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Feasibility of a Pan-Canadian Network of DC Fast Charging Stations for EVs

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Summary

In the Summer and Fall 2015, the authors studied the business case for investing in a Direct Current Fast Charging (DCFC) infrastructure in Canada for the benefit of the Canadian Council of Ministers of the Environment. This paper summarizes our research findings in four areas: Cost of DCFCs, expected utilization of DCFCs, benefits and co-benefits of DCFC stations, evaluation of the business case for DCFCs across Canada.

Keywords: BEV, HEV, charger, fast charge, DC-DC

1 Introduction

Approximately half the EVs on Canadian roads are compatible with DC-DC fast charging. As of May 2015, there were only 48 DCFC locations in Canada (139 ports). These DCFC stations are concentrated in the country's three most populous provinces. Given the size of Canada, a significantly larger number of locations is required to allow an EV driver to travel across the country.

Numerous stakeholders have declared an interest in deploying additional DCFCs in Canada but infrastructure deployment is still in its infancy, having predominantly been the work of governments, their agencies or Crown Corporations to date. This results from the perceived high risk of such an investment and significantly longer paybacks than private investors are generally willing to accept. But is there a business case for DCFCs in Canada?

2 Cost of DC Fast Chargers

The installed cost of DC fast charging stations varies widely depending on a number of factors. The three main cost components are the equipment (or charger), the installation and the real estate (land and amenities).

In the case of the purchase of the DC fast charging equipment, the cost varies depending on the manufacturer, the unit specifications as well as the number of units ordered. While the price of chargers has been declining, most stakeholders contributing to this research cite 2015 prices cited range from $25,000 to $40,000 per unit.

The installation cost varies depending on …

- The availability of a suitable source of 3-phase electricity in close proximity;
- The civil work required on site;
- The importance of the aesthetics to the operator;
- The time of the year at which the installation work is performed (a consideration in all provinces except BC);
- The organization managing the project.

Based on the information gathered from Canadian stakeholders involved in the deployment of DCFCs, the installation cost can vary widely from $15,000 to over $60,000. This does not include the cost or installation of peripheral equipment, such as solar carports and heating pads, to ensure the space is accessible at all times to EV owners.

The cost of real estate can also vary widely, ranging from zero (in several cases where the real estate is granted by a third party without charge) to several thousands of dollars per square meter in major urban centers.

2.1 DC fast charging deployment challenges

2.1.1 Funding

DC fast charging infrastructure deployment within Canada is in its infancy. With the exception of Tesla and AZRA, network scale deployment has largely been the work of governments, their agencies or Crown Corporations in Canada. This results from the perceived lack of acceptable financial returns on investment and significantly longer paybacks than private investors are willing to accept. Given the investment required, the relatively small number of EVs and the low incidence of charging, conventional financing of DC fast charging stations (equity, debt or a mixture of both) has been nearly impossible, and is unlikely to change in the foreseeable future.

The successful DC fast charging infrastructure network deployments have been financed in one of the following ways:

- Highly subsidized by provincial and/or federal government;
- Private investment made by auto manufacturers aimed at reducing range anxiety and increasing EV sales; and,
- One innovative investment model inspired by the commercial real estate market and derivative sources of income.

In most cases, the total amount of investment available is relatively small and the process to obtain government funding (if and when it is available) is rather complicated, onerous and rare. This explains, in large part, the relatively slow rate at which DC fast charging infrastructure is deploying in Canada.

2.1.2 Utility regulations, codes and standards

There are very few regulations, codes and standards that specifically impact the deployment of DC fast charging stations.

A utility will only provide power to installations meeting the electrical code, a subset of the National Building Code (NBC) of Canada (and its provincial versions, where applicable). It applies to any electrical installation, regardless of its purpose. In some provinces, additional guidelines are provided by either utilities (example, Hydro-Québec's Electric Vehicle Charging Stations Technical Installation Guideline) or safety related agencies (example: the Electrical Safety Authority of Ontario). These are meant to help installers apply the NBC properly.

In some Canadian jurisdictions, the law forbids the resale of electricity by a third party. Such is the case in Québec where charging station operators in this province cannot sell energy to EV owners. This may have been an impediment in the very early stages of market development but alternative pricing solutions[1] were quickly designed to avoid this encumbrance and therefore, this is no longer considered a factor in the deployment of DC fast charging solutions in Canada.

2.1.3 Considerations of electricity grid

The main challenge related to the deployment of a DC fast charging station network with consideration to the electricity grid is the availability of 3-phase current where the station is required. This is generally not a major technical impediment, but it can be a source of considerable cost if the station is located far from the source (along highways, for example) or in a building complex not equipped with the adequate power supply.

Destination charging locations are usually less problematic as most of these are located where the grid is readily available. Nevertheless, most operators choose to have a separate meter for their charging station.

[1] This means that the users cannot be charged for the kilowatt-hours (kWh) they consume. But any bundling of services that includes these same kWh can be invoiced to the user as long as the basis for invoicing is not a kWh. To the best of our knowledge, no pricing scheme has ever been challenged in a Canadian court of law.

In this way, they can monitor the power factor of the installation closely and avoid exceeding a demand level that could prove costly for all future charging at the site[2].

With respect to the availability of energy, the low incidence rate and the few DCFCs installed have not proven to cause problems to electrical utilities to date. In the future, however, some utilities may experience limited energy supply during certain periods of the day / week / year that may result in utilities imposing limitations on the availability of the charging service on those relatively rare occasions.

2.1.4 Permit issuance

No significant problems or important challenges associated with permitting for DC fast charging stations have been identified in the context of this research. In the case of BC Hydro, the stations are generally "treated as a utility installation, avoiding any building or development permits". In most cases, the only permit required is an electrical one.

