>
<thead>
<tr>
<th>Charging</th>
<th>voltage (V)</th>
<th>kW</th>
<th>Charging time *</th>
<th>application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>120</td>
<td>1.1</td>
<td>8~12 hours</td>
<td>household</td>
</tr>
<tr>
<td>Level 2</td>
<td>240</td>
<td>3.3~6.6</td>
<td>3~5 hours</td>
<td>Household, workplace, and public space</td>
</tr>
<tr>
<td>Level 3</td>
<td>480~600</td>
<td>50</td>
<td>20 minutes or less</td>
<td>Urban public space, transportation corridor</td>
</tr>
</tbody>
</table>

*depend on the battery size and state of charge.

In order to support the development and proliferation of EVs, several countries have implemented heavily government-funded projects to stimulate the development of charging infrastructures [7]. (See Table 2)
Table 2 Incentive projects by countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Project name</th>
<th>targets</th>
<th>Current achievement (2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>EV projects</td>
<td>U.S. set a goal of 1 million cumulative electric vehicles by 2015 and is about a third of the way to that goal.</td>
<td>Level 1 and level 2: 28150; DCFC: 3524</td>
</tr>
<tr>
<td>Japan</td>
<td>2010 Next Generation Vehicle Plan</td>
<td>2 million standard chargers and 5,000 fast chargers across the country by 2020</td>
<td>By the end of February, 2016, 19,308 charging points have been established, including 12,426 Level 1 and level 2 charging points and 6,882 fast charging points.</td>
</tr>
<tr>
<td>Germany</td>
<td>National Electric Mobility Platform</td>
<td>950,000 charging points, including 150,000 public charging points and 7,000 fast charging stations.</td>
<td>Level 1 and Level 2: 4787; Public fast chargers: 784.</td>
</tr>
<tr>
<td>China</td>
<td>“National new energy vehicle strategy” and “The development guide for the charging infrastructure of EV”</td>
<td>Establish a comprehensive charging network which could meet the demand of 5 million of EVs in 2020, including: 4,000 charging stations for buses, nearly 2,500 for taxis, 2,500 for special vehicles, about 2,400 city public charging stations, 0.5 million public charge points, and about 850 intercity quick-charge stations</td>
<td>DCFC: 780. Level 1 and level 2: 31,000.</td>
</tr>
</tbody>
</table>

Source: Global EV outlook 2016

2. Development and Expected Targets of EVs and Refilling Infrastructures in Canada

2.1 Commitment of Canadian government

The Canadian federal government has articulated a firm intention that Canada will takes action to mitigate the effects of climate change. For example, in its Speech from the Throne, the government stated that Canada would achieve both in environmental protection and economy growth by boosting the clean technology and adopting other incentives to involve all stakeholders [9]. In addition, in 2015 the government announced in Paris that Canada will endorse ambitious targets to limit global warming.
to 1.5 degrees Celsius over preindustrial levels. Therefore, Canada has pledged to cut its emissions by 30 per cent from 2005 levels by 2030[10].

2.2 The expected target of EV in Canada

The transportation sector has been identified as one of the significant Green house Gas (GHG) emission sources in Canada [11]. (See figure 1) They have also indicated a belief that electrification will be one of the main methods of reducing GHGs while ensuring citizens maintain the levels of comfort and convenience they expect. They have also indicated that transportation system must be both efficient and sustainable.

![Figure 1 GHGs Emissions by Sectors in Canada](image)

The government of Canada believed that achieving the environmental, economic and energy benefits required immediate action and investment by both governments and industry. Based on this background, the Technology Roadmap of EV was released on March 3, 2106. In this industry-led, federal government coordinated document, an ambitious development target of EVs was articulated. It said,

“By 2018, there will be at least 500 000 highway-capable plug-in electric-drive vehicles on Canadian roads, as well as what may be a larger number of hybrid-electric vehicles. All these vehicles will have more Canadian content in parts and manufacture than vehicles on the road in Canada in 2008.” [12]

As a reference, several countries’ EV stock targets to 2020 are listed in Table 3. All these countries articulated their ambitious and inspiring targets; however, current
achievements are a little bit frustrating. Although these countries represent the main EV markets across the world, the EV shares in the total 2020 stock are extremely low [7].

Table 3 Electric car stock targets to 2020 based on country commitments

<table>
<thead>
<tr>
<th>Countries with announced targets to 2020 or later</th>
<th>2015 EV stock (thousand vehicles)</th>
<th>2020 EV stock target (million vehicles)</th>
<th>EV share in the total 2020 stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>5.3</td>
<td>0.2</td>
<td>4%</td>
</tr>
<tr>
<td>China*</td>
<td>312.3</td>
<td>4.6</td>
<td>3%</td>
</tr>
<tr>
<td>Denmark</td>
<td>8.1</td>
<td>0.2</td>
<td>9%</td>
</tr>
<tr>
<td>French</td>
<td>54.3</td>
<td>2</td>
<td>6%</td>
</tr>
<tr>
<td>Germany</td>
<td>49.2</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>India</td>
<td>6</td>
<td>0.3</td>
<td>1%</td>
</tr>
<tr>
<td>Ireland</td>
<td>2</td>
<td>0.1</td>
<td>3%</td>
</tr>
<tr>
<td>Japan</td>
<td>126.4</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Netherlands**</td>
<td>87.5</td>
<td>0.3</td>
<td>4%</td>
</tr>
<tr>
<td>Portugal</td>
<td>2</td>
<td>0.2</td>
<td>5%</td>
</tr>
<tr>
<td>South Korea</td>
<td>4.3</td>
<td>0.2</td>
<td>1%</td>
</tr>
<tr>
<td>Spain</td>
<td>6</td>
<td>0.2</td>
<td>1%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>49.7</td>
<td>1.6</td>
<td>5%</td>
</tr>
<tr>
<td>United States***</td>
<td>101</td>
<td>1.2</td>
<td>2%</td>
</tr>
<tr>
<td>Total of all market listed above</td>
<td>814.1</td>
<td>12.9</td>
<td>3%</td>
</tr>
</tbody>
</table>

