Feasibility Study

Zero Emissions Fleet Initiative Pilot Project

Capital Regional District | January 2017

Making a difference...together

Developed by:

The Capital Regional District, Zero Emissions Fleet Initiative Team

Supported by:

Ministry of Energy and Mines, Province of British Columbia
Institute for Integrated Energy Solutions at the University of Victoria

Prepared by:

JCA Judith Cullington & Associates and Roseline Ferré, and Liz Ferris CRD
Winter, 2016

Contents

Preface and Acknowledgement

The commitment and resolve to achieve, if not exceed the CRD's 2020 GHG emissions reduction target combined with an innovative spirit searching for solutions—those are the attributes that led Capital Regional District (CRD) employees Dave Goddard, Central Fleet Manager and Liz Ferris, Climate Action Analyst, to spearhead a potentially transformative climate action initiative in the Capital Region on southern Vancouver Island, British Columbia.

It all began with a question asked within the context of searching for ways to continue reducing the CRD's fleet emissions: "*Could hydrogen powered zero emission sport utility vehicles be a solution?"* That sparked the spirit of inquiry and innovation which surged across professional networks in BC spanning all levels of government, academia and industry. Within a couple of weeks, a team of subject matter experts (listed below) had mobilized to fund and prepare a feasibility study on piloting the use of Zero Emissions Vehicles (ZEVs) in the CRD fleet. This report, with its inherent resource commitments, is the result.

Participants in the list below are acknowledged for their contribution to the feasibility study. As Canada grapples with the challenges of transitioning toward sustainable economic growth, every step toward integrating clean energy alternatives as envisioned in the Zero Emissions Fleet Initiative pilot project helps us leap forward to a greener and more prosperous future.

Zero Emissions Fleet Initiative (ZEFI) Team

CRD Staff and Contract Resource

- Liz Ferris, M.Sc., PMP, Climate Action Analyst
- Dave Goddard, CAFM, Central Fleet Manager
- Judith Cullington, Judith Cullington & Associates (on contract)

BC Ministry of Energy and Mines

- Christina Ianniciello, Director, Communities and Transportation, Communities and Transportation Branch
- Dian Ross, Clean Transportation Engineer (E.I.T.), Communities and Transportation Branch
- Nick Clark, Sr. Policy Analyst, Communities and Transportation Branch

Institute for Integrated Energy Solutions, University of Victoria (IESVic)

- Professor Ned Djilali, PhD, Canada Research Chair in Energy System Design and Computational Modelling
- Professor Curran Crawford, PhD, Associate Professor
- Julian Fernandez PhD, Post Doctorate Researcher
- Graduate Students: Daniel Clancy

Executive Summary

The CRD Zero Emissions Fleet Initiative (ZEFI) will pilot the use of zero emission vehicles to reduce GHG emissions in a local government fleet context while generating new scientific knowledge to help stimulate innovation toward a clean growth economy. In aiming for its 2020 GHG reduction target, the Capital Regional District (CRD) has mobilized a dynamic partnership to implement this project.

The CRD's corporate climate action strategy calls for a GHG emissions reduction to 33% below the 2007 level by 2020. While significant progress has been achieved, fleet emissions still account for just over 50% of the organization's overall emissions despite several pro-active fleet management measures. The advent of fuel cell electric vehicles (FCEV), well suited to CRD operational needs given their travel range, cargo space and off-road travel capabilities, offers promise and led CRD staff to question: "Could hydrogen powered zero emissions sport utility vehicles be a solution?" This question ignited much conversation, exploration and networking through which the ZEFI team was born within a couple of weeks.

Energetically mobilized in August, 2016, the ZEFI team conducted a feasibility study for undertaking a Zero Emissions Fleet Initiative (ZEFI) pilot project, with the ultimate aim of reducing GHG emissions from the CRD fleet to almost zero. Collectively, the ZEFI partners have committed resources valued at 66% of the pilot project cost ($1.04M). Financial support from the Green Municipal Fund (GMF) for the remaining 34% ($350K) will be instrumental in allowing this pilot to achieve its objectives:

Reduce GHG emissions in the CRD fleet

- Conduct a Smart Fleet analysis to develop a suite of tools for fleet optimization;
- Conduct a field trial of six fuel cell electric vehicles (FCEV) as part of the CRD fleet;
- Test and compare the use of other zero emission alternatives, including battery electric vehicles (BEV) and electric bikes (E-Bikes) where operationally appropriate;
- Investigate opportunities to use electric vehicles as an emergency power source.

Reduce GHG emissions from other (non-CRD) vehicles in the Capital Region

- Share knowledge gained with organizations and individuals across BC;
- Support FCEV infrastructure deployment by government and industry partners;
- Support FCEV uptake by other fleets in the Capital Region.

Stimulate clean growth opportunities related to hydrogen fuelling infrastructure

- Generate and share new knowledge to stimulate further progress toward a clean growth economy.

The project's legacy is significant and includes: rigorous evidence-based comparative data on zero emissions vehicles in a fleet context; knowledge mobilization and experience for successful transition to zero emission fleets; new applied research findings for optimizing Smart Fleets; installation of the first publicly accessible hydrogen fuelling station within the Capital Region—a transformative pilot project spillover benefit—to be funded outside the scope of this pilot project.

As the battery power vs. hydrogen fuel cell debate rages on [1] [2] [3], the ZEFI pilot project offers the unique value proposition of measuring and analyzing the performance of both options within a fleet context. This new knowledge will inform a key debate at the dawn of a new age in 21st century transportation.

Project Partnership

The CRD has mobilized a dynamic partnership that has committed 66% of the financial resources and a team with the expertise needed to implement the proposed pilot project. Additionally, other potential partners are keenly interested in the project; the nature of their involvement will be clarified as the initiative progresses.

- Capital Regional District
- British Columbia Ministry of Energy and Mines
- Institute for Integrated Energy Solutions, University of Victoria (IESVic)

Capital Regional District (CRD) – Project Lead

The Capital Regional District (CRD) is the regional government for 13 municipalities and three electoral areas on southern Vancouver Island and the nearby Gulf Islands, serving more than 377,000 citizens. As a local government and shared services provider, the CRD develops partnerships to facilitate and deliver projects and services that benefit municipalities, electoral areas, First Nations and the region as a whole. The CRD has more than 200 service, infrastructure and financing agreements with municipalities and electoral areas to deliver services in the following categories: regional, where all municipalities and electoral areas are served; sub-regional, where two or more jurisdictions are served; and local, in the electoral areas where the CRD is the local government.

In 2015, the CRD re-invigorated its commitment to climate change when the Board identified accelerating corporate activities to reduce GHG emissions as a key strategic priority.[4] Thereafter, in 2016, the Board adopted the CRD Corporate Climate Action Strategy, which aims to integrate climate action into everyday business across the organization.[5]

The CRD is aiming to achieve continuous, significant reductions in GHG emissions from the fleet and strive towards zero emissions for new fleet vehicles. Greenhouse gas emissions from the CRD fleet accounted for 54% of corporate GHG emissions in 2015 (1,249 tCO2e). To meet its stated GHG reduction targets (33% by 2020), the CRD must reduce emissions by about 450 tCO2e annually by 2020.

The CRD has a fleet management policy statement to “reduce fuel use from CRD-owned vehicles and equipment” and has set a goal to “achieve continuous, significant reductions in GHG emissions from the fleet and strive towards zero emissions for new fleet vehicles”.[6] The zero emissions fleet initiative supports these goals, and subsequent actions that have been identified within the 2016 CRD Corporate Climate Action Strategy. The CRD is technology neutral- meaning it is committed to investigating and employing any technology that can meet operational and duty-cycle needs at lowest financial and GHG lifecycle cost.

British Columbia Ministry of Energy and Mines (MEM)

The Province of British Columbia has set legislated targets for reducing greenhouse gas emissions (GHGs) that contribute to global climate change. Under the *Greenhouse Gas Reduction Targets Act*, the Province must achieve a 33% reduction in GHG emissions below 2007 levels by 2020, and an 80% reduction by 2050. Personal and commercial vehicle transportation account for 13% and 24% of B.C.'s GHG emissions respectively, making a transition to zero emissions vehicles an important part of the Province's climate change mitigation strategy.[7]

Through MEM and the Zero Clean Energy Vehicles Program[8], the Province supports the adoption of zero emissions vehicles, including FCEVs. Currently, the purchase or lease of a hydrogen fuel cell vehicle can qualify for an incentive of up to $6,000, while purchasers of battery electric vehicles can qualify for up to $5,000 off the purchase price.[9] The Provincially funded Fleet Champions Program[10], administered by the Fraser Basin Council, assists fleets in British Columbia in their efforts toward deploying zero emissions vehicles by offering technical vehicle telematics and financial support for an EV business case, and charging infrastructure incentives.

Historically, the Province has provided funding towards the installation of a hydrogen fuelling station in Vancouver, and has confirmed that it will do the same for southern Vancouver Island within the context of the ZEFI pilot project (see *Appendix 1*). In addition, MEM staff are providing technical support to this project.

Institute for Integrated Energy Solutions, University of Victoria (IESVic)

IESVic's mission is "*To chart feasible paths to sustainable energy*."[11] It conducts sustainable energy research, using a collaborative approach between mechanical engineers, economists and environmental scientists. It has become a 'go-to' source of expertise for industry leaders and has a track record of collaboration with the hydrogen and fuel cell sector. Accordingly, its role in the project will be pivotal as it will lead the project's applied research design, measuring and monitoring to ensure verifiable results which will be compiled as a Smart Fleet analysis. IESVic's commitment to the pilot project is confirmed in its letter of support (see *Appendix 2*). The CRD will facilitate knowledge transfer by leading the community outreach initiatives in collaboration with IESVic.

The study of fuel cell technologies is part of IESVic's current research. Work is in progress on addressing hydrogen energy system steps, including generation, storage, distribution, economics, and fuel cell electricity generation. Because the transportation sector poses particularly strong challenges to eliminating carbon emissions, fuel cell stack and system development is one of IESVic's key initiatives. The institute was closely involved in the "Hydrogen Highway" initiative that paved the way for the hydrogen fuel cell fleet deployment as part of the 2010 Winter Olympics, and receives support from a number of government and industrial partners for its research into stack modeling and design for vehicle scale polymer electrolyte membrane (PEM) systems. More recently, research on regenerative hydrogen systems driven by renewable energy sources have been investigated with a focus on the dynamic response (*the response of a structure to a dynamic load such as an explosion or earthquake shaking*) and efficiency. As well, IESVic researchers are pursuing the development of novel methods for storing hydrogen with a focus on new liquefaction processes.

IESVic is also working on a Transportation Futures project sponsored by the Pacific Institute for Climate Solutions and focusing on electrification of transportation. This includes a wide range of vehicle classes, from E-Bikes, through to personal vehicles, buses, fleet (e.g., delivery) vehicles and heavy duty transport. The emphasis on the project is optimizing the introduction of these vehicles, understanding battery degradation effects, and quantifying overall CO_2 reductions resulting from plugging into the interconnected Western Electricity Coordinating Council (WECC – a regional forum for promoting regional electric service reliability in Western Canada and the Western United States) with and without control over charging behavior. An aspect of the work also involves comparing battery-electric drivetrains to fuel cell options, in terms of performance, cost and overall round-trip energy efficiency.

Other Potential Partners

Canadian Hydrogen Fuel Cell Association

The Canadian Hydrogen Fuel Cell Association[12] (CHFCA) is the collective voice of the hydrogen and fuel cell industry. Its role is to raise awareness of the economic, environmental, and social benefits of hydrogen and fuel cells. It was formed in January of 2009 through a merger between the Canadian Hydrogen Association (CHA) and Hydrogen & Fuels Cells Canada (H2FCC). The merger unites the members of the former associations to represent the majority of the stakeholders in Canada's hydrogen and fuel cell sector.[13] The CHFCA is keen to support hydrogen and fuel cell technologies, and is encouraging the federal government and provinces to create and adopt a National Hydrogen and Fuel Cell Strategy.[14] The fuelling station provider, as planned to support this project, will be a member of the CHFCA. CRD has been in conversations with the CHFCA about roles they may play, in support of the Pilot Project, and will continue these conversations, as the project progresses.

Potential Fuelling Station and Zero Emissions Vehicle Users

CRD staff will reach out to potential users of the hydrogen fuelling station, such as BC Transit, other local governments and the University of Victoria, to discuss interest in making the station available for their fleets. Some local businesses and private individuals may also be interested in purchasing a FCEV, if fuelling infrastructure were to be available. There is a precedent in BC for mobilizing resources toward innovation, as exemplified when BC Transit pioneered the use of fuel cell electric buses through a demonstration at Whistler during the 2010 Olympics[15]. The project has been designed to ensure that the lessons learned from this project can be transferred and applied within other fleet contexts within British Columbia, and across Canada.

Hyundai Canada

The CRD is in negotiations with Hyundai Canada about leasing six Hyundai Tucson FCEV SUVs for the pilot trial. Subject to fuelling availability, there is agreement that two Tucsons will be available for lease in 2017, with an additional four Tucsons available in 2018.

Objectives

The ultimate aim of this innovative pilot project is to reduce GHG emissions from the CRD fleet to almost zero. This project builds upon past efforts to reduce GHG emissions from the CRD fleet and a solid applied research design foundation in order to rigorously analyze and document several GHG reduction measures in a fleet context. The pilot project objectives include:

Reduce GHG emissions in the CRD fleet

- Conduct a Smart Fleet analysis to mobilize and share knowledge on fleet optimization;
- Conduct a field trial of six fuel cell electric vehicles (FCEV) as part of the CRD fleet;
- Test and compare the use of other zero emission alternatives, including battery electric vehicles and electric bikes where operationally appropriate;
- Investigate opportunities to use electric vehicles as an emergency power source.

