Clean Energy Vehicle Economic Opportunities Assessment

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About MNP

MNP is one of the fastest growing major chartered accountancy and business advisory firms in Canada. Founded in 1945, MNP has grown from a single office in Manitoba to more than 75 offices and 3,000 team members across Canada. MNP is a member of Praxity AISBL, a global alliance of independent firms, which enables us to access a broad range of industry specific expertise worldwide.

Economic and industry studies are carried out by MNP's Economics and Research practice, consisting of a team of dedicated professionals that have a successful track record of assisting clients with a wide variety of financial and economic studies. Our work has encompassed a wide range of programs, industries, company operations and policy initiatives, and has helped clients with decision-making, communication of economic and financial contributions, documentation of the value of initiatives and activities and development of public policy.

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List of Acronyms

Acronym	Definition
ARC	Advanced Research and Commercialization
BC	British Columbia
BEV	Battery Electric Vehicle
CEV	Clean Energy Vehicle
CNG	Compressed Natural Gas
EDC	Export Development Canada
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FCEV	Fuel Cell Electric Vehicle
FTE	Full-time Equivalent
GDP	Gross Domestic Product
H2	Hydrogen
HDV	Heavy Duty Vehicle
HEV	Hybrid Electric Vehicle
HOV lane	High-occupancy Vehicle lane
ICE	Internal Combustion Engine
ITS	Intelligent Transportation Systems
LCFS	Low Carbon Fuel Standards
LDV	Light Duty Vehicle
LNG	Liquefied Natural Gas
LRT	Light Rail Transit
MDV	Medium Duty Vehicle

MURB	Multi-use Residential Building
NAICS	North American Industry Classification System
OEM	Original Equipment Manufacturer
PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
R&D	Research and Development
SDTC	Sustainable Development Technology Canada
SIC	Standard Industrial Classification
SRED	Scientific Research and Experimental Development
TOC	Total Cost of Ownership
TWh	Terawatt-hour
VAT	Value-added Tax

1. Executive Summary

The Clean Energy Vehicle (CEV) sector in BC is an example of an industry sector that is well positioned to capitalize on opportunities in the growing clean economy. With the emergence of new technologies and related businesses, it is an opportune time to assess BC's current economic performance in the sector and identify future opportunities for growth.

To help set the economic development context within the CEV sector in BC, MNP was engaged by the BC Ministry of Energy and Mines to address the following key questions:

- What are BC's strengths and weaknesses for economic development in the CEV sector? What are key challenges to the growth of the sector?
- What opportunities exist to attract business investment and increase economic activity in the sector?
- How can the sector best be supported to build on these strengths, reduce barriers and target business development?

To address these questions, the following research activities were conducted as part of this study:

- A survey of key industry representatives to gather information on revenues, employment, exports, and research and development activity in the sector, as well as information on key opportunities and challenges.
- Interviews with industry representatives to identify opportunities, barriers and considerations.
- Two facilitated workshops with industry representatives to gather input on BC's advantages, challenges and opportunities in the sector, as well as areas for government to support the growth of the sector.
- Collection and review of secondary research to identify global market trends and opportunities.

For the purpose of this study, the CEV sector was defined to include electric vehicles (i.e., battery electric vehicles and plug-in hybrid electric vehicles) and hydrogen fuel cell electric vehicles, and includes companies and organizations involved in all aspects of the supply chain – from raw materials to final consumer products – related to vehicles and vehicle components, fuel and infrastructure, and transferable technologies and services. The sector was defined to encompass a wide range of economic activity that included various industry sectors, as well as related academic, research, policy and advocacy initiatives.

In total, in 2015 the CEV sector was estimated to encompass:

- Approximately 198 companies and organizations involved in all aspects of the CEV supply chain.
- Total direct employment of approximately 3,850 full-time equivalents (FTEs), which support additional indirect and induced employment of approximately 2,820 FTEs.
- Approximately $702.0 million in total direct economic activity, including more than $137.6 million in exports of CEV-related goods and services and more than $68.2 million in spending on research and development and demonstration projects.[1]

[1] The value of total exports and expenditures on research and development and demonstration projects was obtained through a survey of businesses and organizations in the sector, and only represents the amount reported by survey respondents. These values should therefore be considered conservative estimates. (For more information on the survey, please refer to Appendix A.)

It was identified that BC has a number of competitive advantages to pursue opportunities in the CEV sector, including:

- An internationally recognized hydrogen and fuel cell sector that encompasses hydrogen supply and processing, component and systems testing, technology development and commercialization, and standards development, as well as a number of firms engaged in research related to electric battery components and controls.
- A strong network of academic institutions engaged in research in the sector that supply access to a highly educated workforce.
- A history of small business innovation, with the strong presence of a local technology sector encompassing over 9,000 companies involved in clean tech, digital media, wireless, life sciences and information and communications technology employing over 84,000 people.[2]
- A leading position in smart grid (advanced metering technologies) infrastructure deployment and telecommunications, viewed as critical to the mass deployment of electric vehicles.
- High adoption rate of CEVs with environmentally-minded consumers.
- Proximity to West Coast states with vibrant clean tech, clean transportation and aviation sectors, along with proximity to rail, truck and port facilities.
- Progressive environmental policy, legislation and climate leadership at provincial and municipal levels.
- Access to clean, renewable and low cost electricity and existence of end-to-end hydrogen supply chain from production, recovery, purification and compression through to fueling infrastructure.

Challenges faced by companies in BC's CEV sector include:

- Access to capital (both seed funding and venture capital funding).
- Small size and difficulty in scaling.
- Limited government procurement or early adoption limiting the ability of BC companies to test and demonstrate their technologies to potential buyers.
- Small domestic market, meaning reliance on export-oriented growth.
- Lack of automotive supply chain in BC or in close proximity.
- Lack of manufacturing expertise, capabilities and scale.
- Competition for highly qualified people (e.g., programmers and engineers) from other industry sectors (e.g., digital media/gaming) and other jurisdictions (e.g., California).
- Lack of a comprehensive roadmap or strategy for the province with a need to reinvigorate BC's position as a climate leader.
- Regulatory constraints related to the deployment of infrastructure, with utility role in the CEV sector not well defined or understood.

[2] KPMG, *British Columbia Technology Report Card 2014,* Available here: http://www.kpmg.com/Ca/en/IssuesAndInsights/ArticlesPublications/Documents/6943-BC-Tech-Report-card-FY14-web.pdf

Targeted support for the CEV sector to build on existing strengths or eliminate barriers would help enable a number of investment, development and economic growth opportunities in the CEV sector in BC, and could lead to significant job creation, investment attraction, export development and other economic benefits. The following opportunities were identified through stakeholder consultations and were supported by secondary research. While the majority of economic opportunities would likely take place in the Lower Mainland, there is also significant potential for rural economic development in exploring resource-related opportunities (such as graphite and hydrogen production) and opportunities located outside of major urban centres (such as lithium-ion battery recycling).

Vehicles and Vehicle Components

1. Leverage the fuel cell cluster to target and attract more auto manufacturers to BC and to attract foreign direct investment in the sector.
2. Focus on the development of manufacturing capability in BC for the production of fuel cell stacks.
3. Focus on the manufacture of various CEV components to play a more significant role in the global value chain.
4. Continue to pursue lithium-ion battery research and development.
5. Become a leader in lithium-ion battery production, recycling, secondary use and disposal.
6. Explore supply chain opportunities for battery and fuel cell technology, including materials used in the production of these technologies (e.g., graphite and other metals).

Fuel and Infrastructure

1. Continue to encourage CEV adoption to reduce fossil fuel imports and leverage locally sourced and lower cost fuels.
2. Capitalize on funding opportunities to support the installation of additional fueling and charging infrastructure.
3. Explore hydrogen production, storage solutions and bulk export opportunities through electrolysis and waste capture.
4. Leverage BC's design, testing and development of smart grid technology for electric vehicle deployment and utility telecommunications systems.

Transferable Technologies and Services

1. Leverage BC's technology sector to pursue opportunities related to the intelligence inside the vehicle, including a focus on supporting research, development and commercialization activities related to optimized fuel cell efficiency, the connected car, autonomous vehicles, compression and fueling algorithms, and vehicle telematics and controls, and act as a test environment for these technologies.

Assessment of Economic Opportunities

Based on a review of BC's current exports of CEV-related goods and services, as well as historical growth rates and industry projections, it was estimated that pursuing export development opportunities in the CEV sector could result in total exports in the range of $184 million to $222 million annually by 2020, representing a compound annual growth rate (CAGR) of 6 to 10 percent compared with current estimated levels.

In addition to export opportunities, the continued adoption of CEVs is projected to result in additional spending in the local economy as consumers transition from imported fossil fuels to locally sourced and lower cost fuels, and as additional investments are made in CEV-related infrastructure, providing opportunities for local infrastructure providers and contractors.

Export development opportunities and the increased adoption of CEVs (such that they represent five percent of light duty vehicle sales by 2020) were projected to be associated with a total increase in annual employment of approximately 1,400 FTEs, and a total increase in annual GDP of more than $80 million by 2020.

The following areas of strategic support were identified to continue to develop BC's capabilities in the sector and to take advantage of market opportunities.

Strategic Support for Developing BC's CEV Sector

1. Re-establish BC's leadership in climate change and develop an integrated and comprehensive roadmap for the province that considers energy, climate, and economic development goals and objectives.
2. Continue to support CEV adoption and infrastructure deployment.
3. Design and implement a provincial procurement policy that is supportive of CEVs.
4. Continue efforts to improve access to capital (seed funding and venture capital funding).
5. Provide targeted support for prototype development, large scale demonstration projects and commercialization support.
6. Support the development of highly qualified and skilled labour.
7. Support foreign direct investment and export development activities.

2. Introduction

2.1. Background and Study Purpose

The Ministry of Energy and Mines (the Ministry) commissioned MNP LLP (MNP) to conduct a study of the economic opportunities in the Clean Energy Vehicle (CEV) sector in British Columbia (BC). The CEV sector specifically refers to battery electric vehicles, plug-in hybrid electric vehicles and hydrogen fuel cell vehicles, and includes companies and organizations involved in all aspects of the CEV supply chain – from raw materials to final consumer products – related to vehicles or vehicle components, fuel and infrastructure, and transferable technologies and services.

The study supports the Ministry's CEV Program, which is intended to encourage and accelerate the adoption of CEVs in BC for both their environmental and economic benefits.[3] According to the Program Guide for the CEV Program, the increased use of CEVs will help shift spending on imported transportation fuels to locally made electricity and hydrogen, and will help stimulate jobs and economic development in the local clean technology sector.[4]

To support these objectives, the CEV Program will be launching the CEV Advanced Research and Commercialization (ARC) Program in 2016/17 intended to advance the CEV industry sector in BC.

In order to set the economic development context for the CEV Program and support policy direction, the scope of the study involved the following activities:

- Identification of BC companies currently operating in the CEV sector.
- Identification of investment, development and economic growth opportunities in the CEV sector – from raw materials to final consumer products – in the vehicle, fuel and infrastructure, and transferable technologies and services categories.
- Identification and quantification of the potential economic opportunities and impact for BC as a result of developing BC's CEV sector.
- Development of recommendations related to areas of strategic support that would help develop the CEV sector and stimulate related economic development benefits in BC.

The study is intended to provide an environmental scan that will, in part, be used to inform the design of the ARC Program. In addition, the study will be used to understand a current baseline of the CEV sector in BC in order to measure job and economic development progress throughout the CEV Program.

2.2. Structure of the Report

This report is organized as follows:

- Section 3 provides an overview of the CEV sector, including a definition of the types of activities it encompasses, as well as key trends and opportunities in the sector.
- Section 4 describes companies operating in the CEV sector in BC and includes a baseline of economic activity in the sector.

[3] Ministry of Energy and Mines (2015). *Program Guide for the British Columbia Clean Energy Vehicle Program.*

[4] Ibid.

- Section 5 presents an overview of BC's competitive advantages in the CEV sector, challenges constraining growth in the sector and key economic opportunities for the sector.
- Section 6 presents recommendations for strategic support to grow and develop the sector in BC, including a review of support provided in other jurisdictions and sectors.

2.3. Report Limitations

This report is not intended for general circulation, nor is it to be published in whole or in part without the prior written consent of MNP LLP. The report is provided for information purposes and is intended for general guidance only. It should not be regarded as comprehensive or a substitute for personalized business or investment advice.

We have relied upon the completeness, accuracy and fair presentation of all information and data obtained from the BC Ministry of Energy and Mines, industry members and public sources, believed to be reliable. The accuracy and reliability of the findings and opinions expressed in the presentation are conditional upon the completeness, accuracy and fair presentation of the information underlying them. As a result, we caution readers not to rely upon any findings or opinions expressed for business or investment purposes and disclaim any liability to any party who relies upon them as such.

Additionally, the findings and opinions expressed in the presentation constitute judgments as of the date of the presentation, and are subject to change without notice. MNP is under no obligation to advise of any change brought to its attention which would alter those findings or opinions.

3. Overview of the CEV Sector

3.1. Definition of the CEV Sector

For the purpose of this study, the CEV sector refers to electric vehicles (i.e., battery electric vehicles and plug-in hybrid electric vehicles) and hydrogen fuel cell electric vehicles, and includes companies and organizations involved in all aspects of the supply chain – from raw materials to final consumer products – related to vehicles or vehicle components, fuel and infrastructure, and transferable technologies and services (e.g., software and smart grid). The sector encompasses a wide range of economic activity that includes various industry sectors, as well as related academic, research, policy and advocacy initiatives.

What is an electric vehicle?

Electric vehicles (EVs) are vehicles that are capable of connecting to the electrical grid to charge their batteries and are sometimes referred to as plug-in electric vehicles (PEVs). This is to distinguish them from hybrid electric vehicles (HEVs), which do not require connection to the electrical grid and charge their batteries exclusively from onboard power conversion and regenerative braking. PEVs include fully battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). BEVs operate exclusively with grid-supplied electrical energy stored onboard in batteries and are driven only by electric motors. PHEVs are capable of operating both with stored electrical energy, as well as from an internal combustion engine, and are driven either by electric motors, an internal combustion engine and drivetrain or a combination of the two. Hereafter, PEVs will be referred to simply as EVs.

What is a hydrogen fuel cell electric vehicle?

There are two types of on-road hydrogen vehicles. The first simply combusts or burns compressed hydrogen (H2) in much the same way as a traditional internal combustion engine fueled by natural gas. The second are fuel cell electric vehicles (FCEVs) which, along with EVs, are the primary focus of this analysis. FCEVs convert compressed hydrogen stored onboard the vehicle in high pressure tanks into electricity that powers electric motors that drive the wheels. This electrochemical process occurs over fuel cell stacks that function in a manner comparable to that of the battery in an EV. Whereas an EV's energy is stored in a battery that is recharged from the grid, the energy stored in a FCEV is in the form of compressed hydrogen that must be dispensed into the vehicle storage tanks from an external source.

More specifically, the sector includes companies and organizations involved in the research, development, design, manufacture, production, transport, installation and sale of the following products or services:

- On-road and non-road applications of EVs and FCEVs, as well as related components, systems and subsystems;
- Electric charging infrastructure and hydrogen fueling infrastructure; and
- Transferable technologies and services that may apply to the CEV sector.

The following table provides an overview of the types of vehicles that are included within the definition of CEVs, for the purpose of this study.

Table 1: Study Definition of Clean Energy Vehicles (CEVs)

Vehicle Type	Vehicle Description	Examples	Type of CEV	Included in Sector Definition
On-Road				
Light Duty Vehicles (LDV)	Passenger vehicles, car share, taxi fleets and urban fleet	Nissan Leaf, Tesla Model S, Chevy Volt, Hyundai Tucson H2 and Toyota Mirai	BEV, PHEV, FCEV	Yes
Medium Duty Vehicles (MDV)	Pickup trucks and vans	Daimler Sprinter, F550, Via Motors V-Trux/ Van	PHEV	Yes
Heavy Duty Vehicles (HDV)	Semi long haul transport trucks/ commercial vehicles	Cummins, Westport Innovations, Wastetech	Compressed natural gas (CNG) and liquefied natural gas (LNG) vehicles	Not included, except as applicable to truck stop electrification or refrigeration
Transit Vehicles	Buses	GreenPower EV350 Electric Bus, New Flyer XHE60 Fuel Cell Bus	Trolley BEV, PHEV, FCEV, CNG vehicle	Yes, except CNG
Other	2/3 wheeled vehicles, recreational off road	Electric Bikes & Scooters, E-Motorcycles, Brammo, Zero Bikes, Sparrow, FVT and Velo Metro	BEV	Yes
Non-Road				
Materials Handling	Lift trucks, airport tugs, baggage handling, wheeled gantry cranes	Canadian Electric Vehicles Might-E Truck	BEV, H2	Yes
Air, Rail and Maritime applications	Airplanes, trains and ships	Skytrain	Electric	Not included

The following sections provide a list of activities included within the CEV sector. For a more detailed discussion of the industries and activities included in the sector definition, please refer to Appendix A. Note that supporting organizations have been identified separately, as they play a role in one or more aspects of the CEV sector and its related supply chain.

Vehicles and Vehicle Components

Activities that relate to vehicles and vehicle components in the CEV sector include:

- Design, manufacture, distribution and sale of vehicle components, including traction batteries, capacitors cells and modules, onboard hydrogen storage systems, fuel cells, stacks and controls, and battery management systems.
- Design, manufacture, distribution and sale of CEVs.
- Purchase of CEVs, including fleet applications.
- CEV repair and maintenance.
- Recycling of CEVs and related components.

Fuel and Infrastructure

Activities that relate to fuel and infrastructure in the CEV sector include:

- Electricity production, storage and distribution.
- Hydrogen production (industrial by-product and/or deliberate), compression, transportation and storage.
- Design, manufacture, distribution and sale of electric vehicle supply equipment (EVSE) and compressed hydrogen fueling infrastructure.
- Services related to the installation and maintenance of CEV-related infrastructure.

Transferable Technologies and Services

Activities that relate to transferable technologies and services include research, development and commercialization of the following:

- Software, computer systems and computer applications.
- Vehicle automation (autonomous vehicles) and controls.
- Intelligent transportation systems (ITS).
- Intelligent grid interface and smart grid technologies.
- Vehicle lightweighting technologies.

Supporting Organizations

Further to the three specified categories of CEV-related activities, there are a number of supporting organizations involved in the sector, including governments, academic institutions, management and technical consulting firms. Some of their activities include:

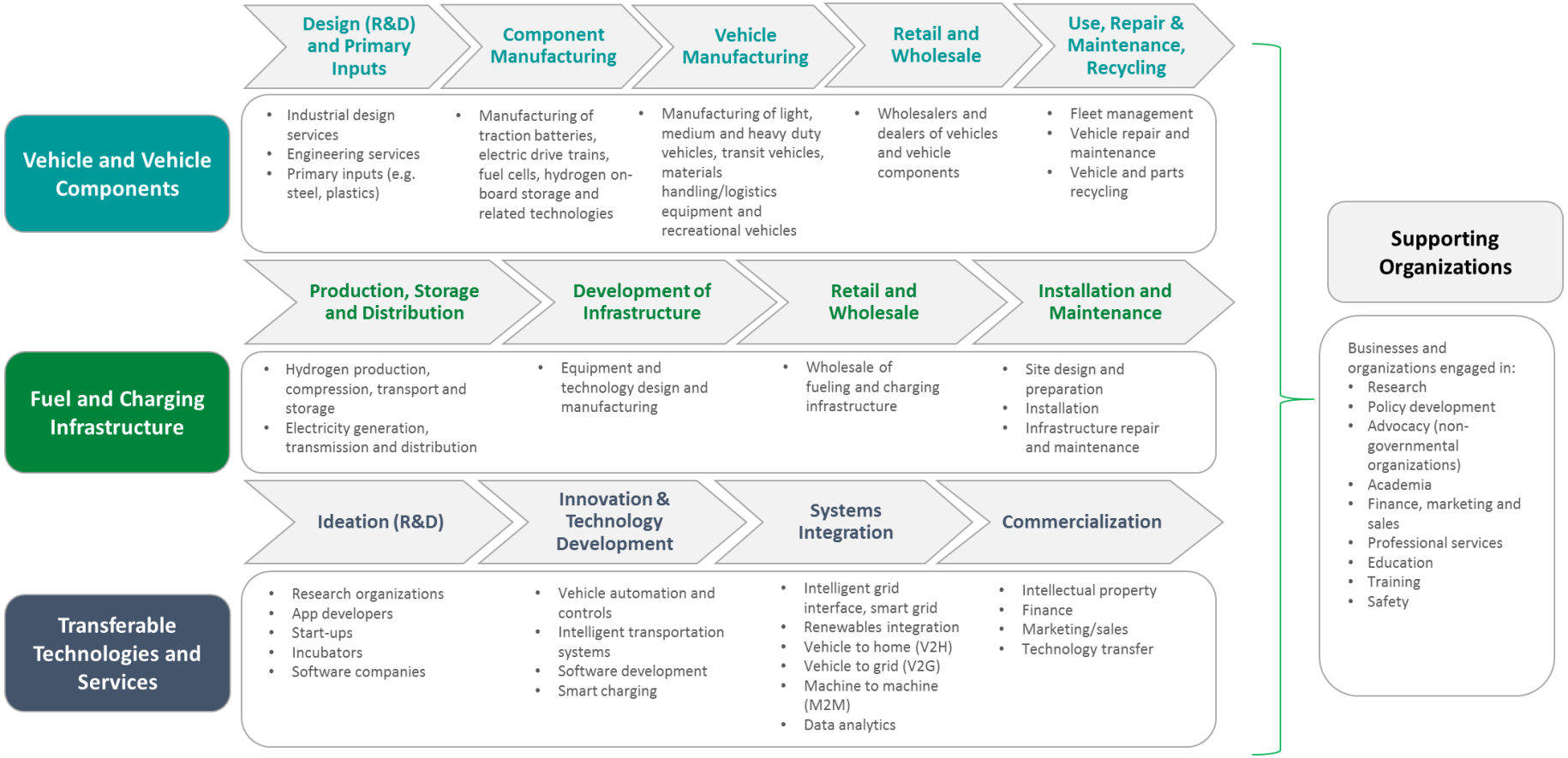
- Policy and program development.
- Research, development and demonstration activities.
- Advocacy.
- Education and skills training.
- Professional services.

3.2. Value Chain of the CEV Sector

A value chain is a high-level model of how businesses receive primary materials as input, add value to these materials through various processes and distribute finished products to customers.

For each of the CEV subsectors, direct impacts arise from the industry's core activities while indirect impacts arise from the linkages that exist with suppliers and other sectors. The activities defined to be associated with the CEV sector are presented in the following value chain.

Figure 1: CEV Sector Value Chain



3.3. Market Trends and Opportunities

Government regulations, incentives and subsidies in a number of jurisdictions – typically linked to climate change and carbon emissions targets – are a key factor supporting investment opportunities in the CEV sector globally. An increasing number of original equipment manufacturers (OEMs) have introduced CEVs in their product lines, driving investment and innovation, improvements in CEV products, and the development of new and related technologies. Decreasing costs for CEV components and growing public awareness and interest in CEVs[5] are also contributing to investment in the sector.

A summary of key market trends and opportunities related to each of the CEV subsectors is presented in the following sections.

Vehicles and Vehicle Components

Electric Light Duty Passenger Vehicles

Currently sitting at about 0.2 percent of the global automotive market, electric vehicles are expected to grow to 10 to 15 percent of the market by 2020[6], representing an overall market potential for the provision of electric vehicles of approximately $340 billion in that year.[7] By 2040, Bloomberg reports that electric vehicles are forecast to hit 41 million units, or 35 percent of the global automotive market.[8]

Eight main markets accounted for 90 percent of the electric vehicle market in 2015 (China, United States, Netherlands, Norway, United Kingdom, Japan, Germany and France).[9] Electric vehicle sales in China tripled in 2015, resulting in China surpassing the United States as the world's largest market for electric vehicles.[10] Slowing growth for electric vehicles in the United States has been attributed to the lack of charging infrastructure, low gas prices in conjunction with the price of higher end electric vehicle models, and the deployment of efficient turbocharged engines in vehicles that lead to better fuel economy and emissions reductions.[11] Inventory levels (supply) also play a role in the purchasing of electric vehicles, especially in the non-luxury vehicle segments where buyers are used to fast delivery times.[12] According a report by FleetCarma, supply of electric vehicles can be highly variable by dealer, time of year, geography and product lifecycle (e.g., key model releases).

Investments from government and industry in research and development for lithium-ion batteries has led to a decrease in production costs, improved functionality and lifespan, and increased range, which in turn

[5] According to a global study conducted by Accenture with 7,000 individuals from 13 countries, 60 percent of those respondents that intended to purchase a car in the next 10 years said they would consider an electric vehicle, although many would require more information before making a decision. Source: Accenture, The Electric Vehicle Challenge: Electric vehicle Growth in an evolving market dependent on seven success factors.

[6] Accenture, The Electric Vehicle Challenge: Electric vehicle growth in an evolving market dependent on seven success factors.

[7] The global market for the provision of electric vehicles, which includes sales and marketing, manufacturing, financing, value-added services and maintenance is estimated to reach $338 billion in 2020. The provision of infrastructure is excluded and is estimated to reach $29 billion by 2020, according to the same source. Source: AT Kearney, *eMobility: The long Road to a Billion-Dollar Business*, 2011.

[8] Bloomberg New Energy Finance News, Electric vehicles to be 35% of Global New Car Sales by 2040, February 2016.

[9] OECD/IEA, Global EV Outlook 2016.

[10] Euromonitor, Plug-in Electric Vehicles (PEVs) Sales Stumbled in the US, but are Poised for Recovery - Euromonitor

[11] Ibid.

[12] FleetCarma, Ease of Purchasing EVs in Canada, 2015.

has resulted in increased sales of electric cars.[13, 14] Factors that are expected to increase electric vehicle sales in the future include a drop in the price of electric vehicles, growing electric charging infrastructure, new product offerings (e.g., electric SUVs) and regulatory pressures on automakers to continue to lower emissions.[15]

Driven by the continued rise in battery electric vehicles, the global market for lithium-ion batteries for use in light-duty vehicles is forecasted to total $221 billion from 2015 to 2024, according to a recent report from Navigant Research.[16] Revenue in the United States alone for lithium-ion batteries is forecasted to reach $6.5 billion in 2020.[17] The majority of lithium-ion batteries are currently manufactured in Asia.[18] Production in the United States is more focused on transportation applications, and the planned Tesla production facility in Nevada could place the United States as a lithium-ion battery leader in the future, according to an IBIS World report.[19]

Suppliers of materials and components used in batteries, including lithium and graphite, could see an increase in demand as the demand for CEV components increases. Looking ahead, new and alternative chemistries are being explored for batteries, such as lithium-air, lithium sulfur and solid-state lithium. This could be disruptive to the lithium-ion battery market, although this disruption would not be expected to take place in the next few years due to the research and testing requirements to bring new products to market.[20]

Fuel Cell Electric Vehicles

The International Energy Agency estimates that approximately 550 fuel cell passenger cars and buses were on the road in Europe, Japan, Korea and the United States in 2014[21], with over 520,000 planned to be deployed by 2020.[22] According to a report from Navigant Research, annual sales of FCEVs are expected to

[13] IBIS World, Lithium Battery Manufacturing in the US, February 2015

[14] Frankfurt School-UNEP Centre/BNEF, Global Trends in Renewable Energy Investment 2016. Available here: http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf

[15] A drop in battery prices is expected to be one of the main drivers of growth. According to Bloomberg New Energy Finance, a fall in battery prices could lead the electric vehicle to be more economic than gasoline or diesel alternatives by the 2020s. Source: Bloomberg New Energy Finance News, Electric vehicles to be 35% of Global New Car Sales by 2040, February 2016.