Source: Global EV outlook 2016

Notes: * This target includes 4.3 million cars and 0.3 million taxis and is part of an overall deployment target of 5 million cars, taxis, buses and special vehicles by 2020 (EVI, 2016b).
** Estimate based on a 10% market share target by 2020.
*** Estimate based on the achievement of the 3.3 million EV target announced to 2025 in eight US states. All indicators in this table refer to the eight US states; market share and stock share are assumed to account for 25% of the total US car market and stock.

2.3 The current situation of EV and its charging infrastructure in Canada

Canada is confronted with similar shortfalls as those described in section 2.2. In recent years, layers of governments across Canada have deployed a wild range of incentives and demonstration projects to increase the uptake of EVs. They hope to achieve a market shift towards cleaner forms of transportation [13]. However, according to the report of Global EV outlook 2016, Canada has only 18,450 EVs on the road, in which there are 10,030 battery electric vehicles and 8,420 plug-in hybrid electric vehicles. This situation is far behind the ambitious target of 500,000 for 2018. Only two years are left for governments and related stakeholders.

So far, federal and provincial governments have introduced some incentive policies listed in Table 4 for boosting the development of charging infrastructures. Data from
Global EV outlook 2016 illustrate that there are 21,810 slow charging stations (Level 1 and Level 2) and 153 DCFC stations in Canada.

Table 4 Overview of incentive programs sponsored by the governments in Canada

<table>
<thead>
<tr>
<th>Government</th>
<th>Program/initiative</th>
<th>Effective date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal</td>
<td><strong>Fast Charging Infrastructure 2016:</strong> Allocating investment to electric vehicles and alternative transportation fuel infrastructure of $62.5M over the next two years. The federal government made this announcement following the launch of <em>Roadmap for Accelerating the Deployment of Electric Vehicles in Canada (2016 to 2020)</em>.</td>
<td>April 2016</td>
</tr>
<tr>
<td>British Columbia</td>
<td>The Province announced on March 23, 2016 that residents in multi-unit buildings will be able to apply for an incentive for the purchase and installation of a Level 2 charging station. Previous programs have proved popular and this new program will further assist residents, building owners, and councils in preparing for the growth in electric vehicles. The incentive will cover 75% of the total cost for the purchase and installation of a charging station up to $4,500 per station. As part of the <em>Clean Energy Vehicle program</em>, British Columbia invested $2.7M towards supporting deployment of public Level 2 charging infrastructures, through the <em>Community Charging Infrastructure (CCI) Fund</em>. The results were 456 stations installed over the span of less than one year. - The City of Vancouver also implemented a charging station program, supporting over 90 stations throughout the city. - <strong>BC SCRAP-IT Electric Vehicle Program</strong>: Provides financial incentive for early retirement of old vehicles that are replaced with lower emitting options. Up to $1,000 for conventional replacement vehicles and PHEVs. Up to $3,000 for BEV.</td>
<td>April 1st, 2015</td>
</tr>
<tr>
<td>Manitoba</td>
<td><strong>Electric Vehicle Road Map:</strong> Manitoba released its road map in April 2011 to accelerate the adoption of electric vehicles within the province. The road map exploits existing charging infrastructures already in use, i.e., for winter block heaters and pre-heaters. Electrification of transportation makes use of</td>
<td>April 2011</td>
</tr>
<tr>
<td>Province</td>
<td>Description</td>
<td>Date</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Ontario</td>
<td><strong>Electric vehicle charging incentive program:</strong> Ontario is showing its support for EVs by offering up to $1,000 to help consumers purchase and install charging stations for home or business use. <strong>Electric Vehicle Chargers Ontario:</strong> The province is putting its new Climate Change Strategy into action by investing $20 million this year from the Ontario Green Investment Fund to support the build-out of a network of public electric vehicle (EV) charging stations across Ontario.</td>
<td>July 1, 2010. Renewed in 2016.</td>
</tr>
</tbody>
</table>
| Quebec    | - The installation of 1,000 charging stations near government buildings.  
- The “Branché au travail” program allows businesses to receive a rebate (50% of the fees or $5,000) for the purchase and installation of 240-volt charging stations.  
- There are 29 DCFC stations (excluding Tesla infrastructures).  
- By late 2016, the Electric Circuit is targeting the establishment of 60 new fast charging stations in Québec on the main highway corridors and in major urban centers.  
- Support the installation of charging stations in multi-unit residential buildings, new office buildings and for on-street parking.  
- In the “Roulez électrique” program, for homeowners who received a provincial electric vehicle rebate and have installed or are planning to install a Level 2 electric vehicle charging station, are eligible for rebates of up to $600 (reviewed 2016) or 50% of the total purchase and installation cost, whichever is lower. | September 2015.    |

3. Problem to Be Addressed

3.1 Problem definition

Although the international community has adopted a range of methods, there are still some barriers hampering the development of EVs. One of the main barriers identified by stakeholders is the lack of charging infrastructures [14]. In order to stimulate the development and proliferation of EVs in Canada, this paper will address how to devise policy recommendations to formulate sufficient charging infrastructures. Here charging infrastructures include charging stations located in private homes, workplaces, and public places, such as supermarkets, highway sides etc.
3.2 Stakeholders’ analysis

Gradually, the market has been opening to EVs. Nowadays, EVs have been woven into the fabric of our society as a whole. A wide range of stakeholders would be involved in the issue of charging infrastructures. This section will address the related stakeholder analysis in brief.