2.1.5 Other challenges[3]

The multiplicity of design standards for DC fast charging stations does not promote fast deployment by independent third parties and it reduces the potential market for individual stations. This situation therefore impacts the eventual profitability of the stations. At present, all commercially available charging stations are conductive. In Canada, most DC fast charging stations use equipment built according to SAE Standard J1772-2009 (IEC 62196-2) or CHAdeMO. Although slightly more expensive[4], dual technology stations - J1772 Combined Coupler Standard (called CCS or "Combo") are also available on the market.

As not all vehicles are compatible with all DC fast charging technologies, dual stations are increasingly being installed, with Tesla Superchargers being altogether different and so far inaccessible to any other car make/model.

In the past, the business models contemplated by station owners were essentially based on obtaining government support for one facet or another in the deployment of stations. This was required because the small fleet of EVs in Canada could not possibly sustain a purely mercantile model.

At an average rate of $5 per charge session, 12,000 sessions are required to recover the fixed costs, averaging $60,000[5]. This calculation excludes the variable costs (including operation and maintenance as well electricity[6]). For a two-year payback, an average of 116 sessions per charger per week would be required to cover only the fixed costs of purchase and installation (excluding cost of capital). None of the DC fast charging stations inventoried in Canada experience this level of usage yet[7]. In fact, there are no tangible examples of *profitable*[8] DC fast charging stations in Canada to date, nor did we identify profitable public DCFC stations in the US or Europe. The lesson learned therefore is that at least in the short term, a more innovative, less station-centric business model must be developed in order to generate enough revenue to cover the station fixed and variable costs.

3 Expected utilization of DCFCs

3.1 EV Sales Forecast for Canada

Forecasting EV sales ten years into the future is challenging given that this is an emerging industry with limited history and that future sales are dependent on a large number of factors, including …

- The price of fuel relative to the price of electricity;
- The range and performance of EVs;
- The price of EVs relative to the price of comparable internal combustion engine vehicles;
- The availability of a greater number and variety of EV makes and models;

[2] Most utilities have a dual base electricity tariff. Their customers are therefore charged for their energy consumption (per kWh) and for the highest power demand (in kW) incurred in the course of the year. It becomes important for operators to minimize their use of power in order to maintain their cost of electricity as low as possible.
[3] Battery usage associated with air conditioning and heating is addressed in section 3.1.
[4] A dual technology station adds 10% more to the total cost (purchase and installation) of a DC fast charging installation (Source: AddEnergie).
[5] Cost of financing is not taken into consideration.
[6] Electricity charges can be considerable, sometimes upwards of $5/kWh.
[7] According to AddEnergie, the DCFC most utilized in Québec is one located in Montréal (on average, 5 charge sessions per day or 35 per week).
[8] A "profitable DCFC station" would be one that generates a financial benefit, one where direct, tangible monetary revenues exceed total costs (capital and operations).

- The availability of government financial rebates for the purchase of EVs and for the installation of charging stations (Level 2, DC fast charging);
- The availability of other incentives to encourage EV ownership (examples: access to HOV lanes, preferential parking, workplace charging programs).

Five (5) EV sales forecast scenarios[9] have been developed ranging from the "worst case" scenario (#1) to the "optimistic" scenario (#5). Scenarios #2, #3 and #4 are based on a "realistic" projection of sales that reflect information available today (examples: significantly greater expected range of EVs from 2016 on, variety of EV models to be introduced in the short term).

The difference between Scenarios #2, #3 and #4 is the number of DC fast charging locations available across the country. Varying this "realistic" scenario assuming all things remain equal with the exception of the number of DC fast charging locations is extremely challenging as no empirical studies demonstrating the quantitative link between the presence of DC fast charging and EV sales exists. Despite this lack of quantitative data, it is generally agreed that the presence of DC fast charging has and will continue to have a positive impact on EV deployment. EV uptake by urban dwellers with no dedicated parking will, in large part, be facilitated by the presence of inner city DC fast charging. For the sake of brevity, only the realistic scenarios are discussed in this paper.

3.1.1 Realistic scenarios

The assumptions for all three are the same, with one exception: the number of DC fast charging locations in Canada. Despite the lack of empirical evidence making the link between the presence of DC fast charging and EV sales, we understand that the presence of DC fast charging on corridors and outside city limits will provide the safety net required by EV drivers, enabling them to make longer distance travel. We made two assumptions underlying the evolution between the three realistic scenarios:

- The greater the number of locations, the more important the safety net, the greater the impact on EV sales;
- The greater the presence of DC fast charging in urban areas, the greater the uptake of EVs by urbanites with no dedicated parking that can be used for the installation of residential charging units.

The assumptions underpinning our realistic scenarios (#2, #3 and #4) are:

- Power train electrification is essential to meeting fuel economy regulations;
- Difference between EV and ICE vehicle ownership will continue to be favourable for EVs[10];
- Declining price of EVs due to economies of scale;
- Battery efficiency improves and battery prices decline (economies of scale);
- Significant battery range improvements thanks to significant investments by auto OEMs, Silicon Valley stakeholders as well as research institutions;
- Availability of at least four more battery electric vehicles (BEV) models with a range of at least 300 km and a maximum price of $40,000 according to Mike Orcutt at the MIT [1];
- Increase in the number of EV makes and models available to Canadian motorists to 20 or more;
- Cost of home charging a 450 km range BEV at a DCFC station remains less than $20;
- Attempts at introducing hydrogen and CNG fuelled cars will be unsuccessful due to the high cost of infrastructure required for gaseous fuel distribution;
- Continued availability of purchase rebates:
- Québec will renew purchase rebate beyond 10,200 EVs sold[11]
- BC purchase rebates of $10.5 million (covering between 1500 and 2000 EVs, depending on whether older ICE vehicles are replaced with electrics)
- Ontario will continue offering its purchase rebate[12];
- Municipal and provincial governments to introduce additional measures to encourage EV adoption[13,14];

9 All scenarios assume a ten-year vehicle life. After ten years, the vehicle is assumed to be withdrawn from the market.

10 Assuming the US Department of Energy's Energy Outlook 2015 is accurate in predicting the price per barrel of oil will increase to $99 USD in 2020 and to $148 USD in 2030.