[16] Navigant Research News Room, *The Global Market for Lithium Ion Batteries for Vehicles Is Expected to Total $221 Billion from 2015 to 2024,* Available here: https://www.navigantresearch.com/newsroom/the-global-market-for-lithium-ion-batteries-for-vehicles-is-expected-to-total-221-billion-from-2015-to-2024

[17] IBIS World, Lithium Battery Manufacturing in the US, February 2015

[18] Clean Energy Manufacturing Analysis Center (CEMAC), Automotive Lithium-ion Cell Manufacturing: Regional Cost Structures and Supply Chain Considerations, 2016. Available here: http://www.nrel.gov/docs/fy16osti/66086.pdf

[19] Ibid.

[20] Navigant Research News Room, *The Global Market for Lithium Ion Batteries for Vehicles Is Expected to Total $221 Billion from 2015 to 2024,* Available here: https://www.navigantresearch.com/newsroom/the-global-market-for-lithium-ion-batteries-for-vehicles-is-expected-to-total-221-billion-from-2015-to-2024

[21] Note that this number of fuel cell vehicles is already expected to be higher in 2016 as OEMs are releasing new vehicles for sale or lease in target markets and continuing to grow their fleets. For example, although the Technology Roadmap cites approximately 102 fuel cell passenger vehicle and buses in Japan in 2014, a report released in 2016 by the Ministry of Economy, Trade and Industry in Japan states approximately 400 fuel cell vehicles on the road. Source: http://www.japantimes.co.jp/news/2016/03/16/business/japan-eyes-40000-fuel-cell-cars-160-hydrogen-stations-by-2020/#.V4UfsGd4deu.

[22] OECD/IEA, *Technology Roadmap: Hydrogen and Fuel Cells*, 2015.

exceed 228,000 by 2027.[23] The number of available FCEV models is expected to reach 17 in the next 11 years[24], with production expected to be primarily in Japan and Korea in the near term, and in Europe in the longer term.[25] The International Energy Agency's Technology Roadmap for hydrogen and fuel cells, however, notes the cost of fuel cell vehicles and installing and operating refueling stations as a current barrier to the growth of the market.[26]

According to IHS, at this time, platinum use in fuel cell catalysts is five to six times the amount used in a diesel catalytic converter.[27] As the demand for fuel cell vehicles increases, this could mean an increase in demand for platinum.

Urban Transit and Delivery Vehicles

According to the Global EV Outlook 2016, the number of battery electric buses in the world in 2015 reached approximately 150,000.[28] The large majority of these buses were located in China, while other countries have deployed smaller fleets (between 20 and 100 vehicles) in major cities to serve as pilot and demonstration projects. China alone plans to have 200,000 electric buses deployed by 2020.[29]

A report by Grand View Research segmented the global fuel cell vehicle market into seven categories: buses, forklifts, motorcycle and bicycles, airplanes, boats, submarines, and trams. According to the report, the bus segment of the fuel cell vehicle market is expected to account for the largest market share, followed by two-wheeler applications (motorcycles and bicycles).[30] According to Grand View Research, North America is currently the leading market for these vehicles, driven by government-led initiatives to develop hydrogen infrastructure in the region. However, Asia Pacific is expected to grow at the highest rate over the next few years, also due to support for the technology from government initiatives.[31]

Fuel costs and environmental concerns are expected to impact the market for medium and heavy duty vehicles as commercial and government fleets look to invest in fuel efficiency and alternative fuels.[32] New regulations and increased emission requirements in the US are also expected to impact the medium and heavy duty vehicle sector, with research and development on alternative fuel technologies currently underway.[33]

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[23] Navigant Research. Fuel Cell Vehicles. Available at https://www.navigantresearch.com/newsroom/annual-fuel-cell-car-and-bus-sales-are-expected-to-exceed-228000-by-2024

[24] There are currently only three products available for sale or lease (Toyota Mirai, Hyundai ix35/Tucson and the Honda Clarity). These products are currently only available in select markets.

[25] IHS Newsroom (May 4, 2016), *Global Hydrogen Fuel Cell Electric Vehicle Market Buoyed as OEMs Will Launch 17 Vehicle Models by 2027, IHS Says*

[26] OECD/IEA, *Technology Roadmap: Hydrogen and Fuel Cells*, 2015

[27] IHS Newsroom (May 4, 2016), *Global Hydrogen Fuel Cell Electric Vehicle Market Buoyed as OEMs Will Launch 17 Vehicle Models by 2027, IHS Says*

[28] OECD/IEA, Global EV Outlook 2016, 2016.

[29] Ibid.

[30] Grand View Research, *Fuel Cell Vehicle Market Analysis, Market Size, Application Analysis, Regional Outlook, Competitive Strategies, and Forecasts, 2015 To 2022*, Available here: http://www.grandviewresearch.com/industry-analysis/fuel-cell-vehicle-market

[31] Ibid.

[32] Navigant Research, *Transportation Forecast: Medium and Heavy Duty Vehicles 2016-2035*, Available here: https://www.navigantresearch.com/research/transportation-forecast-medium-and-heavy-duty-vehicles

[33] IBIS World, Truck and Bus Manufacturing in the US Industry Report, May 2016

Car Sharing and Fleet Vehicles

Car sharing programs have been increasing their use of CEVs in their fleets. In a recent report by Navigant Research, it was estimated that about 20 percent of all car sharing vehicles in use globally were electric vehicles.[34] Issues around charging infrastructure and logistics, however, are reported to be limiting this growth. Fuel cell electric vehicles are also joining in as Linde, in partnership with Hyundai, will be providing a car sharing service in Munich with a fleet of fuel cell vehicles.[35]

The deployment of fuel cell electric vehicles or hydrogen internal combustion engine vehicles as fleet vehicles has also been observed, as their refueling at a base location keeps the infrastructure development risks and costs to a minimum.[36]

Two-wheeled Vehicles

Two-wheeled vehicles – including electric bikes, scooters and motorcycles – are the most purchased types of electric vehicles in the world, with approximately 235 million units deployed as of 2014.[37] The sale of electric bikes globally in 2016 is forecasted to reach approximately 35 million units.[38] While sealed, lead-acid batteries have represented the largest share of the electric bike sales in the past, lithium-ion battery electric technology is expected to lead the market in the future.[39]

According to Navigant Research, the growth of the electric bike market has been attributed to increased urbanization rates, battery technology improvements leading to lighter and lower cost vehicles, bicycling infrastructure and the presence of city energy policies.[40] The lower cost of electric bikes compared to cars, lack of licensing requirement, and a desire by customers to move away from cars for motorized transportation position the electric bike and alternative mobility device markets for continued growth. That being said, barriers are still restricting growth in some markets, including low consumer awareness and gasoline prices, a lack of adequate biking infrastructure and a higher purchase price compared to traditional bicycles.

China is currently by far the largest market for two-wheeled vehicles (electric and conventional), with approximately 230 million units deployed in 2014.[41] However, annual sales are expected to drop due to new bans on electric bike use in some major cities, and market saturation.[42, 43] That being said, markets outside of China, driven by the Western Europe and Asian Pacific markets (including Japan and Vietnam), are

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[34] Navigant Research, *Fuel Cell Vehicles Join the Carsharing World.*

[35] The Linde Group, *Hitting the Road to Hydrogen Mobility*, Available here: http://www.the-linde-group.com/en/clean_technology/clean_technology_portfolio/hydrogen_energy_h2/experience_h2/beezero/index.html

[36] ITM Power, A Review of Hydrogen Internal Combustion Engine Vehicles, 2013.

[37] OECD/IEA, Global EV Outlook 2015: Key Takeaways, 2015.

[38] Navigant Research, *Electric Bicycles: Li-Ion and SLA E-Bikes: Drivetrain, Motor, and Battery Technology Trends, Competitive Landscape, and Global Market Forecasts*, 2016.

[39] Ibid.

[40] Ibid.

[41] OECD/IEA, Global EV Outlook 2015: Key Takeaways, 2015.

[42] Navigant Research, *Electric Bicycles: Li-Ion and SLA E-Bikes: Drivetrain, Motor, and Battery Technology Trends, Competitive Landscape, and Global Market Forecasts*, 2016.

[43] The initial growth of the two-wheeled market in China was driven in part by bans and partial bans imposed on the use of conventional motorcycles in 29 major Chinese cities in 2009, according to the IEA's Global EV Outlook, 2016.

expected to experience growth at an average rate of about eight percent through to 2025.[44] Although the market in North America has remained relatively flat in 2015, the size of the bicycle market in the United States, sitting at approximately 16 million in sales per year, makes it an interesting potential market for the deployment of electric bikes.[45]

Non-road Vehicles

According to IBIS World[46], the major market segments for materials handling equipment include manufacturers, wholesalers, retailers, building contractors, government bodies and repair shops, and are used in virtually all industries, from construction to mining, agriculture and tourism. An increased awareness of environmental impacts and carbon emissions by customers, along with technology advances leading to more energy-efficient equipment, are expected to offer profit-generating opportunities for materials handling equipment manufacturers as they start to offer new, high value product lines.[47]

Demand for non-road vehicles (including materials handling and other transportation equipment) is driven in part by downstream demand in various industries. The construction equipment and mining equipment industries are forecasted to reach $116.2 billion and $136.0 billion respectively by 2021, with the Asia Pacific market expected to show the most growth due to improving socio-economic conditions.[48] Agriculture equipment is forecasted to reach $200 billion in revenue by 2022, with tractors representing the majority of revenue, and with Asia Pacific generating the highest revenue in the market in 2015.[49]

Furthermore, recent regulations adopted in Europe to tighten emissions limits for internal combustion engines installed in non-road mobile machinery (including farm, construction, materials handling, municipal and road operation services) may present additional growth opportunities in the non-road vehicle market.[50]

Fuel and Infrastructure

Hydrogen and Fueling Stations

As of January 2016, there were 214 hydrogen refueling stations in operation worldwide, of which 121 had public access.[51] The majority of stations are located in Europe (95 stations), followed by Asia (67 stations)

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[44] Navigant Research, *Electric Bicycles: Li-Ion and SLA E-Bikes: Drivetrain, Motor, and Battery Technology Trends, Competitive Landscape, and Global Market Forecasts*, 2016.

[45] Navigant Research, *Electric Bicycles: Li-Ion and SLA E-Bikes: Drivetrain, Motor, and Battery Technology Trends, Competitive Landscape, and Global Market Forecasts*, 2016.

[46] IBIS World, Material Handling Equipment Distributors in the US, April 2015

[47] Ibid.

[48] Markets and Markets, *Construction Equipment Market by Construction Equipment Type, Construction Application, Mining Equipment, by Mining Application, and Region (Asia-Pacific, North America, Europe, and ROW) - Global Trends and Forecast to 2021*, July 2016

[49] Allied Market Research, *World Agriculture Equipment Market - Opportunities and Forecasts, 2015 – 2022*, July 2016

[50] CEMA as reported on OEM Off-Highway, *European Parliament Adopts Final Agreement for Stage V Emissions Regulations, July 5 2016*. Available here: http://www.oemoffhighway.com/news/12228247/european-parliament-adopts-final-agreement-for-stage-v-emissions-regulations

[51] Data from H2Stations.org provided by TÜV SÜD, Available here: http://www.tuev-sued.de/company/press/press-archive/54-new-hydrogen-refuelling-stations-worldwide-in-2015

and North America (50 stations).[52] Germany holds the most stations in Europe (34 stations) followed by Great Britain (14 stations). Denmark and France both hold nine stations and Norway has six stations.[53]

In 2016, 104 station sites were announced, the majority in Europe (64 stations), followed by the United States (35 stations) and Japan (5 stations).[54] More than 5,200 hydrogen fueling stations for cars, buses and forklifts are forecasted to be operational worldwide by 2020, driving annual hydrogen demand to an estimated 418 million kilograms.[55] Japan alone plans to have about 160 hydrogen stations by 2020.[56]

Due to the nature of the product and the requirements for transportation, there is limited international trade in the oxygen and hydrogen gas market as a whole, and exports are typically concentrated to nearby regions.[57] According to IBIS World, while the overall international trade for oxygen and hydrogen gas for Canada is expected to remain low, Canadian exports of ultra-pure hydrogen are expected to increase steadily driven by higher trade volume with the United States.[58] The United States accounts for over 94 percent of all Canadian gas exports, which is transported through large pipeline systems and tanker distribution networks operated by large industry players.[59] Canadian gas exports to the United States are expected to reach over $150 million by 2020, representing an annual growth of approximately 1.7 percent over the next five years.[60]

Electricity and Charging Stations

According to the International Energy Association's *Global EV Outlook 2016*, the total number of charging stations reached approximately 1.45 million in 2015, of which about 13 percent were publicly available.[61] Slow and fast chargers grew at a similar rate in 2015 (with growth rates of 73 percent and 63 percent, respectively). Three-quarters of fast-charging outlets installed globally in 2015 were located in Japan and China.

A number of jurisdictions have established goals for the deployment of electric charging stations, typically aligned with goals to increase the number of electric vehicles on the road. Alongside this, the development of clean sources of electricity are welcomed by governments and industry in trying to meet clean emission goals and provide a clean fuel source for electric vehicles.

Smart grid applications (advanced metering technologies) are expected to become more common in the power transmission industry over the next five years in Canada and the United States.[62] The technology has been evolving rapidly and, according to Navigant Research, global smart grid technology revenue is

[52] Ibid. The remaining two stations are in Australia and South America.

[53] Ibid.

[54] Ibid.

[55] Pike Research as reported by Navigant Research. Retrieved here: https://www.navigantresearch.com/newsroom/more-than-5200-hydrogen-fueling-stations-to-be-operational-by-2020

[56] The Japan Times, *Japan eyes 40,000 fuel-cell cars, 160 hydrogen stations by 2020*, March 2016

[57] IBIS World, Oxygen & Hydrogen Gas Manufacturing in the US Industry Report, June 2016

[58] IBIS World, Oxygen & Hydrogen Gas Manufacturing in the Canada Industry Report, November 2015

[59] Ibid.

[60] Ibid.

[61] OECD/IEA, Global EV Outlook 2016, 2016

[62] IBIS World, Electric Power Transmission in Canada (July 2016) and in the US (May 2016)

forecasted to grow from $44.1 billion in 2014 to $70.2 billion in 2023.[63] According to the 2016 International Trade Administration Top Markets Report on Smart Grids, Canada is ranked as the leading market for smart grid information communication technology, as well as the smart grid sector, overall.[64]

Transferable Technologies and Services

There are a number of trends impacting the automotive and technology sectors that may also provide opportunities for the CEV sector. Examples include lightweighting, autonomous vehicles, connected vehicles and applications, and new vehicle service offerings.

Lightweighting

As vehicle manufacturers seek to improve fuel economy to meet fuel economy standards, lightweighting has been top of mind for many automotive OEMs. This trend is expected to continue, and to be specifically relevant for CEVs.[65]

Vehicle Automation and Controls

Semi-autonomous vehicles, such as vehicles that can change lanes on the freeway, adjust their speed and brake autonomously, are already deployed and their market is expected to keep growing. One million semi-autonomous vehicles are expected to be on the road by 2017, and 10 million are forecasted to be on the road by 2020.[66] Fully autonomous vehicles are being developed, but are still in their early stages.

Connected Vehicles and Applications

Connectivity has been linked to the reduction of anxiety for customers as it relates to accessible infrastructure for EVs.[67] Some functions currently in place, or identified as potentially valuable for the adoption of EVs in the future, include[68]:

- Real time information about charging infrastructure availability.
- The ability to reserve charging stations.
- GPS and web based systems to locate charging stations.
- The ability to constantly update the driver on the range of the vehicle and closest charging stations.
- Data communication with electricity providers to receive cost information and make payments in real time.
- Mobile phone or computer controlled battery charging with a smart charging system.
- Remote application with detailed vehicle status (e.g., car location, range, battery charge level, service messages).
- Remote initiation of the charging process.
- Applications to provide coaching on driving techniques and traffic levels to help extend range.

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[63] Navigant Research, *Smart Grid Technologies: Transmission Upgrades, Substation Automation, Distribution Automation, Smart Grid IT and Communications Networking, and Smart Metering: Global Market Analysis and Forecasts*. Available here: https://www.navigantresearch.com/research/smart-grid-technologies

[64] International Trade Administration, *2016 Top Markets Report: Smart Grid*, April 2016

[65] Greener Cars, Market trends, Retrieved July 2016 available here: http://www.greenercars.org/greenest-meanest/market-trends

[66] Ibid.

[67] Accenture, *The Electric Vehicle Challenge: Electric vehicle growth in an evolving market dependent on seven success factors*.

[68] Ibid.

New Service Offerings

The deployment of electric and fuel cell electric vehicles comes with the need for new services, or the need to tailor some existing offerings. These include battery exchanges and breakdown services, as well as installation planning services and warranties.[69] Vehicle repairs, including servicing of high voltage batteries and the maintenance of electric powertrains, may require additional qualifications for service technicians and may also require retrofitting of existing service stations.

[69] Ibid.

4. Overview of BC's CEV Sector

4.1. Description of the CEV Sector in BC

The CEV sector in BC includes a number of organizations participating in various aspects of the value chain, from vehicles and vehicle components to fuel and infrastructure and other transferable technologies and services. Furthermore, the BC CEV sector is supported by a number of educational institutions, associations and other private and public sector organizations. The following section presents an overview of BC companies and organizations that are involved in various aspects of the CEV supply chain.

4.1.1. Vehicles and Vehicle Components

Vehicle Manufacturing

Although BC is not home to any large vehicle manufacturers[70], there are a number of local companies that are involved in the design and manufacture of CEVs. For example, Canadian Electric Vehicles, located on Vancouver Island, is a designer and manufacturer of EVs and EV components. The company specializes in off-road, low speed work vehicles for use at campuses, malls, resorts, parks, airports and other industries, and has been in operation for over 20 years. Electra Meccanica, founded in 2015 and located in Vancouver, is also a developer and manufacturer of EVs. Its first product is an all-electric, single passenger, three-wheeled vehicle.[71]

On the hydrogen side, Hydra Energy is a Vancouver-based company that looks to provide hydrogen-as-a-service by converting fleets to a dual-fuel internal combustion engine system (hydrogen and diesel or gasoline).[72] The company provides a unique service as it covers the cost of upgrading the vehicles and onsite refueling, and only charges for the sale of hydrogen at prices competitive with conventional fuels. Hydrogen internal combustion engines are viewed by Hydra Energy as a low cost, near-term CEV solution as they offer the potential to achieve comparable emissions reductions as fuel cell and hybrid vehicles, with the benefits of being retrofit-compatible (any conventionally-fueled vehicle can be converted to operate on hydrogen).

Vancouver-based GreenPower Motor Company specializes in the development of all-electric buses for transit operators, shuttle operators, schools, universities and governments in the North American market.[73] In November 2015, the company announced the deployment of an all-electric double decker bus pilot project in Victoria, BC, and as of June 2016, the company had received nine letters of intent for 25 all-electric school buses from nine different school districts in California.[74] The company plans to open a manufacturing facility in Porterville, California.[75]

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[70] Innovation, Science and Economic Development Canada, *Automotive Assembly Plants in Canada – 2015*, June 2016, Available here: https://www.ic.gc.ca/eic/site/auto-auto.nsf/eng/am00767.html

[71] Electra Meccanica, News Update - Electra Meccanica Solo Completes First Chassis Test, June 2016. Available here: http://electrameccanica.com/electra-meccanica-solo-completes-first-chassis-test/

[72] MNP interview with Hydra Energy. For more information visit http://www.hydra-energy.ca/

[73] GreenPower Motor Company. Retrieved from

http://www.greenpowerbus.com/wp-content/uploads/2016/06/GreenPower-Investor-Presentation-June-8-2016.pdf

[74] Ibid.

[75] Ibid.

Electric bikes and recreational vehicles also have a presence in BC. Greenwit Technologies, located in Vancouver, specializes in the design, engineering and manufacturing of light EVs including electric two-wheeled scooters, electric power-assisted bicycles and motorbikes.[76] OHM Cycles and Green Light Cycle are other examples of BC-based electric bike manufacturers. Velometro Mobility, also based in Vancouver, is currently working on an electric-assist, enclosed, smartphone-connected pedalled vehicle intended to replace automobiles in urban and sub-urban areas.[77]

Vehicle Components

BC is home to a world-class hydrogen and fuel cell cluster, originating with Ballard Power Systems, a world leader in proton exchange membrane (PEM) fuel cell development and commercialization.[78] Ballard Power Systems develops and commercializes fuel cell technology for a global customer base. In November 2015, Ballard signed an agreement to develop and commercialize a fuel cell engine for low-floor trams to be manufactured in China by CRRC Qingdao Sifang Company, Ltd.[79]

BC has benefited from many spin off companies from Ballard, including The Automotive Fuel Cell Cooperation Corporation (AFCC), established in 2008 as a joint-venture between Ballard, Daimler and Ford Motor Company. AFCC was created to focus on fuel cell research, development and design specifically for automotive applications. As a result of BC's local expertise in the fuel cell sector, BC is now home to the world's first automated fuel cell manufacturing plant, an investment by Daimler/Mercedes of more than $70 million.[80]

The concentration of fuel cell research and development in BC has attracted a number of enterprises involved in hydrogen supply and processing, component and systems testing, technology development and commercialization, and standards development. The following are examples of companies involved in BC's hydrogen and fuel cell cluster:

- Powertech Labs, a subsidiary of BC Hydro located in Surrey, BC, operates one of the most comprehensive compressed hydrogen and CNG testing facilities in the world, where they perform testing on cylinders, components, and fuel systems to international standards.
- The CSA Group recently established a high pressure test facility in Langley, BC, where it tests hydrogen industry products from suppliers located outside of Canada.
- HTEC (Hydrogen Technology and Energy Corp), located in North Vancouver, is involved in the production and distribution of hydrogen, including the delivery of hydrogen to fueling stations and building of fueling stations.[81]

[76] Greenwit Technologies. Retrieved from http://www.greenwit.com/new/

[77] Velometro. Retrieved from http://www.velometro.com/veemo.html

[78] Ballard Power Systems. Retrieved from http://ballard.com/about-ballard/

[79] Trade and Invest BC. Retrieved from http://www.britishcolumbia.ca/export/success-stories/ballard-power-systems-on-track-in-china/

[80] Canadian Hydrogen and Fuel Cell Association, The Emerging Canadian Fuel Cell Supply Chain. Retrieved from: http://www.chfca.ca/resources/chfca-blog/the-emerging-canadian-fuel-cell-supply-chain

[81] Retrieved from http://www.htec.ca/

- Greenlight Innovation manufactures fuel cells, electrolysers, and battery testing and assembly equipment from its Vancouver headquarters.[82]
- ITM Power is a UK-based company with an office in Vancouver. Its focus is on electrolyser technology solutions for hydrogen production. It also provides a refueling self-contained module for hydrogen vehicles and forklifts. Research and development, manufacturing, and testing is done in the United Kingdom.[83]
- Loop Energy, located in Burnaby, focuses on zero-emission power systems for heavy-duty transportation, including both electric and hydrogen technology.[84]

There is also significant expertise in the technology space for EVs in BC, including battery technologies and battery management systems. Companies operating in BC's battery cluster include:

- Delaware Power Systems, serves OEMs of all types of electric and plug-in hybrid vehicles, including scooters, motorcycles, cars and buses with their integrated battery platform. Products are produced in China in a joint-venture manufacturing plant.[85]
- Delta-Q Technologies, headquartered in Burnaby, BC, provides power management and power conversion in the form of battery chargers and converters for application in a number of industries, including lift trucks, golf cars, power sports, and utility and transportation (e.g., utility vehicles, neighbourhood electric vehicles, and low speed electric vehicles).[86] Delta-Q products are manufactured outside of BC.[87]
- E-One Moli Energy (Canada) Limited is a division of a Taiwanese company. Its location in Maple Ridge, BC, focuses on lithium-ion battery research and development and hosts a North American sales and technical support team.[88]
- Corvus Energy, headquartered in Richmond, BC, provides energy storage solutions for heavy duty and industrial applications.[89] While Corvus has a focus on the shipping industry (Corvus batteries will be powering a fully-battery driven ferry, owned and operated by Norled, a Norwegian shipping company[90]), its solutions have also been applied to a number of prototypes for hybrid heavy-duty trucks. Corvus has partnered with Walmart, Peterbilt and Siemens for truck and tram applications.[91]
- As a result of the acquisition of BlueStar Battery Systems International Corp, EaglePicher, a US-based firm, has a facility for its medical power division located in Surrey, BC. BlueStar Battery Systems was initially created when Ballard sold its lithium battery division.

[82] Retrieved from: http://www.greenlightinnovation.com/

[83] Retrieved from http://www.itm-power.com/

[84] Retrieved from http://loopenergy.com/

[85] Retrieved from http://www.delpowersys.com/manufacturing-plant

[86] Retrieved from http://delta-q.com/company/

[87] Ibid.

[88] Retrieved from http://www.molicel.com/ca/

[89] Retrieved from http://corvusenergy.com/prototypes/

[90] Corvus Energy. Retrieved from http://corvusenergy.com/tag/norled-as/

[91] Ibid.

- Xantrex, purchased by Schneider Electric in 2008, holds a Canadian office in Burnaby, BC. Xantrex specializes in the development, manufacturing and marketing of power electronic products for the mobile power market, including recreational vehicles, heavy-duty trucks, work vehicles, buses and specialty vehicles. Schneider Electric has locations in Victoria, Prince George and the Lower Mainland.
- Retriev Technologies (formerly Toxco Inc.), a US-based company, operates a recycling facility for all consumer and large format lithium batteries in Trail, BC. According to the company's website, the facility is the only of its kind globally treating both non-rechargeable lithium and rechargeable lithium-ion batteries under the same roof. The facility also treats scrap components generated by lithium battery manufacturing.[92]

BC is also home to a number of companies involved in the development of other materials or components with vehicle applications. For example:

- Eagle Graphite is one of two graphite producers in North America located just west of Nelson, BC. Eagle Graphite produces a high purity flake graphite, a material used in both battery and fuel cell manufacturing.
- Pacific Insight Electronics is a designer, developer, manufacturer and deliverer of LED lighting systems, electronic control modules, wire harnesses and instrumentation products for OEMs and Tier 1 and 2 suppliers. The company has an office in Burnaby and a Canadian operations centre in Nelson, BC.
- Vancouver-based Grin Technologies designs and manufactures electric bicycle hardware and conversion kits. Its products, as well as some third party parts, are sold to individuals and also directly to electric bike OEMs.
- Associated Plastics & Supply Corp produces components for manufacturing facility equipment and machine guards and is located in Vancouver, BC.