Layers of governments would have a strong motivation to develop EVs by accelerating the charging infrastructures. Boosting the development of EVs could help the government to achieve energy benefits, environmental benefits and economic benefits in the long run [3].

In some jurisdictions, automakers are concerned about compliance with environmental regulations. In a long term view, automakers would be enthusiastic to be involved, because the EV would be one of the most promising vehicle technologies in the future [15].

The Energy sector has mixed feelings about EV adoption. The suppliers and distributors of electricity would like to take positive steps to contribute for this problem just like the Oil & Gas industrial sectors did almost 200 years ago. EVs would be a tremendous terminal market for the electricity industry [16]. However, traditional fossil energy sectors think of EVs as a burgeoning rival and worry about the possible market shrink of fossil fuels in the future [17]. Meanwhile, they also want to be involved in this campaign to take a share of the new charging service market.

Science and education communities would like to discover more innovation opportunities like EV and its infrastructure [18]. EV is a technologically advanced pathway for our society. A great amount of groundbreaking innovations need passionate efforts to be achieved. Science and education communities could research in this area on things like new Material, new electric-chemistry theories, and new types of business models, and so on.

Banks, financial, and insurance institutions also could make more long-range profit margin in this emerging market of EV and its infrastructures [19].

Transportation and city planning sectors should optimize the locations of charging infrastructures to maximize value of charging services in the near term. They should put more attention on the regional planning in consideration of a great amount of EVs running on the road in the future [20].

Of course, the customers of EVs and the public will share and enjoy the environmental, economic and energy benefits of EVs.
4. Literature review

In order to overcome the barrier of lacking sufficient charging infrastructures, governments and other stakeholders accomplished myriad of researches and strategic plans. Although the literature covers a wide range of research topics, this section will focus on 4 themes which have a strongly correlated relationship with this thesis. These themes are: locations of charging infrastructures, leading models, business models and policy evaluation. Notwithstanding these themes were accomplished in different context, this section will mainly touch on how they could facilitate charging infrastructures in a policy perspective.

Charging at home has been thought of as the leading choice for EV owners. USA Nation Research Council and its partners (2015) believed that charging at home was the first choice for EV owners [21]. They also suggested that Local governments streamline permitting and adopt building codes that require new construction to be capable of supporting future charging installations. Obviously, charging at home is a reasonable choice for EV owners in consideration of cost and convenience. Governments are inclined to support this charging model across the world. The UK government (2011) stated same viewpoints in its Plug-In Vehicle Infrastructure Strategy [22]. Furthermore, in this strategy, UK government recommended that the most sustainable model would be charging taking place at home, at night, after the peak in electricity demand.

As an important supplement for charging at home, charging in public places is getting more attention. A study team from University of Waterloo (2010) stated that Region-specific data of vehicle purchases and demand for charging services need to be collected and synthesized [23]. These data will help stakeholders efficiently identify locations of charging points. From another perspective, Jonn Axsen, et, al, (2015) surveyed thousands of existing and potential EV owners and reported that mall, retail store and grocery store are top three public places where EV owners likely charged their EVs [24]. Hence, indentifying locations of public charging infrastructures is a key factor to efficiently meet the demand of EV owners. However, this method would lead the issue of equity. This issue will be deeply discussed in Chapter 7.

As for the developing model of charging infrastructures, several important reports summarized classic developing models. Ronald Edward Hardinge (2015) recommended two types of developing models [25]. The first model was named “Integrated Infrastructure Model”. In this model the public charging infrastructure was totally belonging to a charging service company sponsored by the government. It can be inferred that this model was an effective way to overcome the “chicken-egg” problem in the near term. The second one was “Spot Operator Owned Charging Station Model”. In this model, the market of charging service was open and easily access for any public parking locations owner or operator. The advantage was this model could provide independently the charging service to EV users in a competitive open-access market. In this model, only EV users paid for public charging infrastructures. However, these two
models had embedded drawbacks. For example, the spot operator model may have a possibility that “local monopolies” could be born.

Literatures illustrate that governments strongly supported the model of government leading. For instance, the UK government (2011) emphasized that in the early stage of EV development the government should take a leading role and monitor and facilitate this market [22]. Norway government strongly seconded a model of government leading, which was same in nature with the Integrated Infrastructure Model abstracted by Ronald (2015). Leigh Phillips (2015) asserted that the successful experience of Norway in the field of EVs was the public-sector-led build-out of nationwide (province-wide) charging stations helped overcome ‘range anxiety’ of EV owners [26]. These reports showed that government leading model could be an efficient way to increase the amount of charging infrastructures when the EV still stayed on the nascent stage.

Literatures discover that business model is paramount for the survival of charging service networks. Electric Vehicle Initiative (2013) declared that encouraging the public and private sectors to invest charging networks is an efficient way [27]. However, USA Nation Research Council (2015) argued that federal governments should refrain from extra direct investment in the public charging infrastructures pending an evaluation of the relationship between the availability of public charging and PEV adoption or use [21]. Although there is kind of debate on the business model, Carlos Madina (2016) concluded that profitable business model should allow operators to recover their costs while offering EV users a charging price which makes EVs competitive to conventional vehicles [28].