11 The Québec Ministry of Transportation has already announced the extension of the subsidy program in its latest Electrification of Transportation Plan 2015-2020.

12 Given the decision of the Government of Ontario to join Québec and California in a cap and trade system as well as the continued pro-environmental stance of the Ontario government, it would be reasonable to assume that the purchase rebates will be maintained until the market reaches a tipping point, where enough EVs are on Ontario's roads and where the purchase price of an EV is in line with its ICE counterparts, no longer requiring a purchase rebate.

13 Examples: access to HOV lanes, preferential parking…

14 Example of municipal government action encouraging EV adoption: Montréal's Mayor, Denis Coderre, announced on April 14th 2015 that his government intends to make Montréal the leader in electrification of transportation. One project to lead in that direction: 1000 BEVs in car sharing by 2020 (250 vehicles in spring of 2016, 200-250 vehicles per year thereafter).

- Private stakeholder investments in electrification of transportation[15];
- Municipal, provincial and federal governments undertake increasingly important actions to fight climate change and EVs are an important part of the solution;
- As the number of EVs increase in Canada[16] (including private passenger vehicles, car sharing vehicles and taxis), a greater percentage of Canadians will be exposed to them, contributing to much improved consumer education and interest.

If we were to inflate total industry vehicle sales by 2-3% per annum, we would expect approximately 2.5 million light-duty vehicle sales in Canada in 2025[17]. The realistic scenarios of 460,000 (scenario #2), 480,000 (scenario #3) and 500,000 (scenario #4) EVs sold in 2025 would represent 18.4%, 19.2% and 20% respectively of total light-duty vehicle sales in Canada.

3.1.2 First realistic scenario (#2)

To ensure travel across the country, a DC fast charger would need to be located at 60 km intervals. This distance would allow for a Nissan Leaf (2015 model year) to make the trip in winter conditions, even with charging providing 80% of battery capacity. A total distance of 7,568 km would need to be covered to cross the country and reach all major metropolitan areas.

Scenario 2 therefore assumes the deployment of the DCFCs at 127 strategically positioned locations hosting four to eight chargers at each location, much along the same model Tesla is currently using. The positioning of DCFCs along such a corridor necessitates cooperation and coordination between relevant authorities across provinces. This coordination will ensure that the DCFCs are located across provincial borders at intervals enabling safe EV travel, thereby maximizing range confidence.

In addition to the assumptions already discussed, the right hand column of Table 1 presents additional explanations for the projections between 2015 and 2025. This scenario consequently forecasts 1.64 million EVs on Canadian roads in 2025. Given the greater autonomy of affordable EV models to be introduced starting in 2016, this scenario assumes greater consumer interest for BEVs. Consequently, the latter represent 88% of EVs[18] in Canada in 2025.

Table 1. Scenario #2 EV projections

SCENARIO 2. REALISTIC SCENARIO: 127 LOCATIONS, 4 TO 8 CHARGERS PER LOCATION***							
			EV ADOPTION				
			Cumulative				
Year ending ...	Annual sales	Withdrawal of EVs from market**	Total	BEV	PHEV	% of EV compatible with DCFC	Events impacting scenario
2014*	5 200		11 000	5 500	5 500	50%	
2015	7 800		18 800	9 400	9 400	50%	Increase by 50% compared to 2014 sales due to purchase rebate programs in BC, ON, QC
2016	11 700		30 500	15 250	15 250	50%	
2017	19 305		49 805	29 729	20 076	60%	65% increase in sales compared to 2016: Availability of at least 4 "affordable" (approx. $40K) BEV models with autonomy of 300 km+. From this point, BEVs become an increasingly important proportion of overall EV sales: 75% of 2017 sales
2018	31 853		81 658	53 619	28 040	66%	65% Y/Y increase in sales: Availability of affordable longer-range EV models & greater visibility of EVs contributing to improved consumer awareness. Lack of additional investments in DCFC results in relatively greater interest in PHEV compared to scenarios 3, 4
2019	52 558		134 216	95 665	38 551	71%	
2020	86 720		220 937	165 041	55 895	75%	
2021	130 000		350 937	269 041	81 895	77%	Increasing in number of EV models Battery performance continues to improve Economies of scale contribute to lowering price of batteries & vehicles to the point where purchase rebates are no longer required Lifecycle cost of a BEV is less expensive than an ICE vehicle all over Canada,
2022	200 000	2 000	548 937	438 041	110 895	80%	
2023	275 000	4 000	819 937	669 791	150 145	82%	
2024	375 000	6 000	1 188 937	1 004 291	184 645	84%	
2025	460 000	8 000	1 640 937	1 437 291	203 645	88%	

* Rounding

** Assuming approximately 10-year vehicle life

*** Excluding Tesla SuperChargers

3.1.3 Second realistic scenario (#3)

This scenario foresees 300 DC fast charging locations hosting a total of 1,000 DCFCs. This scenario envisages urban DC fast charging locations in addition to the inter-city locations aimed at facilitating coast-to-coast EV travel. The presence of additional DC fast charging locations will increase the range

15 Private capital being injected in a project to electrify Montréal's taxi fleet. This project would require the deployment of 125 DC fast charging stations scattered throughout the city of Montréal. http://affaires.lapresse.ca/portfolio/transport-electrique/201506/18/01-4879044-objectif-1000-taxis-electriques-a-montreal.php

16 Mobility, particularly urban mobility, is changing rapidly as more transportation options (including various forms of car sharing, ride sharing, taxis and transit) are available to urbanites. As more affordably priced EVs with greater range become available, EVs will likely be used to meet the needs of many of these urban mobility options.