Vehicle Sales and Maintenance

Currently, there a number of dealerships that sell EVs in the province with trained technicians on staff to service EVs. Large auto manufacturers that sell EVs in BC include Tesla, Affinity, Ford, Nissan, Chevrolet, BMW and Mercedes. In addition to new vehicle dealerships, pre-owned EVs are sold by a select number of dealers. For example, Motorize Auto Direct, a Victoria-based used vehicle dealer founded in 2008, specializes in the sale of pre-owned electric cars.

In the Greater Vancouver area, Hyundai offers residents the opportunity to lease its Tucson FCEV at a fixed monthly price, which includes the costs of vehicle maintenance and fuel.[93] As of June 2016, Vancouver was the only market in Canada with access to this leasing program.

Electric bikes and scooters are sold in BC through various retail outlets. Some retailers, such as E-ride (a subsidiary of Greenwit Technologies), Evolution Bikes in North Vancouver and Cit-E Cycles (multiple locations), specialize in selling only electric bikes. Others, such as Cambie Cycles and JV Bike Sales & Rentals, sell a variety of bikes and provide electric options to customers.

[92] Retriev Technologies. Retrieved from http://www.retrievtech.com/locations

[93] Hyundai. Retrieved from http://www.hyundaihydrogen.ca/faq/

Car Sharing

BC is home to four main car sharing programs: Car2go, Modo, Zipcar and Evo. Car2go and Evo offer a one-way service where individuals can pick up and drop off a vehicle anywhere within their respective operating areas. On the other hand, Modo and Zipcar offer a two-way service where individuals must pick up and drop off vehicles in a designated parking space.

Modo currently has three electric vehicles and a number of hybrid vehicles available for its members in BC.[94] Car2go, Zipcar and Evo do not currently offer electric cars, although Evo does have a fleet of all hybrid vehicles (Toyota Prius Hybrid).

4.1.2. Fuel and Infrastructure

Hydrogen and Hydrogen Fueling Infrastructure

There is established leadership and expertise in BC related to standards and testing protocols for hydrogen and hydrogen fueling infrastructure, led by Powertech Labs and now CSA Group. Powertech Labs has provided services for all major OEMs involved in bringing FCEVs to market. Its Advanced Transportation group provides high pressure testing and hydrogen infrastructure solutions to the CEV sector.

A number of companies in this area are exporting services and products to other jurisdictions. For example, Hydrogen Technology and Energy Corporation (HTEC), based in North Vancouver, and Powertech Labs in Surrey have both been successful in winning fueling station development contracts in California, Hawaii and Virginia.[95,96] IRDI System (IRDI), located in Richmond, provides a product line dedicated entirely to hydrogen fueling stations. IRDI possesses certification expertise for various regions of the world including Japan, Europe and North America.

There is the existence of an end-to-end hydrogen supply chain from production, recovery, purification and compression through to fueling infrastructure. Sacré-Davey Engineering of North Vancouver specializes in each of these industrial processes through the provision of project development, planning, implementation and operations engineering support services.[97] Furthermore, Quadrogen Power Systems is a Vancouver-based clean technology company that converts waste gas into clean energy (including hydrogen).[98]

Hydrogen in Motion (H2M) has been involved in the CEV sector since 2014 and is headquartered in Vancouver. H2M is working in collaboration with the SFU School of Mechatronic Systems Engineering to develop a hydrogen storage medium that is stable at ambient conditions and can be packed into vehicle fuel tanks. In addition, H2M also plans to deliver hydrogen in pre-filled tanks directly to consumers.

Furthermore, as part of Hydra Energy's hydrogen-as-a-service offer, Hydra Energy covers the cost of conversion of fleet vehicles to dual-fuel systems (hydrogen and gasoline) and sets up on-site hydrogen refueling stations. In exchange, customers sign fixed-term fuel supply contracts.

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[94] According to a Modo representative, two electric vehicles are available for members in Vancouver and one is available in Victoria. Modo suggests their use only for short trips in the city due to charging logistics. Modo also has some electric vehicles in its fleet for the City of Surrey, but those vehicles are not publicly available to members.

[95] There are 6 stations in California, 2 in Hawaii and 1 in Virginia.

[96] Innovation, Science and Economic Development, *Industry Canada Report: Perspectives On The Challenges And Opportunities For Near-Term Commercialization Of Hydrogen And Fuel Cells Related Technologies*

[97] Sacré-Davey Engineering. Retrieved from: http://www.sacre-davey.com/sectors/clean-technology/

[98] Quadrogen Power Systems. Retrieved from http://www.quadrogen.com/

The majority of hydrogen fueling stations built in BC were installed primarily for research and development and demonstration purposes and are not suited for modern FCEVs. That being said, one public hydrogen fueling station is in operation in BC (Powertech Station in Surrey)[99], and a second station is set to be installed in Vancouver in the near future.

Electricity and Electric Charging Infrastructure

As the province's crown corporation responsible for electricity generation, transmission and distribution, BC Hydro plays a key role in the CEV sector. BC Hydro was a founding member of Plug-in BC[100] and has participated in collaborative research related to the potential impacts of EVs on the electrical grid. BC Hydro has also supported numerous pilot programs and demonstration projects in order to understand charging behaviour and to assist in developing grid impact mitigation strategies and technologies. BC Hydro is also a leader in smart grid infrastructure deployment, including a province wide smart meter system and associated telecommunications network.

FortisBC, a regulated utility with 7,200 kilometres of transmission and distribution power lines in the province[101], will also be instrumental in providing electricity to fuel EVs. An internal working group has been established at FortisBC to better understand the potential impact and opportunities resulting from the increased adoption of EVs.

The following companies are involved in various aspects of the design, installation and servicing of electric charging infrastructure and related technologies:

- Headquartered in Burnaby, SMPC Technologies Ltd. has been involved in the CEV sector for six years. They have developed a Level 2 charger that allows direct connection to the 600V distribution network and are currently developing a 50kW and 100kW DC Level 3 charger. The design of the charging stations is done in BC.
- Powertech Labs provides a range of services for the EV sector, such as the installation and deployment of EVSE including DC fast chargers, development and testing of new EV charging technologies, EV infrastructure optimization services, and smart charging vehicle to grid interoperability solutions.[102]
- Elix Wireless, headquartered in Vancouver, is focused on chargers that use wireless power transfer technology.[103] The technology has a number of applications for buses, trucks, passenger cars, materials handling and mining equipment, as well as for medical and marine applications.
- Foreseeson is a Richmond-based electronic manufacturing services company. Forseeson has established a reseller partnership with Chargepoint, a US charging station manufacturer, to provide Chargepoint products as well as network, installation and financing services to Canadian customers.

[99] Retrieved from http://www.netinform.net/H2/H2Stations/H2Stations.aspx?Continent=NA&StationID=-1

[100] As described later in the report, Plug-in BC is a collaboration between a wide range of stakeholders including the provincial government, BC Hydro, Fraser Basin Council, several academic institutions, regional governments, municipalities, businesses, individuals and EV user groups to advance plug-in vehicles and infrastructure in the province.

[101] FortisBC. Retrieved from https://www.fortisbc.com/About/Pages/default.aspx

[102] Powertech Labs. Retrieved from http://www.powertechlabs.com/clean-transportation-solutions/electric-vehicle-services/#EV2

[103] Elix Wireless. Retrieved from https://elixwireless.com/#company

- Perkuna Charging, a division of Perkuna Engineering, provides electric vehicle charging solutions. Located in Vancouver, Perkuna Charging sells a variety of charging stations from various manufacturers including Charge Point (US), AeroVironment (US) and Fuji Electric (Japan).
- Electrical contractors, such as PowerPros Electrical based in Abbotsford, Olson Electric Ltd. in Sechelt and Perron Electric in Victoria, have participated in the installation of charging stations. Electrical product distributors, such as Wesco, Westburne, Nedco, Beaver Electrical and Electrum Charging, sell charging stations, materials and other components.

According to the Plug-in BC website[104], there are currently over 1,000 charging stations in BC. The deployment of the majority of these stations was funded in part by the BC CEV Program. The majority of stations are public Level 2 charging stations (550 units) followed by home units (306 units), multi-unit building stations (142 units), and DC fast charging stations (30 units).

4.1.3. Transferable Technologies and Services

BC is home to a number of companies that offer solutions directly or indirectly related to the CEV sector. For example, Vancouver-based Thomson Power Inc. is a developer and supplier of software and power management systems to improve performance and efficiency of electric and hybrid drives in medium to heavy-duty trucks and bus applications. Spur Innovations, also in Vancouver, was incorporated in 2013 by previous leaders of Azure Dynamics with experience developing and producing electric and hybrid components and powertrains for commercial vehicles. Spur is now focused on automation, connectivity and electrification with the aim to make vehicles safer and cleaner. Moovee Innovations is also a BC-based company focused on research and development related to driverless EVs.

Some companies in BC, while not currently involved directly in the CEV sector, are developing expertise that could be applied to the CEV sector in the future. For example:

- Moj.io, based in Vancouver, provides a car monitoring and tracking smart system for use with various apps.[105] Although the technology is not currently available for electric or hybrid vehicles, its presence contributes to the cluster of automotive sector related companies in BC. Similar companies involved in fleet management, tracking devices and GPS technologies include BC-based companies Sendum, SilverTip Telematics and Contigo.[106]
- SandVault, located in Richmond, is focused on bike sharing from battery and solar powered recharge/cyclestations, to helmet sharing and water dispensing solutions.[107]
- Enbala Power Networks, headquartered in North Vancouver, provides a platform that helps manage distributed energy. Solutions are provided for utilities, grid operators, energy service providers and energy consumers to help aggregate, control, optimize and dispatch distributed energy in real time with no customer operation disruptions.[108]

[104] Plug-in BC, *Charging Stations*, Accessed May 2016, Available here: http://pluginbc.ca/charging-stations/

[105] Moj.io. Retrieved from https://www.moj.io/

[106] See http://sendum.com/; http://silvertiptelematics.com/; and http://www.contigo.com/About_Us/About_Us.html

[107] SandVault. Retrieved from http://sandvault.com/

[108] Enbala Power Networks. Retrieved from http://www.enbala.com/about/

4.1.4. Supporting Organizations

BC is also home to a number of education institutions, associations and other businesses that help support the industry in various ways. For example, BC hosts a number of research and development institutes at local academic institutions, such as the University of British Columbia's Clean Energy Research Centre and Centre for Interactive Research on Sustainability, Simon Fraser University's School of Mechatronics Systems Engineering, and the University of Victoria's Institute for Integrated Energy Systems. Research and development is also provided by engineering services firms. Misty West, for example, is an engineering design consultancy firm that has conducted full cell research for AFCC and research on PHEVs.[109]

The presence of the National Research Council (NRC) in Vancouver serves as a gateway to access pools of experts and programs from various portfolios across the country. Under the NRC's Automotive and Surface Transport portfolio, CEV stakeholders may access programs such as the Vehicle Propulsion Technologies program, Lightweighting of Ground Transport Vehicles program, Advanced Manufacturing and Design Systems program and the Fleet Forward 2020 program.[110]

The Canadian Hydrogen and Fuel Cell Association is locally based and supports Canadian corporations, governments and educational institutions that are developing, demonstrating and deploying hydrogen and fuel cell products and services in Canada.[111] On the electric side, the Vancouver Electric Vehicle Association is a non-profit organization that promotes the use of battery powered electric vehicles and the Victoria Leaf Club brings together individuals dedicated to electric transportation.

The Fraser Basin Council is a non-profit society seeking to advance sustainability in the Fraser Basin and across the province. Under its *Green Fleets BC* banners, the organization has undertaken a number of partnership initiatives to increase fuel efficiency and reduce emissions for public and private organizations, including through fleet support for EV charging infrastructure. The Fraser Basin Council serves as a delivery agent for a number of provincial initiatives, such as the E3 Fleet Program, BuySmart Network and Plug-in BC, including its multi-unit residential building (MURB) charging program.

Plug-in BC is a collaboration between a wide range of stakeholders, including the provincial government, BC Hydro, Fraser Basin Council, several academic institutions, regional governments, municipalities, businesses, individuals and EV user groups, to advance plug-in vehicles and infrastructure in the province. The initiative is co-chaired by the BC Ministry of Energy and Mines and BC Hydro.

Municipalities are also playing their part through progressive climate policies, including Surrey's alternative fuel bylaw, which requires the provision of low carbon alternative fuel at new service station developments, and Vancouver's Greenest City Action Plan 2020, Renewable Energy Strategy 2050, and charging infrastructure building code requirements for single family and multi-unit residential dwellings.

[109] Misty West. Retrieved from http://www.mistywest.com/portfolio/

[110] For more information on NRC's areas of R&D and various programs, see http://www.nrc-cnrc.gc.ca/eng/rd/index.html

[111] See http://www.chfca.ca/about/about-us/

4.2. Baseline of Economic Activity

4.2.1. Approach and Definitions

The North American Industry Classification System (NAICS) is a system used by North American statistical agencies to classify industries and to collect, measure and report on statistical data related to the economy. In Canada, industries are separated in a hierarchical structure by sector (two-digit codes), subsector (three-digit codes), industry group (four-digit codes), industry (five-digit codes) and Canadian industry (six-digit codes).

The CEV sector, however, is not readily defined using standard industry classification systems, such as NAICS. Rather, the CEV sector spans multiple industries and involves many supporting activities that need to be captured. While up to 40 individual NAICS codes were identified (at the five-digit level) that relate to CEV sector activity, simply applying these codes to a company search would yield many thousands of results, most of which would not be relevant. Furthermore, individual enterprises identified through this process may be engaged in numerous activities, only a few of which contribute to the CEV economy.

As a result, it is not possible to measure a baseline of economic activity in the sector based strictly on data published by BC Stats or Statistics Canada. Economic activity in the sector has instead been estimated based on the aggregation of individual company-level data, along with an assessment of the proportion of an industry's activities that is relevant to the CEV sector. (For more information on the baseline methodology, please see Appendix A.)

Based on the primary and secondary data obtained by MNP as part this study, this section includes estimates of the following economic measures for BC's CEV sector:

- **Number of establishments** – The number of businesses and organizations engaged in industry related economic activity.
- **Employment** – The number of jobs created or supported by an industry or activity. Employment is measured in terms of full-time equivalents (FTEs).
- **Economic output** – The total gross value of goods and services produced by an industry measured by the price paid to the producer. This is the broadest measure of economic activity.
- **Exports** – The total value of goods and services produced for a foreign destination.
- **Investments in research, development and demonstration** – Total spending on research and development activity and demonstration projects.
- **Gross domestic product (GDP)** – The additional value of a good or service over the cost of inputs used to produce it from the previous stage of production. GDP is equal to net output, or the difference between revenues and expenses on intermediate inputs. (GDP is a more meaningful measure of economic impact, as it avoids double counting during each stage of production.)

In addition to the direct economic impacts associated with CEV-related activity, additional economic impacts are generated through spending on goods and services that are not directly captured as part of

the CEV value chain, and through the spending of wages and salaries by individuals that are directly and indirectly employed by the sector.[112] These direct, indirect and induced impacts are defined as follows:

- **Direct impacts** are due to changes to "front end" businesses that receive operating revenue as a direct consequence of an activity or initiative.
- **Indirect impacts** are due to changes in the activity of suppliers and include the spending that suppliers make when purchasing goods and services from their own suppliers.
- **Induced impacts** arise from shifts in spending on goods and services as a consequence of changes to the payroll of the directly and indirectly affected businesses.

To assess the indirect and induced economic impacts, we have relied on Statistics Canada's interprovincial input-output multipliers for BC. An input-output model is based on statistical information about the flow of goods and services among various industries, and is normally used "to simulate the economic impact on the business sector of an expenditure on a given basket of goods and services or the output of one of several industries."[113] Input-output modelling is a widely-used and widely-accepted approach, making it recognizable by many different stakeholders and audiences. The structure of the approach also facilitates easy comparisons between reported results for different projects and facilities.

4.2.2. Economic Activity Baseline

Table 2 summarizes the total direct economic activity estimated to be associated with BC's CEV sector in 2015. In total, the CEV sector was estimated to encompass:

- Approximately **198 companies and organizations** involved in all aspects of the CEV supply chain.
- Approximately **3,850 FTEs** in total direct employment associated with CEV-related activities.
- Approximately **$702.0 million** in total economic output.

Based on primary research conducted by MNP as part of the study, companies in the CEV sector reported $137.6 million in exports of CEV-related goods and services, and spending of $68.2 million on research and development and demonstration projects.[114] As these estimates do not encompass the activity of all CEV-related companies, they should be viewed as conservative.

[112] These impacts are also described in the International Economic Development Council's 2013 report, *Creating the Clean Energy Economy: Analysis of the Electric Vehicle Industry*.

[113] Statistics Canada. (2013, April). *Input-Output Model Simulations (Interprovincial Model)*. Retrieved from http://www5.statcan.gc.ca/bsolc/olc-cel/olc-cel?lang=eng&catno=15F0009X.

[114] Due to data limitations, the value of total exports and expenditures on research and development and demonstration projects was obtained through a survey of businesses and organizations in the sector, and only represents the amount reported by survey respondents. These values should therefore be considered conservative estimates. (For more information on the survey, please refer to Appendix A.)

Table 2: Total Estimated Economic Activity in BC's CEV Sector in 2015

Vehicles and Vehicle Components	
Number & Types of Establishments	• Approximately 81 businesses involved in the development, design, manufacture, sale and distribution of CEVs and CEV components.
Employment	• Total estimated direct employment of 3,019 FTEs.
Economic Output	• $561.3 million in economic output (total revenues/expenditures).
Fuel and Infrastructure	
Number & Types of Establishments	• Approximately 42 businesses involved in the development, design, manufacture, sale, installation and maintenance of fuel and infrastructure.
Employment	• Total estimated direct employment of 214 FTEs.
Economic Output	• $62.9 million in economic output (total revenues/expenditures).
Transferable Technologies and Services	
Number & Types of Establishments	• Approximately 18 businesses associated with the CEV sector providing a transferable technology or service.
Employment	• Total estimated direct employment of 439 FTEs.
Economic Output	• $69.1 million in economic output (total revenues/expenditures).
Supporting Organizations	
Number & Types of Establishments	• Approximately 57 government, non-profit and private sector organizations that support CEV related activity.
Employment	• Total estimated direct employment of 178 FTEs.
Economic Output	• $8.7 million in economic output (total revenues/expenditures).

Additional economic impacts result from spending on goods and services that are not directly captured as part of the CEV value chain, and through the spending of wages and salaries by individuals that are directly and indirectly employed by the sector.

As indicated in Table 3, in 2015 BC's CEV sector was estimated to be associated with the following total economic impacts:

- Total direct, indirect and induced economic output of about **$1.2 billion**.
- Total direct, indirect and induced employment of **6,670 FTEs**.
- Total direct, indirect and induced GDP of **$667.0 million**.

Table 3: Total Estimated Economic Activity in BC's CEV Sector in 2015

	Direct	Indirect	Induced	Total
Economic Output (millions)	$702.0	$227.0	$228.7	**$1,157.7**
Employment (FTEs)	3,850	1,472	1,348	**6,670**
GDP (millions)	$372.9	$144.2	$149.9	**$667.0**

4.2.3. Industry Comparisons

To provide perspective on the size of the economic impacts of the CEV sector in BC, it is useful to compare the impacts with those created by other industries. Three examples of other industries are new home construction, agriculture, and film and television.

- **New Home Construction** – The estimated employment of 6,670 FTEs supported by the CEV sector in BC is equivalent to the direct and indirect employment supported by the construction of 2,752 new homes in BC.[115]
- **Agriculture** – The estimated employment of 6,670 FTEs supported by the CEV sector is greater than the employment supported by the BC beef cattle industry[116] (4,242 FTEs annually) and the BC farmed-raised salmon industry[117] (4,977 FTEs annually).
- **Film and Television** – The estimated annual GDP generated by the CEV sector in BC ($667 million) is similar to what would be generated by the production of two high-end television series in the province lasting five seasons in length ($678 million).[118]

[115] Will Dunning Inc., *Economic and Fiscal Impacts of Residential Construction – 2014.*

[116] MNP, *British Columbia's Beef Cattle Industry*, 2013.

[117] MNP, *Economic Impact Study of the Farm-Raised Salmon Industry in BC*, 2015.

[118] MNP, *Economic Impacts of* Once Upon a Time, 2015.

5. Economic Opportunities for the CEV Sector

5.1. Competitive Advantages for the Sector in BC

To identify BC's competitive advantages in the CEV sector, MNP facilitated two-half day workshops with key industry stakeholders, and conducted interviews with companies and organizations involved in the sector, both in BC and elsewhere. Although there are no large vehicle manufacturers currently headquartered in BC, there are a number of attributes that make BC well positioned to take advantage of opportunities related to CEVs and clean energy transportation technologies.

Local Knowledge and Expertise

The following are some of BC's key competitive advantages related to local knowledge and expertise:

- BC is home to an internationally recognized hydrogen and fuel cell cluster that encompasses hydrogen supply and processing, component and systems testing, technology development and commercialization, and standards development. BC companies have established long-standing OEM relationships built on the history of the hydrogen and fuel cell cluster. These relationships started with Ballard and now include AFCC, Powertech Labs, CSA Group and IRDI, to name a few. As a result, BC has become a well-established centre of automotive advanced research and development and testing related to FCEVs and component systems. These relationships can be leveraged in the EV sector as well.
- BC hosts world class research and development at local academic institutions. Examples include the University of British Columbia's Living Laboratory, Simon Fraser University's School of Mechatronics, and the University of Victoria's Institute for Integrated Energy Systems. Spin offs from these research institutions include Azure Dynamics (now Spur Innovations), which in turn has provided the local engineering community with experts in advanced drivetrains and battery management systems and controls.
- BC is well known for its small business innovation, particularly in clean tech and in technology in general. BC's technology sector includes over 9,000 companies involved in clean tech, digital media, wireless, life sciences and information and communications technology with a labour force of over 84,000 people.[119] As EVs and FCEVs rely heavily on technological inputs and innovations, there is a close link between the CEV sector and the high tech sector.
- BC Hydro is a leader in smart grid infrastructure deployment, including a province wide smart meter system and associated telecommunications network. BC is therefore well positioned to lead the development of smart charging technology considered critical to the mass deployment of EVs. BC Hydro's subsidiary, Powertech Labs, is engaged in smart charging applied research and works actively with major EVSE manufacturers on solutions development, testing, standards and communications protocol development.

[119] KPMG, *British Columbia Technology Report Card 2014,* Available here: http://www.kpmg.com/Ca/en/IssuesAndInsights/ArticlesPublications/Documents/6943-BC-Tech-Report-card-FY14-web.pdf

- BC's aeronautical expertise, particularly in composite materials, leads to opportunities for chassis, vehicle bodies and light weight components.[120] The design of Electra Meccanica's SOLO electric vehicle, for example, includes a lightweight aerospace composite chassis.[121]

Geography, Location and Demographics

BC is acknowledged as fertile ground for new clean technologies, as British Columbians tend to be environmentally aware and willing early adopters. For example, BC accounts for more than twice the national average in hybrid vehicle sales[122] and has the highest per capita EV sales in Canada[123]. The luxury car market is also strong in BC with more than 2,000 vehicles registered in the Metro Vancouver area that retail for over $150,000.[124]

Proximity to the California market and West Coast states in general also serve as an advantage. Geographically and culturally, there are many similarities that are reflected in consumer choices and policy initiatives. These bring synergies and the opportunity to cooperate. An example is the Pacific Coast Collaboration which, among other things, has resulted in joint commitments on alternative fueling infrastructure up and down the West Coast.[125]

Furthermore, BC is known as a gateway location to Asian markets, including China.[126] Considering historic and anticipated future growth of the CEV sector in various Asian markets, this could be a noted advantage for the province.

Additional advantages for BC include access to rail, truck and port facilities, and a desirable place to live for attracting talent.

Policy and Regulatory Environment

BC has a well-deserved reputation for progressive environmental policy, legislation and climate leadership while still maintaining a focus on economic development and growth. Examples include:

- North America's first carbon tax (revenue-neutral).
- Renewable Low Carbon Fuel Regulation.
- Clean Energy Act, 2010.
- 2008 Climate Action Plan (including government led carbon targets for 2020).

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[120] For more details on BC's capabilities in this area, see https://www.britishcolumbia.ca/buy/documents/bc-aerospacedefence-mit-web.aspx/

[121] See https://electrameccanica.com/

[122] 2009 BC Hydro Electric Transportation Strategy

[123] Retrieved from http://www.fleetcarma.com/ev-sales-canada-2015/

[124] Source: ICBC as reported by the New Car Dealers Association on January 21, 2016. Available here: http://www.newcardealers.ca/record-year-sales/

[125] 2012 Globe Advisors, The West Coast Clean Economy, Opportunities for Investment & Accelerated Job Creation, retrieved from http://www.pacificcoastcollaborative.org/Pages/Welcome.aspx

[126] Advantage BC: International Business Centre, *As a gateway location in the Pacific Time Zone, British Columbia is a key hub for Canada-China trade and a vital link between US and Asian markets*, Available here: http://advantagebc.ca/business-advantage/gateway-for-trade/

In 2015, a climate leadership team was established to provide advice and recommendations to government and contribute to the development of a new Climate Action Plan for the province.[127] The new Climate Action Plan is expected to be released in the summer of 2016, and is anticipated to include a number of strategies to further BC's commitment to climate action and climate leadership.

The BC CEV Program is also recognized as an advantage for BC, which was the first program in Canada to include FCEVs as part of its vehicle purchase incentives. Furthermore, BC's comprehensive EV charging infrastructure strategy had led to the highest per capita DC fast charger installations in Canada.[128] The province has also shown commitment to supporting a strategy for hydrogen fueling infrastructure[129], increasing consumer awareness (through the national leading Emotive Communications Program), promoting CEV adoption through HOV lane access, and fostering collaborative policy consultation and partnerships, such as Plug-in BC.

Furthermore, progressive municipal climate policy has played a role in creating a friendly environment for CEV adoption and infrastructure deployment. For example:

- The alternative fuel bylaw in the City of Surrey requires the provision of low carbon alternative fuel at new service stations.
- Vancouver Greenest City Action Plan 2020 calls for a 100 percent renewable energy strategy by 2050.
- The City of Vancouver's building code requirements includes charging infrastructure requirements for new single family and multi-unit residential dwellings.