As mentioned in this section, literature reviews show that charging infrastructures involve a set of factors. Hence, how to assess the priorities of abovementioned factors and facilitate a deliberate policy making would be one of most important concerns for governments and related stakeholders. In this thesis, an approach, named Analytic Hierarchy Process (AHP), is employed to construct the assessment system in Chapter 5. The AHP was developed by Tom Saaty of the University of Pittsburgh [29]. The AHP approach begins with the construction of a hierarchy for the decision-analysis problem under question. Researchers could construct their own hierarchy by selecting specific criteria and sub-criteria according to requirements of issues. The most valuable aspect of AHP process is that it can help policy analysts find out a quantitative method to weigh different impacting factors in complex issues. [30]. However, it should be pointed out that policy analysts with different expertise could work out discrepant policy recommendations, even in the same context, because subjective judgment can impose big impact on the results of AHP.

According to literature reviews, it is clear that building up comprehensive charging network is a multi-factored issue. However, previous studies mostly focused on the charging technology and locations, business models and incentive policies, and so on. To some extent, these policy studies lacked deeply integral approach to assess the
potential outcomes of policy alternatives. Therefore, future research could lucubrate on the assessment approach to contribute to getting a better understanding of policy barriers of charging infrastructures.

5. Objects and Approach

5.1 Policy objective

According to the aforementioned analysis, the policy objective in this paper is formulating convenient and sufficient charging networks to accommodate the development of electric vehicles in Canada in the future.

5.2 Evaluation criteria

For addressing this objective, policy options will be formulated in consideration of different priorities in the development of charging infrastructures. However, how to judge which option is most feasible is a complicated issue. So, this section selects three criteria to evaluate policy options. To be more specific, “Evaluative criteria are not used to judge the alternatives, or at least not directly. They are to be applied to the projected outcomes.”[31] According to general theoretical principles of policy analysis, three criteria have been selected in this section, to project the outcomes of the policy options. They are:

(1) Efficiency
In this paper, efficiency will be used to evaluate what the cost is to achieve the policy objective. Under this criterion, this paper will examine and estimate the possible funds, time span, and social resources that will be deployed in the construction of charging infrastructures.

(2) Equity
Firstly, this criterion will be used to examine if the fruits of improving the network of charging infrastructures could be shared by all stakeholders. Secondly, “Equity” could be used to evaluate if some social parts have to be involved in the related activities unfairly.

(3) Sustainability
Sustainability will judge if the policy could have a continuous effect after the policy expiration. For example, a sustainable alternative option could create a well-running organization system which could keep going after the sunset of the policy option. In this paper, sustainability will be used to value the capability of one policy option to continually bolster the development of charging infrastructures after incentive policies expire one day.
5.3 Methodology

Gauged by the above criteria, three policy options described in chapter 6 could be forecast the potential outcomes. However, for policy makers, there is not an easy way to identify which option is better than the other two. Because formulating a comprehensive charging network will involve many impacting factors. In order to make a deliberate decision as possible as we can, we need a convicitive approach to help policy makers assess the potential outcomes of policy options.

This thesis employs the Analytic Hierarchy Process (AHP) approach to set up an assessment system to measure potential outcomes of policy options. In the context of this thesis, the hierarchy stands for the issue of How to accelerate charging infrastructures. The upper most node represents the overall goal of sufficient charging infrastructures.

Saaty did this in a matrix format, asking the individual to rank the importance of an element relative to another element with the following numerical ranking scale in Table 5. [29]

<table>
<thead>
<tr>
<th>Ranked intensity of importance</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
</tr>
<tr>
<td>3</td>
<td>Moderately Strong Importance</td>
</tr>
<tr>
<td>5</td>
<td>Strong Importance</td>
</tr>
<tr>
<td>7</td>
<td>Very strong importance</td>
</tr>
<tr>
<td>9</td>
<td>Extremely importance</td>
</tr>
</tbody>
</table>

In the whole hierarchy, aspects at the same level are compared against one another. As to comparison of different aspects, the aspect considered most important gets the scale factor placed in its row under the column of the aspect it is being compared against. The reciprocal of the scale factor is placed in the matrix position where the lower importance aspect has its row and the higher importance aspect has its column. The matrix is filled in with a series of pair-wise comparisons of aspects. The priority value for any aspect is the sum of its row elements divided by the sum of all matrix elements.

In order to establish an efficient assessment matrix for policy options, this paper has three main references to address this issue: 1) theoretical thoughts of Saaty about AHP approach; 2) previous research experience of the author of this paper in 2008. [32] 3) experts interviews during the proceeding of this paper. The structure of assessment matrix has two layers, as shown in Figure 2. Three general criteria are Efficiency, Equity, and Sustainability. Furthermore, each general criterion has its own sub-criteria. (See Figure 2)
Figure 2 the Structure of Assessment Matrix

The meaning of all the sub-criteria could be explained as Table 6:

Based on the method developed by Saaty, this paper calculated the priorities for criteria based on the experts opinions. Table 7 is the calculation for the priorities of 1st level factors in the Figure 2.