17 While an analysis of the impact of transit, car sharing, ride sharing and other forms of mobility on passenger vehicle sales in Canada is of interest, it is beyond the scope of this mandate.

18 DCFC compatible EVs

confidence of EV drivers and contribute to increasing EV sales. The EV projections associated with this scenario are presented in Table 2.

Table 2. Scenario #3 EV projections

SCENARIO 3. REALISTIC SCENARIO: 300 DC FAST CHARGING LOCATIONS HOSTING 1000 DCFC***								
EV ADOPTION								
			Cumulative					
Year ending ...	Annual sales	Withdrawal of EVs from market**	Total	BEV	PHEV	% of EV compatible with DCFC	Events impacting scenario	
2014*	5,200		11,000	5,500	5,500	50%		
2015	7,800		18,800	9,400	9,400	50%	Increase by 50% compared to 2014 sales thanks to purchase rebate programs in BC, ON, QC	
2016	11,700		30,500	15,250	15,250	50%		
2017	19,890		50,390	30,168	20,223	60%	70% increase in sales compared to 2016: Availability of at least 4 "affordable" (max $40K) BEV models with autonomy of 300 km+. From this point, BEVs become an increasingly important proportion of overall EV sales: 75% of 2017 sales. Slightly slower progression to 95% of all EV sales than Scenario 4 as fewer DCFC sites results in slightly more range anxiety.	
2018	33,813		84,203	55,527	28,676	66%	70% Y/Y increase in sales: Availability of affordable longer-range EV models & greater visibility of electrics contributing to improved consumer awareness.	
2019	57,482		141,685	101,513	40,172	72%		
2020	97,720		239,405	179,689	59,716	75%		
2021	140,000		379,405	298,689	80,716	79%	Increasing number of EV models Battery performance continues to improve Economies of scale contribute to lowering price of batteries & vehicles to the point where purchase rebates are no longer required Lifecycle cost of a BEV is less expensive than an ICE vehicle all over Canada, Increase in # of DCFC stns compared to Scenario 2 results in greater EV sales	
2022	215,000	2,000	592,405	480,439	111,966	81%		
2023	285,000	4,000	873,405	734,939	138,466	84%		
2024	390,000	6,000	1,257,405	1,102,439	154,966	88%		
2025	480,000	8,000	1,729,405	1,554,439	174,966	90%		

* Rounding

** Assuming approximately 10-year vehicle life

*** Excluding Tesla SuperChargers

In addition to the assumptions previously, the right hand column of Table 2 presents additional explanations for the projections between 2015 and 2025.

This scenario forecasts 1.73 million EVs on Canadian roads in 2025. As with scenario #2, given the greater autonomy of affordable EV models to be introduced starting in 2016, this scenario assumes greater consumer interest for BEVs. Consequently, the latter represent 90% of EVs in Canada in 2025.

3.1.4 Third realistic scenario (#4)

Scenario #4 assumes a greater deployment of DC fast chargers compared to Scenario #3. This scenario foresees a total of 750 DC fast charging locations hosting 1,600 DCFCs by 2025. The details of this scenario, including the number of DC fast charging locations per year, are presented as the basis for the financial projections in section 3.5. The EV sales projections associated with this scenario are presented in Table 3.

Table 3. Scenario #4 EV projections

SCENARIO 4. REALISTIC SCENARIO: 750 DC FAST CHARGING LOCATIONS HOSTING 1600 DCFC***							
EV ADOPTION							
			Cumulative				
Year ending ...	Annual sales	Withdrawal of EVs from market**	Total	BEV	PHEV	% of EV compatible with DCFC	Events impacting scenario
2014*	5,200		11,000	5,500	5,500	50%	
2015	7,800		18,800	9,400	9,400	50%	Increase by 50% compared to 2014 sales thanks to purchase rebate programs in BC, ON, QC
2016	11,700		30,500	15,250	15,250	50%	
2017	20,475		50,975	30,606	20,369	60%	75% increase in sales compared to 2016: Availability of at least 4 "affordable" (max $40K) BEV models with autonomy of 300 km+. From this point, BEVs become an increasingly important proportion of overall EV sales: 75% of 2017 sales & 95% thereafter
2018	35,831		86,806	64,646	22,160	74%	75% Y/Y increase in sales: Availability of affordable longer-range EV models & greater visibility of electrics contributing to improved consumer awareness. The objective of the Government of Québec is to have 100,000 EV by 2020 (this represents just under 40% of the total number of EV forecast: consistent with the fact that QC has traditionally led the CDN market in EV sales)
2019	62,705		149,511	124,215	25,296	83%	
2020	109,733		259,244	228,462	30,782	88%	
2021	150,000		409,244	370,962	38,282	91%	Increasing number of EV models Battery performance continues to improve Economies of scale contribute to lowering price of batteries & vehicles to the point where purchase rebates are no longer required Lifecycle cost of a BEV is less expensive than an ICE vehicle all over Canada Increase in # of DCFC stns compared to Scenario 3 results in greater EV sales
2022	225,000	2,000	632,244	583,712	48,532	92%	
2023	300,000	4,000	928,244	866,712	61,532	93%	
2024	400,000	6,000	1,322,244	1,243,712	78,532	94%	
2025	500,000	8,000	1,814,244	1,714,712	99,532	95%	

* Rounding

** Assuming approximately 10-year vehicle life

*** Excluding Tesla SuperChargers

In addition previously identified assumptions, the right hand column of Table 3 presents additional explanations for the projections between 2015 and 2025. Assuming 2.5 million total light-duty vehicle sales in Canada in 2025[19], 20% of these sales would be EVs.