Reduce GHG emissions from other (non-CRD) vehicles in the Capital Region

- Share knowledge with organizations and individuals across BC;
- Support FCEV infrastructure deployment by government and industry partners;
- Support FCEV uptake by other fleets in the region.

Stimulate clean growth opportunities related to hydrogen fuelling infrastructure.

- Generate and share new knowledge to stimulate further progress toward a clean growth economy.

Given the profile and expertise of the project partners, it is anticipated that the pilot project will draw much attention. As the momentum nation-wide toward clean growth continues to build, the findings resulting from this pilot project will provide guidance and direction for worthy fleet and infrastructure investment opportunities.

Vehicle fleets often contribute a substantial portion of a local government's carbon footprint. The CRD's fleet of 304 vehicles and 51 pieces of equipment accounted for approximately 54% of its total corporate emissions in 2015.[16] The CRD already has four hybrids and one battery electric vehicle (BEV) in its fleet. Wider adoption of BEVs has been limited by the extended daily distances covered by many CRD vehicles and lack of available SUV/ all-wheel drive BEV options. The advent of fuel cell electric vehicles (FCEV) provides an exciting option for the CRD and other local governments to reduce tailpipe emissions from fleet vehicles to zero by replacing gas /diesel vehicles with a zero-emission option.

The ZEFI pilot project includes the gradual replacement of internal combustion engine (ICE) vehicles with zero emission powertrains using hydrogen or electricity for fuel, as well as right-sizing vehicles for the appropriate use, reducing kilometres travelled, improving driver efficiency and in some cases using a modal shift with electric bicycles (E-Bikes) replacing vehicles. An integral component of the field trials will be monitoring drivers/end users uptake. If the field trial proves successful, the CRD intends to replace up to 100 existing ICE vehicles in the coming years as part of its ongoing fleet replacement process.

Components

To meet the project objectives identified above, the Zero Emissions Fleet Initiative Project Team has designed a pilot project with four distinct project components:

- Fuel Cell Electric Vehicle (FCEV) Field Trial;
- Battery Electric Vehicle (BEV) Testing and Smart Fleet Analysis;
- Using BEVs for Emergency Resilience;
- Electric Bike (E-bikes) Trial.

The proposed approach to each component of the project is described in the following section of this feasibility study. It is anticipated that each component of the project will be managed as a discrete project, with graduate students focusing their research on a specific project component. While learnings from each component will be shared and integrated during the project analysis and evaluation phase, managing the project components as separate, discrete projects allows both CRD staff and IESVic researchers to understand, design, evaluate and communicate about a project that otherwise would be quite complex.

Fuel Cell Electric Vehicle (FCEV) Field Trail

The proposed FCEV field test includes the following:

- Lease six FCEVs for a three-year period;
- Provide training for staff on the use and fuelling of these vehicles;
- Work with CRD staff and IESVic to monitor the benefits and challenges of using FCEVs in the CRD fleet;
- Work with the Province and Industry to provide publicly available hydrogen fuelling facilities in the CRD region;
- Work with the CHFCA to promote the 'cleanest' possible source of hydrogen;
- Coordinate training for local fire crews (in managing fuel cell vehicles).

Hyundai Tucson. Image from Hyundai

The Hyundai Tucson Fuel Cell has an estimated driving range of approximately 425 km, depending on driving conditions.[17] It can refuel from empty in less than five minutes. This provides much greater range than can be currently achieved with commercially available BEVs (with the exception of the Tesla). Its cargo space, high clearance, and the anticipated availability of all wheel drive capabilities in the planned 2018 version meet CRD's operational fleet needs.

These FCEVs will be leased for a three-year term, as Hyundai does not currently make these vehicles available for purchase. Hyundai has agreed to make two of its pre-production Tucson FCEV available for the CRD to lease in 2017, with a further four Tucsons (production models) available for lease in 2018. CRD will also investigate other available models for 2018, as applicable.

In 2015, Hyundai brought eight hydrogen-powered Tucsons into Canada and currently leases six of them to drivers in the Vancouver area. The vehicles are fueled at Powertech Labs, a subsidiary of B.C. Hydro, in Surrey B.C.[18]

Hydrogen Fuelling Station (HFS)

While hydrogen fueling infrastructure is critical to the FCEV field trial, the development and instillation of Hydrogen Fuelling Station (HFS) infrastructure is being completed separately but synergistically with the CRD's ZEFI pilot project.

Image from Powertech Labs

The BC Ministry of Energy and Mines is working with industry and leveraging existing Clean Energy Vehicle program funding and compliance pathways under the *Renewable and Low Carbon Fuel Requirement Regulation* to support the development of a no-or-low GHG emission hydrogen fuelling station in the capital region to enable the CRD's Zero Emissions Fleet Initiative Pilot Project to proceed.

The pilot project is a critical factor enabling the Province and Industry to work together in the instillation of a hydrogen fuelling station in the region, a targeted area for hydrogen infrastructure in BC. Without this assurance of vehicles using the station, there would be no incentive for Industry to consider the south island. Likewise, automakers with plans for broader market FCEV deployment will only consider regions where there is hydrogen fuelling infrastructure. Consequently, the pilot project will be transformative in enabling the Capital Region to kick-start the process of transition to widespread use of Hydrogen Fuel Cell Vehicles. Further details about the commitment toward the instillation of hydrogen infrastructure within the Capital Region to enable this project to proceed can be found in Appendix 1.

The CRD is working with a hydrogen fuel cell industry partner to identify appropriate sites for the installation of a Hydrogen Fuelling Station (HFS) in the Greater Victoria area.

The CRD intends that this facility should be built and operated by industry, and be made publicly available. The CRD recognizes the role it has to play as an organization to encourage investment in hydrogen fuelling in the Capital Region as a facility user and as a regional leader.

On October 12th, 2016, the CRD Board endorsed a resolution for staff to further develop the Fuel Cell Electric Vehicle Project, including exploring opportunities to support the development of hydrogen fuelling infrastructure within the Region. The HFS technology and site are yet to be finalized, but will be selected using the following parameters:

- **GHG Emissions:** As identified in the project aims, critical to the success of this project is the ability of the project to minimize GHG emissions, including the lifecycle emissions associated with the energy used to produce hydrogen. Feasibility analysis included later within this report has identified that lifecycle emissions would be minimized through selection of hydrogen production technology options that have low or no GHG emissions including electrolysis using clean electricity or carbon-neutral waste hydrogen sourced locally, on Vancouver Island. The British Columbia Climate Leadership Plan has set a goal of 100% clean or renewable electricity within British Columbia by 2025. If this goal is achieved, lifecycle emissions associated with the production of hydrogen through electrolysis would be minimized to zero by 2025;
- **Fuelling Infrastructure Siting:** This project envisions hydrogen fuelling infrastructure that is accessible to both the CRD fleet for operational needs, and to the community, more broadly. A centrally located fuelling site that is publicly assessable will be necessary to achieve these aims. Fueling infrastructure may initially be sited on CRD-owned property. Over the mid-to long term, the project will seek to site infrastructure at a public fueling site;
- **Fuelling Infrastructure Technical Requirements:** Operationally, CRD envisions piloting sport-utility vehicles that have a range of 400–500 kms and fit within the 'light-duty' vehicle category. Infrastructure will be designed to meet minimum capacity requirements for piloting six vehicles of this nature. While this represents a minimum requirement, it is expected that in the future, the fuelling infrastructure in the Capital Region could have capacity for over 100 vehicles/week, as its availability is expected to stimulate adoption of FCVs by other organizations and the extension of the personal vehicle lease programs within the Capital Region.

Catalyst for Clean Growth Economy Investment

This project is targeting locally made Hydrogen, using electricity from the BC Hydro grid (which has a very low emission factor of 10.67 tonnes/GWh, and will be 100% clean and / or renewable by 2025, in line with a commitment made within the BC Climate Leadership Plan), or sourced from locally available waste hydrogen from industrial operations.

A key component of this project is to ensure that lifecycle emissions associated with the production and transport of the hydrogen to the fuelling site are minimized.

Conducting the pilot project energizes the spirit of inquiry and innovation that is needed to press forward in achieving long-term clean growth objectives. Examples of other hydrogen projects that the CRD zero emissions fleet initiative will build upon include:

- In preparation for the Whistler 2010 Winter Olympics, BC Transit supported BC's Hydrogen Highway by implementing the world's largest demonstration fleet of fuel cell electric buses in Whistler, BC. CRD staff have spoken with staff at BC Transit to learn from BC Transit's demonstration project experience, and integrated these learnings into the project design of the Zero Emissions Fleet Initiative. These include leasing vehicles instead of buying them for the initial pilot period, and ensuring there is a local, affordable, low embodied GHG source of hydrogen available to fuel the vehicles.

- In 2010, the City of Surrey tested two zero emissions hydrogen fuel cell vehicles, as part of the City's Green Energy Fleet Plan. The findings were measured and ranked against traditional gas and diesel powered vehicles. CRD staff have spoken to the City of Surrey Fleet Manager, and have integrated the lessons learned in that pilot in the design of the CRD pilot. CRD is building upon Surrey's pilot experience by utilizing next generation vehicles that were not available in 2010, and by partnering with IESVic to study, analyze and publish the results of the pilot project, and ensure they are widely shared.

A 2016 Canadian Hydrogen Sector Profile developed by the Canadian Hydrogen and Fuel Cell Association (CFHCA) found that the British Columbia is a center of hydrogen and fuel cell innovation with 31% of all Canadian hydrogen facilities and activities located in the Province.

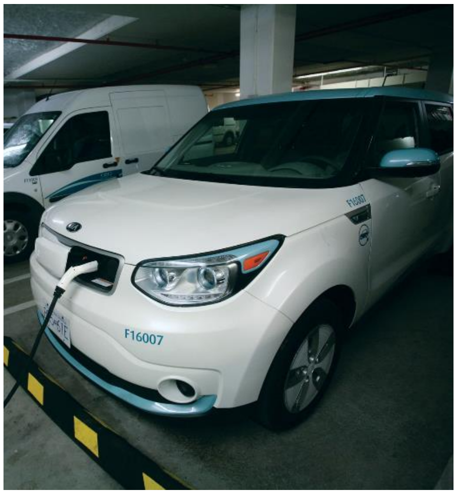
While the Province is a home to hydrogen research, development, manufacturing, supply, professional services and commercialisation support, there is opportunity to build upon British Columbia's expertise in hydrogen technology and expand the application of hydrogen fueling infrastructure within the Province to create a catalyst for investment in clean growth. According to a letter of support for this Project provided by the BC Ministry of Energy and Mines, the CRD's Zero Emissions Fleet Initiative Pilot project will "enable the installation of a hydrogen fuelling station in the Region, a targeted area for a hydrogen infrastructure network in B.C." (see appendix 1). This will be of great benefit to the Region, the Province, and the hydrogen industry as BC continues to solidify its leadership within Canada, a country that is already internationally recognized for its leadership in fuel cell research, development and early stage commercialization.

More information about hydrogen, FCEVs, and hydrogen fuelling infrastructure can be found in appendix 4.

Battery Electric Vehicle (BEV) Testing and Smart Fleet Analysis

In 2016, the CRD fleet acquired its first BEV: a KIA Soul. In the near term, CRD's climate action strategy aims to identify a path to meeting the highest level of the West Coast Electric Fleet Pledge (striving towards purchasing at least 10% zero emissions vehicles for all new light-duty fleet purchases) and in the long term, the organization is striving towards zero emissions for all new fleet vehicles.

CRD KIA Soul



Battery electric vehicles show promise as CRD looks towards transitioning the fleet towards this zero emissions goal. The Battery Electric Vehicle Testing and Smart Fleet Analysis component of the project is designed to identify further opportunities for electric vehicle uptake, within the CRD fleet. The pilot project includes:

- Purchasing two 'tester' BEVs , incremental to normal fleet requirements;
- Adding at least two more BEVs to the fleet, replacing current fleet ICE vehicles;
- Conducting Smart Fleet analysis by adding telematics to up to 40 fleet vehicles;
- Identifying opportunities for future EV procurement and fleet optimization.

With support from the GMF grant, the CRD intends to purchase two 'tester' BEVs that are incremental to normal fleet requirements. These will be made available for trial purposes to staff across the organization, with an aim to provide staff the opportunity to test out BEVs. Staff have expressed concerns about the ability of electric vehicles to meet operational requirements including range anxiety, concerns about cargo capacity and concerns about increased overall lifecycle cost. In practice, the user of CRD's first electric vehicle has found that these concerns are unfounded. This project will allow staff to test the vehicles to validate, or disprove the current concerns related to BEVs. IESVic will design a testing framework to ensure reliable, measureable, verifiable and transferable results. These BEVs will be used in a series of different locations for a test period of 2–6 weeks so that staff can test them out and provide feedback on the results.

Over the two-year testing timeframe, CRD employees who use light-duty fleet vehicles will have the opportunity to test these BEVs. It is hoped that this 'try before you buy' approach will enable CRD's divisions and departments to gain the confidence necessary to assess the opportunity of moving towards zero emissions alternatives to ICE vehicles, when future fleet vehicle purchases are made.

To conduct the Smart Fleet analysis, CRD will install telematics (also called data loggers; more information on p. 26) on 40 fleet vehicles to track driving patterns and, with the support of IESVic, conduct comparative analysis relative to the use of ICE vehicles. The resulting Smart Fleet analysis results will inform optimum permanent deployment of the 2 ‘tester’ BEVs as well as the purchase of additional BEVs and/or FCEV purchases to replace aging ICE vehicles according to the fleet management vehicle replacement schedule. To assess BEV capability for emergency power supply, one of the ‘tester’ BEV vehicles will also be used for the emergency power system research objective of the pilot project as described in the next section.