<table>
<thead>
<tr>
<th>criteria</th>
<th>Sub-criteria</th>
<th>Meaning of sub-criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>efficiency</td>
<td>Time-efficiency</td>
<td>How long will the option take to be fully in effect?</td>
</tr>
<tr>
<td></td>
<td>Cost-efficiency</td>
<td>How much funding will the option need to achieve the goal?</td>
</tr>
<tr>
<td>equity</td>
<td>Resource sharing</td>
<td>If charging infrastructures could be fairly used by all stakeholders?</td>
</tr>
<tr>
<td></td>
<td>Responsibility sharing</td>
<td>If the related responsibility will be taken by the stakeholders according to their roles and capability?</td>
</tr>
<tr>
<td>sustainability</td>
<td>Quantity increasing</td>
<td>If the option could continuously and benignly spur the increasing of charging infrastructures? And to what extend?</td>
</tr>
<tr>
<td></td>
<td>Technology development</td>
<td>If the option could incent the innovation of charging technology and business model in the long run? And to what extend?</td>
</tr>
</tbody>
</table>
### Table 7 Priorities of general criteria

<table>
<thead>
<tr>
<th></th>
<th>Efficiency</th>
<th>Equity</th>
<th>Sustainability</th>
<th>Global Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>1</td>
<td>3</td>
<td>1/5</td>
<td>0.28</td>
</tr>
<tr>
<td>Equity</td>
<td>1/3</td>
<td>1</td>
<td>1/3</td>
<td>0.11</td>
</tr>
<tr>
<td>Sustainability</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Repeat the same method, the priorities of sub-criteria could be worked out as Table 8.

### Table 8 Global priorities of sub-criteria

<table>
<thead>
<tr>
<th>factors</th>
<th>Local priority</th>
<th>Global priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-efficiency</td>
<td>0.6</td>
<td>0.17</td>
</tr>
<tr>
<td>Cost-efficiency</td>
<td>0.4</td>
<td>0.11</td>
</tr>
<tr>
<td>Resource sharing</td>
<td>0.7</td>
<td>0.08</td>
</tr>
<tr>
<td>Responsibility sharing</td>
<td>0.3</td>
<td>0.03</td>
</tr>
<tr>
<td>Quantity increasing</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Technology development</td>
<td>0.5</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Here,

\[
\text{the global priority of subcriteria} = \text{the global priority of criterion one level up} \times \text{local priority} \quad \text{(Formula 1)}
\]

### 6. Policy options

Based on the literature reviews, this section suggests three options to encourage the development of charging infrastructures of EVs in Canada.

#### 6.1 Option 1: Government-owned agency leading model

**Basic Premise:**

Presently, EVs occupy a small share of market. There is not a big profit to attract more private companies to invest in charging infrastructures in the short term [33]. In order to encourage the development of EVs and charging infrastructures, and achieve the environmental and energy benefits, governments should take the responsibility to lead, providing incentive to boost the construction of charging networks.

The core of this policy option is that governments should play the leading role to control the development of charging infrastructures in Canada. To be more specific, this option could include:

(1) A government-oriented organization system.
Canada could draw on experience from Norway and the province of British Columbia and formulate a governmental agency to be responsible for the construction of public charging infrastructures. Under the leadership of the agency, an organization could be established to coordinate all stakeholders, including for example, automakers, the energy sector, transportation sector, an science and education communities. All stakeholders would play their roles according to their expertise and functions.

(2) Level 1 and level 2 infrastructures as the mainstream.

In this option, Level 1 and level 2 infrastructures would be the main stream of charging infrastructures. Here, the primary concern would not be the charging rate, but the cost of infrastructure. The goal of government would be to construct a comprehensive charging network at minimum cost. So Direct Current Fast Charging (DCFC) would be a supplemental charging method because of its expensive cost.

Governments would focus mainly on the installation of Level 1 and Level 2 infrastructures in households, residential buildings and multi-dwelling apartment buildings. According to a survey from Simon Fraser University, the majority of charging events (63%) occurred at home as opposed to work or public charging stations. Charging at the workplace and other public places accounted for 19% and 18% of all charging events, respectively [34].

![Figure 3 Charging events by locations](Source: Simon Fraser University)

(3) Launching large-scale demonstration projects
In this option, the Government of Canada would invest a great amount of funds to launch large-scale EV demonstration projects and national R&D programs, like the Chinese government has been doing [35]. The public sector and private companies would deploy EVs in a large scale and construct a myriad of charging infrastructures. Layers of governments would subsidize private customers to purchase EVs and install charging equipment. The government would cover the fee of public charging stations from EV customers.

6.2 Option 2: Private charging service company leading model

Basic Premise

In option 2, the formulation of charging network would rely on the free market. Private charging service companies would play the main roles. This option could include:

(1) Layers of governments in a supervising role.

In this option, governments would regulate charging services provided by private companies to protect the public. Regulations related to safety requirements, price transparency, and service norms would be introduced into markets. Governments could offer some tax deductions and exemptions to support the private companies in developing charging infrastructures.

(2) Paid fast-charging services as the mainstream.

In this option, the DCFC would be the main charging technology in the public places. EV users could overcome ‘range anxiety’ and feel comfortable when they drive outside their regular trip profile. However, EV customers would pay for the charging at a rate based on the supply and demand relationship of market.

(3) Deploying market-oriented strategy.

Due to EVs’ modest market penetration, it is necessary to locate charging infrastructures in areas where the most potential EV owners live. Thus, a geospatially focused policy could be devised by considering demographics that are tightly aligned with potential future EV owners. When the demographics are defined clearly, specific census data based on geography could be draw on to identify the areas that are most interested in embracing EV-related policies and disseminating policy information. For example, such a strategy could draw from consumer studies which characterize early EV potential owners as well-educated, higher income, older, male, politically active, environmentally conscious, and technologically savvy [36].


6.3 Option 3: “to be a smart follower” model

**Basic Premise**

In this option, governments, industries and science communities would present an important opportunity to showcase and verify the viability and practicality of EVs in Canada. In this policy option, three main points would be embraced:

(1) **An ambitious target of EVs adoption would not be necessary.**

In option 3, the Canadian governments would not need to do anything special to encourage EVs and charging infrastructures. They would hold a relative conservative view on the current government-oriented EV adoption across the world.