[19] Changes in mobility such as greater use of car sharing, may result in lowering the total light-duty vehicles sales in Canada. Even under such circumstances, EV sales as a percentage of overall light-duty vehicles sales would fall well within the range of forecasts presented in Figure 19.

This scenario forecasts 1.81 million EVs on Canadian roads in 2025. As with scenarios 2 and 3, given the greater autonomy of affordable EV models to be introduced starting in 2016, this scenario assumes greater consumer interest for BEVs. Consequently, the latter represent 95% of EVs in Canada in 2025.

Table 4 presents the number of urban and *en route* DC fast charging locations and stations associated with the sales forecasts provided in scenario #4.

Table 4: Urban and *en route* DC fast charging locations and stations associated with Scenario #4

Chargers and locations	2016	2019	2022	2025
Total number of locations	83	195	300	750
Urban station	18	70	125	500
En route station	65	125	175	250
Number of chargers	83	275	625	1600
Urban charger	18	150	340	950
En route charger	65	125	285	650

3.2 Current and future utilization of DC Fast Chargers

The utilization of DC fast charging stations is low for two principal reasons:

- Relatively limited number of electric vehicles in Canada;
- The large majority of recharging is being completed at home, and to a lesser extent, at work.

While DC fast charging stations located closer to, or in, urban areas may be used more frequently than those located on highways, chargers located on highways play an important role in EV adoption by providing EV owners with the safety net required to make longer distance travel (maximizing range confidence).

As more EV models are introduced with longer range, it would be reasonable to expect that EV adoption will increase. More EVs will result in greater use of the DC fast charging infrastructure available. However, a report from the Electrical Power Research Institute (EPRI) [2] indicates that as EV range increases, the percentage of the vehicle population using DC fast charging decreases.

4 Benefits and co-benefits of DCFC stations

Numerous potential benefits are associated with the deployment of a DC fast charging network; some are more easily measured than others. Following is a sample list of some of benefits our presentation will describe:

- Direct revenue generated from the charging session,
- "Peripheral" revenues from the sale of products in nearby retail establishments
- Value of the attractive power of DCFCs to fuel station operators
- Cross-promotion revenues from more affluent EV owners.
- Revenues of Canadian electric utilities that generate electricity in Canada and provide jobs for

The calculations distinguish between urban and *en route* DCFCs. Pricing forecasts assume an increase in pricing over time and higher pricing for *en route* stations compared to their urban counterparts. The study provides calculations for the anticipated payback for urban and *en route* DCFCs.

4.1 Measured and unmeasured co-benefits

Numerous potential benefits are associated with the deployment of a DC fast charging network; some are more easily measured than others. Following is a list of some of these benefits.

- In addition to the revenue generated from the charging session, there is an opportunity to generate "peripheral" revenues from the sale of products in retail establishments that are located near (or not so near) the charging station.

AZRA's current model is to install a DC fast charging station along with the other building and equipment at the service station. In a survey of its members, the Quebec association of EV owners (AVÉQ) has measured that an EV driver who stops for a charge will spend between \$3 and \$14 on food, drink or other products while the vehicle is charging.

- By targeting EV owners with cross-promotions (coupons and special promotions for products and services that are not necessarily offered in the periphery of the DCFC), there is an opportunity to generate additional revenues. The network operator can therefore benefit by partnering with businesses that wish to target their products and services to a segment of the population that is relatively more educated and relatively more affluent than the average [3].

For the EV owner, this increases the value of being a member of the network and being an EV driver.

- In section 2.4, we describe the benefits to specific stakeholders involved in DC fast charging. For many, DC fast charging is a visible message of the organization's pro-environment stance.
- Beyond the above-noted benefits, DC fast charging contributes to reducing GHG emissions and air pollutants by encouraging consumers to purchase and use electric vehicles instead of their ICE counterparts. These environmental benefits are also associated with health benefits.
- Finally, DCFCs increase the revenues of Canadian electric utilities that generate electricity in Canada and provide jobs for Canadians.

In addition to potential job creation resulting from additional revenues, the co-benefits by stakeholder category are summarized in Table 5.

Table 5. Stakeholder co-benefits from the deployment of DC fast charging projects

Stakeholder	Co-benefits
Governments	• Environmental benefits • Health benefits • Positive for citizens (lower noise & air pollution) • Generates revenues for government-owned utilities • Use of domestic kWh results may contribute to lowering fossil fuel import requirements and improving trade balance[20] • Increased adoption of EVs helps jurisdictions meet their GHG emissions reductions obligations • Visible example of government's pro-environmental stance
Electric utilities	• Fits with sustainability initiatives • Positions for future V2G (vehicle to grid) opportunities
EV auto manufacturers	• Positive brand exposure • Gaining access to charging data provides valuable insights to manufacturers about vehicle usage and charging behaviours of customers • Increased sales of EVs would improve compliance of auto manufacturers with federal regulations limiting GHG emissions from passenger automobiles and light trucks
Retailers (service station owners, fast food chains, big box retailers, etc.)	• Fits with sustainability initiatives of some of these companies • Unlike many sustainability initiatives, a DCFC is a very visible sustainability measure
Restaurants, hotels, etc.	• Fits with sustainability initiatives
Real estate developer	• Adds value to properties for lease • Fits with sustainability initiatives

5 The business case for a DCFC network across Canada

5.1 Business model calculations

The following factors were taken into consideration in the development of the business case:

- Motorist travel behaviours (distances driven)

[20] Canada is a net importer of fossil fuel. Canadian electricity is generated domestically. Using domestic kWh hours to power vehicles (EVs) instead of fossil fuel to power ICE vehicles helps lower the fossil fuel requirements and improves the country's trade balance.