The telematics devices and smart fleet analysis will be conducted with support from the provincially funded Fleet Champions program. Through the program, eligible fleets can apply for an EV business case assessment. This analysis can help fleet managers understand the costs and savings of adopting EVs. As part of this assessment, the program provides the hardware and a 1-year subscription for use of telematics (data logger) devices that track vehicle usage and fuel consumption patterns in up to 40 ICE vehicles and 10 electric vehicles. As part of the ZEFI Pilot Project, CRD is applying for additional funding from GMF to extend the use of these data loggers into the fleet for an additional year. This will give IESVic researchers two years of baseline data to understand CRD’s fleet usage patterns, to use in the fleet optimization analysis.

If the data logger telematics devices prove to be useful tools for managing the sub-segment of the fleet that CRD is testing them within, CRD intends to move towards implementing telematics within the entire vehicle fleet, and integrating this data within the organization’s ‘SAP’ enterprise software and accounting system.

Using ZEVs (BEVs and FCEVs) for Emergency Resilience

Large fleets of ZEVs hold an added value of energy storage potential. This creates interesting new possibilities for local governments, including:

- Using the ZEV to provide power to the grid in emergency situations (vehicle-to-grid);
- Using the ZEV as emergency vehicles during major power outages;
- Using ZEV as emergency vehicles during disasters when fossil fuels are limited or unavailable;
- Using the vehicle to power tools and equipment on-site, avoiding idling and fossil fuels to provide stationary power.

Vehicle-to-Grid (V2G) has been widely addressed by the scientific community. It is also possible to use vehicles to power individual buildings (V2B) however its relevance during major events, such as earthquakes, remains relatively unexplored. In principle, in cases of emergency when the power system fails, a fleet of alternative fuelled electric vehicles (AFEV) would have the potential to provide back-up power, with relatively small or no additional infrastructure. This operational mode would could also cover stationary off-grid power operation, when the AFEV would be in idle mode and electricity is required for a specific task.

On the other hand, during major disaster events the emergency electric network infrastructure has proven to be more reliable than fossil fuel delivery infrastructure. A few days after the tragic events in Japan in 2011, the emergency electric infrastructure supporting city halls was already in operation, whereas the fossil fuel stations were out of service (also for security reasons). Plug-in Electric Vehicles were donated by Mitsubishi, Toyota and Nissan and deployed by city halls in order to support emergency operations. Working with CRD's Protective Services department and Staff, this project will look into the technical and economic aspects of the utilization of a fleet of electric vehicles for emergency resilience considering the major risks of disaster that characterize Vancouver Island.

Outside of emergency situations, many day-to-day work tasks require the vehicles to be idling to provide power for equipment, or the use of on-vehicle generators. Beyond the electrical capabilities of the vehicles' own systems, there is an opportunity to replace idling and power requirements with portable power packs (battery or H2). These could be swapped between vehicles, and depending on the fleet usage characteristics provide large emissions reductions. More detail on this research project is provided in Appendix 7.

Electric Bike (E-Bikes) Trial

CRD’s source control inspectors travel to conduct inspections across the region. However the downtown core area, near CRD’s headquarters has a high density of inspection sites. While these locations are relatively near CRD’s headquarters, staff require heavy equipment that is difficult to carry, when walking. Driving to these sites isn’t ideal, as parking in the downtown core can be difficult to find. Given these constraints, staff in this group have identified E-Bikes as a potential solution. As part of the FCEV pilot project, CRD source control staff will pilot use of E-Bikes for carrying out their work, including inspecting businesses. The City of Victoria is currently upgrading its cycling infrastructure to enable safe and efficient travel. The E-Bikes will be equipped with data loggers that IESVic will monitor and analyze.

The comprehensive E-Bike trial involves:

- Purchasing two E-Bikes of different types for comparison purposes, and associated gear (helmets, lights, high-vis vests, locks, battery charging docks etc.);
- Determining WCB and insurance requirements for use of bikes in the work place and ensuring these are met;
- Coordinating safety training for inspectors using the bikes;
- Mapping the inspection territories for E-Bike travel;
- Creating standard operating procedures (and ensuring adherence to) to guide E-Bike use and care (safety, parking, anti-theft, re-charging etc.);
- Defining minimums for use (e.g., minimum twice per week dependent on safety / weather factors);
- Tracking the mileage and electric energy use and estimate GHG savings;
- Providing a final report on number of trips, distances travelled, cost/benefits, challenges, observations and recommendations for knowledge transfer.

[19]E-Bike images sources

Results from the trial will be used to determine if there are opportunities to incorporate e-bikes into the CRD fleet, and use them more broadly within CRD operations. More information on the e-bike pilot can be found in appendix 5.

Feasibility Considerations

This feasibility study aims to assess the feasibility of the Zero Emissions Fleet Initiative Pilot Project objectives and components. The following feasibility questions have been identified:

- What are the CRD's GHG reduction targets and the plans to attain them?
- What are the opportunities for reducing GHG emissions from the CRD Fleet?
- What are the benefits and challenges of adding FCEVs, BEVs and E-Bikes to the fleet?
- How will the project results be measured?
- How will the project results be shared?
- What are the expected outcomes of the project?
- What is the project budget and how will it be funded?
- What is the project schedule?
- What are the risks of the project and how will these be mitigated?

The responses to these questions forms the basis of this feasibility study, and attests to the feasibility and value of undertaking this pilot project.

What are the CRD's GHG reduction targets and the plans to attain them?

The CRD has clearly acknowledged and committed to taking action to address climate change within operations as well as at the regional level to reduce contributions to climate change and to prepare for the uncertainty of a changing climate brings. The impacts of climate change are already being felt globally and locally, and these impacts will continue to intensify and affect the capital region for decades to come.

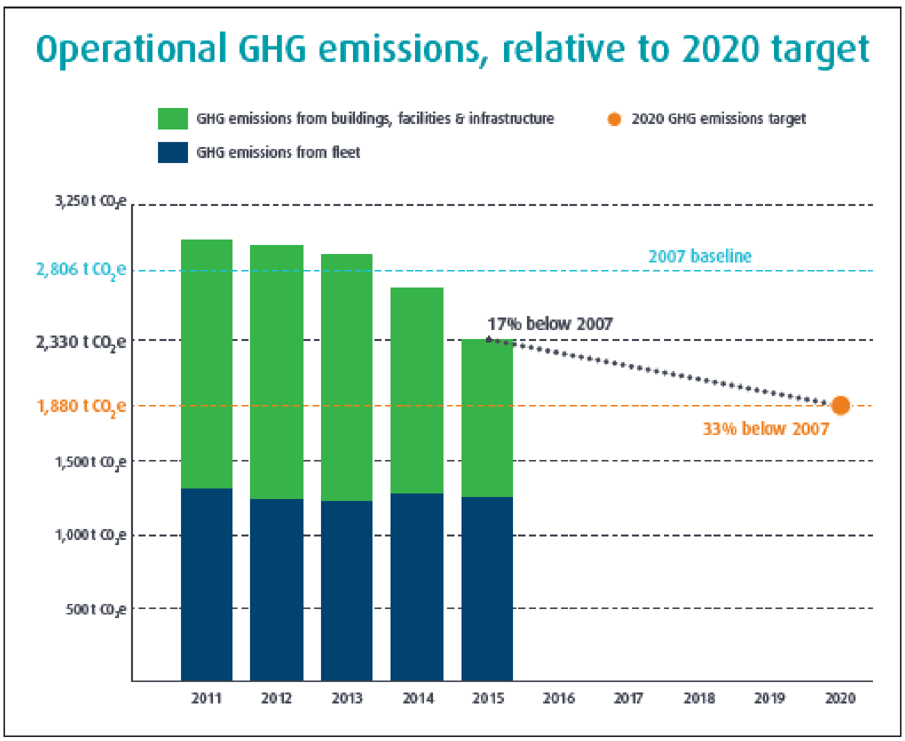
In response to this context, the CRD has made a series of commitments to address climate change:

- In 2008, the CRD signed the British Columbia Climate Action Charter and additionally committed to a 33% reduction in corporate GHG emissions over 2007 levels by 2020;
- In 2015, the CRD board committed to accelerating activities to meet its GHG reduction commitments within the 2015 Corporate Plan;
- The 2016 Corporate Climate Action Strategy identifies several opportunities for further reductions in GHG emissions reductions, including achieving "continuous, significant reductions in GHG emissions from the fleet and strive[ing] towards zero emissions for new fleet vehicles."[20]

- The 2016 Regional Climate Action Strategy[21] commits CRD to supporting continued electric vehicle (EV) infrastructure deployment in co-ordination with local governments and the private sector. The strategy recognizes EV infrastructure as both fuel cell and plug-in charging infrastructure.
- The CRD is a signatory to the West Coast Electric Fleets and has pledged to: "evaluate Zero Emission Vehicles (ZEVs) as part of all fleet purchases". The organization is aiming to increase its pledge commitment over time, in line with the West Coast Electric Fleets goals of [taking] "actions to expand the use of zero-emission vehicles, aiming for 10 percent of new vehicle purchases in public and private fleets."[22]

Analysis completed as part of the 2015 Corporate Climate Action Strategy shows that the organization has made progress towards the 2020 GHG reduction target, with current annual emissions outputs at approximately 17% below, 2007 levels. However, to meet the targeted 2020 reductions, the CRD needs to further reduce emissions by 450 tCO_2e annually, in the next four years.

FIGURE 1: Corporate GHG emissions baseline (2007) compared to 2011–2015

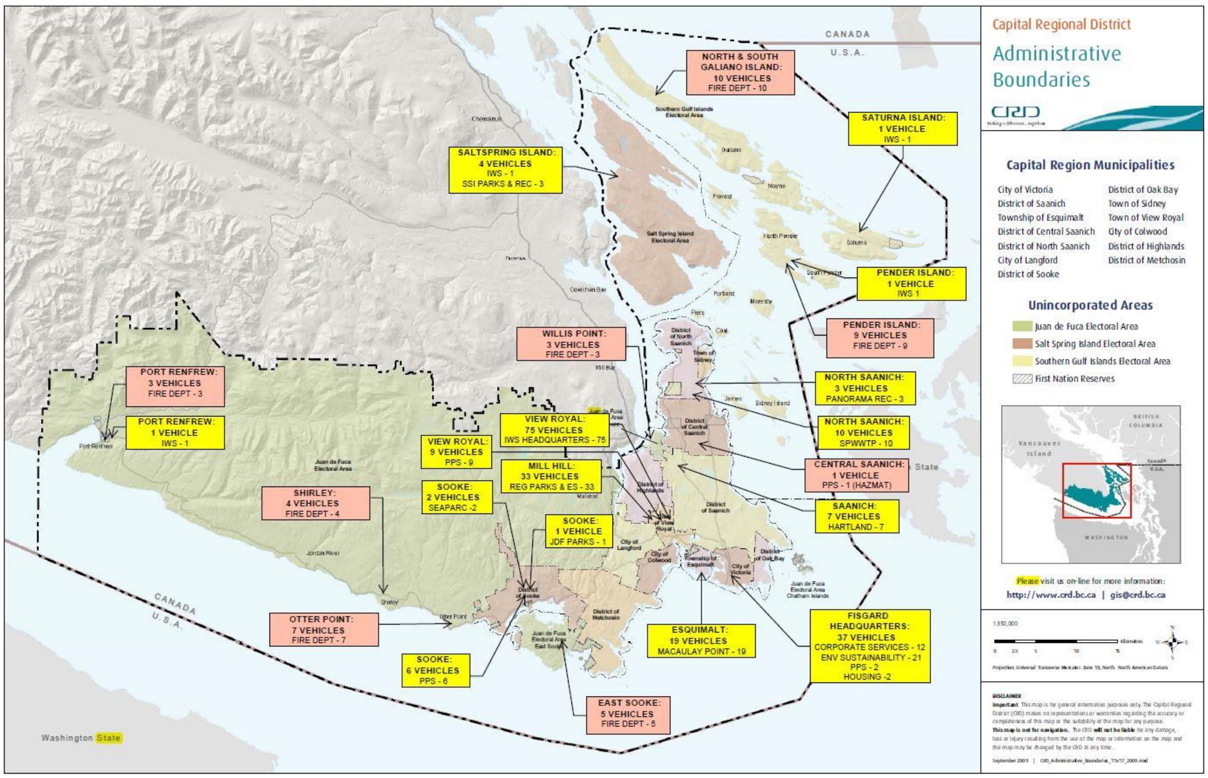


This poses a challenge given that the CRD has implemented several successful emission reduction initiatives over the past few years and will be continuing to expand its asset base moving forward. Given that the CRD fleet still accounts for 54% of overall operational emissions—despite implementation of numerous pro-active fleet management strategies—more substantive fleet measures are needed to achieve the 2020 CRD climate action target (See Figure 1).

What are the opportunities for reducing GHG emissions from the CRD Fleet?

The CRD maintains a fleet of about 304 vehicles and 51 pieces of equipment, located at numerous centres of operation around the region (*see FIGURE* 2). The fleet includes a range of vehicle types, from cars and light duty trucks to heavy equipment including backhoes and tractors (*see Appendix 3*). Some vehicles are part of a centrally managed fleet, while others are owned and controlled by the applicable CRD service. Many of the vehicles are heavy equipment or large pick-up trucks, with a need to cover large distances in a single day and / or to travel in rough or off-road.