Supply of Clean Energy

BC benefits from an abundant source of clean and renewable electricity at low rates[130], supporting energy-intensive manufacturing and adoption of EVs.[131] The carbon intensity of BC electricity generation is one of the lowest in North America, estimated at 24 tonnes of equivalent carbon dioxide (tCO_2e).[132] Translated into driving an EV, this results in 4 grams CO_2e per kilometre versus 240 grams for a similar sized internal combustion engine vehicle. Furthermore, BC Hydro's generation and transmission systems are robust and have ample capacity to support high penetration of EVs.[133]

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[127] BC Government – Office of the Premier, *B.C. names Climate Leadership Team*, Available here: https://news.gov.bc.ca/stories/bc-names-climate-leadership-team. Information on the team and their recommendations are available here: http://www2.gov.bc.ca/gov/content/environment/climate-change/policy-legislation-programs/climate-leadership-team

[128] ChargeHub, Public EV Charging Stations in Canada. Retrieved from https://chargehub.com/blog/en/canada-public-ev-charging-station-locations/

[129] For more information visit http://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/clean-transportation-policies-programs/clean-energy-vehicle-program/hydrogen-fuelling

[130] BC Hydro rates are the third lowest in Canada.

[131] Annual fuel cost savings for EV owners in BC are estimated to equal $1300 per year (this estimate is based on 18,000 km of driving and a gas price of $1.15/ litre).

[132] Whereas total electricity consumed ranges in intensity from 84-140 tCO_2e with the difference primarily due to imported power from Alberta. By contrast, fossil fuel based generation in North America ranges from 400-900 tCO_2e. Source: 2011 ISIS, Sauder School of Business, UBC – in partnership with the Pacific Institute for Climate Solutions (PICS) "Lifecycle analysis of GHG intensity in BC's energy sources"

[133] BC Hydro Integrated Resource Plan: Meeting B.C.'s Future Electricity Needs, November 2013.

BC is also home to an end-to-end hydrogen supply chain from production, recovery, purification and compression, through to fueling infrastructure.

BC's Brand

BC enjoys a reputation of being green. This applies to the image portrayed and reflected in tourism industry promotions, and also when it comes to international trade and business.[134] The City of Vancouver and the province recognize the importance of this brand in growing economic development opportunities.[135] Success of the BC brand is reflected in the Globe Conference, held every two years in Vancouver. It is the largest gathering of its kind devoted to sustainable business related to clean technology innovation.

5.2. Challenges for the Sector in BC

MNP's interviews with BC sector participants, facilitated workshops and survey of stakeholders identified a number of challenges constraining the growth of the sector in BC. (Note that many of these challenges are similar in nature to those faced by BC tech companies, as described in more detail in Appendix D.)

Access to Capital

Access to capital is viewed as an issue constraining growth in the CEV sector. This was reinforced through the survey findings, where 47 percent of respondents indicated a lack of access to capital or difficulty obtaining financing as a barrier/impediment to growth. Both early stage start-up funding and venture capital are considered a challenge and a constraint on growth.

While some accelerator programs and government supports were viewed as beneficial, in other cases government funding opportunities were viewed as fragmented, inconsistent, or insufficient to meet the industry's needs. To add to this, there is limited government procurement of BC-based CEV technologies that would allow BC companies to scale their operations, unlike government procurement in the United States[136]. To supply international markets requires a certain size and scale, but companies in BC face challenges in growing to this size.

Market Constraints

While there is significant growth potential in the market (particularly through an export oriented strategy), lack of market demand was the second most cited barrier/impediment to growth from survey respondents. According to industry stakeholders, low demand for CEVs currently makes it difficult to attract investment, and also means that investments are associated with a longer payback period. This challenge applies both to companies involved in the research, development and manufacture of CEVs, as well as those involved in CEV-related infrastructure investments. New vehicle dealerships, for example, have made significant investments to sell and service CEVs in BC, with the expectation of a long-term payback.

Low demand for CEVs is somewhat magnified in BC as a result of a small domestic market, which has required a greater reliance on exports to the United States and other jurisdictions. As companies tend to

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[134] See http://www.britishcolumbia.ca/export/industry-sectors/technology/clean-technology/

[135] See http://vancouver.ca/files/cov/gc2020-goal1.pdf, http://www.vancouvereconomic.com/focus/green-economy/, http://vancouver.ca/green-vancouver/greenest-city-action-plan.aspx

[136] Vehicles purchased in the US with public funds require a high percentage of components and final assembly in the US through 'Buy America' regulations. As a result, many Canadian companies are required to have branch plants in the US. Source: EMC International Business Development Strategy, Canadian Electric Transport Sector, Years 2014 to 2017

locate assembly/manufacturing where there is demand, BC may be missing opportunities to other, larger jurisdictions. (For example, although BC had the highest number of electric vehicles per capita in Canada as of December 2015, the total number of electric vehicles in the province was about 3,326 vehicles – approximately 2,600 vehicles less than in Ontario and over 5,000 less than in Quebec.[137])

Local Knowledge and Expertise

Unlike other Canadian jurisdictions, vehicle manufacturing has not been an industry focus in BC. While assembly plants for large foreign automakers (including Fiat Chrysler, Ford, GM, Honda and Toyota) and manufacturers of parts and systems represent the majority of the automotive industry activity in Canada, all major automotive vehicle assembly plants in Canada are located in Ontario.[138] BC does not currently have the manufacturing capability and scale of other provinces and, as a result, does not have a meaningful supply chain of automotive parts and suppliers.

The CEV sector in BC also faces competition for highly qualified people (e.g., programmers and engineers) from other industry sectors, such as digital media and gaming, and other jurisdictions, such as California. Housing costs and the cost of living (particularly in Vancouver) are also viewed as a challenge for local companies wishing to attract and retain highly qualified personnel, especially at the senior level.

Geography, Location and Demographics

The distance to traditional automotive manufacturing centres in Ontario and the US Midwest create limitations for BC's growth in the sector, as there is a desire from automakers to be in close proximity to suppliers in order to manage logistics and costs. Furthermore, BC's geography poses challenges to CEV infrastructure deployment, as 75 percent of the population is concentrated in the Metro Vancouver and Fraser Valley regions, which represent only 1.4 percent of the province.

Regulatory Constraints

Constraints related to the retail sale of electricity for non-utility entities is seen as an impediment to the deployment of EV charging stations. For example, provisions under part 3 of the BC Utilities Commission Act preclude private sector (non-utility) business models that involve selling electricity with a mark-up, creating a barrier to entry in the electric charging infrastructure market.[139,140] Furthermore, BC Hydro is currently prevented from rate-basing EV charging infrastructure (that is, recovering costs associated with charging infrastructure through customer rates) in the manner of major investor-owned utilities in California.[141]

There are also regulatory issues related to strata regulations in MURBs that, along with technical challenges, create significant barriers to the deployment of charging infrastructure. This is particularly challenging when

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[137] FleetCarma, Electric Vehicle Sales in Canada: 2015 Final Number, 2016. Available here: http://www.fleetcarma.com/ev-sales-canada-2015/

[138] Innovation, Science and Economic Development Canada, *Automotive Assembly Plants in Canada – 2015*, June 2016, Available here: https://www.ic.gc.ca/eic/site/auto-auto.nsf/eng/am00767.html

[139] Retrieved from http://www.bclaws.ca/Recon/document/ID/freeside/00_96473_01#section71

[140] The BCUC has granted exemptions to part 3 of the act specifically related to EV charging. Most recently in May 2016 to the Baker view Eco Dairy allowing them to sell electricity dispensed from a DC fast charger located in Sumas, BC. http://www.ordersdecisions.bcuc.com/bcuc/orders/en/item/144369/index.do

[141] The most recent California Public Utilities Commission ruling in January 2016 allowed SDG&E to build and operate 3500 stations.

one considers that 40 to 60 percent of households in major urban centres of BC reside in multi-unit buildings.[142]

BC's Brand

It was identified that BC's image as a leader in climate action may be diminishing, with a recent shift in focus towards resource development. For example, since the Climate Action Plan was first introduced in 2008, the carbon tax remained at $30 per tonne, despite previous commitments to increase the rate. Similarly, in 2012, LNG was exempted from the Clean Energy Act.[143] BC also does not have a clear roadmap for the growth of the CEV sector in the province, unlike other jurisdictions such as Quebec.

As a result, it was expressed that there is a need to reinvigorate BC's commitment to climate leadership, and to develop a comprehensive provincial strategy that encompasses climate, energy and environmental objectives. The upcoming Climate Leadership Plan, informed by the climate leadership team's recommendations, may help address this challenge.

[142] Retrieved from http://www.metrovancouver.org/services/regional-planning/PlanningPublications/MV_Housing_Data_Book.pdf

[143] For more information on the discussion, see "Regaining Lost Ground" by Andrew Findlay (BC Business, May 2016).

5.3. SWOT Analysis

The following tables present a high-level assessment of BC's strengths, weaknesses, opportunities and threats (SWOT) related to vehicles and vehicle components, fuel and infrastructure and transferable technologies and services.

Table 4: SWOT Analysis of BC's CEV Sector – Vehicles and Vehicle Components

Vehicles and Vehicle Components	
Strengths • Internationally recognized advanced automotive research cluster with strength in fuel cell technology design, development and manufacturing and lithium-ion battery research. • Skilled labour force, strong network of academic institutions and R&D facilities. • Proximity to US and California market. • Low cost clean and renewable electricity.	**Weaknesses** • Access to capital is a challenge for BC companies. • Small domestic market and limited government procurement or early adoption affects the ability of BC companies to test and demonstrate their technologies to potential buyers. • Not a large automotive manufacturing centre (lack of supply chain and manufacturing expertise).
Opportunities • Strong interest in CEV-related R&D and investments by large auto manufacturers. • Large export potential for BC companies specializing in vehicles and vehicle components, with annual sales of FCEVs expected to exceed 228,000 by 2027 and sales of electric vehicles forecast to reach 41 million by 2040. • Projected growth for materials used in battery and fuel cell production present opportunities within the CEV supply chain (e.g., graphite production, lithium-ion battery recycling and secondary use).	**Threats** • Other jurisdictions including US, Japan, China, Korea and Europe are investing hundreds of millions of dollars annually in the fuel cell and electric vehicle sectors.[144,145] • 'Buy America' regulations in the US requires vehicles purchased with public funds to have a high percentage of components and final assembly in the US. As a result, many Canadian companies are required to have branch plants in the US, exporting accompanying jobs.[146]

[144] According to the CHFCA, in 2014 just 7 percent of research funding came from public sources. However, the US DOE had an annual fuel cell research budget of US$100 million in 2014 and in 2014/2015 the government of Japan made available 13.6 billion Yen (US$128 million) for hydrogen and fuel cell research and fueling station development.

[145] EMC Electric Vehicle Technology Roadmap for Canada. Retrieved from https://emc-mec.ca/wp-content/uploads/ElectricVehicleTechnologyRoadmap_e.pdf

[146] EMC International Business Development Strategy, Canadian Electric Transport Sector, Years 2014 to 2017.

Table 5: SWOT Analysis of BC's CEV Sector – Fuel and Infrastructure

Fuel and Infrastructure	
Strengths • Leader in hydrogen fueling station research, development, commercialization testing and manufacturing. • Leader in smart charging applied research. • High deployment of EV charging stations per capita. • Supportive provincial and municipal governments through incentives and regulations. • Growing private sector interest in station hosting.	**Weaknesses** • Lack of hydrogen fueling infrastructure in BC. • Prohibitive regulatory constraints preventing private entrants into the market for EV charging infrastructure deployment.
Opportunities • An increase in the demand for electric and fuel cell electric vehicles will go hand in hand with increased demand for fuel and infrastructure, and may also provide opportunities for the export of locally produced hydrogen. • Recent federal infrastructure investments present a significant opportunity for local infrastructure deployment. • Smart charging technologies and telecommunications are expected to play a role in optimizing the grid.	**Threats** • Costs of hydrogen fueling stations are still prohibitive. • Established companies providing electric charging infrastructure may limit opportunities for local product development.

Table 6: SWOT Analysis of BC's CEV Sector – Transferable Technologies and Services

Transferable Technologies and Services	
Strengths • Leader in smart grid infrastructure deployment and telecommunications. • Strong research environment. • Vibrant technology, clean transportation and aviation sectors. • Desirable place to live for attracting talent. • Favourable tax regime. • Location – proximity to Silicon Valley and Asia Pacific. • Government funding support, incentives and initiatives.	**Weaknesses** • Access to capital is a challenge for BC companies. Limited government procurement or early adoption affects the ability of BC companies to test and demonstrate their technologies to potential buyers. • High cost of living and competition for talent from other sectors and jurisdictions. • Small size and difficulty in scaling.
Opportunities • Automotive industry is going through disruption with a focus on intelligence inside the vehicle (connected car, autonomous vehicles), which has synergies with BC's tech sector. • Newly formed BC Venture Capital Fund of $100 million may improve access to capital for BC start-ups.	**Threats** • Innovation hubs focused on autonomous vehicles and related vehicle technologies are developing in other markets in North America, including Silicon Valley (California), Waterloo and Oshawa (Ontario), and Ann Arbour (Michigan).

5.4. Opportunities for Developing BC's CEV Sector

Projecting the opportunities for developing BC's CEV sector is challenging because of the rapid progression and changes in the industry, and in government policy. In this section we present an assessment that is based on our review of the information and projections that are currently available. Because of the continued evolution of the industry, our assessment is necessarily high-level in nature, and is intended to illustrate the direction in which these opportunities appear at present.

5.4.1. Assessment of Opportunities

There are a number of global trends that are affecting the automotive sector in particular and the clean transportation sector in general. Concerns over global greenhouse gas emissions and a renewed focus on climate action have resulted in many jurisdictions looking to transition transportation from fossil fuel based systems to cleaner energy sources.[147,148] Furthermore, the automotive sector is in a period of transition, requiring significant capacity in highly technical fields (including software development and engineering). A focus on the technology inside the vehicle, including battery management and fuel cell applications, the connected car, and autonomous vehicles, presents an opportunity to participate in automotive sector activity outside of traditional manufacturing hubs.[149] These factors, combined with a growing trend by automakers to outsource vehicle value to suppliers (from design to development and production)[150,151], presents a significant opportunity for BC companies to play an increasing role in this sector.

A number of opportunities were identified to develop the CEV supply chain in BC and to increase economic activity in the province. Tables 7 to 9 provide a summary of these opportunities. While the majority of economic opportunities would likely take place in the Lower Mainland, there is also significant potential for rural economic development in exploring resource-related opportunities (such as graphite and hydrogen production) and opportunities located outside of major urban centres (such as lithium-ion battery recycling).

Although it is difficult to predict the total export market potential of developing BC's CEV sector, based on a review of BC's current exports of CEV-related goods and services, as well as historical growth rates and industry projections, we conservatively estimate that pursuing export development opportunities could result in total exports in the CEV sector in the range of $184 million to $222 million annually by 2020, representing a compound annual growth rate (CAGR) of 6 to 10 percent compared with current estimated levels.

In addition to export development opportunities, there are also significant opportunities related to the continued adoption of CEVs in BC through a transition to locally sourced and lower cost fuels and increased spending in the local economy. The substitution of imported fossil fuels to lower cost and locally supplied

[147] At the United Nations Climate Conference (COP21) held in Paris in December 2015, Canada, alongside 194 other participating countries, agreed to take steps towards a global low-carbon economy by limiting the global temperature increase to less than 2 degrees Celsius above pre-industrial levels.

[148] As identified in Canada's 2016 federal budget, the transportation sector represented 23 percent of Canada's greenhouse gas emissions in 2013, and is the second largest source of emissions in Canada.

[149] As a result of increased outsourcing, vehicles are being manufactured in multiple regions (although typically designed centrally). Source: OECD Market development for Green Cars.

[150] OECD Market development for Green Cars.

[151] The increasing number of electronic gadgets present in cars and trucks are typically outsourced to a supplier. Source: IBIS World, SUV & Light Truck Manufacturing in the US, December 2015.

electricity or hydrogen is projected to stimulate increased spending in the local economy.[152, 153] Furthermore, increased adoption of CEVs is expected to encourage additional investments in CEV-related infrastructure, providing opportunities for local contractors.

To illustrate the potential benefits of these opportunities, we have relied on Statistics Canada's input-output model for BC to estimate the economic activity that would result from the following:

1. Growth in exports by CEV-related companies equivalent to six percent per year.[154]
2. Increased CEV adoption such that CEVs represent five percent of light duty vehicle sales by 2020.[155]
3. Increased public and private sector investment in fueling and charging infrastructure of $41 million from 2016 to 2020 to support the increased adoption of CEVs.

The total projected employment and GDP impacts (including direct, indirect and induced impacts) associated with this increased level of activity are presented in Figures 2 and 3. By 2020, these opportunities are projected to be associated with a total increase in annual employment of approximately 1,400 FTEs, and a total increase in annual GDP of over $80 million.

[152] For example, the CEV Program in BC estimates fuel cost savings for EV owners of $1,600 per year. Source: British Columbia's Clean Energy Vehicle Program Phase 1 Review. July 9, 2015.

[153] According to a study conducted in California, "PEV adoption stimulates economic growth by promoting transport efficiency, reducing the cost of transportation fuel, reducing carbon fuel use, and saving money for households and enterprises. These savings return as different expenditures that are, on average, more job-intensive and less import-dependent than the petroleum fuel supply chain. Consequently, the new expenditures have stronger "multiplier" effects on state product and create many more jobs than they displace." Source: Roland-Holst, D., *Plug-in Electric Vehicle Deployment in California: An Economic Assessment*. September 2012.

[154] Note that many CEV sector companies export engineering and technical design services. From 2010 to 2013 (the most recent period for which data is available), BC's exports of professional, technical and scientific services increased at a CAGR of 6.1 percent. Source: BC Stats, High Technology Sector Profile.

[155] The increased adoption of CEVs is expected to result in a transition from imported fossil fuels to locally sourced and lower cost fuels. We have modelled the net impact of this transition to account for losses in the gasoline retail sector.

Figure 2: Total Projected Employment Impacts (2016 to 2020)

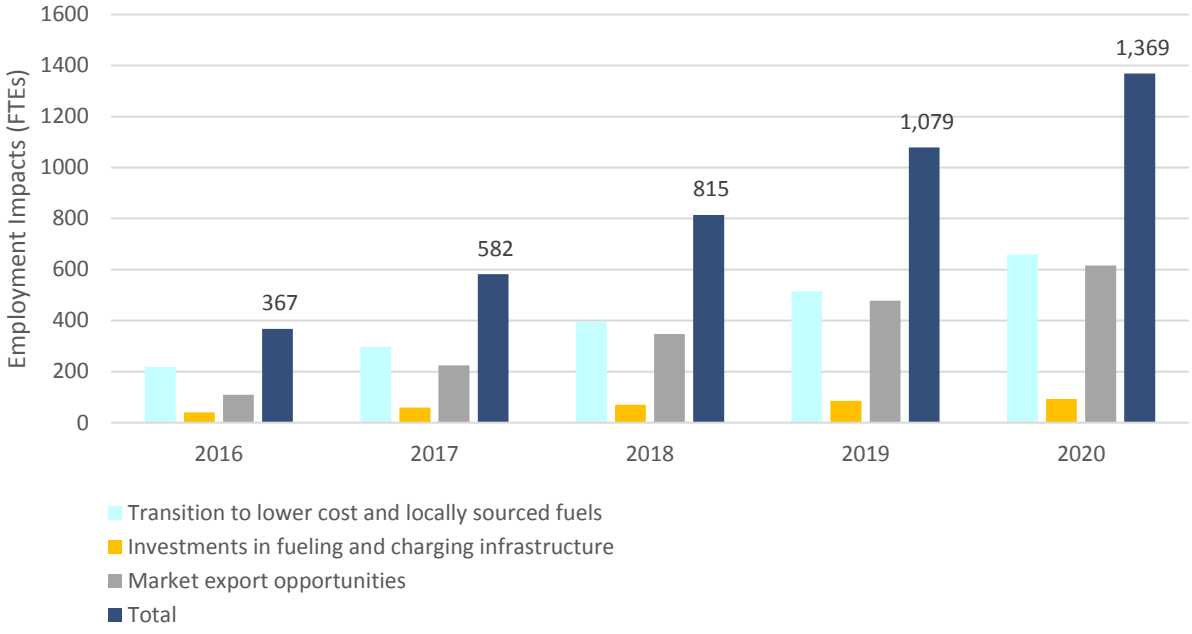


Figure 3: Total Projected GDP Impacts (2016 to 2020)

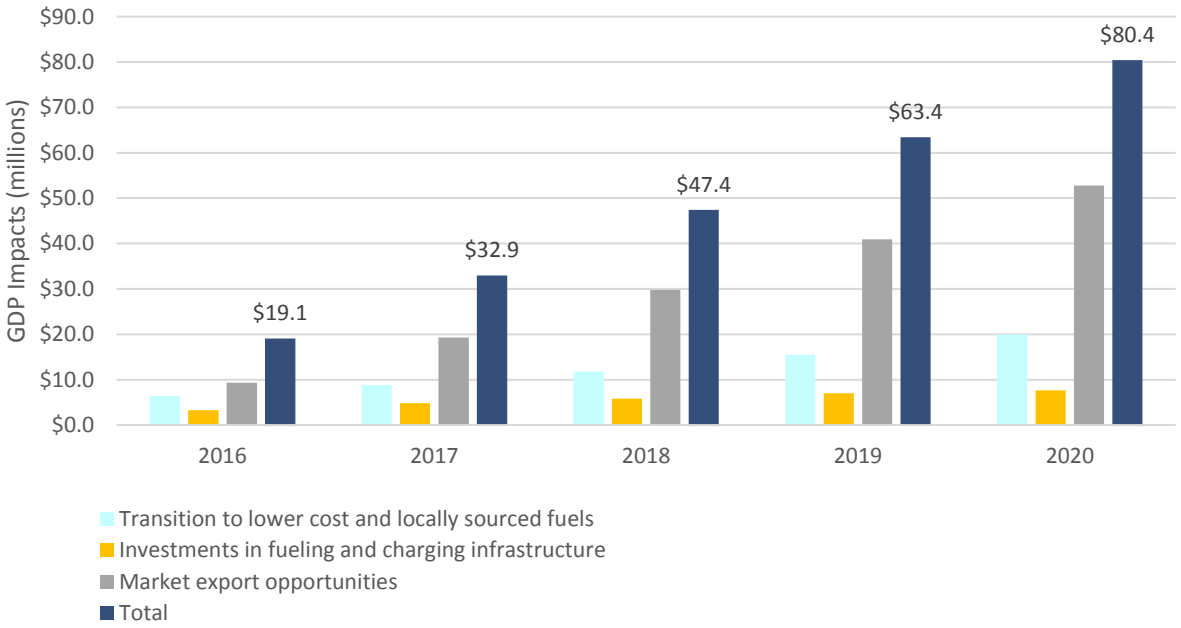


Table 7: Opportunities Assessment – Vehicles and Vehicle Components

Vehicles and Vehicle Components			
Opportunity	**Description/Rationale**	**Potential Economic Benefits**	**Assessment of Potential Economic Benefits**
1. Leverage the fuel cell cluster to target and attract more auto manufacturers to BC and to attract foreign direct investment in the sector.	Attracting other automakers to BC will build on the existing fuel cell sector and attract investment to BC.	• **Job creation** • **Investment attraction** • **Industry investment in research, development and demonstration**	Successful past examples in BC include the Mercedes/Daimler investment of $70 million in the world's first automated fuel cell production plant. The facility is associated with the creation of 50 jobs.[156]
2. Focus on the development of manufacturing capability in BC for the production of fuel cell stacks (equivalent to the Tesla giga-factory in Nevada).	Although BC has not traditionally been a centre for automotive manufacturing, BC is well positioned to manufacture fuel cell stacks given the concentration of local knowledge and expertise and research and development activities. As with other technologies, larger scale production could result in cost reductions and efficiencies.	• **Job creation** • **Investment attraction** • **Business output** • **Export opportunities**	Tesla's gigafactory in Nevada, for example, is associated with an investment in manufacturing equipment and property of $3.5 billion and is projected to directly employ 6,500 people.[157] The global market for fuel cells is expected to reach $340 billion by 2020, representing a significant market opportunity.
3. Focus on the manufacture of various CEV components to play a more significant	BC has a number of small companies producing CEVs and CEV-related components. There is an opportunity for these companies	• **Job creation** • **Investment attraction** • **Business output** • **Export opportunities**	The expansion of a battery plant in Boucherville, Quebec was reported to be associated with a $176 million investment and 245

[156] Retrieved from http://www.britishcolumbia.ca/invest/success-stories/?StoryId=31

[157] "Inside Nevada's $1.25 billion Tesla tax deal". Reno Gazette-Journal. September 16, 2014.

Vehicles and Vehicle Components			
Opportunity	**Description/Rationale**	**Potential Economic Benefits**	**Assessment of Potential Economic Benefits**
role in the global value chain.	to play a more significant role in the global value chain.		jobs.[158] A lithium iron phosphate plant in Candiac, Quebec announced in 2010 was reported to be associated with a total investment of $78 million and 52 jobs.[159]
4. Continue to pursue lithium-ion battery research and development.	Significant growth is expected in the market for lithium-ion batteries. With existing capabilities and resources in BC (e.g., Corvus Energy, E-One Moli Energy, and Eagle Graphite), there is an opportunity to further develop BC's research and development capabilities in pursuit of developing new technologies and products. For example, there may be an opportunity to explore secondary or tertiary processing and testing of BC's flake graphite deposits for use in lithium-ion batteries.	• **Job creation** • **Investment attraction** • **Business output** • **Export opportunities**	The global market for lithium-ion batteries for use in light-duty vehicles is forecasted to total $221 billion from 2015 to 2024.[160] This represents a significant market opportunity.
5. Become a leader in lithium-ion battery production, recycling,	Significant growth is expected in the market for lithium-ion batteries, which will also require proper recycling, secondary use and disposal. BC is well positioned to lead the	• **Job creation** • **Investment attraction** • **Business output**	According to a report by Frost & Sullivan, the lithium-ion battery recycling market is expected to be worth more than $2 billion by

[158] Running on Green Power – Electric Vehicles: 2011-2020 Quebec Action Plan, Alternative Fuel Vehicles Conference, September 27, 2012, The Biosphere, Montreal.

[159] Ibid.

[160] Navigant Research News Room, *The Global Market for Lithium Ion Batteries for Vehicles Is Expected to Total $221 Billion from 2015 to 2024,* Available here: https://www.navigantresearch.com/newsroom/the-global-market-for-lithium-ion-batteries-for-vehicles-is-expected-to-total-221-billion-from-2015-to-2024

Vehicles and Vehicle Components			
Opportunity	**Description/Rationale**	**Potential Economic Benefits**	**Assessment of Potential Economic Benefits**
secondary use and disposal.	recycling, secondary use and disposal market, given existing facilities and capabilities in this area.		2022.[161] A facility expansion in Ohio, associated with an investment of $9.5 million, is expected to create or sustain 25 full time positions.[162,163]
6. Explore local supply chain development, research and development, and export opportunities related to raw material suppliers for battery or fuel cell technology, including graphite production and other strategic elements such as rare earth metals.	BC benefits from significant natural resources, including an operational quarry for flake graphite (a material required for fuel cell manufacturing and lithium-ion battery production). These resources present an opportunity for BC to develop the local supply chain for CEV-related technologies, and also present an export opportunity through the extraction and processing of these resources.	• **Job creation** • **Investment attraction** • **Business output** • **Export opportunities** • **Industry investment in research, development and demonstration**	A lithium mining and processing project for batteries near Val-d'Or, Quebec was reported to have an investment value of $200 million with 200 direct jobs, of which 70 were in processing.[164]

[161] Frost & Sullivan. *Global Electric Vehicles Lithium-ion Battery Second Life and Recycling Market Analysis*.