- Technology improvements leading to improved range
- Costs associated with the purchase and installation of the DC fast charging station
- Variable costs for maintenance and operation of the station
- Projected number of EVs in Canada (five scenarios)
- Projected number of DCFCs

The calculations distinguish between urban and *en route* DCFCs. Pricing forecasts assume an increase in pricing over time and higher pricing for *en route* stations compared to their urban counterparts. The study provides calculations for the anticipated payback for urban and *en route* DCFCs. Scenario #4 was used in this paper to illustrate the business case calculations.

5.1.1 Working hypotheses

Table 6 establishes the DC fast charger requirements for the number of EVs forecasted in scenario #4. Scenario 4 forecasts of the number of BEVs on Canadian roads are presented in line (a) of the following table. The model is based on the premises that there are significant differences between urban and *en route* stations and therefore, specific hypotheses are formulated for each type of station.

Table 6. Number of DCFC charges required per year[21]

		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
a	Number of BEVs on Canadian roads	9,400	15,250	30,606	64,646	124,215	228,462	370,962	583,712	866,712	1,243,712	1,714,712
	Number of charges per annum country wide											
	Urban stations											
b	Percentage of fleet requiring DCFC services	0.5%	0.5%	0.5%	1.0%	2.0%	4.0%	8.0%	10.0%	10.0%	10.0%	10.0%
c	Number of charges per week	2	2	2	2	1	1	1	1	1	1	1
	Annual number of recharges in urban settings in Canada	4,888	7,930	15,915	67,232	129,184	475,201	1,543,202	3,035,302	4,506,902	6,467,302	8,916,502
	En route stations											
d	Average number of car trips per car per year in Canada	2080.5	2080.5	2080.5	2080.5	2080.5	2080.5	2080.5	2080.5	2080.5	2080.5	2080.5
e	Percentage of trips*	0.2%	0.2%	0.2%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
	Annual number of *en route* recharges in Canada	6,862	11,133	22,343	235,958	453,386	833,886	1,354,011	2,130,549	3,163,499	4,539,549	6,258,699
	TOTAL NUMBER OF DCFC CHARGES REQUIRED PER YEAR	**11,750**	**19,063**	**38,258**	**303,189**	**582,570**	**1,309,087**	**2,897,213**	**5,165,851**	**7,670,401**	**11,006,851**	**15,175,201**

The number of chargers needed in Canada is dependent upon the percentage of the fleet of BEVs (a) that will require DC fast charging.

It would be reasonable to assume that, by 2025, 10% of the BEVs sold in Canada will be owned by urbanites with no access to private parking or charging facilities at work[22]. It is anticipated that the range of these vehicles will reach 480 km over the period. We therefore foresee that the number of charges required by urban EV owners will drop to a single event per week in the vast majority of cases (reflected in line "c" of the preceding table).

As for *en route* requirements, we have used the Transport Canada statistics indicating that Canadians make, on average, 5.7 trips per day (reflected in line "d" of the preceding table) and have assumed that this statistic remains unchanged over the 10-year forecast period. We foresee that the relatively small number of long-range trips undertaken by BEV owners will change as a result of two factors:

- Current EVs are often the household's second car; the other (ICE) car continues to be used for longer distance trips. This will change as the range improves.
- With BEVs able to reach the 480 km mark before the end of the forecast period, EPRI expects the use of DCFCs dropping to 1% of the vehicles on any given day (the line indicated by the letter "e" in the preceding table).

The number of DC fast charges will exceed 15 million events per year by 2025. Pricing assumptions were also made to anticipate market behaviour. These are presented in Table 7.

Table 7. Pricing forecasts by station location

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Average price of charging (80% of battery capacity)											
Urban station	$ 7.00	$ 7.50	$ 8.00	$ 10.00	$ 11.00	$ 15.00	$ 17.50	$ 20.00	$ 22.50	$ 25.00	$ 30.00
En route station	$ 10.00	$ 11.00	$ 12.00	$ 15.00	$ 20.00	$ 25.00	$ 30.00	$ 35.00	$ 40.00	$ 45.00	$ 50.00

Currently, charging a Nissan Leaf at a public DCFC can cost as much as $10[23]. Given the range of the vehicle, this price is not unreasonable and was used as a starting point. Future improvement in range will not be coming from an enhancement in the efficiency of the motor drive. Rather, the improved range will

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21 Please note that the table presents the number of CHARGES required per year, not the charging stations required.

22 According to the 2011 Census, more than 80% of the Canadian population is urban (http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo62a-eng.htm) and the trend is for increasing urbanization of the population. The lack of availability of dedicated parking to urbanites in many Canadian cities is addressed in section 4.3.

23 See http://www.aveq.ca/actualiteacutes/puissance-nergie-pointe-et-le-cot-rel-dune-recharge-au-qubec

result from an increase in battery capacity by as much as four times the current 24 kWh on board a Nissan Leaf. The cost of recharging a vehicle is therefore expected to increase to reflect this added capacity as well as a modest 5% increase in rates in the first few years of the forecast period.