FIGURE 2: *Location of CRD Fleet Vehicles*



If the CRD were to continue its fleet replacement program and replace fleet vehicles with similar ICE models, this would result in a reduction of about 6 tCO_2e annually, simply because the newer models are more efficient. However, this falls far short of the target of 450 tCO_2e annual reductions, in the next four years.

“Right-sizing” of the vehicle fleet has been taking place for more than ten years, aiming to eliminate un-needed vehicles and replace older vehicles so as to increase fuel efficiency and cost-effectiveness. Where possible, diesel vehicles have replaced gasoline vehicles for greater fuel-efficiency, and the regional district currently operates four hybrids and one battery electric vehicle (BEV). Staff has also been working to increase fuel efficiency, for example through anti-idling programs.

In 2014, CRD worked with the Fraser Basin Council to conduct an “E3” (energy, environment, excellence) review of the CRD fleet as part of the CRD’s effort to better understand its options for improvements to the fleet. This review identified several options for improvement, including driver training to reduce idling, replacement of vehicles with BEVs and hybrids (as possible), and better tracking of individual vehicle performance. Results of the E3 analysis can be found in Appendix 3. Since 2007, the CRD has increased the number of on-road fleet vehicles by 13%; however, GHG emissions from the fleet have gone down by 5%.[23] Until better unit-by-unit fuel consumption tracking is established through the use of data loggers, it is difficult for CRD to accurately quantify the impact that change in procurement decisions is having. The research and evaluation design proposed for the pilot will close this critical data gap.

Subject to the results of the Zero Emissions Fleet Initiative Pilot Project and the ability of zero emission vehicles to meet operational requirements in a cost effective manor, the CRD fleet manager has identified approximately 100 units (30 car / SUV and 70 light pick-ups) that could be considered for replacement to zero emission vehicles currently on the market. The 100 light duty zero emissions units would reduce emissions by an estimated 440 tCO_2e/year.

The CRD fleet creates more than half of the corporate emissions. As the vehicle fleet is replaced on a continuous basis, it provides an obvious opportunity for finding significant GHG reductions. This opportunity is particularly attractive, if ZEVs are able to meet operational requirements at a cost equivalent to, or less than current operations.

What are the benefits and challenges of FCEVs, BEVs, and E-Bikes?

FCEV

Fuel cell electric vehicles are zero-emission vehicles that will reduce GHG inventory and tailpipe emissions by 100% compared to their conventional counterparts. The Center for Climate and Energy Solutions has calculated that the life-cycle FCEV emissions are less than the life-cycle emissions for hybrid electric vehicles (HEVs), and it is anticipated that this project will further exceed this outcome. Additional information on FCEV, hydrogen fuel cells and hydrogen fuelling is provided in Appendix 4.

Benefits of FCEV

- **Reduced emissions:** FCEVs are zero tailpipe emission vehicles. Each FCEV will reduce the CRD operational carbon emissions between 2.2 and 4.4 tCO2e/year for each ICE vehicle it replaces. While embodied GHG emissions are associated in the production and transport of hydrogen to the fuelling site, this project seeks to minimize lifecycle emissions by using low / no emissions sources of hydrogen (see page 11).
- **Suitability:** The FCEVs will replace ICE vehicles for operational situations where currently available BEV models are not an option. The additional range, rapid fuelling and four-wheel drive system on the vehicle models anticipated in 2018 allow it to be used in conditions and locations where a BEV is not well suited. An example is the CRD watershed, with rough steep roads and no place to recharge a BEV.
- **Replicability:** The CRD hopes that by making a HFS publicly available, it will encourage others—other local governments, fleets and individuals—to adopt FCEV technology and reduce their GHG emissions. If there is sufficient uptake, it could lead to additional hydrogen fuelling stations on the south and mid-Vancouver Island areas.
- **Scalability:** The intention is to begin with piloting the use of the FCEV technology with six vehicles within the CRD fleet, and scale up as the initial pilot phase is successful. The scale up would include

both acquisition of more vehicles within the CRD fleet, and the adoption of the technology within other fleets within the Region (potentially provincial, municipal and the University) along with private citizens. The hydrogen fuelling station (HFS) is also scalable, and could be designed to provide additional capacity as the need arises.

- **Economic opportunity:** The creation of a HFS creates direct economic opportunities and jobs relating to the production and sale of hydrogen. As well, it will be a catalyst allowing OEMs (such as Toyota, Hyundai and others) to sell FCEVs in this market.
- **Reduced hydrocarbon impacts:** By avoiding the use of fossil fuels, these vehicles reduce hydrocarbon impacts such as no oil leaks, gas spills that can impact water quality, reduced health impacts from breathing gas fumes (with benzene content) while fueling.
- **Leadership:** The pilot project positions the CRD as a leader in this field. This is consistent with the aim of the CRD Corporate Climate Action Policy Statement to guide the CRD's operations:[24]
  "The CRD will demonstrate leadership within operations and the management of the CRD owned facilities, assets and lands to reduce greenhouse gas emissions and adapt to climate change. The CRD will provide a climate lens for Board decision making. Implementation of this policy and all related sub-policies will be guided by the CRD Corporate Climate Action Strategy and is the responsibility of all divisions and departments"

Challenges of FCEV

- **It's new:** FCEVs are still a relatively new concept in Canada, although they have gained acceptance in some other world markets. A big challenge for this CRD pilot project is the unknowns in terms of setting up and conducting this pilot—which is precisely why the CRD is undertaking the project: to learn about how FCEVs function in a fleet environment and then share this knowledge with others.
- **Embodied GHG Emissions:** GHG emissions can be embodied in the production of hydrogen used to power FCEVs, and the transport of hydrogen to the fuelling site. Critical to the success of this project will be minimizing the embodied emissions, including the lifecycle emissions associated with the energy used to produce hydrogen and transport it to the fuelling site. This will be achieved through targeting hydrogen production methods that have low or no GHG emissions.
- **There is no fuelling station:** A significant challenge to this pilot project is the current lack of fuelling infrastructure in the Capital Region. To enable this pilot project to proceed, the Province of BC Ministry of Energy and Mines has committed to working with Industry to enable the instillation of a hydrogen fueling station within the Capital Region, a targeted area for a hydrogen infrastructure network in B.C. This will be a lasting legacy of the pilot project that's value extends far beyond CRD's operations.
- **Limited vehicle availability:** Obtaining vehicles is a challenge. The CRD had originally hoped to lease six Hyundai Tucsons starting in 2017; however Hyundai can only make two Tucsons available for lease in 2017, with an additional four vehicles in 2018. The good news is that there are a growing number of vehicles about to hit the market, such as the Chevrolet Equinox FCEV (also an SUV) due to be released for testing in the US market in 2018.[25]
- **Maintenance:** Hyundai will remain responsible for maintenance; however, staff will need to be trained on how to use and fuel the vehicles.
- **Emergency response:** FCEVs are a new technology to emergency responders. If an FCEV were to be involved in an accident, emergency responders would need information on any special methods,

including existing hydrogen codes and standards, to keep themselves and others safe. (This is similar to the initial response to BEVs, where emergency responders initially expressed concerns about electrocution.)

BEV

Benefits of BEV

- **Zero emissions:** There are no tailpipe pollutants or GHGs associated with the operation of a BEV. Further, in British Columbia, the electricity used is very clean (10.67 tCO_2e/GWh), so the embodied GHG emissions associated with the electricity production are very low. British Columbia has targeted 100% clean electricity by 2025, reducing this emissions factor to zero.
- **Very low fuel costs:** A typical CRD vehicle uses about $4,000–5,000 of fuel each year. A BEV will use about $250 of electricity/year.
- **Low maintenance costs:** An electric motor is a very simple device, with only one moving part. With no need for oil changes, mufflers, transmission concerns, etc., the cost of maintenance is typically lower than an ICE vehicle. Most OEMs warranty the battery for seven to eight years, which aligns with CRD's planned replacement schedule. Regular maintenance on tires and brakes are of course required.
- **Reliability:** As with maintenance, the reduced number of moving parts in an electric motor make it less prone to breakdown.
- **Reduced hydrocarbon impacts:** By avoiding the use of fossil fuels, these vehicles reduce hydrocarbon impacts such as no oil leaks, gas spills that can impact water quality, reduced health impacts from breathing gas fumes (with benzene content) while fueling.

Challenges of BEV

- **Lower range, slow re-charging:** Even with a level 2 (240V) charging station, BEVs typically take 3–5 hours to recharge. This means the vehicles must be used in places where the daily usage is less than 100-150 km (depending on the model and the driving conditions), unless fast chargers become readily available. (*In the CRD, there are currently fast chargers in Saanich and Colwood, reducing charging time to about 30 minutes.*)
- **Range and battery capacity loss:** BEVs can suffer from significant loss of range/battery capacity with time depending on driving and charging cycles, and battery capacity is lowered when operating in cold environments.
- **Availability of suitable models:** While the variety of available models is gradually increasing, there are still limited or no models of light pick-up trucks, SUVs or four-wheel / all-wheel drive options.
- **User perception:** Some employees are concerned about switching to a fully electric vehicle, because of concern about the distances typically travelled (range anxiety).
- **Maintenance:** Very low maintenance requirements are a benefit of BEVs. However, as they are relatively new to the fleet, it will require some re-training of maintenance staff so that they are aware of what maintenance schedules are required.
- **Availability of charging infrastructure:** The CRD will install additional charging stations at its headquarters in Victoria and at the Integrated Water Service location. However, for some of the

remote parts of the CRD (such as in Port Renfrew), there are no EV charging stations and any charging will have to be done using a level 1 (110V) charge (thus extending charging time to 12–15 hours).

- **Cost:** On a lifecycle basis, BEVs are less expensive than their ICE counterparts for capital and operating. However, the upfront cost is generally much higher (although there may be reductions for fleet purchases). While this is somewhat offset by the Province's Zero emissions vehicle incentives, it is still a challenge for a fleet which has limited capital funds available each year for vehicle replacement.

E-Bikes

A portion of the CRD fleet operates solely in the urban core of the region, with most trips being for very short distances. As part of the move towards a zero emissions fleet, the CRD intends to test the use of electric bicycles (E-Bikes) as a potential replacement for ICE vehicles. The initial testing will be done by source control staff. More details on the E-Bike project is provided in Appendix 5.

Benefits of E-Bike

- **Zero emissions:** All E-Bike trips that replace ICE vehicle trips will result in a 100% reduction in emissions for that trip.
- **Healthier staff:** Bicycle riding offers many health and fitness benefits, which in turn lead to fewer sick days for staff.
- **Easy parking:** Parking in Victoria can be challenging, whereas it is almost always possible to find bike parking space close to destinations, saving employees time finding a parking space and walking to their final destination. An added advantage is that bike parking is free.
- **Staff willingness:** E-bikes provide power-assist and will be adopted by a wider spectrum of individuals than conventional bikes as they do not require the same level of effort or fitness.
- **Reduced hydrocarbon impacts:** By avoiding the use of fossil fuels, E-bikes reduce hydrocarbon impacts such as no oil leaks, gas spills that can impact water quality, reduced health impacts from breathing gas fumes (with benzene content) while fueling.

Challenges of E-Bike

- **Storage:** Staff need to be able to carry files and equipment, so the choice of bike needs to include appropriate cargo capacity.
- **Weather:** Staff will need raingear for wet weather usage (as well as safety gear, including helmets, lights, high visibility vests etc.)
- **Security:** Bikes will need to be equipped with anti-theft devices. The bikes can be securely stored at CRD HQ overnight and when not in use.
- **Staff willingness:** The test will start with people who enjoy bike riding—it may not be popular with all staff.

How will the project results be measured?

Telematics

The project will involve use of telematics, which is a technology used to monitor the location, movement, status, performance and behavior of a vehicle within a fleet. A GPS receiver and an electronic GSM device is installed in each vehicle to enable communication with the driver and web-based software. Detailed information is tracked for each vehicle in the fleet, such as: start time, stop time, idling status, location, and speed. This results in a comprehensive tracking of fleet activity in one centralized web-based interface for analysis and decision-making relating to:

- Increasing productivity
- Reducing labor costs
- Controlling fuel costs
- Improving customer service
- Increasing fleet safety and security
- Reducing operating expenses
- Driving cycles
- Optimized scheduling
- Reducing unauthorized vehicle use[26]

Smart Fleet Analysis

The Smart Fleet analysis will focus on the existing fleet and its usage. Telematics will be installed on up to 40 ICE vehicles through the provincially-funded Fleet Champions Program to gather detailed information on vehicle usage, with a focus on reducing GHG emissions, enhancing utilization and reducing operating costs. All staff driving a vehicle with telematics devices will be notified, so they are aware of the initiative. Current data relies on information provided by vehicle users and the quality of data varies. IESVic will analyse this data to answer the question of the adequacy of each alternative fuel technology (including a combination of FCEV, BEV, Plug-In Hybrid Electric Vehicles, and Hybrid Electric Vehicles) or any combination of them that will lead to the lowest GHG emissions per year; this may be identified as the planning optimization problem. The analysis will then look at the question of the optimal scheduling of functions / operations associated to each unit in the fleet over a time span, having the fundamental targets of minimizing the operation cost and associated GHG emissions; this may be identified as the scheduling problem. Both the planning and the scheduling problem would be bounded by the operational and corporate constraints, and informed by drivers' behaviour.

Operational constraints may include vehicle status / performance, weather conditions, fuelling / charging locations, etc. Corporate structural constraints are those imposed by the corporate body of the CRD which is characterized by a fleet distributed throughout a wide region in sub-fleets, each one of them serving the specific needs and under the particular conditions of each CRD service. Corporate constraints may include topology and / or geography, spectrum of ranges served, services provided, number and classes of vehicles assigned, etc. Comparing the scenarios with and without the corporate constraints, will be essential for future policy decision making regarding GHG emissions.