[162] Toxco, Inc. (now Retriev Technologies). May 13, 2013. 2013 DOE Vehicles Technologies Program Review Presentation: Lithium-Ion Battery Recycling Facilities. Retrieved from http://energy.gov/sites/prod/files/2014/03/f13/arravt020_es_coy_2013_p.pdf

[163] The investment includes matching funds awarded by the Department of Energy to promote sustainable hybrid and EV batteries. Source: Retriev Technologies, accessed at http://www.retrievtech.com/locations

[164] Running on Green Power – Electric Vehicles: 2011-2020 Quebec Action Plan, Alternative Fuel Vehicles Conference, September 27, 2012, The Biosphere, Montreal.

Table 8: Opportunities Assessment – Fuel and Infrastructure

Fuel and Infrastructure			
Opportunity	**Description/Rationale**	**Potential Economic Benefits**	**Assessment of Potential Economic Benefits**
1. Continue to encourage CEV adoption to reduce fossil fuel imports and leverage locally sourced and lower cost fuels.	The transition from imported fossil fuels to locally sourced electricity and hydrogen creates economic activity within the supply chain for these fuels in BC. Furthermore, savings on annual fuel costs result in additional consumer spending in the economy, which has a positive impact on other goods and service producing sectors.[165]	• **Job creation** • **Business output**	The vision of the CEV Program in BC is to stimulate the market such that by 2020, 5% of new light duty vehicle purchases in BC are CEVs. Based on this adoption rate, MNP estimates that the transition to locally sourced and lower cost fuels would support net annual employment of 660 FTEs by 2020.
2. Capitalize funding opportunities to support the installation of additional fueling and charging infrastructure.	The federal government recently announced $62.5 million in funding opportunities to support the demonstration of electric vehicle infrastructure and to support the near term deployment of electric vehicle and alternative fuel infrastructure.[166] According to stakeholder feedback collected through MNP interviews, there is a need for further deployment of fueling and charging infrastructure, specifically with public access and with a focus on "charging at work" as well as MURBs.	• **Job creation** • **Business output**	Capitalizing on this funding opportunity would support job creation in BC through the installation of additional fueling and charging infrastructure. Increased infrastructure will also likely support the continued adoption of CEVs in the province, along with the associated fuel cost savings.

[165] For a full discussion of these benefits, see Roland-Holst, D., *Plug-in Electric Vehicle Deployment in California: An Economic Assessment*. September 2012.

[166] See http://www.nrcan.gc.ca/energy/science/programs-funding/18356

Fuel and Infrastructure			
Opportunity	**Description/Rationale**	**Potential Economic Benefits**	**Assessment of Potential Economic Benefits**
3. Explore hydrogen production, storage solutions and bulk export opportunities	BC is home to an abundant source of clean and renewable electricity, which provides an opportunity for the production of clean hydrogen as a transportation fuel through electrolysis. As the demand for hydrogen increases, BC is well positioned to produce and distribute a local source of clean hydrogen as a transportation fuel.	• **Job creation** • **Investment attraction** • **Business output** • **Export opportunities** • **Industry investment in research, development and demonstration**	More than 5,200 hydrogen fueling stations for cars, buses and forklifts are forecasted to be operational worldwide by 2020, driving annual hydrogen demand to an estimated 418 million kilograms. There may be an opportunity for BC to support the clean supply of hydrogen to the US and other markets.
4. Leverage BC's design, testing and development of smart grid technology for EV deployment and utility telecommunications systems.	BC Hydro's leadership in smart grid infrastructure deployment and technology, combined with Powertech's research in EV deployment and telecommunications, may provide opportunities for BC to commercialize related applications and technologies that support and optimize the integration of EVs on the grid.	• **Job creation** • **Business output** • **Export opportunities**	Incentivizing EV charging during off-peak hours may result in a number of benefits for electric utilities and ratepayers. By selling electricity during times of low-cost and surplus electricity (e.g., night-time charging), EVs may lead to lower average costs of service, reducing pressure on rates.

Table 9: Opportunities Assessment – Transferable Technologies and Services

Transferable Technologies and Services			
Opportunity	**Description/Rationale**	**Potential Economic Benefits**	**Assessment of Potential Economic Benefits**
1. Pursue opportunities related to the intelligence inside the vehicle, such as research, development and commercialization activities related to optimized fuel cell efficiency, the connected car, autonomous vehicles, compression and fueling algorithms, and vehicle telematics and controls, and act as a test environment for these technologies.	BC's research facilities and existing knowledge base in the technology, aviation and clean energy vehicle sectors present opportunities for investments in research, development and commercialization of CEV-related software and technologies. A focus innovation, starting with research institutes, could develop BC as a hub of advanced automotive research activity and result in highly skilled and high paying jobs.	• **Job creation** • **Investment attraction** • **Business output** • **Export opportunities** • **Industry investment in research, development and demonstration**	In June 2016, General Motors announced plans to expand research into self-driving vehicles and open a new software centre in Markham, Ontario, resulting in the creation of more than 700 new engineering jobs.[167]

[167] GM to expand engineering team in Ontario, create more than 700 new jobs. Retrieved from http://globalnews.ca/news/2749546/general-motors-to-announce-up-to-1000-new-jobs-in-oshawa-media-reports/

6. Recommendations for Strategic Support to Develop BC's CEV Sector

6.1. Learnings from Quebec, California and BC's Technology Sector

To provide economic development context for supporting BC's CEV sector, MNP reviewed information related to initiatives undertaken in Quebec and California that have supported the growth and development of the CEV sector. Existing strategic government support for BC's technology sector was also reviewed. While detailed information on each of these jurisdictions and sectors is provided in a set of case studies contained in Appendix D, the following are key learnings that could be applied to BC's CEV sector:

1. A comprehensive and coordinated long term strategy with broader climate policy supports economic development.

The initiatives undertaken in each jurisdiction or sector were supported by an overarching strategy that clearly identified state or provincial objectives related to economic development and, in the case of California and Quebec, coordinated these efforts with other policy considerations such as emissions targets or climate goals. A comprehensive strategy provides the foundation for economic development activity and supports private sector investment by showing a long term commitment to the growth of the sector.

2. Business incentives, funding and investment capital can help existing businesses grow and attract additional investment.

Examples of financial support provided by other jurisdictions and sectors include funding programs to support clean technology investments, direct subsidies or tax incentives to attract business investment, the provision of loan guarantees to support investment and venture capital funds to improve access to capital.

3. Government procurement can be an effective tool to support the development of the sector.

The CEV sector in California has benefited from the American Recovery and Reinvestment Act, which requires that vehicles purchased in the US with public funds have a high percentage of components and final assembly in the US. The government of Quebec, on the other hand, has shown support for the CEV sector by requiring 1,000 electric or hybrid vehicles be integrated into its fleet by 2020 (and has specifically allocated $15 million to this initiative to "lead by example"). The BC Tech Strategy identified "making it easier to sell to government" as a strategic action.

4. Tap into market potential through export oriented growth.

The Quebec Electrification Transportation Action Plan includes $4.75 million in funding to support the marketing and export of innovative products. The BC Tech Strategy outlines a goal of increasing the number of tech companies connecting with buyers outside BC by 10 percent, by delivering targeted activities in key markets, including international trade shows, government-led trade missions, and international marketing.

5. Successful deployment of fueling and charging infrastructure involves government support, and a defined role for electric utilities.

California and Quebec are successful examples of the importance of long term investments in fueling and charging infrastructure, and the active role utilities can play in supporting infrastructure development.

6.2. Recommendations for Strategic Support for Developing BC's CEV Sector

Targeted support would help enable a number of investment, development and economic growth opportunities in the CEV sector in BC, and could lead to significant job creation, investment attraction, export development and other economic benefits. The following are specific areas of opportunity where the government can provide strategic support for BC's CEV sector. These recommendations were identified through consultations with CEV sector stakeholders and were reviewed with members of the Steering Committee.

1. Re-establish BC's leadership in climate change and develop an integrated and comprehensive roadmap for the province.

Literature reviewed as part of this study indicated that jurisdictions enjoying significant levels of CEV-related economic activity (such as Oregon, Quebec, Ontario, California and Norway) have a comprehensive and long term strategy in place that combines the central elements of energy, climate and economic development. In each of these examples, transportation plays an important role in these strategies. BC enjoys unique attributes and advantages related to its progressive climate policy, clean electricity generation and innovation culture particularly in clean tech. These advantages present significant opportunities for re-affirming BC's leadership in climate change and accelerating economic growth in the CEV sector and the economy in general.

CEV sector stakeholders noted that while there are numerous disparate programs and policy initiatives aimed at supporting various technology-related economic activity in the province, there is a need to support all of these various initiatives in a coordinated fashion – province-wide and across all government ministries and agencies. This includes seeking synergies and alignment with federal and provincial climate and transportation-related policies and initiatives. To achieve this, BC should develop a broad strategic vision that incorporates clear objectives related to energy policy, climate policy and economic development.

Note that the BC government's forthcoming Climate Leadership Plan is anticipated to address many of these elements through the development of a low-carbon transportation strategy for the province.[168] For example, recommendations made in 2015 by the climate leadership team included zero emission vehicle targets, increases in low carbon fuel standards and broadening of coverage, enhancing incentives and infrastructure, and establishing a revenue neutral PST for all vehicles based on grams of CO_2 per kilometre.

A provincial strategy would support the coordination of efforts across various ministries, agencies and departments, including those involved in export development, provincial branding for foreign direct investment, government procurement, job creation and industry development, and the development of skilled labour through the primary, secondary and post-secondary education systems. This alone would send a clear signal that would attract investment in the CEV and related sectors leading to investment attraction and economic development.

2. Continue to support CEV adoption and infrastructure deployment.

Local demand for CEV technologies leads to economic benefits, resulting from both consumer spending of fuel savings as well as the development of the supply chain and related activities. Consumer driven

[168] Climate Leadership Team, *Recommendations to Government*, October 31, 2015.

economic activity is well documented in the literature, and the economic benefits of supporting CEV adoption and infrastructure deployment was strongly supported by interviews carried out during the study.

Demand side measures include the suite of policies that remove barriers to adoption, such as building code amendments, changes to parking regulations and revised strata rules. Layering in additional consumer focused benefits like HOV access, preferential parking, lower taxes and insurance costs are all expected to result in accelerated CEV adoption. Furthermore, incentive programs should continue to support fleet applications and be expanded to allow for electrified non-road applications and other technologies (e.g., hydrogen internal combustion engine vehicles).

To accelerate the adoption of electric charging infrastructure, the BC Government should work with the BC Utilities Commission to allow the resale of electricity for EV charging and the establishment of time-of-use rates specific to EV owners. Industry stakeholders suggested that removing these barriers would increase private investment in the sector. It was also noted in stakeholder consultations that there should be a more well-defined role for utilities in the market, as is the case in California and Quebec.

Higher numbers of CEVs bring ancillary benefits through the substitution of imported transportation fuel with domestically produced electricity and hydrogen. In the case of electricity, this positively impacts utility revenues and may also result in lower rates. Household savings resulting from lower fuel costs are also significant and those savings then recirculate in the local economy, providing additional economic stimulus. On the supply side, local suppliers, dealers and technology providers benefit from locally generated sales. More vehicles on the road also increases demand for infrastructure and supply service providers, leading to the expansion of economic activity and a growing cluster.

The BC government should continue to support an accelerated transition to sustainable transportation through direct consumer support mechanisms for CEVs and policies aimed at removing barriers to adoption. There is evidence that the transition to clean energy transportation is not only a critical element towards achieving climate objectives, but also a means to stimulate economic activity.

3. Continue to encourage provincial procurement of CEVs and BC-based technologies.

The government currently provides incentives for consumers to purchase CEVs, but more support could be provided for provincial ministries and agencies to purchase CEVs over conventional vehicles. The BC Government has an opportunity to lead by example, by developing a procurement strategy that gives merit to CEVs and promotes the deployment of CEVs within the BC public sector.

Through the Pacific Coast Collaborative, a joint-initiative by BC, Washington, Oregon and California, the BC Government has already committed to the increased uptake of zero emission vehicles as part of the West Coast Electric Fleets Initiative. The initiative calls for the increased uptake of zero emission vehicles in public and private sector fleets to 10 percent of new vehicle purchases by 2016.[169]

4. Continue efforts to improve access to capital (seed funding and venture capital funding).

The $100 million Venture Capital Fund recently announced for the tech sector in BC is a positive development in improving access to capital for BC tech companies, including many CEV-related companies. It was suggested during stakeholder consultations that a portion of the Venture Capital Fund be set aside for CEV-related investments, as these investments may be associated with a longer payback period than other investments considered under the fund.

[169] West Coast Electric Fleets, *About the West Coast Electric Fleets*, Available here: http://www.westcoastelectricfleets.com/about/

5. Provide targeted funding for prototype development, large scale demonstration projects and commercialization support.

The CEV sector would benefit from a reliable source of funding during early stages of technology development through to commercialization. There is a need to provide support to BC companies to invest in product development and commercialization activities that would allow them to move beyond the research stage, and go to market with a viable product. Existing programs could be leveraged, such as the federal Industrial Research Assistance Program, National Science and Engineering Research Council (NSERC) Engage, the Automotive Supplier Innovation Fund, or accelerator programs offered through the BC Innovation Council that are aimed at assisting companies in overcoming these challenges.

Where possible, it was recommended that the provincial government provide coordinated support with existing programs, initiatives or projects funded by the federal or municipal governments, or otherwise ensure that new programs address gaps in coverage.

It was also viewed that the funding of larger scale and long term demonstration projects would be beneficial in ensuring that the performance of the technology is validated at scale and over a longer period, while also ensuring that public and private funds are invested more strategically with higher long term value.

Based on our research, we recommend the following focus areas or priorities related to the targeted funding available through the ARC Program:

- **Target funding at CEV activities with significant export potential.** As a result of a small domestic market in BC, growth of BC-based CEV companies will require a greater reliance on exports to the United States and other jurisdictions. As a result, an area of focus for growing BC's CEV sector should be on identifying and pursuing export opportunities. Although additional research would be required before pursuing any individual opportunity, our primary and secondary research suggests that areas with export potential in BC include hydrogen production, graphite production, fuel cell design/manufacturing, lithium-ion battery design/production and a number of CEV-related software/technology applications.
- **Encourage the development of a stronger cluster of CEV-related activity in BC.** Rather than dispersing funding too broadly, we recommend that funding be targeted at activities that enhance BC's position as an industry centre and encourage collaboration among key players in the sector. For example, industry led research with academic partnership or support would encourage greater collaboration among sector participants, help develop BC's talent pool, and may also be more likely to result in product development and commercialization. The development of a CEV Centre of Excellence in BC could also yield similar benefits, and attract additional research investment to BC. Funding should be targeted with a broader strategy in mind to ensure that "the whole is greater than the sum of the parts".
- **Support the use and demonstration of BC-based technologies.** We would also recommend targeting funding to support the use and demonstration of BC-based technologies. This could be achieved through government procurement (e.g., being the "first customer" for BC companies), or by supporting projects with other federal or municipal partners. Supporting the deployment of BC-based technologies locally would allow BC companies to showcase their technology to potential buyers or investors, increase the scale of their operations for export opportunities and improve their market readiness.

6. Support the development of highly qualified and skilled labour.

The CEV sector requires highly qualified and skilled labour in areas related to engineering, programming, manufacturing and vehicle repair and maintenance. There is an opportunity for the government to provide strategic support in these areas, by funding specific education, training, internship or employment programs or by ensuring BC participates in the creation of a national Centre of Excellence for CEV advanced innovation. BC is already home to a number of strong research institutes participating in the sector (as outlined in the table below), and should work to ensure that programming and curricula are aligned with the needs of CEV sector companies.

Table 10: BC CEV-related Research Institutes

Post-secondary / Research Institute	Description
University of British Columbia	Clean Energy Research Centre Centre for Interactive Research on Sustainability
Simon Fraser University	School of Mechatronics Engineering
University of Victoria	Institute for Integrated Energy Systems
Kwantlen Polytechnic University	Advanced Manufacturing Diploma and CEV Service, Maintenance and Repair programs are currently under consideration.
BC Institute of Technology	Smart Micro-grid Program

A proposed campus expansion for clean technology facilities in Surrey includes a $44 million investment in a Foresight Cleantech Manufacturing Centre through Kwantlen Polytechnic University, and a proposed Sustainable Energy and Environmental Engineering Building at Simon Fraser University's Surrey campus (which will support research activities related to fuel cell and electric vehicle technologies). As BC's CEV sector currently lacks capacity in advanced manufacturing, the proposed 200,000 square foot facility could provide a collaborative setting for companies to scale up their production alongside the support of local research institutes.

7. Support foreign direct investment and export development activities.

There are a number of opportunities where BC could play a more significant role in the global CEV value chain, either by reducing gaps in the supply chain or by continuing to encourage the growth within BC's areas of strength or expertise. The government should consider identifying target companies with these capabilities to locate and invest in BC. Potential targets may include:

- OEMs to attract fuel cell manufacturing.
- Battery manufacturers to attract research, development or testing of BC metals or raw materials.
- Large auto manufacturers to attract investment related to connected vehicle applications or other technologies.

Furthermore, as the domestic market for CEV companies is relatively small, companies must expand their customer base beyond provincial boundaries in order to grow in size and scale. For small companies this can be a difficult task due to limited resources or a lack of knowledge of international markets and opportunities.

There is an opportunity for government to support small and medium-sized companies in the CEV sector in pursuing exports, attending trade missions, and attracting conferences and industry events to BC to promote and showcase the sector. Supporting these conferences sends a message that the sector is important to the BC government, further increasing the profile of BC companies. These activities should be designed in a coordinated approach to facilitate collaboration within and across various levels of government, and with industry and other relevant partners/stakeholders.

Appendix A. Study Methodology

The study involved the analysis of data and information from a number of primary and secondary research sources. A description of the research and analysis methods is included in the following sections.

Literature Review and Secondary Research

The purpose of the literature review was to inform the development of the CEV sector overview, opportunities in the sector and identification of case studies to develop examples of lessons learned in other industries or jurisdictions. The literature review also helped identify gaps in publicly available information to inform other data collection activities.

As part of the study, MNP collected, reviewed and catalogued approximately 60 individual reports, whitepapers, academic journals, and conference proceedings from various sources. MNP also collected secondary data from sources such as BC Stats and Statistics Canada to help inform the analysis.

Online Survey

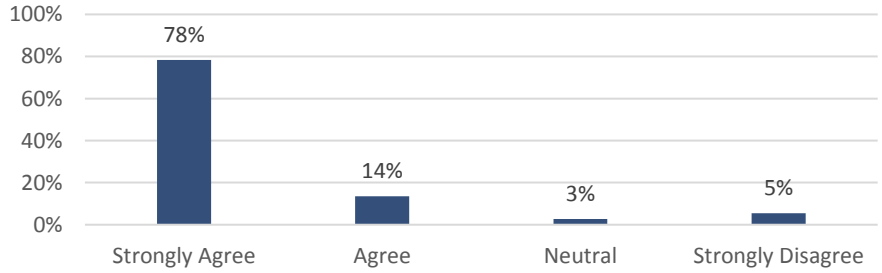
The purpose of the online survey was to gather information to help measure the economic contributions of the BC CEV sector organizations. Surveys were distributed to over 200 organizations of which the majority (approximately 130) were identified as companies or organizations with operations in BC.

Combined with previous survey information related to organizations involved in the hydrogen and fuel cell sector resulted in 87 total combined survey responses for inclusion in the study[170], of which 51 were identified as companies or organizations with operations in BC.

As part of the survey, organizations were asked a set of forward looking questions related to opportunities and challenges within the CEV sector in BC. Below are some of the findings from the survey[171]:

- The majority of survey respondents (78 percent) strongly agreed that government can play a significant role in accelerating the development of the CEV sector in BC.

To which extent do you agree or disagree with the following statement: | Government can play a significant role in accelerating the development of the CEV sector in BC

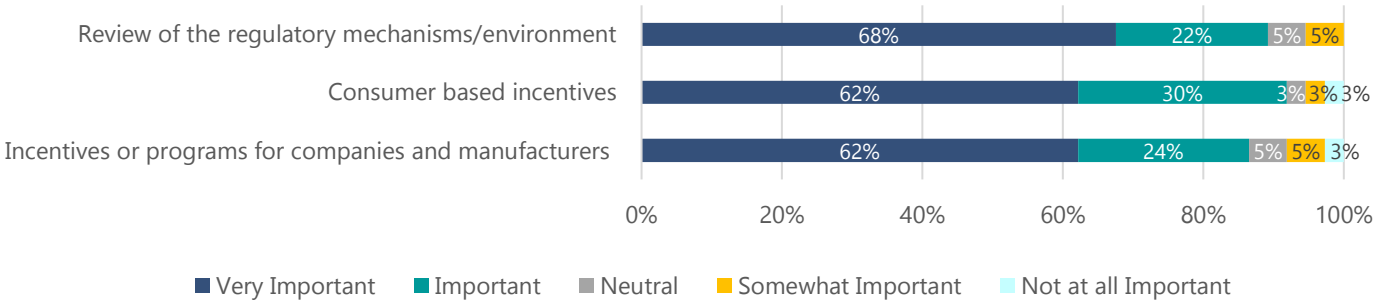


[170] Note that this includes responses from the 2015 CEV survey as well as from the 2015/2016 Canadian Hydrogen and Fuel Cell Sector Survey, which was administered by MNP on behalf of Innovation, Science and Economic Development Canada (ISED). The Canadian Hydrogen and Fuel Cell Survey had 59 responses for inclusion in this study, while the CEV Survey received 45 completed responses so far. Some respondents answered both surveys; their responses were only counted once.

[171] Note that not all survey respondents provided an answer to every question and findings present the results for those that provided an answer.

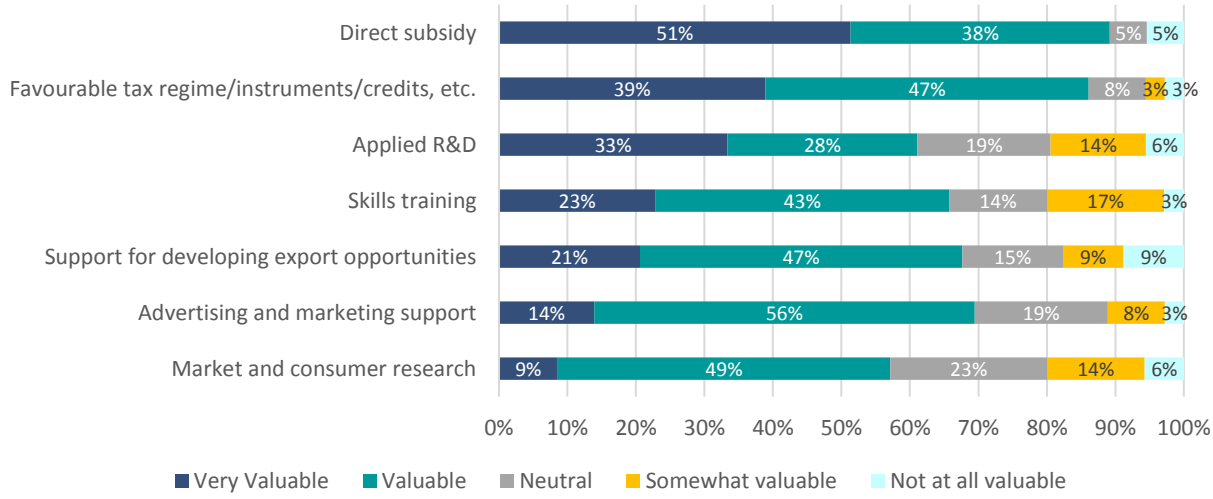
- The government focus considered most important by survey respondents was the provision of incentives to help increase the demand for CEVs, followed by reviewing the regulatory mechanism/environment for the sector in BC and providing incentives for companies and manufacturers to help develop the sector.

In your opinion, how important is it for the government to focus on each of the following to support BC's CEV sector:



- The most valuable type of government support for the CEV sector in BC reported by survey respondents was direct subsidies followed a favourable tax regime/instruments/credits.

In your opinion, how valuable would each of the following types of government support be for the CEV sector in BC?



- The barrier/impediment to growth in the CEV sector in BC most often reported by survey respondents was a lack of access to capital or difficulty obtaining financing, following by a lack of market demand and the perception of the industry in BC.

Workshops

The purpose of the workshops was to collect information on BC's competitive advantages, opportunities, challenges, barriers, and priority markets in the CEV sector. Secondly, the workshops explored areas of strategic government support mechanisms to best advance the growth of the sector.

In total, 36 individuals from CEV-related companies and organizations attended one of two half-day workshops offered in Vancouver. Findings from the workshops were incorporated in the report.

Targeted Interviews

MNP conducted a series of interviews to build on the themes identified in the facilitated workshops, and to gather information on leading practices from other industries and jurisdictions. A total of 20 interviews were completed with contacts from CEV-related companies (some with operations in BC, and some without), and with subject matter experts from other jurisdictions and industries.

Representatives from the following companies and organizations were interviewed as part of the study:

- City of Vancouver
- BMW
- AddEnergie
- Automotive Fuel Cell Corporation
- Tesla
- Hydra Energy
- Greecon
- ITM Power
- Canadian Electric Vehicles
- FortisBC
- Corvus
- Spur Innovations
- Daimler/Mercedes
- BC New Car Dealers Association
- Hydro Quebec
- Pulse Energy (acquired by EnerNOC)
- Hyundai
- General Motors
- BC Hydro
- BC Technology Innovation Association

Economic Activity Baseline Methodology

As previously mentioned, the CEV sector in BC is not readily defined using standard industry classification systems such as NAICS. Rather, BC's CEV sector activities span multiple industries and involve many supporting activities that need to be captured.

This problem of classification is not unique to the CEV sector; rather it applies across the spectrum of so called "green economy" activity[172,173], and also applies to other sectors in BC, such as tourism and high technology, that span multiple industry classifications[174]. As a result, the approach used to quantify an economic baseline for BC's CEV sector relied on well-established methods used in a number of previous studies.

In brief, the baseline assessment involved the following two-step approach:

- First, the set of activities that encompass the CEV sector were defined through the identification of relevant industry NAICS codes.
- Secondly, intensity ratios were developed for each industry sector to isolate only CEV-related economic activity.

To develop the intensity ratios, we relied on the following sources of information:

- A list of companies involved in CEV-related activities in BC, developed by MNP as part of the study. (See Appendix B for the full list of companies.)
- Revenue, employment and other company-specific data obtained by MNP through a survey of CEV-related companies.
- Previous studies related to the quantification of the clean transportation sector in BC and elsewhere.