As it is the case for conventional fuels, the price of *en route* charging will also be considerably higher than the cost of urban charging. This *en route* service being used rarely (two or three times a year), we feel a much higher price per charge is justifiable and acceptable when compared with urban charging provided to EV urbanites with no other option but to charge at public stations.

5.1.2 Acquisition and operation costs of DC fast chargers

Currently, charging station networks are comprised of stations owned by one or several parties (Station Owners), and operated by another (Network Operator). For example, Hydro-Québec's Circuit électrique is operated by VERnetwork (réseauVER)[24]. In the case of Tesla's charging network, it is composed of Tesla owned SuperChargers and Tesla subsidized Level 2 destination chargers.[25]

Typically, the space for the installation of a DCFC is provided by a sponsoring station owner at a location such as a service station (called *en route* location) or an urban (often public) space.

The owner also purchases the equipment and pays, in whole or in part[26], for its installation. The capital costs for the station owner are therefore limited to:

- The cost of the DCFC itself;
- The cost of the electrical installation;
- The cost of any civil work required to accommodate the station.

The price of stations (discussed in section 2.5) most often cited for recent purchases of DCFCs is $30,000. Due to economies of scale, the price of a DC fast charger is expected to drop by 10 to 15% before the end of the decade[27].

Aside from the cost of the charger itself, the balance of the cost can vary significantly depending on the location and the pre-existing conditions[28] of the location where it is installed. The particular requirements and practices of the organization that owns the station can also have a significant impact on the cost of installation.

The cost of the electrical installation is dependent on the availability of an appropriate electrical feed at the location. An en route type station located in a green-field location with no other facilities to share the expense burden can cost upwards of $100,000 if a power line and a power line transformer must accommodate that new station. Conversely, installing a DCFC on the wall of a garage in close proximity to a distribution panel that can accommodate the additional load of 3-phase current can cost as little as $12,000.

The cost of civil work is also subject to wide variations. Civil work related to indoor installations is limited to a sign on the wall, some paint on the floor and possibly minor repairs after the electric conduits have been installed. On the other hand, the potential cost of an outdoor station can be very high if the owner wants to light it, heat it, cover it, add amenities (such as washrooms), equip it (with Wi-Fi capabilities for example) and decorate it.

The cost of installation varies considerably depending, in large part, on location, availability of three-phase power and who undertakes the installation[29]. According to AddEnergie, manufacturer and distributor of charging stations and operator of a charging network called VERNetwork, the cost of installation can be as low as $18,000 but can exceed $100,000 in certain situations. The ideal situation would involve using a transformer that has the potential for additional load and where no trenching in pavement is required. In this situation, the total installation cost could be less than $20,000[30].

For the purposes of analysis and development of the business case, an average capital cost of $60,000 has been used to cover both the purchase price and installation of the DCFC. Table 8 presents typical costs

[24] The network is now branded VERnetwork
[25] Tesla declined to provide specific costs for their Superchargers.
[26] Contributions from partners can be used to lower the price of purchase and installation (example, Nissan's contribution to deployment of 25 DCFCs in Québec).
[27] Source: interviews undertaken with electric utilities, charging station manufacturers and network operators.
[28] For example, if trees needs to be cut and the area cleared.
[29] Installation by a private company tends to cost less than installation by a government body.
[30] Source: BC Hydro

associated with the cost and installation of a DCFC in an indoor urban environment and an outdoor en-route location.

Table 8: Average cost of purchase and installation of DCFC by location[31]

	LOCATION OF STATION	
	Indoor Urban	Outdoor *en route*
DCFC	$30,000	$30,000
Electrical Installation	$8,000	$15,000
Civil Work	$7,000	$15,000
TOTAL	**$45,000**	**$60,000**

Our calculations assume that the owners already own or had the space for the DC fast charging stations and no costs have been associated with the cost of acquiring space. Station owners also must assume the costs related to the operation if DC fast charging stations (OPEX). These are mostly variable costs such as electricity, station management, equipment maintenance and transaction fees.

An independent station owner wishing to install its equipment on a property he does not own would have to make an arrangement with the site owner. If the latter operates a commercial concern of interest to motorists, he might well forgo rent in favour of the added patronage from EV owners. Otherwise, rent would have to be paid for the site where the station is installed. The same would apply to snow removal and ancillary services at the site if the fast charging equipment is simply complementing an array of other services[32].

5.1.3 Network operators

Although network operators can own the DC fast chargers they network, they are generally not the owners. Instead, they offer an integrated station management service to their customers. Some, as in the case of Sun Country, also offer the equipment for sale to station owners and sometimes provide installation services. In other cases, such as VERnetwork, a sister organisation (in this case, AddEnergie[33]) sells the equipment.

The main purpose of Network Operators is to bring management tools and expertise to the industry. Therefore, they assume operation and maintenance responsibilities on behalf of Station Owners and add an additional component to the marketing mix: a brand. The services generally provided by Network Operators include management, equipment repair and maintenance, network administration and promotion and cross-marketing activities in certain cases.

The management ($750.00/year), equipment maintenance contract ($750.00/year) and network fees (15% of station usage fee) cover all these services. In some cases, EV owners must pay a small membership fee but in most cases, such membership fees are offset by "free" charging services as it is important for networks to gain the largest possible membership early in the lifecycle of this industry.

Other working hypotheses include the costs of financing based on a 10% interest rate[34].

5.2 Financial forecast

Table 9 presents the results for an average urban DCFC based on the number of stations described in scenario #4.

31 Does not take into consideration such costs as opportunity cost, property taxes and inspection costs.
32 We have conservatively chosen to retain these costs in our model.
33 AddEnergie also manufactures level 2 and DC fast charging stations in Canada for public, at work and private organisations.
34 Dow Jones average annual compound return: 11.12%. The rate of 10% is a round number reflecting the opportunity cost of investing the money in the market.