On one hand, EV is only one of a range of alternative fuel vehicles. That means EV has been facing a powerful competition from other alternative fuel vehicles, such as fuel cell vehicles. Natural gas based fuels (CNG, GTL, LNG), biomass-based fuels (biodiesel, ethanol, BTL), and other alternative fuels could support the desire of governments to alleviate the GHGs emissions from the transportation sector [37]. Even the traditional ICE technologies still holds a great potential to improve the efficiency and lower the energy consumption significantly. So the government does not need to put all eggs into one basket of EVs.

On the other hand, due to many barriers, all stakeholders should be aware of technological uncertainties of EVs and not commit prematurely. Governments should slow down and deliberate the order-of-magnitude of funds and social resources they are planning to invest into the EVs in the future. In option 3, the most serious risk for Canada would be the paramount opportunity cost. In another words, if insurmountable technical and practical barriers exist, the technology pathway of EVs would have been verified a failure eventually. This possible situation would make Canada lost its momentum in the sustainable transportation sector.

(2) **Stakeholders should actively draw on successful international experience.**

In option 3, the Government of Canada would deliberately deploy several small-scale demonstrations of EVs and infrastructures. Consequently, these demonstrations would cost limited funds because of their small scale nature. Demonstrations would be designed to verify the technological flexibility and regulatory feasibility. Based on the acquired experience from domestic demonstrations, all stakeholders could draw on the successful experience from other jurisdictions more efficiently. For example, stakeholders could initiate or take part in international cooperation partnerships in the field of EVs and charging infrastructures. This would be an effective way to compare, categorize, and synthesize valuable technical information and expertise.
(3) Very limited subsidies would be provided to personal EV owners.

In this option, governments would subsidize the personal EV owners to install charging equipment in garages, private parking lots, etc. Governmental subsidies should drop out the construction of public DCFC, which is considered as a money-intensive charging model currently. [38]

7. Evaluation and Decision Analysis

7.1 Evaluation of efficiency

Option 1 is a governmental leading model. In this context, government is the main responsible party for the construction of charging network. Government should negotiate with all stakeholders and facilitate policy making and implementation. For example, when the federal government is planning to formulate an EV national strategy, all the stakeholders will be invited to represent different group interests. Considering the bureaucracy of governments, the time efficiency of option 1 would not be satisfactory by stakeholders.

However, in option 1, governments have the advantage to being able to integrate social resources, such as funds and technology, to implement policies. Canadian federal government would be implementing a national roadmap for EV diffusion. Layers of governments would be striving to formulate a comprehensive public charging network mainly by installing charging equipment in households (See Table 9). Besides, DCFC stations would be the important supplement for charging networks [12].

In option 1, governments make the development of infrastructures feasible by regulations, codes, and legislations, and so on. For example, governments could align the charging standards, such as the plug standards, on a national scale. This kind of effort would avoid potential confusions in the charging market in the future and facilitate charging services to be shared more efficiently.

Table 9 Federal financial incentives for charging infrastructures (budget)

<table>
<thead>
<tr>
<th>items</th>
<th>Year</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workplace: subsidies</td>
<td></td>
<td>$7.5M</td>
<td>$15M</td>
<td>$15M</td>
<td>$15M</td>
<td>$7.5M</td>
<td>$60M</td>
</tr>
<tr>
<td>Workplace: charging points</td>
<td></td>
<td>2,500</td>
<td>5,000</td>
<td>5,000</td>
<td>5,000</td>
<td>2,500</td>
<td>20,000</td>
</tr>
<tr>
<td>DCFC: subsidies</td>
<td></td>
<td>$1.0M</td>
<td>$1.75M</td>
<td>$1.75M</td>
<td>$1.5M</td>
<td>$1.5M</td>
<td>$7.5M</td>
</tr>
<tr>
<td>DCFC: charging stations</td>
<td></td>
<td>20</td>
<td>35</td>
<td>35</td>
<td>30</td>
<td>30</td>
<td>150</td>
</tr>
</tbody>
</table>

Source: Electric Mobility Canada
Option 2 will have a better rapid-response to market demands. Here, private companies devise an efficient business schedule. The pace is fast because they have the strong will to pursue profits. Thus, the locations or areas where the charging service will be needed most could be identified efficiently. One of the disadvantages of this is that private companies may not have adequate social resources to facilitate the whole process of constructing charging stations. Private companies need to coordinate related stakeholders and keep things run smoothly. Sometimes, it is beyond their capability.

Option 3 will accomplish some small-scale demonstrations with limited monetary and other social resources. That will help all stakeholders generate achievement in multidimensional fields, such as standard setting, business models, and technology innovations. The government could focus on certain aspects of charging infrastructures and adjust focuses in a timely manner to meet the dynamic market demands.

7.2 Evaluation of equity

In option 1, the equity would be questioned by some critics. Governments will put the budget into charging infrastructures to facilitate the convenience of EV customers. This is kind of unfair for the people who do not currently own EVs. In a more broad view, governmental support for the EV and its infrastructure will be kind of inequity for the other types of alternative fuel vehicles, for example, Fuel Cell Vehicle, which also have the great advantage in reducing GHGs emissions and lowering our dependence on the fossil energy.

To some extent, option 2 is an acceptable solution in the view of equity. It is the people who take the charging service pay the bill rather than all taxpayers. And the charging service market will be open to all stakeholders. Private companies will bear construction cost of DCFC stations, rather than the whole taxpayers. However, the real risk of this option is the services and equipment of charging providers would be not uniform across the country. That means the EV users would probably lost their freedom to some extent to select the charging service providers as they want or need. According to the experience from other jurisdictions, a negative possibility should be noticed and supervised that service companies prefer to construct charging infrastructures in the area where a better business-potential is existing. That will lead some low population-density areas are not on the agenda, at least in the short term. This will not be helpful for the development of EVs at the initial developing stage.