Relying on multiple sources of information allowed us to combine the benefits a top down analysis (through the use of intensity ratios) with a bottom up approach that involved the aggregation of individual company information. This resulted in a more meaningful assessment of current economic activity in the sector compared with what would have been achieved by relying on only one information source.

Tables A-1 to A-5 present a list of NAICS codes and intensity ratios relied on for the analysis.

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[172] United States Department of Labour, Bureau of Labour Statistics. http://www.bls.gov/green/

[173] "*Previous work conducted by GLOBE Advisors in BC and elsewhere in North America, combined with information obtained through industry research, key informant interviews, and through recent work by the US BLS to identify intensity ratios within green industries in the United States as part of their Green Goods and Services survey, resulted in a hybrid methodological approach to calculating industry intensity ratios for BC's three clean economy sectors under investigation.*"

Globe Advisors (2012 September) Market report, British Columbia's clean transportation sector.

[174] See, for example, BC Stats' methodology for estimating economic activity in the tourism and high technology sectors, available at: http://www.bcstats.gov.bc.ca/StatisticsBySubject/BusinessIndustry/Tourism.aspx and http://www.bcstats.gov.bc.ca/StatisticsBySubject/BusinessIndustry/HighTechnology.aspx

Table A-1: Industry NAICS Codes Related to Vehicles and Vehicle Components

Activity	NAICS	Definition
Design, Manufacture and Sale of Vehicle Components	**54142**	**Industrial design services** Establishments primarily engaged in creating and developing designs and specifications that optimize the function, value and appearance of products.
	54133	**Engineering services** Establishments primarily engaged in applying principles of engineering in the design, development and utilization of machines, materials, instruments, structures, processes and systems.
	33531	**Electrical equipment manufacturing** This industry comprises establishments primarily engaged in manufacturing equipment that generates and distributes electrical power, including electric motors and generators.
	3359	**Other electrical equipment and component manufacturing** Establishments primarily engaged in manufacturing electrical power storage and transmission devices, and accessories for carrying current including fuel cells.
	33621	**Motor vehicle body and trailer manufacturing** Establishments primarily engaged in manufacturing motor vehicle bodies and cabs, truck trailers and non-commercial trailers.
	3363	**Motor vehicle parts manufacturing** Establishments primarily engaged in manufacturing motor vehicle parts, including engines.
	4152	**New motor vehicle parts and accessories merchant wholesalers** Establishments primarily engaged in wholesaling new and rebuilt motor vehicle parts and accessories.
	4413	**Automotive parts, accessories and tire stores** Establishments primarily engaged in retailing automotive parts and accessories.
Manufacture and Sale of Vehicles	**3361**	**Motor vehicle manufacturing** Establishments primarily engaged in manufacturing motor vehicles.
	33699	**Other transportation equipment manufacturing** Establishments primarily engaged in manufacturing transportation equipment and parts.
	4151	**Motor vehicle merchant wholesalers** Establishments primarily engaged in wholesaling new and used automobiles, trucks, truck trailers, buses and recreational vehicles.
	4411	**Automobile dealers** Establishments primarily engaged in retailing new and used automobiles, sport utility vehicles, and light-duty trucks and vans, including mini-vans.
	4412	**Other motor vehicle dealers** Establishments primarily engaged in retailing new and used vehicles, except automobiles, sport utility vehicles, and light-duty trucks and vans, including mini-vans.
Purchase and Use of Vehicles	**4851**	**Urban transit system** Establishments primarily engaged in operating local and suburban mass passenger transit systems.
	4852	**Interurban and rural bus transportation** Establishments primarily engaged in providing passenger transportation, principally outside a single municipality and its suburban areas, primarily by bus.
	4853	**Taxi and limousine service**

		Establishments primarily engaged in providing passenger transportation by taxi and limousine.
	4854	**School and employee bus transportation** Establishments primarily engaged in operating buses and other motor vehicles to transport pupils to and from school or employees to and from work.
	4855	**Charter bus industry** Establishments primarily engaged in providing charter bus services.
	4859	**Other transit and ground passenger transportation** Establishments, not classified to any other industry group, primarily engaged in providing shuttle services to airports and similar facilities, special needs transportation services and other transit and ground passenger transport.
	48811	**Airport operations** Establishments primarily engaged in operating international, national and other civil airports. The activities involved in operating airports include renting hangar space, and providing air traffic control services, baggage handling, cargo handling and aircraft parking services.
	48832	**Marine cargo handling** Establishments primarily engaged in providing stevedoring and other marine cargo handling services.
	5321	**Automotive equipment rental and leasing** Establishments primarily engaged in renting or leasing vehicles, such as passenger cars, passenger vans, trucks, truck tractors, buses, semi-trailers, utility trailers and recreational vehicles (RVs), without drivers.
Vehicle Repair and Maintenance	**8111**	**Automotive repair and maintenance** Establishments primarily engaged in repairing and maintaining motor vehicles, such as cars, trucks, vans and commercial trailers.
Vehicle and Vehicle Component Recycling	**5629**	**Remediation and other waste management services** Establishments, not classified to any other industry group, primarily engaged in waste management activities, including the operation of material recovery facilities.

Source: Industry Canada, North American Industry Classification (NAICS) Definitions

Table A-2: Industry NAICS Codes Related to Fuel and Infrastructure

Activity	NAICS	Definition
Energy production, storage and distribution	**2211**	**Electric power generation, transmission and distribution** Establishments primarily engaged in the generation of bulk electric power, transmission from generating facilities to distribution centres, and/or distribution to end users.
	23713	**Power and communication line and related structures construction** Establishments primarily engaged in the construction of power lines and towers, power plants (except hydroelectric generating facilities), and radio, television, and telecommunications transmitting and receiving towers.
	3251	**Basic chemical manufacturing, which includes industrial gas manufacturing** Establishments primarily engaged in manufacturing industrial organic and inorganic gases in compressed, liquid and solid forms, which includes hydrogen manufacturing.
Manufacture and Sale of Charging and Fueling Infrastructure	**5413**	**Architectural, engineering and related services, more specifically engineering services** Establishments primarily engaged in applying principles of engineering in the design, development and utilization of machines, materials, instruments, structures, processes and systems.
	5417	**Scientific research and development services** Establishments primarily engaged in conducting original investigation, undertaken on a systematic basis to gain new knowledge (research), and in the application of research findings or other scientific knowledge for the creation of new or significantly improved products or processes (experimental development).
	3353	**Electrical equipment manufacturing** Establishments primarily engaged in manufacturing equipment that generates and distributes electrical power.
	41611	**Electrical wiring and construction supplies merchant wholesalers** Establishments primarily engaged in wholesaling electrical wiring supplies and electrical construction material.
Installation and Maintenance of Charging and Fueling Infrastructure	**23821**	**Electrical contractors and other wiring installation contractors** Establishments primarily engaged in installing or servicing electrical wiring and equipment.
	23891	**Site preparation contractors** Establishments primarily engaged in site preparation activities, such as excavating and grading, demolition of buildings and other structures, and septic system installation.

Source: Industry Canada, North American Industry Classification (NAICS) Definitions

Table A-3: Industry NAICS Codes Related to Transferable Technologies and Services

Activity	NAICS	Definition
Technology Development and Systems Integration	**5112**	**Software publishers** Establishments primarily engaged in publishing computer software, usually for multiple clients and generally referred to as packaged software.
	54133	**Engineering services** Establishments primarily engaged in applying principles of engineering in the design, development and utilization of machines, materials, instruments, structures, processes and systems.
	5415	**Computer systems design and related services** Establishments primarily engaged in providing expertise in the field of information technologies through one or more activities, such as writing, modifying, testing and supporting software to meet the needs of a particular customer.
Manufacture of Transferable Technologies	**33422**	**Radio and television broadcasting and wireless communications equipment manufacturing** Establishments primarily engaged in manufacturing radio and television broadcast and wireless communication equipment.
	33441	**Semiconductor and other electronic component manufacturing** Establishments primarily engaged in manufacturing semiconductors and other electronic components.

Source: Industry Canada, North American Industry Classification (NAICS) Definitions

Table A-4: Industries NAICS Codes Related to Supporting Organizations

Activity	NAICS	Definition
Policy and Program Development	**9119**	**Other federal government public administration** Establishments of the federal government, not classified to any other industry group, primarily engaged in executive and legislative activities; fiscal and related policies and the administration of the public debt; assessing, levying and collecting taxes; conducting relations with other governments; and the administration of federal programs.
	9129	**Other provincial and territorial public administration** Establishments of provincial and territorial governments, not classified to any other industry group, primarily engaged in executive and legislative activities; fiscal and related policies and the administration of the public debt; assessing, levying and collecting taxes; conducting relations with other governments; and the administration of provincial and territorial government programs.
	9139	**Other local, municipal and regional public administration** Establishments of local governments, not classified to any other industry group, primarily engaged in executive and legislative activities; planning, fiscal and related policies and the administration of the public debt; assessing, levying and collecting taxes; conducting relations with other governments; and the administration of local, municipal, and regional government programs.
Advocacy	**8139**	**Business, professional, labour and other membership organizations** Establishments primarily engaged in promoting the interests of their members. Examples of establishments in this industry group are business associations, professional membership organizations, labour organizations and political organizations.
Education and Training	**6112**	**Community College's and CEGEPS** Establishments primarily engaged in providing academic, or academic and technical courses and granting associate degrees, certificates or diplomas that are below the university level.
	6113	**Universities** Establishments primarily engaged in providing academic courses and granting degrees at the bachelor or graduate levels.
	6115	**Technical and Trade Schools** Establishments primarily engaged in providing vocational and technical training in a variety of technical subjects and trades. The training often leads to non-academic certification.
Other Professional or Technical Support Services	**5416**	**Management, scientific and technical consulting services** Establishments primarily engaged in providing expert advice and assistance to other organizations on management, environmental, scientific and technical issues.

Source: Industry Canada, North American Industry Classification (NAICS) Definitions

Table A-5: Intensity Ratios

NAICS	Definition	Intensity Ratio	Direct FTEs
Design, Manufacture and Sale of Vehicle Components			
54142	Industrial design services	0.150	12
54133	Engineering services	0.001	21
335312	Motor and generator manufacturing	0.250	13
3359	Other electrical equipment and component manufacturing	0.797	1,316
33621	Motor vehicle body and trailer manufacturing	*	*
33632	Motor vehicle parts manufacturing	0.217	212
4152	New motor vehicle parts and accessories merchant wholesalers	0.001	5
5629	Remediation and other waste management services	0.009	20
4413	Automotive parts, accessories and tire stores	0.000	-
Manufacture and Sale of Vehicles			
3361	Motor vehicle manufacturing	*	*
3369	Other transportation equipment manufacturing	0.292	60
4151	Motor vehicle merchant wholesalers	0.000	-
4411	Automobile dealers	0.020	357
4412	Other motor vehicle dealers	0.020	65
Purchase and Use of Vehicles			
4851	Urban transit system	0.181	903
4852	Interurban and rural bus transportation	0.002	1
4853	Taxi and limousine service	0.000	-
4854	School and employee bus transportation	0.013	10
4855	Charter bus industry	0.005	5
4859	Other transit and ground passenger transportation	0.005	5
48811	Airport operations	0.001	1
48832	Marine cargo handling	0.000	-
5321	Automotive equipment rental and leasing	0.000	-
Vehicle Repair and Maintenance			
8111	Automotive repair and maintenance	0.001	14
Energy production, storage and distribution			
2211	Electric power generation, transmission and distribution	0.002	13
23713	Power and communication line and related structures construction	0.000	-
3251	Basic chemical manufacturing, which includes industrial gas manufacturing	0.043	30
Manufacture and Sale of Charging and Fueling Infrastructure			
2382	Building equipment contractors, including electrical contractors	0.000	-
3353	Electrical equipment manufacturing	0.024	21

416110	Electrical wiring and construction supplies merchant wholesalers	0.006	13
5413	Architectural, engineering and related services, more specifically engineering services	0.002	44
5417	Scientific research and development services	0.004	29
Installation and Maintenance of Charging and Fueling Infrastructure			
23821	Electrical contractors and other wiring installation contractors	0.003	50
23891	Site preparation contractors	0.002	13
Technology Development and Systems Integration			
5112	Software publishers	0.025	203
54133	Engineering services	0.001	10
5415	Computer systems design and related services	0.011	226
Manufacture of Transferable Technologies			
33422	Radio and television broadcasting and wireless communications equipment manufacturing	0.000	-
33441	Semiconductor and other electronic component manufacturing	0.000	-
Policy and Program Development			
9119	Other federal government public administration	0.000	3
9129	Other provincial and territorial public administration	0.000	5
9139	Other local, municipal and regional public administration	0.001	10
Advocacy			
8139	Business, professional, labour and other membership organizations	0.012	19
Education and Training			
6112	Community College's and CEGEPS	0.000	-
6113	Universities	0.003	100
6115	Technical and Trade Schools	0.000	-
Other Professional or Technical Support Services			
5416	Management, scientific and technical consulting services	0.003	41

Note that the intensity ratios and direct FTE numbers were rounded for presentation.
* Data suppressed by Statistics Canada to maintain confidentiality of individual companies

Appendix B. List of Companies and Organizations

The table below lists the companies and organizations in the CEV sector in BC identified as part of the study.

Organization Name	Website	Sector	Value Chain
5N Plus Trail Inc.	http://www.5nplus.com/en/	Hydrogen and Fuel Cells	Supplier - Metal and chemical manufacturer
9Dot Engineering Inc.	http://www.9doteng.com/	Electric	Engineering services
ABB Inc.	http://www.abb.com/	Electric	Electric charging infrastructure and components
Affinity Auto	http://www.affinityauto.com/	Automotive	Vehicle Sales - electric/hybrids
Alpha Technologies	http://www.alpha.ca/	Engineering	Engineering services
Analytic Systems	http://www.analyticsystems.com/	Electric	Electrical components manufacturer
Associated Engineering	https://www.ae.ca/	Engineering	Engineering services
Associated Plastics & Supply Corp	http://associatedplastics.com/	Other	Plastic components manufacturing
Aurora Scientific	http://www.aurorascicorp.com/	Other	PVD coating reduces the wastes during production
Aurora Solar Technologies Inc.	http://www.auroracontrol.com/	Other	Components for power production
Automotive Fuel Cell Cooperation (AFCC)	http://www.afcc-auto.com/	Hydrogen and Fuel Cells	Fuel cell manufacturer
Autoway.ca	http://www.autoway.ca/	Electric	Vehicle Sales - electric/hybrids
Bala electric Ltd.		Electric	Vehicle components
Ballard Power Systems Inc.	http://www.ballard.com/	Hydrogen and Fuel Cells	Full cell manufacturer and services
BC Bioenergy Network	http://bcbioenergy.ca/	Other	Network for bioenergy development
BC Hydro	https://www.bchydro.com/index.html	Electric	Electric power production and distribution
BC Inovation Council (BCIC)	http://www.bcic.ca/	Innovation	Support Organization
BC Ministry of Energy and Mines	http://www2.gov.bc.ca	Government	Policy Development and Support
BC Technology Industry Association	http://www.bctia.org/About-Us	Association	Technology Industry Association
BC Transit	http://bctransit.com/*/choose-transit-system	Government	CEV User
BCAA	https://www.bcaa.com/	Association	Automobile Association

Big Green Island Transportation	http://www.biggreenisland.com/	Electric	Charging Infrastructure
Blue Fuel Energy Corporation	http://bluefuelenergy.com/	Hydrogen and Fuel Cells	Fuel Manufacturing
Blue System Integration Ltd.	http://www.bluesystem.ca/	Hydrogen and Fuel Cells	Performance and Characterization Tests for Fuel Cells
Bosch Rexroth	http://www.boschrexroth.com/en/xc/home/index	Electric	Vehicle and vehicle components manufacturing
British Columbia Institute of Technology (BCIT)	http://www.bcit.ca/		Training
BYD	http://www.byd.com/index.html	Electric	Vehicle and vehicle component manufacturer
Cambie Cycles	http://www.cambiecycles.com/	Electric	Vehicle manufacturing (sell/rent e-bikes)
Canadian Electric Vehicles	http://www.canev.com/	Electric	Vehicle Manufacturing
Car2go Canada	https://www.car2go.com/en/vancouver/	User	Car Share
Catalysis Research for Polymer Electrolyte Fuel Cells (CaRPE-FC)	http://www.carpe-fc.ca/	Hydrogen and Fuel Cells	Pan-Canadian academic network
CHFCA (Canadian Hydrogen and Fuel cells Association)	http://www.chfca.ca/	Hydrogen and Fuel Cells	Industry Association
Circuitrax Electronics Ltd.		Electric	Electronics store
City of Surrey	http://www.surrey.ca/	Government	Policy Development and support
City of Vancouver	http://vancouver.ca/	Government	Policy Development and support
Clean Technology Community Gateway	http://ctcg.org/	Association	Clean energy association
Clearmetals	http://clearmetalsinc.com/	Automotive	Vehicle components - metal oxide deposition technology
CO2 Impact		Clean Tech	Professional services - Carbon Consultancy
Coast Mountain Bus Company (CMBC)	http://www.translink.ca/en/About-Us/Corporate-Overview/Operating-Companies/CMBC.aspx	User	CEV User
Code II Computers Inc.		Other	Computer software and computer services
Contigo	http://www.contigo.com/index.html	Other	GPS dashboard for vehicles, assets and personnel.
Corinex Communications Corp.	http://www.corinex.com/	Other	Smart Grid and Smart metering with a primary focus on BPL (Broadband over Powerline) communications
Corvus Energy	http://corvusenergy.com/	Electric	Energy Storage

Cowichan Energy Alternatives	http://www.cowichanenergy.org/	Electric	Non-profit Association
C-rate	http://www.c-rate.com/#home	Electric	Energy storage business development, marketing and application-side engineering.
CSA Goup	http://www.csagroup.org/	Hydrogen and Fuel Cells	Standards/Testing
Daimler (Mercedez Benz)	https://www.daimler.com/	Automotive	Vehicle and vehicle component manufacturer
Delaware Power Systems	http://www.delpowersys.com/	Electric	Integrated Battery Platform ("IBP") technologies developer
Delta-Q Technologies	http://delta-q.com/	Electric	Vehicle component manufacturer
Downtown Nissan	http://www.downtownnissan.ca/en/	Other - Services	Vehicle Sales - electric/hybrids
Dynamic Energy Solutions	http://www.dynamicenergysolutions.net/	Electric	Project manager and systems integration for power storage solutions
Eagle Graphite	http://www.eaglegraphite.com/	Supplier	High Carbon Flake Graphite
Eagle Pitcher	http://www.eaglepicher.com/	Electric	Power systems including cells and batteries and lithium-ion technology research
EAS Electric Autosports Inc.	http://www.easpower.com/	Electric	Vehicle components including batteries, battery modules and battery management systems
Ebony Electric Ltd.		Electric	Other - Electricians
EcoSpark Technologies		Electric	Charging infrastructure
Electra Motor Corporation	http://electramotorcorp.com/	Electric	Vehicle component manufacturer
Electric Coast Vehicles Inc.		Electric	Vehicle manufacturing - light electric transportation
Electrical Joint Training Committee	http://ejtc.org/	Electric	Training Committee
ELIX Wireless Charging Technologies	http://elixwireless.com/	Electric	Charging infrastructure (Wireless charging)
Elworthy Electrical Services Ltd.	http://www.elworthy.bc.ca/	Electric	Vehicle components
Emily Carr University	http://www.ecuad.ca/		Education
Enbala Power Systems	http://www.enbala.com/	Electric	Other - power distribution
EnerNOC	https://www.enernoc.com/	Other	Energy management solutions
Ensol Systems	http://www.ensolsystems.com/	Other	Manufacturing and services specializing in industrial power solutions for remote locations

E-One Moli Energy (Canada) Ltd.	http://www.molicel.com/ca/index.htm	Electric	Components manufacturing (Lithium-Ion Batteries)
Evolution Bikes Ltd.	http://www.evoebikes.com/	Electric	Vehicle sales - electric bikes
Finning	http://www.finning.ca/	Vehicles	Vehicle dealer (machinery equipment dealer)
Foreseeson Technology Inc.	http://foreseeson.com/	Electric	Vehicle components/charging - electronic manufacturing services
Foresight Cleantech Accelerator Centre	http://foresightcac.com/	Clean Tech	Professional services for clean tech
Forevergreen Electric Cars Inc.	http://www.forevergreenelectriccars.com/	Electric	Vehicle manufacturer (Golf Carts)
FortisBC	https://www.fortisbc.com/Pages/default.aspx	Electric	Power generation
Fraser Basin Council	http://www.fraserbasin.bc.ca/	Electric	Industry Association
FuelCon Systems Inc.	http://www.fuelcon.com/cms/	Hydrogen and Fuel Cells	Battery and Fuel cell testing
Future Vehicle Technologies	http://fvtresearch.com/	Electric	Electric systems integrator
GHG Accounting Services	ghgaccounting.ca/		Support services: Specialized carbon and sustainability consulting and greenhouse gas accounting services
Greenlight Innovation	http://www.greenlightinnovation.com/	Hydrogen and Fuel Cells	Manufacturer of fuel cell, electrolyser and battery testing & assembly equipment.
GreenPower Motor Company	http://www.greenpowerbus.com/	Electric	Vehicle Manufacturer (Electric Bus)
Greg Murray of EAS Power (PV and electric boat conversions)	http://www.easpower.com/node/2	Electric	Vehicle components - battery systems
Grin Technologies	http://www.ebikes.ca/	Electric	Vehicle components - electric bike parts
HTEC Hydrogen Technology & Energy Corp.	http://www.htec.ca/	Hydrogen and Fuel Cells	Hydrogen production, distribution, fueling infrastructure and technical services
Hummingbird Urban Biomass (Hummingbird Energy)	http://hummingbird-energy.com/	Electric	Energy producer
Hydra Energy	http://www.hydra-energy.ca/	Hydrogen and Fuel Cells	Vehicle Manufacturing
Hydrogen in Motion Inc. (H2M)	http://www.hydrogeninmotion.com/	Hydrogen and Fuel Cells	Vehicle Components

IBX Datasystems Ltd. (Variable Grid)	http://www.variablegrid.net/index.php	Electric	Adaptive EV load management
Innovation, Science and Economic Development Canada	https://www.canada.ca/en/innovation-science-economic-development.html	Hydrogen and Fuel Cells	Policy Development and support
Institute for Integrated Energy Systems (IESVic) (University of Victoria)	http://www.uvic.ca/research/centres/iesvic/index.php	Sustainability	Research
IRDI System	http://irdisystem.com/?page_id=8	Hydrogen and Fuel Cells	Components for fueling infrastructure
ITM Power	http://www.itm-power.com/	Hydrogen and Fuel Cells	Component manufacturer for hydrogen solutions
JV Bike Sales & Rentals	http://www.jvbike.com/	Electric	Vehicle sales and components - electric bikes
Kwantlen Polytechnic University	http://www.kpu.ca/	Supporting organizations	Education
Landsea Tours	http://vancouvertours.com/	Hydrogen	Other - hydrogen powered bus
Leviton Mfg of Canada Ltd.	http://www.leviton.com/	Electric	Vehicle charging
LGM Financial Services	https://lgm.ca/	Automotive	Professional services - Finance and insurance for the automotive sector
Loop energy Inc. (formaly PowerDisc Development Corporation Ltd.)	http://loopenergy.com/	Hydrogen and Fuel Cells	Vehicle component manufacturing (zero emission transport truck powertrain)
Mercedes-Benz Fuel Cell Division Canada	http://www.mercedes-benz.ca/	Hydrogen and Fuel Cells	Vehicle and vehicle component manufacturing
Metro Vancouver	http://www.metrovancouver.org/		Policy/Program development and support
misty west	http://www.mistywest.com/	Electric/Fuel cells	Fueling infrastructure and vehicle components
Moovee Innovations	http://www.mooveeinnovations.com/	Electric	Autonomous vehicles
Motorino	http://www.motorino.ca/	Electric	Vehicle sales - electric motorcycles, scooters and bikes
Motorize direct	http://motorizevictoria.ca/	Electric	Electric Vehicle sales
Myhneer	http://www.vonmynheer.com/	Electric	Vehicle manufacturing - electric vehicles specializing in niche market vehicles
Nano One Materials Corp.	http://nanoone.ca/	Electric	Supplier of materials for Li-ion batteries

Nedco	https://west.nedco.ca/	Other - Services	Electrical product distribution
New Car Dealers Association of BC	http://www.newcardealers.ca/	Automotive	Industry association
NORAM Engineering & Constructors Ltd.	http://www.noram-eng.com/	Hydrogen and Fuel Cells	Engineering services
OGO Car Share	https://www.ogocarshare.ca/	Automotive	Car Share in Kelowna
Ohm Cycles	https://ohmcycles.com/	Electric	Electric Bike manufacturer
Olson Electric Ltd.	http://olsonelectric.ca/	Electric	Electrical contractor (installed Electric Charging Stations)
Pacific Insight	http://www.pacificinsight.com/	Automotive	Design, development, manufacturing and delivery of electronic products and full service solutions to the automotive and commercial vehicle markets
Pacific Rim Engineering	http://www.pacificrimeng.com/index.html	Electric	Transferable Technologies / Services
Palcan Energy Corporation	http://www.palcan.com/home.html	Hydrogen and Fuel Cells	Hydrogen and fuel cell manufacturing
Pathway Industries	http://www.pathwayindustries.com/		Engineering services, Manufacturing, Industrial design
People's Hybrid	http://www.peopleshybrid.com/	Electric	Fuel and Charging Infrastructure
Perkuna Engineering	http://www.perkuna.com/	Electric	Vehicle Manufacturing
Port of Prince Rupert	http://www.rupertport.com/	Clean Transportation	Other
Power Pros Electrical	http://www.powerpros.ca/	Electric	Electrical contractor
Power Up Systems	http://www.powerupelectrical.ca/renewable_energy.html	Electric	Electric Contractor
Powertech Labs	http://www.powertechlabs.com/home/		Clean energy consulting
Praxair	http://www.praxair.ca/en-ca	Hydrogen and Fuel Cells	Fuel and Charging Infrastructure
Profile Composites		Other - Services	Parts and components - manufactures lightweight composite products
Quadrogen Power Systems Inc.	http://www.quadrogen.com/	Hydrogen and Fuel Cells	Hydrogen production
Rainforest Automation	http://rainforestautomation.com/	Other - Services	Transferable Technologies / Services