The outcomes of this research will include:

- A mathematical tool for planning replacement of fleet units, considering alternative fuel drive train technologies
- A mathematical tool for optimal scheduling of a mixed fleet of vehicles
- Data based recommendations for fleet renewal decisions and policy developments to promote reduction of corporate GHG emissions in the public sector in BC

This information will enable CRD to identify improvements to fleet use with existing vehicles, as well as vehicles that could practically be replaced by BEV or FCEV options.

All of the new FCEVs and BEVs will be fitted with telematics (*see box*). IESVic and CRD will monitor both the physical and social parameters of this field trial:

- Do the vehicles perform as expected: do they meet operational requirements; what challenges and benefits do they provide?
- How do drivers respond to using these vehicles? Is this a positive experience (and if not, why not)?
- What challenges / benefits arise from fuelling and maintenance?
- How does the public respond to the FCEV?
- What challenges are encountered in establishing a HFS, and how are these overcome?

This information will be gathered from the telematics and interviews with staff. CRD staff will monitor media and social media to track public comments on this project.

Environmental Performance Targets

Through the feasibility work, the Zero Emissions Fleet Initiative project team has identified the following indicators, baseline and performance targets for the pilot project:

Project Parameter	Unit	Baseline performance before pilot project	Anticipated performance after project completion
Greenhouse gas emissions per light duty vehicle	tonnes co2-e	4.4	0
Total annual fleet GHGs	tonnes co2-e	1,249	1,196
Vehicle kilometers travelled (entire fleet)	VKT	1,443,823	1,400,000
Number of EVs (BEV and FCEV) in CRD fleet	Number	1	11
Number of e-bikes in CRD fleet	Number	0	2

Number of hydrogen fuelling stations in region	Number	0	1

The results of the project compared to the environmental performance targets established by the Project Team will be presented in the project final report.

How will the project results be shared?

An important part of this pilot project is to share the learnings with others to enable further deployment of zero emissions vehicles across BC. This will take several forms. The novel nature of this pilot project has already generated interest in the local media[27], and CRD will be providing news releases and spokespeople at various points throughout the project.

Good communication with accurate information will be especially important as hydrogen fuelling infrastructure is established within the Region, during the technology selection, site selection and instillation of the HFS phases. While CRD won't be directly involved in these activities, the organization can act as a conduit to share information between industry, and the public. The potential for impromptu conversations that might happen between CRD staff driving the ZEVs and members of the public is significant and helps raise awareness of zero emissions alternatives. As part of the ZEV user training, staff will be oriented on how to make the best of these impromptu communications opportunities to help engage the general public in the project.

Experience elsewhere shows that people can be concerned about explosions / leaks / other events in relation to the HFS, and there may be resistance to some proposed locations. The Canadian Hydrogen Fuel Cell Association has published information related to the safety of hydrogen, and the Canadian Hydrogen Instillation Code (CHIC) defines the requirements applicable to the instillation of hydrogen equipment[28]. CRD can help share this information to create public awareness about hydrogen, and its safety.

Pubic Events

The CRD often participates in community events with information on water conservation, watershed management, climate action and many other topics. Handouts will be prepared and made available in print and online to provide information about the FCEVs and the zero emissions fleet initiative, and used for community events and at other locations (e.g., at the CRD HQ) where it can be shared.

In addition, the Emotive Program (operated by the Fraser Basin Council on behalf of the Province) offers 'ride and drive' and information events to enable the public to learn about and try out EVs. In Vancouver, there has been considerable interest when the FCEVs have been taken to events, and CRD could bring a Tucson for showing at some of these events.

Outreach to other Fleet Managers

CRD will reach out to other fleet managers in the region, including BC Transit and municipal fleet managers to share information about the pilot and successes and challenges.

Symposium

In the third year of the project (2019), CRD intends to host a symposium to share information with interested parties. This will include information on the successes and challenges of the pilot project, the results of the IESVic research, and other lessons learned.

Webinar

Given the rapidly evolving market for zero emission vehicles in BC, a webinar after year 1 sharing the experience to date with other fleets in the province will also be considered.

Published Information

CRD and IESVic will write and publish results of the project, including the planning phase. For example, this report compiles the information gathered by the ZEFI Team for completion of the feasibility study. Research conducted by IESVic may be published within academic or grey literature, and presented at conferences and industry-academia events.

What are the expected outcomes of the project?

This project is expected to bring several benefits:

- Reduced GHG emissions (corporate and community-wide)
- Reduced operational costs
- Economic opportunities
- Innovation
- Community benefit
- Replicability

Reduced GHG Emissions

As shown in TABLE 1, there is significant potential for GHG savings from switching a Jeep Patriot, ½ ton eco-diesel or ½ ton gas truck to a Kia Soul EV or Ford CMax (a plug-in hybrid electric vehicle). In all cases there are substantial GHG reductions, ranging from 9.8 tCO_2e to 29.4 tCO_2e over the vehicle lifetime. Since FCEV have zero GHG emissions, the savings would be as good as or better than for the Soul EV.

TABLE 1: Estimated cost savings and emissions reductions from BEV / hybrid compared to ICE vehicles

ICE Vehicles	Kia Soul			Hybrid (Ford CMax)		
Timeframe	**7 Years**	**9 Years**	**11 Years**	**7 Years**	**9 Years**	**11 Years**
JEEP PATRIOT						

Cost Premium/(Savings) ($)	$ 2,213	$ 256	$ (1,701)	$ (1,284)	$ (2,688)	$ (4,093)
GHG Savings (tCO2e)	(14.970)	(19.247)	(23.524)	(9.874)	(12.695)	(15.516)
½ ECO DIESEL						
Cost Premium/(Savings) ($)	$ (13,504)	$ (15,388)	$ (17,272)	$ (17,001)	$ (18,333)	$ (19,664)
GHG Savings (tCO2e)	(18.027)	(23.178)	(28.328)	(12.931)	(16.626)	(20.320)
½ TON GAS						
Cost Premium/(Savings) ($)	$ (5,820)	$ (6,432)	$ (7,045)	$ (7,104)	$ (9,121)	$ (11,138)
GHG Savings (Kg C02e)	(18.727)	(24.079)	(29.429)	(13.632)	(17.527)	(21.421)

As a signatory of the BC Climate Action Charter, the CRD reports operational GHG emissions using guidance provided by the joint Provincial UBCM Green Communities Working Group. This guidance requires that local governments report tailpipe GHG emissions, along with the emissions associated with electricity production. At this time, embodied emissions associated with hydrogen production are not reported in local government GHG inventories. However, CRD is targeting low-to-no embodied GHG hydrogen production methods for this project, including electrolysis with clean electricity, or the use of carbon-neutral waste industrial hydrogen.

Reducing fleet GHG emissions to near zero, in as many vehicles as possible, is a key objective of this pilot project. The 2014 E3 Fleet Analysis found that the annual emissions per year of the Capital Regional District (CRD) fleet is about 1,179 tCO_2e. Light vehicles in the CRD fleet produce between 2.1 and 4.4 tCO_2e per vehicle annually. Assuming all 12 vehicles / bikes in this project replace an ICE vehicle, the total GHG emissions reduction for the project would be about 132 tCO_2e.

The Smart Fleet analysis will consider the GHG implications of the zero emissions vehicles— both tailpipe and lifecycle emissions. It will also examine various technology options for hydrogen generation, including utilizing waste hydrogen, extracting hydrogen through steam reformation and electrolysis.[29] Additional details on GHG reduction calculations are provided in Appendix 6.

Reduced Operational Costs

Transition to zero emissions vehicles within the CRD light duty vehicle fleet is expected reduce the lifecycle costs of a vehicle when factoring in the reduced fuel costs of ZEVs. Cost analysis and comparison between the Jeep Patriot, a common vehicle in the CRD fleet, and the Kia Soul plug-in electric vehicle (inclusive of a $5,000 purchase incentive) reveals a $2,212 premium in the cost of a Kia Soul to conventional vehicles, over a 7 year timeframe. This premium shifts, however, to saving of $256 and $1,701 over 7 and 9 years respectively (*see Table 1*). Further testing under expected operating conditions is required to determine if these anticipated cost savings can be realized.

Economic Benefits

The creation of the HFS will provide jobs and economic development during its construction and operation. These impacts are unknown at this time, but will be tracked as part of the project. Canada-wide, the hydrogen and fuel cell industry has a significant impact. In 2014, survey respondents from the Canadian hydrogen and fuel cell sector reported:[30]

- Revenue of $199 million
- $119 million of revenue from product sales
- $70 million of revenue from the provision of services
- Research, development and demonstration expenditures of $158 million
- Employment of 1,662 jobs
- 15 demonstration projects
- 79 strategic alliances
- 191 research partnerships

As of 2014, the majority of facilities and activities were in British Columbia (34%) and Ontario (17%), followed by Quebec (10%) and Alberta (3%). The rest of Canada (3%) included facilities located in Manitoba and Newfoundland.[31]

An economic impact study completed in March 2010 conservatively estimates that by 2020, the Canadian hydrogen and fuel cell sector will create 14,500 new jobs, achieve revenues of $1.2 billion, generate $650 million wages and pay $122 million in corporate and personal income tax.[32] A more recent study prepared for the BC MEM in 2015[33] reveals that the clean emission vehicles (CEV) sector could generate exports in the range of $184 million to $222 million annually by 2020. 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 electricity or hydrogen is projected to stimulate increased local spending. The total projected employment and GDP impacts by 2020 include approximately 1,400 full-time equivalent jobs and a GDP annual increase of $80 million.

As of 2015, the BC CEV is estimated to be associated with the following economic impacts:

- $1.2 billion direct, indirect and induced economic output;
- 6,670 full time equivalent direct, indirect and induced employment;
- $667.0 million in direct, indirect and induced GDP.

Innovation

This pilot project creates opportunities for innovation and creativity:

- The pilot project includes work with IESVic to test ways that EVs can share power with buildings, for use during power outages. It will also test ways that EVs can meet on-site power needs, eliminate the need for vehicle idling to generate the power;
- The FCEV pilot testing is one of the first in Canada for a local government fleet; it is envisioned as a catalyst that will lead other jurisdictions using similar fuel cell technologies to reduce their emissions;
- The HFS will need a supply of hydrogen. The CRD will encourage the industry to source hydrogen locally using the “greenest” possible option.

Community Benefits

There will be advantages to Hyundai (and other FCEV suppliers such as Toyota) to having a hydrogen fuelling station on southern Vancouver Island, as this will encourage and enable uptake of FCEV vehicles. A network of Vancouver Island fuelling stations that includes a station near downtown Victoria, a station in the West Shore and a station in Nanaimo would likely serve the needs for FCEV users for the early adoption phase.

Replicability

The project is being developed to be replicated within other Regional Districts, with all materials including the feasibility study, and documentation such as RFPs being made available. The Province of BC hopes to take the model developed within the CRD, and use it to scale-up this infrastructure across the Province.

What is the project budget and how will it be funded?

As a result of the Zero Emissions Initiative Team's work, 66% of the resources needed to implement the pilot project have been secured. The total project cost (cash and in-kind) is $1.04 million; a contribution of $350k (34% of the project total) is required from the Green Municipal Fund (GMF) to realize the full scope and value of the pilot project.

The sources of funding for the project, including the proposed contribution from the GMF is outlined in Appendix 8. Description of the project costs and funding sources is provided below.

Vehicles

- Hyundai Canada has offered a three-year lease on the first two Tucsons, with $6500 down and $848 monthly. The same pricing structure is assumed for the additional four Tucsons. The budget includes costs for vehicle commissioning, wraps and staff training;
- The cost for a Kia Soul EV is $35,500 (before tax). The budget of $40,000 per vehicle includes vehicle commissioning, wraps and staff training. The cost of charging infrastructure has been added as an additional line-item;
- Electric cargo bicycles typically cost $5000–$7500. The budget of $10,000 per bike includes safety gear, raingear, racks and panniers, staff training, bike telematics and locks;
- Vehicle telematics retail for $600 per data logger, plus an annual fee of $505 per data logger per year for licencing.

IESVic Research

There will be three research projects (Smart Fleet analysis, E-Bike analysis and use of EVs for emergency power), each with two Masters or Post-Doctoral Fellows for two years (a total of six student years).

- The total cost for student contributions is $250,000 for the first two years of the project;
- The University of Victoria will provide in-kind support from faculty members, as well as computers, licencing and the power pack;
- Support costs ($30,000) relate to software licences and computer usage at the University of Victoria.

Support and Outreach

- The project feasibility study was completed in late 2016 as part of preparing the application to the GMF fund ($9,000);
- CRD will undertake a study of the market for HFS on Vancouver Island; this study will be completed in early 2017 ($15,000);
- Project management includes CRD staff time to conduct communications and outreach, as well as overall project management;
- The symposium costs include venue and refreshments, as well as the conference planning, management and implementation.

Funding Sources

A total budget of about $1.04 million is required for this project. Funding sources are as follows.