Option 3 will give governments more space to make the development of the alternative fuel vehicles balanced. Layers of governments will have enough funds and technical resources to support different public policies and programs for alternative fuel vehicles. For example, other types of infrastructures, like hydrogen refilling station, are also eligible for getting rebate and tax credits to lower their upfront cost.
7.3 Evaluation of sustainability

In option 1, governments could articulate a long-term agenda for formulating the charging network. Level 1 and level 2 will be main charging technologies in the future. In terms of the cost, option 1 is economic for governments and the public because of the relatively low cost of level 1 and level 2.

Actually, option 1 is also practical for EV users in consideration of the current battery technology. Table 10 indicates that many EV models have a relative lower range than the conventional vehicles. But According to Statistics Canada, the average daily commute for Canadians is less than 25 km with 90% of Canadians having a commute of less than 45 km [39]. That means the current EVs could meet the demand of most daily travel. Furthermore, the slow home charging model (level 1 and level 2) supported by the option 1 is adequately meet the commute demand of common people.

Table 10 Range of some EV models

<table>
<thead>
<tr>
<th>Model</th>
<th>Range per fully charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model S 70D</td>
<td>240 miles</td>
</tr>
<tr>
<td>Kia Soul EV</td>
<td>93 miles</td>
</tr>
<tr>
<td>Fiat 500 e</td>
<td>87 miles</td>
</tr>
<tr>
<td>Mercedes B-class Electric Drive</td>
<td>87 miles</td>
</tr>
</tbody>
</table>

So it is safe to say that option 1 is very economic to mitigate the challenge of charging demands from EV users. However, the drawback is the relative lower charging rate of level 1 and level 2 charging technology. EV users should endure the “boring time” they would have during the charging.

Option 2 could mitigate the range anxiety of EV owners to most extent. But the investment for DCFC infrastructures is tremendous. The schedule of charging network is easily affected by available funds because of the higher cost of DCFC. Basically, a typical DCFC will cost $ 65,000 and $ 2,000 maintenance fee per year additional [14]. In order to overcome the barrier from the investments, it could be expected that a range of smart and profitable charging business models will emerge in Canada. Drawing on experiences from China and Washington State, private charging service companies could get the financial support from other private sector entities that gain indirect value from EV charging station deployment to improve the financial performance of EV charging.
station investments [40]. For example, in January 2015, automakers including BMW, Volkswagen, and Nissan stated major investments in public charging infrastructures. They planned to install more than 1,000 charging stations in key markets in Oregon, California, the Northeast, and elsewhere. However, those business models just started small pilot demonstrations.

One more concern about option2 is almost all charging service companies have their own technical protocols and service procedures. Standards for charging equipment, installations and communications are currently under development by several main academic entities (See Figure 4) [41]. This will lead the incompatibility in charging standards and service norms. This situation would hamper the development of a sustainable, open and fully competitive charging service market. That means government intervenes are necessary.

Although option 3 can save funds and other social resources, Canada will be confronted with several disadvantages. The first concern is all achievements we can achieve will be from some relative small demonstrations or experiments which are constrained by the limited funds and time. To some extent, that means there would be uncertainty and risk of technology when Canada will plan to transplant and magnify previous achievements to new large-scale practices. The second concern is all non-governmental stakeholders will not get enough confidence from layers of governments because of limited actions adopted in option 3. This point is paramount especially during the nascent stage of EV development. Once there were a policy void, all stakeholders would be likely to stop their steps and take a wait-and-see attitude. This potential situation will be harmful for keeping the momentum of Canada in the field of EVs.

7.4 Decision analysis
In sections of 7.1, 7.2 and 7.3, possible outcomes of three policy options have been forecast based on efficiency, equity, and sustainability. In this section, the approach for decision analysis, which is described in chapter 5, will be employed to assess the outcomes of the three policy options.

Ideally, governments should invite as many experts as possible to make a comprehensive survey and give the scores for policy options. By this way, a convictive assessment could be achieved. However, because of limited time and no funding for the research, this thesis demonstrates the employment of decision analysis approach based on a small scale investigation. During the research of this thesis, the author had interviewed several experts for scoring three options based their expertise.

Gauged by all the criteria, the three policy options could get the marks in each sub-criterion. Eventually we can get the final marks for each policy options. The calculation can be explained by the following formula:

$$Mark = \sum submark \times global\ priority\ of\ subcriterion$$ (Formula 2)

<table>
<thead>
<tr>
<th></th>
<th>time-efficiency</th>
<th>cost-efficiency</th>
<th>resource sharing</th>
<th>responsibility sharing</th>
<th>quantity increasing</th>
<th>technology development</th>
<th>marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>global priority</td>
<td>0.17</td>
<td>0.11</td>
<td>0.08</td>
<td>0.03</td>
<td>0.3</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>option 1</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>7</td>
<td>7.27</td>
</tr>
<tr>
<td>option 2</td>
<td>8</td>
<td>9</td>
<td>6</td>
<td>8</td>
<td>6</td>
<td>7</td>
<td>6.97</td>
</tr>
<tr>
<td>option 3</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6.41</td>
</tr>
</tbody>
</table>

According to the results listed in table 11, the radar chart could be established to visualize clearly the comparisons among these three options.
Finally, option 1 has a relative advantage in the aspect of sustainability. It will boost the amount of charging infrastructures more effectively than the other two options. Although option 1 will not satisfactory in efficiency, its integral mark is the best among these three options. Option 2 and 3 are better in efficiency than option 1, but the total marks are a little bit lower than option 1. So the policy makers will need a deliberate trade-off when they make policy decisions.