Table 9. Urban DCFC financial forecasts

URBAN CHARGER BUSINESS CASE	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	CUMULATIVE
REVENUES from charging events (Yearly)	$ 4,277	$ 3,304	$ 5,093	$ 14,940	$ 9,473	$ 75,032	$ 163,673	$ 178,547	$ 202,811	$ 230,975	$ 281,574	$ 1,169,699
EXPENSES												
CAPEX												
CAPEX Depreciation / 10 year linear	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 49,500
Cost of capital (5 year loan)	$ 4,500	$ 3,600	$ 2,700	$ 1,800	$ 900	$ -	$ -	$ -	$ -	$ -	$ -	$ 13,500
OPEX												
Electricity	$ 1,100	$ 833	$ 1,263	$ 6,226	$ 5,025	$ 34,474	$ 67,681	$ 82,907	$ 103,876	$ 120,395	$ 128,423	$ 552,204
Management fee (variable)	$ 642	$ 496	$ 764	$ 2,241	$ 1,421	$ 11,255	$ 24,551	$ 26,782	$ 30,422	$ 34,646	$ 42,236	$ 175,455
Management fee (fix)	$ 750	$ 788	$ 827	$ 868	$ 912	$ 957	$ 1,005	$ 1,055	$ 1,108	$ 1,163	$ 1,222	$ 10,655
Equipment maintenance contract	$ 750	$ 788	$ 827	$ 868	$ 912	$ 957	$ 1,005	$ 1,055	$ 1,108	$ 1,163	$ 1,222	$ 10,655
Site maintenance												$ -
Miscellaneous & unforeseen	$ 500	$ 525	$ 551	$ 579	$ 608	$ 638	$ 670	$ 704	$ 739	$ 776	$ 814	$ 7,103
TOTAL COST	$ 12,741	$ 11,528	$ 11,432	$ 17,083	$ 14,277	$ 52,781	$ 99,412	$ 117,003	$ 141,753	$ 162,644	$ 178,417	$ 819,072
NET PROFIT (LOSS)	**-$ 8,464**	**-$ 8,224**	**-$ 6,339**	**-$ 2,142**	**-$ 4,803**	**$ 22,250**	**$ 64,261**	**$ 61,544**	**$ 61,058**	**$ 68,331**	**$ 103,157**	**$ 350,627**
ROI	**-19%**	**-18%**	**-14%**	**-5%**	**-11%**	**49%**	**143%**	**137%**	**136%**	**152%**	**229%**	78%

With a breakeven in the sixth year of operation, the anticipated payback is just under 8 years.

As indicated in Table 10, with a breakeven in the fourth year of operation, the anticipated payback period for the average case DCFC en route charger is slightly better at just under 7 years.

Table 10. En route DCFC financial forecasts

EN ROUTE CHARGER BUSINESS CASE	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	CUMULATIVE
REVENUES from charging events (Yearly)	$ 2,745	$ 1,884	$ 3,575	$ 35,394	$ 72,542	$ 115,818	$ 142,527	$ 261,646	$ 361,543	$ 408,559	$ 481,438	$ 1,887,671
EXPENSES												
CAPEX												
CAPEX Depreciation / 10 year linear	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 66,000
Cost of capital (5 year loan)	$ 6,000	$ 4,800	$ 3,600	$ 2,400	$ 1,200							$ 18,000
OPEX												
Electricity	$ 494	$ 324	$ 591	$ 9,833	$ 21,162	$ 31,928	$ 34,380	$ 69,425	$ 104,162	$ 118,311	$ 131,748	$ 522,358
Management fee (variable)	$ 412	$ 283	$ 536	$ 5,309	$ 10,881	$ 17,373	$ 21,379	$ 39,247	$ 54,231	$ 61,284	$ 72,216	$ 283,151
Management fee (fix)	$ 750	$ 788	$ 827	$ 868	$ 912	$ 957	$ 1,005	$ 1,055	$ 1,108	$ 1,163	$ 1,222	$ 10,655
Equipment maintenance contract	$ 750	$ 788	$ 827	$ 868	$ 912	$ 957	$ 1,005	$ 1,055	$ 1,108	$ 1,163	$ 1,222	$ 10,655
Site maintenance	$ 1,000	$ 1,050	$ 1,103	$ 1,158	$ 1,216	$ 1,276	$ 1,340	$ 1,407	$ 1,477	$ 1,551	$ 1,629	$ 14,207
Miscellaneous & unforeseen	$ 500	$ 525	$ 551	$ 579	$ 608	$ 638	$ 670	$ 704	$ 739	$ 776	$ 814	$ 7,103
TOTAL COST	$ 15,906	$ 14,556	$ 14,035	$ 27,015	$ 42,890	$ 59,130	$ 65,779	$ 118,893	$ 168,826	$ 190,249	$ 214,850	$ 932,129
NET PROFIT (LOSS)	**-$ 13,161**	**-$ 12,672**	**-$ 10,460**	**$ 8,378**	**$ 29,652**	**$ 56,688**	**$ 76,748**	**$ 142,753**	**$ 192,717**	**$ 218,310**	**$ 266,588**	**$ 955,542**
ROI	**-22%**	**-21%**	**-17%**	**14%**	**49%**	**94%**	**128%**	**238%**	**321%**	**364%**	**444%**	**159%**

In both cases, there is a very attractive return on investment for a station owner willing to take the risk and be patient. However, the risks are at least commensurate with the expected ROI: sales of BEVs may be slower than expected for a number of reasons. Consequently, few investors are currently willing to deploy large numbers of DC fast charging stations, especially with no government support or guarantees.

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