- **Capital costs for FCEV:** These are based on leasing six FCEV with $6,500 down and $848 monthly (2 vehicles for 36 months, 4 vehicles for 30 months), plus 6 wraps @$1000, for a total of $222,363. The Province will pay $6000 per vehicle from its Zero emissions vehicle Program, and the CRD will pay $11,250 per vehicle from its equipment replacement fund (the equivalent cost of replacing an ICE vehicle), plus the cost of applicable taxes. The cost differential ($104,316) is requested from GMF;
- **Operating costs for FCEV:** It is assumed that Hyundai will assume maintenance costs while the vehicles are on lease. Other maintenance costs, including hydrogen fuelling, insurance etc. is estimated at $5,500 per vehicle per year, for a total of $88,000. The CRD will pay operational costs from its equipment operating fund;
- **Capital cost of BEVs:** The cost of the BEVs is based on $40,000 per vehicle, which includes the cost of purchase ($35,500), vehicle wraps and commissioning. The Province will contribute $5000 per vehicle from the Clean Energy Vehicle Program, and the CRD equipment replacement fund will pay for two BEVs ($40,000 each) and all applicable taxes from its fleet replacement fund. The request from GMF ($58,000) covers most of the cost of the purchase of the two 'tester' BEVs, with the remainder from the CRD equipment replacement fund;
- **Operating cost of BEV:** The GMF will pay for the first three years of operation for the two 'tester' BEVs (~$250 per vehicle year for electricity costs and $1000 per vehicle per year for insurance). The CRD fleet operating fund will cover all operating costs for the two replacement BEVs: one for two years (purchased in 2018) and one for one year (purchased in 2019);
- **E-Bikes and equipment:** The cost for E-Bikes, associated safety equipment and bike telematics will be shared by CRD (source control program) and GMF;
- **Telematics**: The cost for up to 40 vehicles (capital cost of $600 each and annual licencing fee $505 for one year) will be contributed by the Fleet Champions Program, funded by the Province of BC. The request for GMF funds covers the second year of licencing. The Fleet Champions Program also covers the $15,000 cost for an EV suitability assessment;
- **BEV charging stations:** This cost will be shared equally by the Fleet Champions Program, CRD (equipment replacement fund) and GMF. The Province's Fleet Champions Program covers up to $2,000 per charging station, up to 33% of the total cost;

- **IESVic research costs**: This includes 6 Masters/PhD students for two years (12 student years) ($250,000). The GMF request covers approximately 1/3 of this cost; IESVic has committed to finding the remaining funds through supporting grants and will also contribute in-kind time from faculty members to support the project;
- **Project support and outreach:** The cost of outreach communications will be cost shared by the CRD (in-kind time) and GMF. The Province is paying for a feasibility study on the HFS; the GMF request includes the cost of this feasibility study. A symposium and other outreach will be cost shared by GMF, with additional funding to be requested from the private sector if required. Project management (approximate value $94,700) is an in-kind contribution from the CRD;
- **Hydrogen FCEV and Fuelling Infrastructure Feasibility Study:** CRD will undertake a study of the market for HFS on Vancouver Island; this study will be completed in early 2017 with a Provincial contribution of $15,000.

The CRD contribution is about 29% of the total budget, excluding in-kind contribution of approximately $70,000 of staff time to manage and coordinate the Project.

What is the project schedule?

PHASE	TASK	DATE
1. Develop pilot plan	○ Conduct feasibility study; ○ Develop project plan.	October 2016- March, 2017
2. Prepare and set up pilot	○ Procure ZEVs and E-Bikes; ○ Purchase and install charging stations. Liaise with the Province and industry on installation of the HFS station which is proposed as indicated in Appendix 3; ○ Purchase and install telematics.	January 2017-July 2018
3. Conduct Pilot	○ Establish IESVic research design ○ Initiate data collection and analysis methodology; ○ Operate zero emissions vehicles; ○ Complete licensing of telematics; ○ Conduct ZEV suitability analysis; ○ Complete outreach and communications	July 2017- June 2020
4. Analyze results and make recommendations	○ IESVic analysis and reporting; ○ Conduct symposium; ○ Publish project results.	July 2018- June, 2020
5. Report results	○ Complete GMF reporting ○ Present final project report and recommendations to the CRD Board ○ Transfer knowledge gained by making results readily accessible in a format that enables/encourages replicability and/or continued progress and innovation	August 2020 to September, 2020

	toward clean growth and clean transportation technologies.	

What are the project risks and how will these be mitigated?

CRD staff have identified three categories of project risks:

1. Risks to the feasibility of the project;
2. Risks associated with the use and operation of ZEVs and E-Bikes;
3. Risks associated with Hydrogen Fueling Infrastructure.

Risks to the feasibility of the project

Risks to the feasibility of the project arise as CRD and project partners including IESVic and the BC Ministry of Energy and Mines work to be able to complete and deliver the proposed project, meeting the timeline and budget requirements as identified within this feasibility study. Staff are completing a risk register associated within this project. Key identified risks within this category include:

1. Access to the funding and capital necessary to complete the project requirements

To date, the project team has put together a project budget that is reflective of the financial requirements needed to meet the project objectives and complete the project tasks. Market research and expert knowledge have been used to compile the project budget. Over 64% of total financial and in-kind resources have already been identified and pledged by the three project partners: CRD, IESVic and the BC Ministry of Energy and Mines. The remaining funds of $350,000 are being requested by the Green Municipal Fund to enable to project to proceed. Staff view the ability to secure this funding as the largest risk to the project as without securing external project funding, the project will be unable to proceed as currently envisioned. If CRD is unsuccessful in its application to the Green Municipal Fund, the Project Team will meet to identify other potential funding sources, or re-design the project to match available funding.

2. Staff capacity to complete all of the associated project tasks

The project team has designed the project using project management principles, and relying upon project team members who have experience managing and leading other projects, similar in scope. Contingencies have been built into project timelines, and the project schedule has been designed to be flexible to address unforeseen risks. CRD staff have incorporated project requirements into work plans, and the objectives of the ZEFI Pilot Project align with the goals and actions identified within CRD’s Corporate Climate Action Strategy. The overall project will be led by Liz Ferris, CRD’s Climate Action Analyst who is an accredited Project Management Professional (PMP) and David Goddard, CRD’s fleet manager, who has a career worth of experience in testing and employing vehicles within fleet settings. CRD has also submitted an application to the Pacific Institute for Climate Solutions (PICS) for a student intern, to help the Climate Action Analyst in meeting the 2017 Corporate Climate Action Strategy activities, including the ZEFI Pilot Project.

3. Capacity in IESVic to complete the research component

The IESVic research component of this project was designed collaboratively by IESVic Professors, Post-Graduate researchers and Graduate Students to ensure that the research components of the project are feasible. IESVic has years of experience conducting research and publishing this research for academic and industry purposes. The research component of the project has been designed to be scalable to allow for progressive elaboration and further inquiry as the answers to research questions elicit new avenues of inquiry.

4. Access to and availability of the equipment and vehicles necessary to complete the project

This project is bringing together many moving parts, including instillation of fueling infrastructure, acquisition of pre-production FCEVs, acquisition and instillation of telematics devices on CRD fleet vehicles, and procurement of BEVs and E-Bikes. As there are so many moving parts that are reliant on so many bodies external to the project, the ability of the Project Team to acquire the necessary equipment and vehicles at the appropriate point in the project lifecycle is critical to the overall success of the project, and a significant area of project risk. To account for this, the Project Team has undertaken detailed feasibility analysis- as detailed within this study- and has developed a detailed project plan to guide project activities. Clear and consistent communication amongst all stakeholders will be necessary to ensure that the project objectives- including the delivery of vehicles and equipment can be achieved on time and budget.

The ZEFI Pilot Project has been designed to leverage the capacity, expertise and programming provided by all three project partners to pull off a unique and innovative pilot project. The project was designed as an initial pilot specifically to identify solutions that work well- and those that don't work- within a local government fleet context. As with any pilot project, it is expected that there will be lessons learned, which will be integrated into future approaches to fleet management at the CRD, and within other local government fleets.

Risks Associated with the Use and Operation of ZEVs and E-Bikes

While ZEVs and E-Bikes are not new technology, the approach of integrating the use of these along with Smart Fleet analysis in partnership with a research institution within a local government fleet context is unique.

ZEVs and E-Bikes have their own inherent benefits and challenges, detailed at length in pages 23-26 of this feasibility study. A key area of innovation that is brought forward by the Zero Emission Fleet Initiative is the use of hydrogen fuelled Fuel Cell Electric Vehicles within a local government fleet context. While CRD will be the first local government fleet to use the Hyundai Tucson small sized sport utility vehicle, British Columbia has been an early leader in fuel cell technology and deployment, and so the Project Team has had local experience and expertise to draw from, in the design of this project.

In preparation for the Whistler 2010 Winter Olympics, BC Transit supported BC's Hydrogen Highway by implementing the world's largest demonstration fleet of fuel cell electric buses in Whistler, BC. CRD staff have spoken with staff at BC Transit to learn from BC Transit's demonstration project experience, and integrated these learnings into the project design of the Zero Emissions Fleet Initiative. These include leasing vehicles instead of buying them for the initial pilot period, and ensuring there is a local, affordable, low embodied GHG source of hydrogen available to fuel the vehicles.

In 2010, the City of Surrey tested two zero emissions hydrogen fuel cell vehicles, as part of the City's Green Energy Fleet Plan. The findings were measured and ranked against traditional gas and diesel powered vehicles. CRD staff have spoken to the City of Surrey Fleet Manager, and have integrated the lessons learned in that pilot in the design of the CRD pilot. CRD is building upon Surrey's pilot experience by utilizing next generation vehicles that were not available in 2010, and by partnering with IESVic to study, analyze and publish the results of the pilot project, and ensure they are widely shared.

Risks associated with Hydrogen Fueling Infrastructure

In early 2017, CRD will work with industry partners to undertake a study of the market for HFS on Vancouver Island; this study will be completed in early 2017 with a Provincial contribution of $15,000. This study will include in depth analysis on the safety features of hydrogen fueling infrastructure. Power Tech labs, a potential future partner in this initiative will provide information on the safety of hydrogen fueling infrastructure, including the fuelling infrastructure they operate at their site, in Surrey, BC.

To be able to be operated on Canadian roads, all vehicles sold in Canada, including FCEVs, must meet Transport Canada standards, CMVSS Canadian Motor Vehicle Safety Standard. CRD isn't a regulator of these vehicles and so will be relying on the federal regulators to ensure the safety standards are met. However Hyundai has addressed safety concerns: the following information has been adapted from the Hyundai marketing material for the Tucson vehicle.

How safe is the Fuel Cell vehicle?

Hyundai Fuel Cell vehicles have been subjected to extensive safety testing, including destructive and non-destructive evaluations at the component, system and vehicle level. All Hyundai vehicles must complete a rigorous crash test program before they are ever driven on public roads. The Tucson FCEV has undergone crash tests for front, side and rear impact, as well as fire, ballistics and leakage test. Hyundai has also conducted over 3-million kilometers test driving of the Tucson FCEV, which includes hot weather testing in the Death Valley in Arizona and cold weather testing in Sweden. Additionally, the Tucson FCEV is equipped with several internal safety mechanisms to ensure the safety of the passengers in the vehicles. This includes impact sensor that stops the release of hydrogen from the tanks in event of a crash.

How safe is hydrogen?

Hydrogen, like any fuel used today, requires certain precautions to ensure its safe production, transport, storage and usage. With proper handling, hydrogen is as safe as any other fuel, such as gasoline, diesel or natural gas – and in some instances even safer. Hydrogen is produced, shipped, distributed and used safely worldwide for the use in everything from welding to hydrogenated peanut butter. Over 50 million tonnes of hydrogen is produced annually worldwide. Hydrogen is the most common element in the universe, and it's also the lightest. This means that if there is a leak in a storage tank, the hydrogen rises and diffuses quickly into non-flammable concentration.

Are the hydrogen storage tanks safe?

Yes, the tanks are very safe. Carbon fiber composite tanks used to store hydrogen are very resilient to rupture, even upon high impact. Hydrogen tanks are designed to withstand high internal gas pressure, high-speed collisions and even ballistic tests without rupture or puncture. Even if a leakage occurs, the risks are low because hydrogen is lighter than air and dissipates immediately. Additionally, four hydrogen sensors are located onboard the Tucson FCEV, which are designed to detect leaks and sound an alarm[34].

More information about hydrogen, hydrogen fuelling infrastructure and safety can be found in appendix 4.

Project Team

CRD will be the overall project manager for this pilot project, led by Liz Ferris, M.Sc, PMP. Ms. Ferris, Climate Action Analyst, will be working with David Goddard, CAFM, Manager of the CRD Central Fleet. Ms. Ferris will report to the CRD Board through the Executive Management Team. Ms. Ferris is the Climate Action Analyst within the Risk, Facilities and Property Management Division. Mr. Goddard is within the Customer and Technical Services Division.

The IESVic studies will be led by faculty members Ned Djilali and Curran Crawford. Dr. Djilali is the Canada Research Chair, and Professor of Mechanical Engineering at the University of Victoria, with specialities in energy systems and fuel cell technology. He will work with associate Dr. Curran Crawford, Assistant Professor in the Department of Mechanical Engineering, who focuses on the design of sustainable technologies, notably energy-related technologies. They will be assisted by five graduate students and one Post Doctoral researcher. Several members of the IESVic team have experience directly related to electric vehicle fleet analysis.

The BC Ministry of Energy and Mines will provide advice and support for the project in addition to funding. They will also support the development of Hydrogen fuelling Infrastructure within the Region. Christina Ianniciello, (Director of Communities and Transportation), Dian Ross (Clean Transportation Engineer (E.I.T.), Communities and Transportation Branch) and Nick Clark (Sr Policy Analyst, Communities and Transportation Branch) are part of the project team, and have already successfully negotiated the development of hydrogen fuelling in BC's Lower Mainland, expected completion Spring 2017.