8. Recommendations
According to the aforementioned evaluation, each policy option has its own advantage in different aspects. Based on this situation, a set of mixed policy recommendations are put forward in this section.

(1) In the near term (before 2020), Option1 (Government-owned agency leading model) would be recommended in Canada.

During this period, the EV market would be increasing gradually but will not big enough yet compared with conventional vehicles. Increasing the number of charging infrastructures would be one of the most important ways to meet customer needs and enlarge EV market penetration. Thus, it would be a pressing task to cultivate a customer-friendly charging service market as quickly as possible. However, in this period, profits from charging services might not meet the expectation of stakeholders because of the small amount of EVs. So the governmental financial support would be necessary and vital. Therefore, option 1 would be the preferable solution.

(2) If the technology development of batteries and charging equipment does not advance, option2 would be a better choice in the middle term (before 2030).
In the middle term, if there are no groundbreaking technologies in batteries, option 2 would be a better policy solution. In this stage, more and more common customers will accept EVs as efficient transportation tools and will change their behavior to drive EVs. EV customers will be accustomed to charging their EVs when parking at home, at work or in public places. DCFC could be a supplementary charging method in this period. It can alleviate the “range anxiety”, when EV drivers travel a long distance.

If batteries or other types of energy storage onboard are improved significantly, the range per full charge of EVs would be greatly increased. This situation would mitigate customers’ “range anxiety” effectively. In this situation, Option 1 would be recommended. Since roughly 90% of charging occurs overnight – when the EV is parked at home – the availability of home charging is critically important and usually taken care of when buying an EV [12]. In view of cost, the charging equipments adopted in the option 1 are far more economic than DCFC adopted in option 2.

Besides the above recommendations, here are some policy implementation suggestions.

(3) Unifying charging technology standards.

This measure will be helpful for developing an integral and open charging service market in the long run. In a unified standards system, many products (batteries, plugs, etc) and services (safety supervision, maintenance records) of charging infrastructures could be compatible and interchangeable. This measure could bring many benefits. On one hand, common EV customers, fleets and other stakeholders could enjoy more convenience, and eventually a booming EV market will benefit from this uniform and convenient charging service market. On the other hand, uniform charging infrastructures and services could avoid the waste of social wealth at most. For example, the suppliers of charging equipment need not produce different plugs to meet the demands of EV makers.

(4) Making charging available in residential building.

As 63% of charging events occurred at home at present in Canada [26], it is paramount to make the installation of charging equipment easier in new houses and multi-unit residential dwellings [42]. Governments could develop some incentive policies to encourage building contractors to conceive construction plans for charging equipments at the very beginning of planning for residential communities.

(5) Subsidizing the retrofitting of old multi-dweller residential buildings.

Nowadays, a relatively big share of old condos is not suitable to install charging equipment. For example, almost 30 per cent of condos in Toronto area are not designed for EV Charging [43]. Governments could provide funds to retrofit the condos and make
them charging-friendly to EVs. In this context, introducing a technical service company is an effective way to make the charging easy and accessible for residents.

9. Conclusions

The evaluation of policy options in the previous sections indicates that accelerating charging infrastructures is a complex policy issue. Chapter 8 has already put forward several policy recommendations to boost the development of charging infrastructures in Canada. Furthermore, some conclusions are given in this section below:

(1) Currently government interventions are necessary.

According to the aforementioned analysis, charging service is not yet a profitable market for private companies. In order to resolve this “egg-and-chicken” dilemma, government interventions of are needed to accelerate the formulation of charging networks in Canada.

(2) Uniform standards are vital for charging service.

As discussions in chapter 6, no matter which policy option would be taken, governments should lead and facilitate the establishment of standards, codes, and service norms, etc. It would help Canada form an integral and vibrant charging market and keep Canada competitive in the field of EV across the world.

(3) Improving public awareness is the key part of policy implementation.

Based on the evaluation of equity in chapter 7, it is absolutely necessary to have the public receive complete information. So the implementation of a clear, neutral, and routine communication and education strategy on EVs on a national scale should be considered a major priority and supported by all stakeholders. All-around information should be provided to the public to help them understand the benefits and drawbacks of policies so that they can make reasonable decisions.

(4) Knowledge and expertise related with EVs and infrastructures should be prepared in advance.

Because of obviously different technology characteristics, EVs and charging infrastructures need the creation and dissemination of new knowledge, new expertise and professional training, such as fire management and accident rescue, and so on. That means layers of governments, universities, colleges and secondary schools should adjust the framework of curriculum and professional courses to cultivate qualified engineers, technician, and academics, etc.
(5) **Timely and periodically reevaluate policies**

As discussed in the section of decision analysis, accelerating charging infrastructures is a multi-factored and complex issue. Making policy decision requires trade-offs and weighing the pros and cons of policy options. This situation will require that governments reevaluate the implemented policies in season. Therefore, Policy makers need to formulate a dynamic and timely mechanism to adjust policies efficiently and insure executive policies are compatible with the updated demands of all stakeholders.

(6) **EV is not the silver bullet.**

Last but not least, although this thesis is dedicated to encouraging the development of EVs and charging infrastructures, governments should consider the technological uncertainty of EVs. As discussed in chapter 7, federal governments should give sufficient support to other alternative fuel vehicles in terms of the potential of technology. Putting all eggs in one bucket is not a wise strategy. The final decision factor is always market selection by common customers rather than the decision by policy makers or politicians.
Reference

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22. Making the Connection, the Plug-In Vehicle Infrastructure Strategy, Office for low emission vehicle, UK, June, 2011.
Acknowledgment

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