Redlen Technologies Inc.	http://redlen.ca/	Electric	Transferable Technologies / Services
Renewable Energy Consultant - Matthew Klippenstein	https://ca.linkedin.com/in/matthewklippenstein	Other - Services	Transferable Technologies / Services
Retriev Technologies (Toxco Waste Management Ltd.)	http://retrievtech.com/	Electric	Fuel and Charging Infrastructure
Sacre-Davey Engineering	http://www.sacre-davey.com/	Hydrogen and Fuel Cells	Engineering services
SandVault	http://sandvault.com/	Electric	Battery management - battery powered, solar powered recharge/cycle stations for bikes
SASI Autocraft Ltd.	http://www.sasiautocraft.com/	Other - services	Vehicle collision repair
Schneider Electric	http://www.schneider-electric.ca/en/	Electric	Energy management solutions and equipment
SCRAP-IT Program Society	https://scrapit.ca/	Electric	Vehicle Disposal/Incentive program
Sendum Wireless Corp.	http://sendum.com/	Other	Package Tracking Technology
Shipstone Energy Corporation	http://www.shipstoneenergy.com/index.html	Charging infrastructure	Battery management - energy storage solutions
Sierra Semi Conductor	http://pmcs.com/	Clean Transportation	Transferable Technologies / Services
Signature Renewables Inc.	http://www.signaturerenewables.com/	Supporting organizations	Professional services - provides consulting services in renewable energy, monitoring and measurement, smart grid and electric vehicles etc.
SilverTip Telematics	http://silvertiptelematics.com/	Other	Wireless technology including tracking devices for cars
Simon Fraser University	http://www.sfu.ca/	Other	Research
SMPC Technologies Ltd.	http://smpct.com/index.php	Other - Services	Other
Sonic Environmental Solutions Inc.		Clean Transportation	Other
Southern Railway of British Columbia	http://www.sryraillink.com/	Clean Transportation	Other
Spur Innovations Corp.	http://www.spurinnovations.com/	Electric	Vehicle components - electrification

Sun Country Highway	http://suncountryhighway.com/	Electric	Charging Infrastructure and components
Sunshine Coast Regional District	http://www.scrd.ca/	Supporting organizations	Regional governing body
Tantalus Systems Corp	http://www.tantalus.com/	Electric and Other	Fuel and Charging Infrastructure
TBF Environmental Technology Inc.	http://tbfenvironmental.com/	Other - Services	Transferable Technologies / Services
Tedco Electric Inc.	http://www.tedcoelectric.com/	electric	Vehicle components - does not specify products
Telus	http://www.telus.com/en/on/index.jsp	Other - Services	Fuel and Charging Infrastructure
Teradici Corporation	http://www.teradici.com/	Other - Services	Transferable Technologies / Services
Terra 2 Imports		Other - Services	Vehicle Sales - electric/hybrids
Terrella Energy Systems Ltd.	http://www.terrellaenergy.com/	Hydrogen and Fuel Cells	Component manfacturer
Tesla	https://www.teslamotors.com/en_CA/	Electric	Vehicle Manufactuing
Thomson Power	https://www.thomsonps.com/	Electric	Energy production - manufacturer of electrical products for use in the power generation industry
Trader Corporation	http://www.tradercorporation.com/en/	Other - Services	Vehicle Sales - electric/hybrids
TransLink	http://www.translink.ca/	Clean Transportation	Other
Truckenbrodt Clean Energy Consulting	http://cleanenergyconsulting.ca/	N/A	Clean energy consulting
University College of the Fraser Valley	http://www.ufv.ca/	Supporting organizations	Education
University of British Columbia - CERC Clean Energy Research Centre	http://cerc.ubc.ca/	Hydrogen and Fuel Cells	Research
University of Victoria	http://www.uvic.ca/	Electric	Other
Vancouver Economic Commission	http://www.vancouvereconomic.com/	Other - Services	Other
Vancouver Electric Vehicle Association (VEVA)	https://veva.ca/	Other - Services	Industry association
Vancouver industrial sales & service		Other - Services	Other
VeloMetro Mobility Inc.	http://www.velometro.com/index.html	Electric	Vehicle Manufacturing (Bikes)
Victoria Car Share Coop		Electric	Other

Victoria Electric Vehicle Club	http://victorialeafclub.com/	Electric	Other
Victoria LEAF Club	http://victorialeafclub.com/	Supporting organizations	Advocacy
Victoria Transport Policy Institute (VTPI)	http://www.vtpi.org/	Other - Services	Other
Vireo Technologies Inc.		Clean Transportation	Vehicle Manufacturing
Volkswagen Group Canada Inc. (Fuel Cell Program)	http://www.vw.ca/en.html	Hydrogen and Fuel Cells	Vehicle Manufacturing
Vossloh Kiepe Corporation	http://www.vossloh-usa.com/en/home/home.html	Electric	Vehicle and vehicle components manufacturing (Electric Buses)
VSB	https://www.vsb.bc.ca/	Supporting organizations	Education
Wavefront Inc.	http://www.wavefrontinc.ca/	Other - Services	Other
Wazuku Advisory Group	http://www.wazuku.ca/	Other - Services	Other
Webtech Wireless	http://www.webtechwireless.com/	Technologies services	Provider of Intelligent Transportation Systems (ITS) technology
Wekking Electric	http://www.wekkingelectric.com/	Supporting organizations	Trades - electricians
Western Economic Diversification Canada	http://www.wd.gc.ca/eng/home.asp	Other - Services	Other
Western Pacific Enterprises	http://www.westernpacificent.citymax.com/home.html	Supporting organizations	Industrial construction
Westport Innovations Inc.	http://www.westport.com/	Clean Transportation	Fuel and Charging Infrastructure
Xantrex Technology Inc.	http://www.xantrex.com/	Electric	Vehicle components - developing and manufacturing of advanced power electronic products and systems for the mobile power markets.
XRG Energytech		Hydrogen and Fuel Cells	
ZincNyx Energy Solutions Inc.	http://www.zincnyx.com/	Electric	Fuel and Charging Infrastructure
Zolair Energy Ltd. (formerly AEDC Alternative Energy Development Corporation)	http://zolair-energy.com/	Hydrogen and Fuel Cells	Fuel Cell Manufacturing

Appendix C. Company Profiles

1. IRDI System Inc.

Description

IRDI System Inc. is a supplier and manufacturer of components used in hydrogen fueling infrastructure located in Richmond, BC. Founded in August 2010, the company currently operates with 10 employees, all located in BC.

IRDI has been exporting its components to Japan and Europe since 2012. In 2015, it started exporting to the United States, as well as selling in Canada (Ontario and BC). IRDI System recognizes itself as the market share leader in Japan, Europe and the United States.

Some of IRDI System's customers include: WEH (Germany), Linde (Germany), Nitto Kohki (Japan), Iwatani (USA), First element fuel (USA), Powertech Labs (BC), Hydrogenics (Ontario).

For more information, visit http://irdisystem.com/.

Location of BC Operations • 120-5951 No. 3 Road Richmond, BC V6X 2E3	**Company Focus** • Components supplier for hydrogen fueling infrastructure
Products • Test signal generator • Protocol converter • Nozzle receiver • IR transmitter	**Services** • Customer support, if required
CEV Activities in BC • Headquarters • Manufacturing	**CEV Activities in Other Jurisdictions** • Sales in Europe, US, Japan

2. Ballard Power Systems Inc.

Description

Headquartered in BC, Ballard Power Systems Inc. (Ballard) has been involved in fuel-cell related activities for over 30 years and according to its annual report, had revenues of over $55 million in 2015.

Ballard specializes in the design, development, manufacture, sale and service of fuel cell products for a variety of applications, such as telecom back up power, materials handling (e.g., forklifts, automated guided vehicles, and ground support equipment), bus and distribution generation.

In the transportation sector, Ballard has supplied fuel cell stacks that have been installed in over 8,000 clean energy lift trucks in North America and Europe. They have also produced over 150 power modules which have been installed in 100 buses. At the end of 2014, there were 29 Ballard-powered fuel cell buses operating in seven cities worldwide in Europe, the United States and South America.

Ballard also provides technology solutions including engineering services and the license and sale of intellectual property and knowledge.

Since 2010, Ballard has a controlling interest in Dantherm Power which manufactures and sells fuel cell backup power solutions for communications networks. In 2015, Ballard also acquired Protonex Technology Corporation, a designer and manufacturer of advanced power management products and portable fuel cell solutions

For more information, visit: http://ballard.com/.

Location of BC Operations	**Company Focus**
• 9000 Glenlyon Parkway Burnaby, BC V5J 5J8	• Fuel cell developer • Engineering services • Research
Products	**Services**
• Stationary systems (backup & extended backup power and supplemental & prime power) • Motive modules (bus, light rail, materials handling) • Stacks (air-cooled, liquid-cooled)	• Systems interface • Testing services • Test stations • Product development • Component manufacturing • Licensing and technology transfer
CEV Activities in BC	**CEV Activities in Other Jurisdictions**
• Headquarters • Production Facility • BDF IP Holdings Ltd. holding intellectual property assets • Ballard Services Inc. providing engineering services	• Production Facility – Mexico • Systems development Centre – Oregon, USA • Ballard Fuel Cell Systems Inc. – Delaware, USA • Dantherm Power – Denmark • Protonex – Massachusetts, USA

3. Hydrogen in Motion (H2M)

Description

Hydrogen In Motion Inc. (H2M) was founded in 2014 with the purpose of addressing a main impediment of the hydrogen economy: the high cost of hydrogen storage and delivery. H2M is addressing this problem in a number of ways leading with the development of advanced nanomaterials to store hydrogen at ambient conditions. H2M is developing a non-compressed portable hydrogen fuel tank for hydrogen storage applications including hydrogen fuel cell vehicles. These tanks would be delivered directly to consumers for off-board refuelling.

Hydrogen in Motion Inc. (H2M) is headquartered in Vancouver and is working in collaboration with the Simon Fraser University School of Mechatronic Systems Engineering, developing their ground-breaking hydrogen storage medium at the SFU facility at Powertech Labs in Surrey, BC.

As of 2015, H2M employed 8 employees. The company plans to significantly increase its number of employees in the next 18 months.

For more information, visit: http://www.hydrogeninmotion.com/.

Location of BC Operations	**Company Focus**
• 718 Main Street, Unit 206 Vancouver, BC Canada, V6A 0B1	• Vehicle Components • Fueling (Hydrogen)
Products	**Services**
• Hydrogen portable storage	• Hydrogen delivery
CEV Activities in BC	**CEV Activities in Other Jurisdictions**
• Headquarters • Laboratory	• N/A

4. Canadian Electric Vehicles Ltd.

Description

Located on Vancouver Island, Canadian Electric Vehicles Ltd. has been designing and manufacturing electric vehicles and electric vehicle components for over 20 years. The company specializes in off-road, low speed work vehicles for use at campuses, malls, resorts, parks and airports and for use in other industries.

While the company is focused primarily on commercial trucks, it also sells conversion kits to individuals who would like to convert their gas-emission vehicle into an electric vehicle.

As of 2015, the company had four employees with revenues under a million dollars. In the same year, all revenue was attributed to exports outside of BC, with 40% attributed to Ontario and the remainder outside of Canada.

For more information, visit: http://www.canev.com/.

Location of BC Operations	**Company Focus**
• 1184 Middlegate Road Errington, BC V9P 2C4	• Vehicle and vehicle component manufacturing • Electric drivetrains and components • Vehicle sales
Products	**Services**
• Heavy duty electric utility vehicles • Electric towing units • Electric powered utility carts • Electric drivetrains and components • Conversion kits and components	• Vehicle conversions to electric • Research and development services
CEV Activities in BC	**CEV Activities in Other Jurisdictions**
• Headquarters • Assembly	• Sales in Ontario, United States, Asia

5. Power Pros Electrical

Description

Power Pros is an electrical contractor operating in Vancouver and the surrounding municipalities. Founded in 1999, Power Pros has been involved in the CEV sector for about five years. Power Pros' 60 employees now spend about 5 to 10 percent of their time working on electric vehicle chargers.

Power Pros has provided electrical services to companies and municipalities operating in the CEV sector such as Powertech Labs, BCIT, the City of Surrey, the City of Port Moody and the City of Vancouver.

For more information, visit: http://www.powerpros.ca/.

Location of BC Operations	**Company Focus**
• 30445 Progressive Way, Abbotsford, BC V2T 6W3	• Charging infrastructure • Transferable technologies/services
Products	**Services**
• N/A	• Electrical services contracts
CEV Activities in BC	**CEV Activities in Other Jurisdictions**
• Headquarters	• N/A

6. Retriev Technologies

Description

Retriev Technologies (formerly Toxco Inc.) is a US-based battery recycling and management company in operations since 1984. Retriev recycles various types of batteries including consumer and industrial batteries and electric and hybrid vehicle batteries. The company also offers logistics services and custom solutions for customers.

Retriev Technologies has operated a recycling facility in Trail, BC since 1992. The 70,000 square foot facility handles all consumer and large format lithium batteries for the company. Both non–rechargeable lithium and rechargeable lithium-ion batteries are treated in this facility making it, according to Retriev, the only facility of its kind. The Trail facility also has the capability to treat scrap components generated from lithium battery manufacturing.

For more information, visit: http://www.retrievtech.com/.

Location of BC Operations	**Company Focus**
• 9384 Highway 22A Trail, BC V1R 4W6	• Electric vehicle components • Battery recycling
Products	**Services**
• N/A	• Battery recycling (electric and hybrid vehicles) • Consulting services • Logistics services
CEV Activities in BC	**CEV Activities in Other Jurisdictions**
• Recycling Facility, Trail	• Corporate Headquarters, California • Research and development, Pennsylvania • Handling facility , Ohio • Recycling facility, Ohio

7. Thomson Power Inc.

Description

Thomson Power Inc. is a developer and supplier of software and power management systems to improve performance and efficiency of electric and hybrid drives in medium to heavy-duty trucks and bus applications. The company was founded in 2012, in Vancouver, and currently has 12 employees.

Thomson Power provides electrification services for trucks and buses with the use of a turn-key electric powertrain managed by a supervisory controller that incorporates Thomson Power's energy management strategies. Thomson Power's two key products include:

- The ThomsonDrive: a scalable propulsion system developed using a backplane philosophy to provide a plug and play retrofit service from diesel to zero emission in medium and heavy duty vehicles. The ThomsonDrive is manufactured in the United States.
- The ThomsonController: an adaptive software platform focused on optimizing energy efficiency and preparing for next generation autonomous control utilizing sensors and artificial intelligence principles.

For more information, visit: http://www.thomsonpower.com/.

Location of BC Operations	**Company Focus**
• 1111 W Georgia St. Vancouver, BC V6E 4M3	• Autonomous vehicles • Electric vehicles
Products	**Services**
• ThomsonDrive • ThomsonController	• Electric conversions
CEV Activities in BC	**CEV Activities in Other Jurisdictions**
• Headquarters	• Demonstration Center (California) • European Office (London)

8. Spur Innovations

Description

Spur Innovations Corp. (Spur) is a Vancouver-based technology company focused on vehicle control. Incorporated in 2013, Spur was founded by former leadership from Azure Dynamics Corporation (no longer in business).

Spur provides products including active vehicle gateway controllers and intelligent vehicle controls that run with owner programmable applications that can control speed, acceleration, idle-off time, engine rpm limits and offers location based performance limits and tracking. It also provides electrification services for trucks.

For more information, visit: http://www.spurinnovations.com/.

Location of BC Operations	**Company Focus**
• 1475 East Georgia Street Vancouver, BC V5L 2A9	• Vehicle controls • Vehicle Electrification for Trucks
Products	**Services**
• Active Vehicle Gateway • Intelligent Vehicle Controls • Driveline Electrification • Owner Programmable Application	• Consulting for vehicle electrification including controls development, product planning, testing and analysis.
CEV Activities in BC	**CEV Activities in Other Jurisdictions**
• Headquarters	• N/A

9. Eagle Graphite

Description

Eagle Graphite is one of two natural flake graphite producers in North America, a material used in both lithium-ion battery and fuel cell manufacturing. Located about 35 kilometers west of Nelson, BC, its Black Crystal graphite quarry project operates with approximately six employees and has a total of 300 hectares in mining leases, including an active quarry area and plant facilities. Historically, the project has produced 4,000 tonnes of graphite per year with production expected to increase to 7,500 tonnes by 2017.

Eagle Graphite prides itself on being strategically located as the only source of graphite in Western North America for lithium-ion battery and electric vehicle applications.

For more information, visit: http://www.eaglegraphite.com/.

Location of BC Operations • P.O. Box 40 Slocan Park, BC V0G 2E0	**Company Focus** • Material supplier for component manufacturing
Products • Natural Flake Graphite	**Services** • N/A
CEV Activities in BC • Quarry operations • Sales • Investor Relations	**CEV Activities in Other Jurisdictions** • Head Office, Ontario

10. Hydra Energy

Description

Hydra Energy has been involved in CEV-related activities for approximately four years and is focused on hydrogen production, distribution and hydrogen internal combustion engine conversion. More precisely, Hydra Energy provides hydrogen-as-a-service by converting fleets to a dual-fuel system (hydrogen and gasoline or diesel). In order to provide its services, Hydra Energy covers the cost of upgrading the vehicles and onsite refueling and only charges for the sale of hydrogen based on fixed-term fuel supply contracts at prices competitive with conventional fuel.

Hydra Energy offers its services to fleet operators of cars (e.g., taxi and corporate operators) and heavy duty trucks (regional haul) with return to base vehicles. Located in Vancouver, Hydra Energy has approximately 9 employees in BC and plans to increase significantly its number of employees over the next 18 and 36 months.

For more information, visit: http://www.hydra-energy.ca/.

Location of BC Operations	**Company Focus**
• #15 – 1610 Derwent Way Delta, BC V3M 6W1	• Vehicle and Vehicle Components • Fuel and Charging Infrastructure
Products	**Services**
• Hydrogen	• Fleet conversion to dual-fuel system • Hydrogen delivery/fueling
CEV Activities in BC	**CEV Activities in Other Jurisdictions**
• Headquarters • Research and Development	• N/A

Appendix D. Case Studies

The following case studies highlight examples of policy initiatives, programs or other government support mechanisms that have been undertaken in other sectors and jurisdictions.

Case Study 1: California

California's climate and air quality actions began with the establishment of the California Air Resources Board (CARB) in 1967. Since its establishment, CARB has been at the forefront of California's clean air and climate initiatives that have supported a transition to clean energy transportation and alternative low carbon fuels. Transportation accounts for 36 percent of California's GHG emissions and criteria pollutants that impact air quality, and thus has been a key focus of policies aimed at mitigation.[175]

The shift to clean energy in the transportation sector is essential to realizing California's bold climate and air quality goals. California's *2050 Vision* goals are outlined in the *State Alternative Fuels Plan of 2007* and the *Global Warming Solutions Act of 2006* which state the following:[176]

- Reduction of GHG emissions to 1990 levels by 2020 and 80 percent below 1990 levels by 2050.
- Reduction of petroleum fuel use to 15 percent below 2003 levels by 2020.
- Increased use and production of alternative fuels in the state by 26 percent by 2022.
- Increased in-state biofuels production to 40 percent by 2020.

California has adopted a wide range of regulations and policies to support these goals, which have in turn spurred both innovation and economic activity throughout the clean energy supply chain. Related to the clean energy transportation system, California's regulations and policies have supported economic development in the areas of:[177]

- Infrastructure development, including supporting the implementation of EV charging stations and hydrogen fueling stations.
- Increased use of both electricity and hydrogen as a fuel source.
- Innovation and investment related to vehicle technology.
- Development of IP related to the sector.

In addition to these supply side impacts, there have been a range of policies that target consumer adoption, thereby creating a large domestic market for CEVs and related technologies and further stimulating economic activity in the sector. California is the leading North American jurisdiction for the adoption of CEVs[178], leads the country in infrastructure deployments and, as of 2011, had attracted close to 70 percent of global EV related investment.[179]

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[175] California Air Resources Board, California Greenhouse Gas Emissions for 2000 to 2014 – Trends of Emissions and Other Indicators.

[176] Alternative and Renewable Fuel and Vehicle Technology Program Overview. Retreived from http://www.energy.ca.gov/drive/investing/.

[177] California Initiatives Part 1: Air Resources Board. CPUC SB 350 Workshop April 29, 2016.

[178] Retrieved from http://www.eia.gov/todayinenergy/detail.cfm?id=19131

[179] Next 10, Powering Innovation: California is Leading the Shift to Electric Vehicles from R&D to Early Adoption. Retrieved from http://next10.org/powering-innovation-california-leading-shift-electric-vehicles-rd-early-adoption

The table below summarizes key regulations and policies that encourage economic development of the CEV sector in California.

California Regulations and Policies Supporting Economic Development of the CEV Sector[180]

Policy/Regulation	Policy Objectives
Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP)	The ARFVTP program initiated in 2008 provides financial incentives for businesses, vehicle and technology manufacturers, workforce training partners, fleet owners, consumers and academic institutions to develop and deploy alternative and renewable fuels and advanced transportation technologies.[181] The ARFVTP distributes as much as $100 million per year through a competitive bid process, leveraging large federal and private investments to help grow encourage long term economic development of the clean energy sector. The fund provides for vehicle retrofits, fueling and charging infrastructure and research and development of low carbon fuel alternatives.
Air Quality Improvement Program (AQIP)	The AQIP is the companion program to the Energy Commission's ARFVTP. The AQIP provides up to $40 million per year through 2015 for clean vehicle and equipment projects that reduce criteria pollutants and GHG emissions.
Zero Emission Vehicle (ZEV) Regulation	The ZEV regulation was adopted in 1990 and has been modified several times since then. It requires large automakers to produce certain percentages of "pure zero" emission and "near-zero" emission vehicles for sale in California to meet California's air quality goals. The ZEV Action Plan was released in 2013 with the goal of putting 1.5 million ZEVs on California's roadways by 2025.[182]
Zero Emission Bus Regulation	Zero Emission Bus (ZEB) regulation is designed to encourage the operation and use of zero emission buses in California urban bus fleets. The regulation affects large transit agencies with more than 200 buses and includes a 15% fleet ZEB purchase requirement.
Clean Fuels Outlet Regulation	The Clean Fuels Outlet (CFO) Regulation, adopted in 1990, is intended to ensure fueling infrastructure is available for the alternative fuel vehicles that might be required by state regulations. More recently, in 2013, Assembly Bill 8 was passed, which included dedicated funding for hydrogen fueling infrastructure to support the market launch of hydrogen fuel cell vehicles.[183]
Low Carbon Fuel Standard (LCFS)	Established in 2007, the LCFS uses a market-based cap and trade approach to lowering the GHG emissions from petroleum-based transportation fuels like reformulated gasoline and diesel. The LCFS requires producers of petroleum-based fuels to reduce the carbon intensity of their products,

[180] Key Policies, ARFVTP Program. http://www.energy.ca.gov/drive/investing/policies.html

[181] ARFVTP Program overview. http://www.energy.ca.gov/drive/investing/.

[182] California Clean Cars Campaign. http://www.calcleancars.org/learnMore-CCP.html

[183] Ibid.

Policy/Regulation	Policy Objectives
	beginning with 0.25% in 2011 culminating in a 10% total reduction in 2020. Petroleum importers, refiners and wholesalers can either develop their own low carbon fuel products, or buy LCFS Credits from other companies that develop and sell low carbon alternative fuels, such as biofuels, electricity, natural gas, or hydrogen.
Renewable Fuel Standard	The Energy Policy Act of 2005 established the Renewable Fuel Standard Program (RFS), which was revised under the Energy Independence and Security Act of 2007 into the RFS2. The RFS2 mandates 36 billion gallons of renewable fuel to be blended into transportation fuels nationwide by 2022. The RFS2 will allow for credits to be generated and traded by producers and distributors of alternative fuels.
Renewable Portfolio Standard	Established in 2002, accelerated in 2006, and expanded in 2011, California's Renewables Portfolio Standard (RPS) is one of the most ambitious renewable energy standards in the United States. The RPS program requires investor-owned utilities, electric service providers, and community choice aggregators to increase procurement from eligible renewable energy resources to 33% of total procurement by 2020.

According to the International Economic Development Council, California state regulations and policies, combined with federal fuel economy standards, will enable California to enjoy significant reductions in energy dependence and global warming pollution, while stimulating statewide economic activity and employment, with substantial fuel savings.[184]

Under the assumption that the Low Carbon Fuel Standard and 2016 state vehicle emissions standards remain unchanged until 2025, it is predicted that these will result in the following economic outcomes:[185]

- 38,000 additional new jobs; and
- An additional 0.3 percent growth in Gross State Product (GSP).

California Utilities Regulation and EVs

Adequate charging infrastructure is vital to the successful transition to EVs. Barriers still exist, however, in part due to utilities regulation, early stage market penetration and lack of clear private sector business models for provisioning of EV charging. As has been the case in California, amendments to utility regulation and the participation of electric utilities in the market may help overcome these barriers.[186]

California utilities, both municipal and investor owned, along with the state utilities' regulatory agency, the California Public Utilities Commission (CPUC), have played a key role in enabling California's transition to clean transportation. California's three largest utilities are seeking to invest $1.1 billion in infrastructure to

[184] International Economic Development Council. Analysis of the Electric Vehicle Industry. 2013.

[185] David Roland Holst. Driving California's Economy: How Fuel Economy and Emissions Standards Will Impact Economic Growth and Job Creation. Retrieved from: http://next10.org/sites/next10.huang.radicaldesigns.org/files/Final_vehicle_efficiency_report.pdf

[186] See http://www.corporateknights.com/channels/transportation/heres-secret-tesla-going-mainstream-14343480/

support 60,000 publicly available charging ports.[187] By comparison, the federal contributions to EV charging infrastructure through the 2009 stimulus package only totalled $400 million for the nation.[188] It is evident that this investment from private utility companies is crucial to the long term development of the sector, and by partnering with charging companies and automakers, utility companies have the opportunity to make the most effective use of their investments.

In addition to these direct investments, California utilities are leading the way with innovative rate structures that incentivize charging behaviours that optimize grid performance.[189] These initiatives are intended to save consumers money by incentivizing utilization during off-peak hours, and may also have the effect of reducing rates over the long run.

California, Tesla and Economic Development

Tesla Motors, Inc. is headquartered in California where it designs, develops, manufactures and sells electric vehicles and energy storage products. The company has grown since its founding in 2003 to be the largest manufacturer of electric vehicles in California in terms of employees, and is expecting significant growth in the coming years.[190]

From a business perspective, California is an ideal location for Tesla to manufacture its vehicles. The state is a manufacturing and engineering hub, positioning Tesla in close proximity to its supply chain. While Tesla's vehicles are manufactured in Fremont, California, Tesla, specializing in electronics, only manufactures the batteries for the vehicles itself – all other parts for the vehicles come from its manufacturing partners.[191]

California was a frontrunner in the development of clean energy legislation introducing state regulations and policies that played a large role in supporting favourable conditions for Tesla, and other companies of its type. The zero emission vehicle (ZEV) requirements implemented as early as 1990, were very effective at initiating innovation among vehicle manufacturers like Tesla to develop in the region and increased the supply of CEVs. In combination with the California's large population base, vehicle rebates and incentives worked to increase consumer demand for CEVs.

In 2014, Tesla announced that they would build a "gigafactory" in Nevada based on a tax deal negotiated with the Nevada legislature, making the state much more competitive. The deal included a 20-year 100 percent sales tax abatement, 10-year 100 percent property tax abatement, $120 million in transferable tax credits, $75 million in job-related transferable tax credits, 10-year 100 percent modified business tax abatement, and $8 million discounted electricity rates for eight years.[192]

Despite the tax breaks afforded to Tesla, the economic impact that will be generated by the gigafactory will be staggering for the region. It is estimated that the economic impacts would total $100 billion over 20 years, equalling more than three percent of the state's GSP and more than 20 percent of the region's economic output. The factory would employ 6,500 people with an average wage of $25 per hour, with

[187] Ibid.