APPENDIX 1: BC Ministry of Energy and Mines Letter of Support

BRITISH COLUMBIA

Capital Regional District
625 Fisgard Street
Victoria, BC
V8W 1R7

January 4, 2016

Attention: Liz Ferris, Climate Action Analyst

Dear Ms. Ferris:

I am pleased to provide a letter for support for the Capital Regional District's (CRD) application to the Federation of Canadian Municipalities' Green Municipal Fund (GMF), and recognize the CRD's initiative in developing the *Capital Regional District Zero Emission Fleet Pilot Project*. The Province of British Columbia has appreciated the opportunity to work with the CRD to develop a strategy to reduce the CRD's fleet greenhouse gas (GHG) emissions and help meet commitments under the Climate Action Charter and CRD Corporate Plan, while enabling other fleets to take similar measures to reduce their emissions. I understand that the Project includes purchasing battery electric and fuel cell electric vehicles, the installation of charging infrastructure, and the completion of a study to learn from and optimize these applications both within the CRD fleet and other fleets. This Project will also enable the installation of a hydrogen fuelling station in the region, a targeted area for a hydrogen infrastructure network in B.C.

The Province of British Columbia is dedicated to climate action and has set legislated targets for reducing GHG emissions by 80 percent below 2007 levels by 2050, a commitment which has recently been reaffirmed in the Province's August 2016 Climate Leadership Plan. The transportation sector represents approximately 37 percent of GHG emissions in British Columbia, making it a key focus for impactful climate action. The Province introduced the Clean Energy Vehicle (CEV) Program in 2011 and has invested over $31 million for vehicle incentives, infrastructure, fleet assistance, public outreach and awareness, research, training, and economic development.

…/2

Ministry of Energy and Mines | Electricity and Alternative Energy Division | Mailing Address: PO Box 9314, Stn Prov Govt Victoria, BC V8W 9N1 | Location: 4th Floor 1810 Blanshard Street Victoria

The Province has targeted the increased adoption of hydrogen fuel cell electric vehicles (FCEVs) through a point-of-sale purchase incentive of $6,000 per vehicle, the first of its kind in North America, and the investment of $470,000 in B.C.'s second hydrogen fuelling station which is expected to be operational and publically available by Spring 2017. In addition, the CEV Program provides a point-of-sale purchase incentive of up to $5,000 for battery electric vehicles, and is making significant investments in public charging infrastructure.

The Province commends the CRD's initiative and ability to secure the lease of two pre-production (2017) and four production (2018) for a total of six Hyundai Tucson hydrogen fuel cell electric vehicles (FCEVs) for field trial in the CRD fleet at a time when the allocated FCEV in Canada is extremely limited. The Province further applauds the CRD's leadership in being an early B.C. signatory to the West Coast Fleets initiative, and the recipient of funding through the Provincial Fleet Champions Program which will provide the telematics support and data analysis necessary to evaluate fuel switching in the CRD's fleet to zero emission vehicles.

The Ministry of Energy and Mines (the Ministry) confirms that the CRD has consulted with the Province on the Project and is pleased to confirm its contribution of $15,000 to fund a hydrogen FCEV and fuelling infrastructure feasibility study under the CEV Program. In addition, Ministry staff will work with industry, and leverage existing CEV Program funding and compliance pathways under the *Renewable and Low Carbon Fuel Requirement Regulation* to support the development of a no-or-low-GHG emission hydrogen fuelling station in the capital region to enable the Project to proceed. The Ministry looks forward to its continuing partnership with the CRD on this Project in an advisory role.

If you or the GMF requires further information, or wish to discuss the Ministry's support, please do not hesitate to contact me. I trust that this letter provides the assurance of Provincial financial support needed to facilitate your GMF application and I wish you success as you work through the final stages of project review.

Sincerely,

Daniel Green
Executive Director

Ministry of Energy and Mines
Electricity and Alternative Energy Division
Mailing Address:
PO Box 9314, Stn Prov Govt
Victoria, BC V8W 9N1
Location:
4th Floor
1810 Blanshard Street
Victoria

APPENDIX 2: IESVic Letter of Support

University of Victoria | Institute for Integrated Energy Systems

Peter Wild, PhD
Executive Director, IESVic

January 18, 2017

Ms. Liz Ferris
Climate Action Analyst
Capital Regional District
625 Fisgard Street
Victoria, BC V8W 1R7

Dear Ms. Ferris,

Subject: Capital Regional District Zero Emission Fleet Pilot Project

The Institute for Integrated Energy Systems (IESVic) is enthusiastically partnering with the CRD in their initiative to conduct a feasibility study and deploy a pilot fleet of fuel cell and electric vehicles. This initiative is in complete alignment with IESVic's mandate to "chart feasible paths to sustainable energy systems", and with the University of Victoria's strategic priority in promoting community-engaged research.

Starting from the Next Generation Fuel Cell Technology program launched in 1994 in collaboration with Ballard Power Systems and British Gas, IESVic has a track record of high impact research and collaboration with industrial partners on many aspects of hydrogen and fuel cell technology. More recently, IESVic is working on the "Transportation Futures for BC" project with a focus on examining the prospects for GHG reductions through drivetrain electrification of transit buses, commercial fleets, personal vehicles and bicycles. The work spans modeling of battery degradation, optimal charging and operation, and techno-economics aspects of integration of EVs in the electricity grid.

The proposed CRD project provides an opportunity to both expand and apply this research by assisting the CRD in: (i) planning, monitoring, and analyzing field trials of fuel cell electric vehicles; (ii) testing, comparing and identifying suitable operational settings for zero emission alternatives, including battery electric vehicles (BEV) and electric bikes (E-Bikes); and (iii) developing tools for fleet optimization, for both operationally and capital acquisition. The partnership will involve the engagement of two experienced IESVic faculty, Drs. Crawford and Djilali, and several of their graduate students who will develop thesis topics that will directly inform the project. IESVic will commit $230,000 towards the project, 67% of which will be towards the stipend of the graduate students and 33% in-kind contribution corresponding to the time commitment of Drs. Crawford and Djilali.

University of Victoria/IESVic, PO Box 1700, STN CSC, Victoria, BC V8W 2Y2 CANADA
Tel: (250) 721 8901 Fax: (250) 721 6323 Email: pwild@uvic.ca www.iesvic.uvic.ca

Beyond the broad objectives of stimulating further progress toward a clean growth economy in Canada, we specifically anticipate the project to:

- Provide techno-economic and operational data and planning tools to inform and promote suitable adoption of zero emissions vehicles by governmental and private organization in the capital regional district and elsewhere in Canada.
- Train young engineers with the required range of skills, breadth of knowledge and practical experience to work in the myriad organizations that will be engaged in the upcoming shift of transportation toward electrification.

IESVic is excited to partner with and support the CRD in this initiative and expects the synergies will spur new applied research initiatives and partnerships to facilitate the adoption of zero-emission vehicles.

Sincerely,

Peter Wild, PhD
Executive Director, IESVic
Chair, Mechanical Engineering

PW:sjw

APPENDIX 3: CRD Fleet Vehicles

The E3 fleet review provided several key performance indicators (KPI).

KPI		CAPITAL REGIONAL DISTRICT (Sample)	MEASURE
1	Fleet Size	304 51	Vehicles Equipment
2	NPV	$95,926,242	$
3	Current of capital and/or lease payments	$3,825,261	$
4	Fleet average age	5.9	Years
5	Total annual distance travelled	1,443,823	Kms
6	Fleet median fuel efficiency	23.2	l/100 kms
7	Fleet annual fuel usage	375,741	Litres/yr.
8	Fleet GHG intensity (tailpipe)	0.572	Kg/Kms
9	Annual GHG emissions (tailpipe)	826	Eq. Tonnes CO2
10	Fleet GHG intensity (lifecycle)	0.817	Kg/Km
11	Annual GHG emissions (lifecycle)	1,179	Eq. Tonnes CO2
12	Corporate average utilization	7,329	Kms
13	Corporate average utilization	5,579	Engine hours
14	Fleet availability	n/a	%
15	Fleet average downtime	n/a	Days
16	Annual downtime cost	n/a	$
17	Annual fuel cost	$516,722	$
18	Annual repair cost	$506,331	$
20		$4,689,222	$/yr.

APPENDIX 4: FCEV and Hydrogen

"…the first fuel cell was developed in the 1840s. NASA became the first to put fuel cells in use with the Gemini and Apollo space crafts, Skylab and the Space Shuttles. In the 1960s, auto companies began working with fuel cells in vehicles. Over the decades, fuel cells have become smaller, more powerful and longer lasting."[35]

A fuel cell is a device, similar to a battery that converts the energy stored in chemical bonds of a fuel (typically hydrogen) to electrical energy. Fuel cells convert energy more efficiently than traditional combustion engines. Unlike a battery, a fuel cell isn't recharged and can produce electricity continuously when it is supplied with a flow of fuel (e.g., hydrogen) that reacts with an oxidant (e.g., air or pure oxygen). When hydrogen is the fuel, the only byproduct is water. For an animated version of a fuel cell in action, see the US Department of Energy website http://energy.gov/eere/fuelcells/fuel-cell-animation.

A hydrogen fuel cell car is an electric vehicle in which the electric motor is powered by electricity supplied by the fuel cell stack as opposed to a battery. It can be refuelled almost as quickly and easily as a gas car, and the electric motor does not store its energy in a battery.

Commercially available FCEVs include the Hyundai Tucson, Toyota Mirai and Honda Clarity. The Mirai is a sport model, the Clarity is a sedan, whereas the Tucson is an SUV with greater cargo space, an important consideration for a fleet vehicle. (Chevrolet is also developing a fuel cell vehicle, a truck that will be unveiled by the US Army later this year,[36] and Nikola is developing an electric semi-truck for US and Canadian markets that will be powered by hydrogen fuel cells.[37]) The California Air Resources Board estimates that there will be tens of thousands of FCEV in California by 2020,[38] and industry watchers anticipate that there could be as many as 20 million FCEV sold by 2032.[39]

Current commercial fuel cells use platinum, a rare and expensive metal, as the catalyst. Researchers are working on new catalysts that use less of this expensive metal, or that require much less platinum[40].

FCEV adoption

"Early users of these vehicles are fleets and high-end consumers. As fuelling infrastructures expand in the 2020's, hydrogen fuel cell vehicles will begin to garner grater market acceptance, resulting in faster market penetration. In the year 2032, over 5 million of these vehicles will be sold with projected revenues of over $250 billion."[41]

The Australian Capital Territory government has recently ordered 20 Hyundai FCEV, with the hydrogen to be produced using wind power.[42] Hyundai is already working on a next-generation FCEV for 2018, an SUV that will have even greater range than the 2017 Tucson.[43]

Fuel cell technology has been around for many years, but the use of fuel cells for automobiles is still limited in North America. Adoption of FCEVs necessarily goes hand-in-hand with the availability of hydrogen fuelling stations.

California, Scandinavia, Germany and Japan have taken the lead in hydrogen fuelling, with support from governments, car manufacturers and fuel retailers.[44] Germany has plans to install up to 400 stations by 2023.[45] Toyota aims to sell 2,000 of its Mirai FCV this year, with up to 3,000 in 2017.[46]

Safety (Hyundai Tucson)

In addition to meeting normal vehicle safety standards, Hyundai has ensured that in the event of a crash, sensors stop the release of hydrogen from the tanks. If the vehicle is stored in an enclosed space, four onboard hydrogen sensors are designed to detect leaks and sound an alarm.[47]

Hyundai claims that there have been no reported cases of catastrophic failure of a storage tank and that if a leak were to occur, there is almost no risk of explosion because hydrogen is lighter than air and rises immediately, minimizing the risk of explosion.[48]

Sourcing Hydrogen

Fuel cells can in principle operate with a variety of fuels, however hydrogen is the preferred one as it ensures zero tailpipe emissions. It is often said that Hydrogen is the most abundant element in the universe, but it is not readily available on earth in its basic molecular form (H_2), and has therefore to be produced from a “feedstock”. The main hydrogen production techniques are electrolysis of water, steam reforming of natural gas, and biological production from organic matter. From “well-to-wheels” (i.e., for its life cycle), hydrogen is a very clean fuel. Hydrogen in an FCEV is about two times more efficient than gasoline through a gas engine, but about 40% less efficient than battery electric vehicles.