[188] Ibid.

[189] See for example http://www.pge.com/myhome/environment/whatyoucando/electricdrivevehicles/rateoptions/

[190] Tesla. Retrieved from https://www.teslamotors.com/en_CA/about

[191] Retrieved from http://www.businessinsider.com/tesla-the-origin-story-2014-10

[192] "Inside Nevada's $1.25 billion Tesla tax deal". Reno Gazette-Journal. September 16, 2014.

indirect job creation predicted to reach 22,000 or two percent of the state's work force and 11 percent of the region's work force.[193]

The success enjoyed by Tesla is attracting foreign direct investment from other automotive OEMs and technology companies, most recently from China.[194] California is rapidly turning into a centre of automotive research with the like of Ford, Toyota, Hyundai, Honda and Volkswagen establishing R&D facilities in the state.[195]

Key Findings and Lessons Learned: The BC Context

There are several key learnings from California's successes and challenges in developing the CEV sector that can be applied to BC:

- **Strategic climate action plan:** California's success in developing the CEV sector in the state is in a large part attributed to its long term and clearly outlined strategic plan. This plan is supported by a wide-range of regulations and policies that support the widespread adoption of EVs and the overall economic development of the sector.
- **Utility investments in infrastructure:** In order for widespread adoption of CEVs, substantial long term investments must be made in infrastructure. In California, private utility companies have committed significant funds to invest in the necessary infrastructure to support the sector.
- **Role of business incentives:** Business incentives play a significant role in attracting investment. While ZEV regulations and other state regulations continue to be effective at encouraging the development of the sector in California, tax incentives like those offered by the State of Nevada, are extremely important factors in determining where manufacturers will choose to locate and invest.
- **Opportunities for the supply chain:** There may be an opportunity for suppliers in BC (raw materials, parts or components) to benefit from the development and expansion of the sector in California.

[193] Ibid.

[194] Retrieved from http://evobsession.com/chinese-auto-manufacturer-baic-just-opens-ev-rd-center-in-silicon-valley/

[195] Retrieved from http://www.latimes.com/business/autos/laautoshow/la-fi-hy-california-auto-industry-20151118-story.html

Case Study 2: Quebec

Quebec is a leading CEV jurisdiction in North America with the highest CEV sales in Canada[196] and significant related CEV supply chain economic activity. The Quebec government has long recognized the opportunities to utilize CEVs as a key component of climate, energy, industrial and economic development strategies in the province.

Hydro Quebec has historically played a vital role in the economic development of Quebec.[197] The exploitation of Quebec's abundant hydroelectric resource has long driven industrial strategy in the province and electrification remains central to the growth of various sectors of the economy including transportation. Quebec deliberately pursues the development of new sources of electricity load to serve with domestically generated energy, from both the legacy hydroelectric system and more recently from renewable sources.

Economic development drivers are now merging with climate action imperatives to accelerate electrification. Fuel switching is a pivotal part of this strategy. In April 2016 the Quebec government released *The 2030 Energy Policy*[198] which outlines the following ambitious targets to be achieved by 2030:

1. Enhance energy efficiency by 15 percent.
2. Reduce by 40 percent the amount of petroleum products consumed.
3. Eliminate the use of thermal coal.
4. Increase by 25 percent overall renewable energy output.
5. Increase by 50 percent bioenergy production.

Transportation electrification plays a central role in the overall 2030 plan. The transportation sector consumes 75 percent of all of the petroleum products used in Quebec for energy purposes. The 2030 plan calls for a transition away from these fossil based fuels to locally generated clean electricity. This abundant, renewable and low cost energy will also drive economic development: "Through the energy available to it, Quebec can develop new manufacturing sectors, in particular the electric vehicle and vehicle components industry, and renewable energy production technologies".[199]

Furthermore, the 2030 Energy Policy provides a mandate to Hydro Quebec to:

- Continue to support and expand the Electric Circuit (network of electric charging stations).
- Participate technically and financially in the establishment of the necessary infrastructure and equipment for the electrification of transportation.

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[196] Retrieved from http://www.fleetcarma.com/ev-sales-canada-2015/

[197] "The energy sector contributes, through its investments in capital and expenditures, to the vitality of other economic sectors. In 2014, it accounted for nearly 4.2% of Québec's gross domestic product (GDP), i.e. $13 billion. The same year, Hydro-Québec paid the Québec government more than $2.3 billion in the form of dividends and more than $0.9 billion in taxes on public services and water-power royalties. Hydro-Québec's investments totalled $3.4 billion, making the government corporation Québec's biggest investor. To date, total investments carried out or under way to develop Québec's wind farms stand at roughly $8 billion. The invitations to tender stipulate that at least 60% of this amount must be spent in Québec. For several decades, the development in Québec of energy-intensive industries has hinged, to a large extent, on hydroelectricity. Québec's renewable electricity has thus contributed markedly to the development of its regional industrial fabric." Source: Retrieved from https://politiqueenergetique.gouv.qc.ca/wp-content/uploads/Energy-Policy-2030.pdf

[198] Retrieved from https://politiqueenergetique.gouv.qc.ca/wp-content/uploads/Energy-Policy-2030.pdf

[199] Ibid

- Pursue investments in research and innovation in electric vehicles.
- Support households and businesses that acquire new electric vehicles or vehicles with a low carbon footprint, including hydrogen-powered vehicles that will be marketed in the future.
- Replace its current fleet vehicles with wholly or partially electric vehicles of equivalent capacity.

The 2030 Energy Policy calls upon the Quebec Government to:

- Cooperate with the states and provinces committed to supporting the "zero-emission vehicles" market, in particular by tabling zero-emission legislation.
- Ensure that households that opt for electric and low-GHG-emitting vehicles can rely on low-carbon fuel distribution networks and sufficient numbers of charging stations in public venues and along main roads throughout the territory.
- Establish within the coming year a network of multi-fuel service stations offering gasoline, biofuels, natural gas, propane, electricity and hydrogen and extend it by 2030 throughout Quebec. The service stations will first be installed in regions with high potential for use. After 2030, all government authorizations for new facilities or the modernization of service stations must be accompanied by multi-fuel offerings.
- Lead by example through government procurement programs, requiring fleets to:
    - Reduce by 50 percent the unit energy consumption (L/100 km) of its light-duty vehicles fleet.
    - Integrate 1000 electric or hybrid vehicles into its fleet by 2020.

The 2030 Energy Policy is only the latest in a series of policy directives related to CEVs that have been evolving over the past number of years; each more ambitious than the last.

Transportation Electrification Action Plans and Economic Development Measures

Starting in 2010, the Quebec government outlined specific initiatives to encourage the electrification of transportation in the province with the goal to increase jobs and investment in the sector, and help achieve its broader climate change action plan goals in a series of transportation electrification action plans. These include:

- *Action Plan for Electric Vehicles 2011-2020,* released in 2011.
- *Transportation Electrification Strategy 2013-2017,* released in 2013.
- *Transportation Electrification Action Plan 2015-2020*, released in 2015.

The policy directions addressed in each document focus on encouraging the use of EVs, supporting the industry and leading by example through government procurement. The following table presents the policy directions and budgets of the three action plans and strategies for transportation electrification in Quebec.

Policy Directions/Focus and Budget of Quebec's Action Plans for Transportation Electrification

Action Plan	Policy Directions/Focuses	Budget
Electric Vehicles: 2011-2020 Quebec Action Plan	a) Support and inform EV users b) Plan and implement deployment of EVs c) Accelerate electrification of public transit d) Bolster the industrial sector	Measures in place before April 2011: $85 million New measures: $165 million $250 million (total)
Transportation Electrification Strategy 2013-2017	a) Rapidly increase the use of electrical transportation b) Take advantage of Quebec's electrical expertise c) Build the future around a strong and productive industrial network d) Make the Quebec State an example to be followed	$516 million by 2017
Transportation Electrification Action Plan 2015-2020	a) Promote Electric Transportation b) Develop the Industry c) Create a Favourable Environment for Electric Transportation	$420 million

The most recent action plan, the *Transportation Electrification Action Plan 2015-2020*, identifies 35 measures centered on three policy directions. The next table presents an overview of the type of measures included as part of this most recent Action Plan.

Overview of Types of Measures from the Transportation Electrification Action Plan 2015-2020

Priorities	Type of Measures	Budget (in millions)
Policy Direction 1: Promote Electric Transportation		
Increase the availability of Electric Public Transportation	• Programs to support Public Transportation showcase projects and acquisition of electric school buses • Support to carry out pilot projects for the electrification of taxi fleets • Support for various major public transportation projects	$156.0
Promote the use of light electric vehicles	• Support for the installation of fast charging stations along main roads and in multi-unit residential buildings, new office buildings and for on-street parking and expansion of the Electric Circuit network. • Implementation of a concerted approach and structuring actions with partners to increase the number of ZEV. • Incentive programs such as "Roulez électrique" and "Branché au travail"	$115.9
Develop innovative solutions for freight transportation	• Measures to support showcase projects in the freight transportation sector and electrification incentives	$38.4
Policy Direction 2: Developing the Industry		
Intensify research development and innovation of SMEs	• Support collaborative industrial innovation projects and the development of new technologies or innovative processes • Implement mobilizing projects • Support SMEs with acquisitions, implementation and market equipment/technologies • Support the organization of scientific and technical international events in Quebec	$52.1
Support the marketing and export of innovative products	• Support businesses in the sector to develop markets outside of the province • Support the introduction of innovative products to the market	$4.75
Stimulate investment	• Support investment projects and encourage foreign companies to settle in the province	$30
Train skilled labour	• Introduction of a certificate of college studies in transportation electrification and of a Master's degree	No specific budget allocated
Policy Direction: Create a Favourable Environment		
Propose the implementation of a legislative and regulatory framework promoting	• Provide EV with privileged access to reserved lanes where carpool is authorized and free access to toll bridges and ferry services • Review the construction code to provide for the installation of charging stations in new residential buildings	No specific budget allocated

transportation electrification	• Modify the Highway Safety Code to allow low-speed vehicles to travel on public road and to regulate access to parking spaces with charging stations • Modify the diesel compensation program for school buses • Implementation of measures to support urban planning favouring ecomobility • Adopt new government policy directions in land use planning that will promote transportation electrification	
Lead by Example	• Proceed with the electrification of the government's fleet • Install public charging stations in government buildings	$15.0
Promote Electric Vehicles and Government Action	• Establish a government communication strategy and implement the Action Plan • Support awareness initiatives for electric vehicles carried out by external partners	$8.6

While the Ministry of Transport (renamed the Ministry of Transport, Sustainable Mobility and Transport Electrification in January 2016) is responsible for the implementation of the 2015-2020 Action Plan, a number of other Ministries and Agencies are involved in the implementation of its different measures. Other ministries and agencies involved include: Hydro-Quebec; Investissement Quebec; Ministry of Sustainable Development, the Environment and the Fight against Climate Change; Ministry of Energy and Natural Resources; Ministry of Economy, Innovation and Exports; Ministry of Education, Higher Education and Research; Ministry of Municipal Affairs and Land Occupancy; Régie du bâtiment du Quebec; Société de l'assurance automobile du Quebec and Société Quebecoise des infrastructures.[200]

Additionally, the 2030 Energy Policy calls for the creation of a new agency devoted to energy conservation and the energy transition.[201] This agency will have a broad mandate that will, among other things, coordinate the implementation of energy related innovation initiatives and provide funding to green technology enterprises.

Hydro-Quebec's role remains central to the implementation of transportation electrification. For example, it is responsible for the expansion of the Electric Circuit network. According to the strategy, Hydro-Quebec has as a goal the installation of 785 charging stations, including 60 fast charging stations (400V) by December 2016. Furthermore, Hydro-Quebec is mandated to assist municipalities in the planning of the development of charging sites. This mandate was reinforced in the 2030 Energy Policy with a new strategic direction that requires Hydro Quebec to "promote it's contribution to … transportation electrification"[202].

Funding for the 2015-2020 action plan comes from three sources:

- Fonds Vert[203] ($253.5 million or 60 percent of funding), a fund administered by the Ministry of Sustainable Development, the Environment and the Fight against Climate Change with income

[200] Note that the names of some Ministries have changed since the release of the Action Plan.

[201] Retrieved from https://politiqueenergetique.gouv.qc.ca/wp-content/uploads/Energy-Policy-2030.pdf, p. 25.

[202] Ibid, p. 23.

[203] Fonds Vert, Ministry of Sustainable Development, the Environment and the Fight against Climate Change, May 2016 Available: http://www.mddelcc.gouv.qc.ca/ministere/fonds-vert/#provenance

mainly derived from the sale of carbon emission allowances through the carbon market.

- Ministries and agencies appropriations ($84.25 million or 20 percent)
- Fonds des réseaux de transport terrestre (FORT – $83 million or 20 percent)

Outcomes

Outcomes of the 2015-2020 Action Plan have not yet been fully released, however, there are early results from previous action plans. Measures focused on the industrial sector of the 2011-2020 Action Plan have yielded the following outcomes (reported in 2012)[204]:

- A number research and innovation projects were funded including: CVT transmission for EVs, refrigerated trucks, recharging stations (AddEnergie), Electric motors (TM4), Hybrid bucket truck, Electric bogie, electric vehicles for mines, electric motorcycle.
- A major electric bus project was launched in 2012 for $73 million, including $30 million from government funding. One hundred people were assigned to this project which was meant to produce two prototypes (microbus and city bus) for spring 2014.
- An EV group was created as part of the Quebec ground transportation cluster of excellence in the summer of 2011. This group, made up of industry and government representatives, was tasked with the mobilization of EV stakeholders to ensure the sector's competitiveness
- An EV research group overseen by the Quebec ground transportation cluster of excellence was in the approval stages. With a budget of $4 million over three years, this group was anticipated to bring together industry members and research centers to conduct applied research that would meet industry needs.
- A $7.4 million subsidy was provided to Süd-Chemie-Phostec Lithium for a new lithium iron phosphate (LFP) plant in Candiac in April 2011. The project was reported to have a total $78 million investment and have created 52 jobs.
- Hydro-Quebec, Süd-Chemie, and other partners formed an alliance for LFP licenses.
- A joint venture to manufacture LFP in South Korea was formed with Süd-Chemie-LG Chem in 2011 and another joint-venture was formed with TM4-Prestolite to provide electric engines for heavy vehicles to Asia in 2012.
- Investissement Quebec provided a $75 million loan guarantee to Canada Lithium for a lithium mining and processing project for batteries near Val-d'Or. The project is reported to have had an investment value of $200 million with 200 direct jobs, of which 70 were in processing.
- To help attract international manufacturers, a $16 million subsidy to help expand a battery plant in Boucherville for Bathium Canada was provided. The expansion is reported to have represented a $176 million investment and created 245 jobs.

Two financial assistance programs are now in place including Green Technologies Demonstration Program Aiming to Reduce Greenhouse Gas Emissions (Technoclimat) and the Energy Innovation Assistance Program

[204] Running on Green Power – Electric Vehicles: 2011-2020 Quebec Action Plan, Alternative Fuel Vehicles Conference, September 27, 2012, The Biosphere, Montreal

(PAIE). The programs covered between 25 percent and 75 percent of eligible expenses to a maximum of $1 million to $3 million depending on the program.

One company that benefited from the PAIE funding is AddEnergie Technologies Inc. (AddEnergie). AddEnergie's *Development and commercial demonstration of electric and plug-in vehicle charging infrastructures project* had the main objective of creating an electric-vehicle charging infrastructure in Quebec adapted to northern environments. The project, which cost $529,550, received $251,961 in financial assistance from PAIE. The project led to 17 tons of CO2 avoided per year and 661,388 GJ saved per year.

Add Energie represents a successful outcome of the economic development strategy related to the CEV supply chain. In addition to early successes enjoyed through commercial demonstration projects funded by PAIE and other sources the company has recently secured substantial funding though Caisse Depot. This government supported funding signifies an important step on the road to full commercialization and has allowed Add Energie to expand and commercialize its product offerings to include DC fast chargers, solutions for MURB applications and a residential EVSE for home based charging. Add Energie is now the leading EVSP in Canada having recently opened a branch in Mississauga, Ontario with plans to expand to BC in 2016.

Key Findings and Lessons Learned: The BC Context

Some of the Key findings from Quebec's efforts to electrify transportation include:

- **Overarching strategy.** Transportation Electrification is part of a broader province wide climate, energy and industrial strategy with the provincial utility at its core.
- **A holistic approach.** The policy directions address multiple aspects of the sector including road and non-road, multiple vehicle classes, transit, rail and marine even school buses. Both the consumer (demand) side and the supply chain are addressed including funding, investment, manufacturing incentives, infrastructure R&D and policy mandates.
- **Demonstrated continuous commitment to transport electrification.** With the release of successive strategies and action plans that build on previous iterations, each providing dedicated and sustained funding.
- **Cross-ministry and agency involvement.** The measures identified in the action plan involve a number of ministries and government agencies in their implementation in a unified approach.

Case Study 3: BC Tech Sector

BC's technology sector includes over 9,000 companies involved in clean tech, digital media, wireless, life sciences and information and communications technology.[205] The tech sector is considered a vitally important contributor to the BC economy employing over 84,000 people and contributing $15 billion to provincial GDP.[206] As the BC economy diversifies from resource dependent to a knowledge-based economy, the contribution and importance of the sector to the economic well-being of the province will increase. Accordingly, the technology sector has been a significant focus of provincial economic development policy and job creation strategies in recent years. As a result, a number of studies have been released to help assess the economic contributions of the sector in BC, identify the barriers to growth and priority areas for support, and develop strategies to help grow the sector in the province.

The *BC Technology Report Card* was first released in 2012 to provide an overview of the BC Technology sector's current state.[207] The main conclusions from the report stated that although the BC technology sector was a significant economic driver for the province, it was underperforming compared to other Canadian and international jurisdictions. While it was identified that the technology market globally presented significant opportunity for the BC technology sector, it was mentioned that continued government support and a higher level of intention in terms of policy and industry development would be required to enable BC to take advantage of this opportunity.

Following the release of the 2012 *BC Technology Report Card*, the BC Technology Industry Association (BCTIA) developed a 4-Point Plan for Growth[208] for the technology sector in BC. The purpose of the plan was to propose a policy framework that could help increase the growth rate for technology in the province and address key issues for the sector.

The recommendations from BCTIA's 4-Point Plan included:

- **Improving access to capital** by investing $100 million to revitalize venture capital in BC and increasing and enhancing BC's Small Business Venture Capital Program.
- **Investing in talent attraction and training** through the acceleration of foreign worker approvals through the Provincial Nominee Program, the establishment of an Expert Panel to make recommendations on increasing graduation rates from post-secondary science/technology programs, the expansion of BC's Training Tax Credit program to include co-op and internship placements, and supporting the industry in strategic talent attraction and retention initiatives.
- **Leveraging procurement** through the federal Industrial and Regional Benefits (IRB) program, the institution of a pre-commercial technology adoption program, and the introduction of set-asides in procurement for SMEs across government, agencies and crown corporations.

[205] KPMG, *British Columbia Technology Report Card 2014,* 2014, Available here: http://www.kpmg.com/Ca/en/IssuesAndInsights/ArticlesPublications/Documents/6943-BC-Tech-Report-card-FY14-web.pdf

[206] Ibid.

[207] KPMG, *British Columbia Technology Report Card 2012,* 2012, Available here: https://www.kpmg.com/Ca/en/IssuesAndInsights/ArticlesPublications/Documents/British-Columbia-Technology-Report-Card-2012.pdf

[208] BCTIA, *Growing BC's Technology Industry: A 4-point Plan for Growth*, 2012 (updated in 2014)

- **Investing in company capacity building** by supporting industry accelerator programs with measurable results.

A second *BC Technology Report Card*[209] released in 2014 reassessed the position of BC's technology sector compared to other provinces and countries. In this follow up study, past investments in the sector were identified as beneficial for the sector. More specifically, the 2014 Report Card mentions that programs such as the Small Business Venture Capital tax credit, the angel tax credit, the Scientific Research & Experimental Development (SR&ED) tax incentive, the Interactive Digital Media tax credit and the BC Renaissance Capital Fund had beneficial impacts on the sector. That being said, the 2014 Report Card also stated that the sector still required continued investment and government support in three key areas:

- Access to early stage venture capital.
- Expanding talent availability.
- Growing the size of firms.

In 2016, a strategy for the technology sector in BC, *#BCTECH Strategy*, was released by the BC Government. The strategy has three main focus areas: capital, talent and markets. The table below presents a summary of the measures included in the #BCTECH strategy.

Overview of Measures included in #BCTECH Strategy

Strategy	Actions
Improve access to capital and continue to support BC's tax system and research environment	**Invest in a new venture capital fund.** $100 million to expand venture capital and address early stage (A-round) funding gaps. **Continue to offer tax rates and credits.** Digital animation or Visual Effects (DAVE) credit, or interactive Digital Media Tax Credit (IDMTC) and BC's small Business Venture Capital Act. **Continue to build a strong research environment.** Including attracting and keeping research talent through research funding, revised BC Knowledge Fund criteria to focus on provincial government priorities and provide funding to post-secondary institutions to increase commercialization potential.
Deepen the BC Technology Talent Pool	**Industry-focused programs in the post-secondary system.** Targeted funding, financial aid, promotion of co-op grants and recognition of the importance of hands-on experience for students. **Timely and relevant labour market information.** Provide better information to career educators and students about wider range of careers in BC, support the tech sector to customize labour market information, include an annual provincial 10-year forecast of job openings by occupation including tech sector occupations. **Applied learning and entrepreneur development.** Support companies to train/up-skill new and existing employees, build on existing programs in post-secondary institutions, and support post-secondary institution initiatives.

[209] KPMG, British Columbia Technology Report Card, 2014 edition, Available here: http://www.kpmg.com/Ca/en/IssuesAndInsights/ArticlesPublications/Documents/6943-BC-Tech-Report-card-FY14-web.pdf

	Streamlined in-migration pathways after BC has maximized our local talent. Help companies that need to recruit and access workers from outside Canada, work with other provinces and federal government to improve labor mobility, provide funding for a foreign qualification recognition project and promote federal government's express Entry Program for workers with in-demand tech skills. **Dedicated programs in the K-12 education systems.** Phase in a new K-12 curriculum over three years with new standards in mathematics, sciences and other curricula. Increase students earning credit from Work Experience Electives participations in the technology sector, and support student opportunities to learn coding in and outside of school.
Make it Easier to Access New Markets	**Making it easier to sell to government.** **Making it easier to share ideas.** **Making BC the most connected province.** Provide high-speed internet to 100% of the province by 2021 and improve the reliability of high-speed internet access for northern and coastal communities. **Facilitating business growth through exports.** **Encouraging commercialization.** Increase adoption of clean tech through government's LNG technology fund and legislation regarding net-zero gas emissions yearly for the entire BC public sector.

Key Findings and Lessons Learned: The BC Context

The Clean Transportation sector, it could be argued, represents a subset of the BC technology sector and shares many of the same characteristics, challenges and opportunities. Government actions and policies that impact the tech sector in general will impact the CEV sector as well. Most if not all of the priorities identified by the CEV stakeholder groups directly align with the *#BCTECH Strategy* findings.

Appendix E. Summary of Literature Reviewed

Further to the sources identified in the footnotes of this report, a number of other documents were reviewed during the study. The following table presents some of these documents. Note that this list is not comprehensive, but represents a number of key sources of related research.

Title of Document	Source	Date
Sizing The Clean Economy	The Brookings Institution, Metropolitan Policy Program	2011
An Economic Assessment Of Low Carbon Vehicles	Cambridge Econometrics and Ricardo-AEA	2013
Plug-In Electric Vehicle Deployment In California: An Economic Assessment	University of California	2012
The West Coast Clean Economy: Opportunities For Investment And Accelerated Job Creation (And Methodology Document)	Globe Advisors	2012
British Columbia's Clean Transportation Sector: Industry Insights On Job Creation And Investment Promotion In BC's Clean Economy	Globe Advisors	2012
Oregon's Electric Vehicle Industry	Northwest Economic Research Center	2013
Economic Impact of the Electrification Roadmap	Electrification Coalition	2010
Transportation Electrification: Market Assessment, policy overview and utility pursuant to Senate Bill 350	Energy Division, California Public Utilities Commission	2016
Gap Analysis for B.C.'s Electric Vehicle Direct Current Fast Charging Network	Fraser Basin Council	2015
2016-2017 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program	California Energy Commission	2016
Electromobility in Norway - experiences and opportunities with Electric vehicles	Institute of Transport Economics, Norwegian Centre for Transport Research	2013
Electrifying Vehicles Insights from the Canadian Plug-in Electric Vehicle Study	Simon Fraser University	2015
Plug-In Electric Vehicle (PEV) Readiness Guide	Electric Mobility Canada	2014
Roadmap for Accelerating the Deployment of Electric Vehicles in Canada 2016 to 2020	Electric Mobility Canada	2016
Strategic Planning To Implement Publicly Available Ev Charging Stations: A Guide For Businesses And Policymakers	Center for Climate and Energy Solutions	2015

The Economic Impact of Electric Vehicle Adoption in Ontario	Windfall Centre	2014
Driving Electrification A Global Comparison Of Fiscal Incentive Policy For Electric Vehicles	The International Council on Clean Transportation	2014
Evaluation Of State-Level U.S. Electric Vehicle Incentives	The International Council on Clean Transportation	2014
Creating the Clean Energy Economy: Analysis Of The Electric Vehicle Industry	International Economic Development Council	2013
International Business Development Strategy Canadian Electric Transport Sector 2014 - 2017	Electric Mobility Canada	2016
Learning From California's Zero-Emission Vehicle Program	Public Policy Institute of California	2007
A Plan For Climate Leadership In British Columbia: Forecasting The Benefits And Costs Of Strengthening British Columbia's Greenhouse Gas Policies	Navius Research	2015
Propelling Quebec Forward With Electricity 2015 >2020 : Transportation Electrification Action Plan	Gouvernement du Quebec, Ministère des Transports du Quebec.	2015
Renewable Energy Challenge: Finding Transportation, Building And District Energy Solutions For A 100 Percent Renewable Energy Future	Vancouver Economic Commission	2016
Evaluating California's Zero-Emission Vehicle (ZEV) Credits And Trading Mechanism And Its Potential Suitability For Implementation In Chinese Cities	Innovation Center for Energy and Transportation	2014
Green Provinces & States : 2014 Report Card	Corporate Knights	2014
Clean Tech Report Card	BC Ministry of International Trade	2015
The #BCTECH Strategy 2016	BC Government, Ministry of Technology, Innovation and Citizen's Services	2016
British Columbia's Clean Energy Supply & Storage Sector: Industry Insights On Job Creation And Investment Promotion In BC's Clean Economy	Globe Advisors	2012
Clean Tech Sector Value Proposition	BC Government	2015
Canada's Policy Support For Clean Technology Exports : Report Card	Pembina Institute	2015