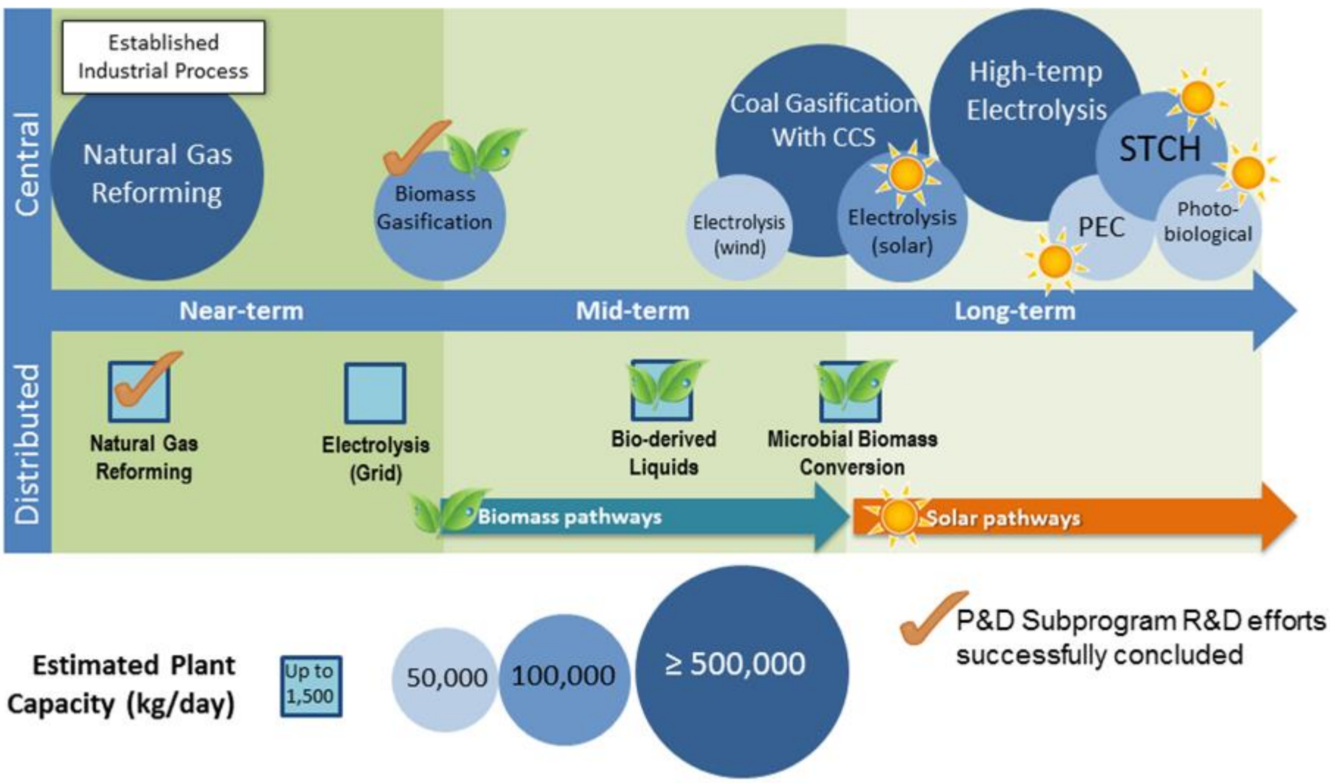
Hydrogen can be produced from different sources, such as water and natural gas. One option is to purchase hydrogen from a Quebec facility; however this would generate significant shipping costs and create a greenhouse gas footprint from both production and shipping. Since a key goal of this project is to reduce greenhouse gas emissions, the intent is to produce hydrogen locally using clean electricity (such as that available from the BC Hydro grid), or to source waste industrial hydrogen, locally available on the Island. BC has a potential supply of low carbon intensity hydrogen through the processing of industrial hydrogen off-gas or electrolysis of water using BC’s low carbon electricity. If these pathways were used for this project, the well-to-wheels greenhouse gas emissions would be very low.[49]

The use of electrolysis for hydrogen generation, which utilizes electricity to split water into hydrogen and oxygen, is even more advantageous given the favourable emissions intensity for electricity generation in BC.[50],[51] In BC, more than 93% of the production of electricity comes from renewable sources[52] which has very low associated carbon emissions (BC Hydro emissions factor is 10.67 tCO2e compared to Alberta’s power system for which the emissions factor is 793 tCO2e[53]). On Vancouver Island, electricity supply is almost entirely from hydropower. Thus, the energy consumed during local production of hydrogen via electrolysis would be supplied by renewable non-pollutant sources, and therefore, the well-to-tank emissions would be low.

The *BC Renewable & Low Carbon Fuel Requirements Regulation* was introduced to reduce BC’s reliance on non-renewable fuels, help reduce the environmental impact of transportation fuels and contribute to a new low-carbon economy[54]. Under Part 3 of the Regulation, fuel suppliers must progressively decrease the average carbon intensity of their fuels to achieve a 10% reduction in 2020 relative to 2010. Fuel suppliers may choose their own approach for compliance, including acquiring credits through a Part 3 agreement. Through the BC Ministry of Energy and Mines "Part 3 Agreements Program" the Ministry has issued a call out to conventional, GHG intensive fuel suppliers who are in a carbon deficit to develop or partner on projects that will significantly reduce GHG emissions, thereby creating carbon credits. This program may be

An overview of several hydrogen production technologies, is shown in Figure 3.[55] The technologies are classified depending on their location (centralized if the focus is in large scale production or, decentralized in small scale), the capacity (kg/day), their time frame viability and state of the research, development and deployment. It is important to notice that decentralized electrolysis powered by grid is related to the US context in which pollutant energy sources are dominant. A more detailed study on the hydrogen production technology impacts on the lifecycle emissions of FCEVs.

FIGURE 3: Hydrogen production techniques



APPENDIX 5: E-Bikes

The E-Bike program will be trialled through the CRD Regional Source Control Program (RSCP). The RSCP is a regulatory program aimed at reducing the amounts of contaminants that industries, commercial businesses, institutions and households discharge to sanitary sewers throughout the district. The RSCP team of five inspectors, administer the Sewer Use Bylaw (the main regulatory instrument for source control within CRD sanitary sewer systems) primarily through site inspections. The RSCP regulates roughly 1,850 businesses on sewer through waste discharge permits, authorizations or sector-specific codes of practice.

Approximately 82% (1,500) of the regulated businesses fall within three codes of practice: Automotive (164), Dental (101) and Food Services (1,252). Of these sectors, approximately 78% are (1,170) are located within the municipalities of Victoria, Saanich, Oak Bay and Esquimalt. The bulk of the businesses within these municipalities fall within a five kilometer or less radius, making a strong business case for the use of electric bicycles (E-Bikes) for inspection transportation.

The greatest concentration of regulated commercial activity, is the downtown core of Victoria, primarily restaurants. While many of these businesses are within reasonable walking distance (0.5km radius), the use of E-Bikes would extend the range of inspection efforts to, allow for easy transportation of equipment, and eliminate the need for paid parking. Further, E-Bike transportation would lighten demand on fleet vehicles, decrease the corporation’s GHG emissions, and demonstrate progressive corporate responsibility and leadership in a very visible way.

Supporting Research

This E-Bike pilot project will be monitored by IESVic. Primary research questions will be:

- What is the real world environmental performance of E-Bikes in replacing ICE vehicles for short-range commercial trips?
- What are the motivators for people to use E-Bikes to replace ICE vehicles for short-range commercial trips?
- What are the real world financial savings of using E-Bikes to replace ICE vehicles for short-range commercial trips?
- Is there an ideal scenario in which E-Bikes can be deployed within a commercial fleet in regards to minimizing GHG emissions, minimizing financial costs, and maximizing employee satisfaction?
- What is the optimal level of assist (motor size) to minimize emissions, minimize economic costs, and maximize user uptake?

The environmental performance of E-Bikes can be determined through the deployment of several E-Bikes within the CRD for use in local trips from the CRD head office. Two different models/makes of bikes will be examined in the pilot for comparison, to determine which E-bike features are of most use to CRD staff. The performance characteristics of the various types of E-Bikes will be investigated to determine what type of trips are appropriate for the selection of E-Bikes over other modes of transport; factors such as vehicle weight, energy consumption, range, cargo capacity, operational cost, and environmental performance will all be used as indicators for the identification of ideal trip type for E-Bikes.

These E-Bikes should be equipped with data loggers that record the power output of the user and the motor, as well as GPS information tracking location. Power measurements are the key to running detailed analysis of the GHG emissions reductions due to the replacement of ICE vehicle use with E-Bikes can be determined; ongoing programs at the CRD are outfitting up to 40 vehicles with data loggers which will potentially be the source of duty cycle and use cycle information for ICE vehicles in the CRD fleet. In addition to the environmental performance, the economic performance can be determined through operation costs of both modes of transport (ICE vehicles and E-Bikes) over each trip due to the detailed trip information acquired.

Users should be surveyed before and after the deployment of E-Bikes to understand the human aspect of mode switching from ICE vehicles to E-Bikes in a corporate setting. A partnership with appropriate researchers within IESVic would be required to ensure effective surveys are created. By better understanding the human aspect of E-Bike uptake, future deployment programs can be better optimized to increase success (diminished emissions and decreased operation costs) through best-matching technological and logistical considerations to user preferences that are likely to be more acute than traditional vehicle switching.

Using the captured data, a model can be built and optimized that relates the GHG emissions from electricity consumption of the E-Bike as well as the dietary GHG emissions of the rider to the rated power of the motor for a range of trip types. By optimizing the size and assist level of the motor, perhaps better legislation can be recommended for allowable E-Bike motor sizes for commercial applications. Experience gained in fleet deployment, in a unionized environment, will also be extremely valuable for more widespread deployment to other municipalities, including maintenance, scheduling and user education.

Proposed Outcomes

- Detailed environmental performance metrics for E-Bikes (kg CO2,e / km) under various duty cycle and use cycles in comparison to conventional vehicles;
- Detailed economic performance metrics of E-Bikes for commercial trips, in addition to lessons-learned on pre-deployment and post-deployment operation of the bikes;
- Policy recommendations for improved adoption rates of E-Bikes, including appropriate fleet mixes and regulatory structure;
- A successful GHG emission reduction program for the CRD in an urban environment with lessons for other municipalities.

Suggested Equipment

Several pieces of equipment are key to the deployment of E-Bikes for the CRD fleet. First is the E-Bike itself; from initial consultations, the type of E-Bike most suited for use with the CRD (within the limit of the author's knowledge of the CRD requirements) appears to be a cargo bike given the requirement to carry some equipment. Cargo type E-Bikes can range from approximately $5000 to $7500.

The next required set of equipment is data loggers and power meters. A sturdy reliable data logger that captures the motor characteristics (voltage, amperage, energy, power, as well as GPS) can be obtained for as little as approximately $150 CAD and connects to the motor [http://www.ebikes.ca/shop/ebike-parts/cycle-analysts/ca-dps.html]. Bicycle power meters are built into some E-Bike systems, or retrofitted for $500-$1000. Data loggers for the vehicles the E-Bikes would replace will be part of another associated project in the proposal.

For the case of rider power measurements, a pedal-crank type power meter can be purchased for between approximately $700 to upwards of $2000. The specific of the measuring equipment will depend on what type of E-Bike the CRD chooses.

APPENDIX 6: Greenhouse Gas Emissions Reductions

The Zero Emissions Fleet Initiative Pilot Project will produce immediate GHG emissions during the pilot period, and anticipates generating further long term emissions as Zero Emission Vehicle uptake increases as a result of the project implementation. The primary aim of the project is to consider GHG implications of the project- both tailpipe and lifecycle emissions. Technology selection will be evaluated based on GHG analysis conducted by IESVic.

To give a broad idea of the future GHG tank-to-wheel (tailpipe) emissions avoided by the acquisition of FCEVs in the short term, several scenarios are compared based on the current fleet vehicles identified for replacement.

TABLE 3 Fleet for replacement according to CRD database

Model Year	**Make/Model**	**Class**	**Engine**	**NR Can Rating**		**CO2-e/km (tank-to-wheel)**	**Annual Km**
				L/100KM (city)	**(Hwy)**		
2007	Jeep Liberty	SUV	3.7 v6	14	9.9	290.4	8,397
2008	Chevy Equinox	SUV	3.6 v6	13	8.3	261.6	13,137
2011	Jeep Patriot	SUV	2.4 i4	9.9	7.5	202.4	4,604
2011	Jeep Patriot	SUV	2.4 i4	9.9	7.5	202.4	8,838
2008	Ford Escape	SUV	2.3 i4	10.9	8.5	218.4	9,221
2008	Ford Escape	SUV	2.3 i4	10.9	8.5	218.4	8,953
2009	Ford Ranger	Pickup	4L v6	15.7	11.7	333.6	4,350
2010	Ford Ranger	Pickup	4Lv6	15.7	11.7	333.6	13,227
2009	Ford Escape Hybrid	SUV	2.3 i4	6.8	7.3	168	26,511

Error! Reference source not found. The figure below illustrates the comparison between the technologies HG emissions against the market price per unit. It is clear that the FCEV is the best option when the main focus is the GHG emissions. On the other hand, the price of the Hyundai Tucson FCEV was assessed considering an 18% annual effective interest rate, considered as a worst case scenario.

FIGURE 3: Comparing three drive train technologies regarding their market price per unit against the amount of GHG emissions (tCO_2e)

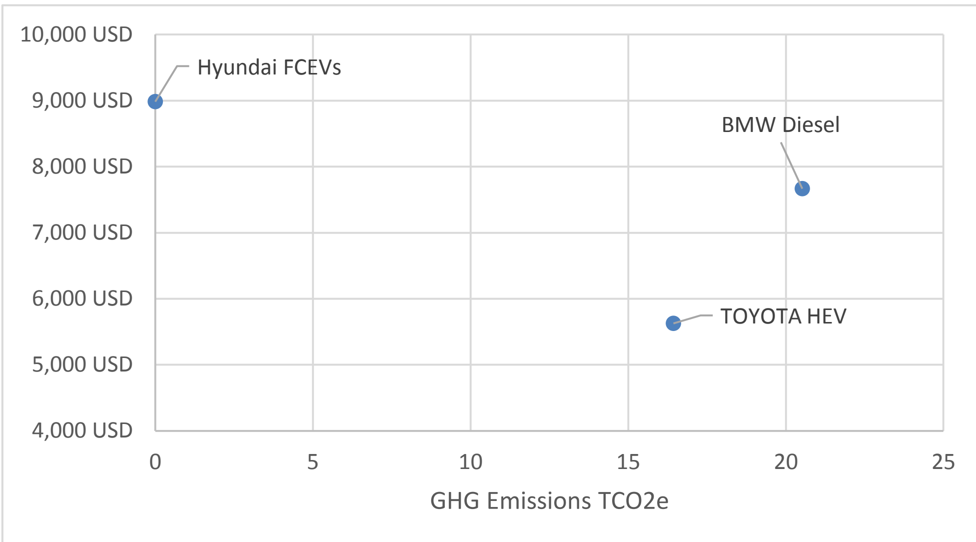
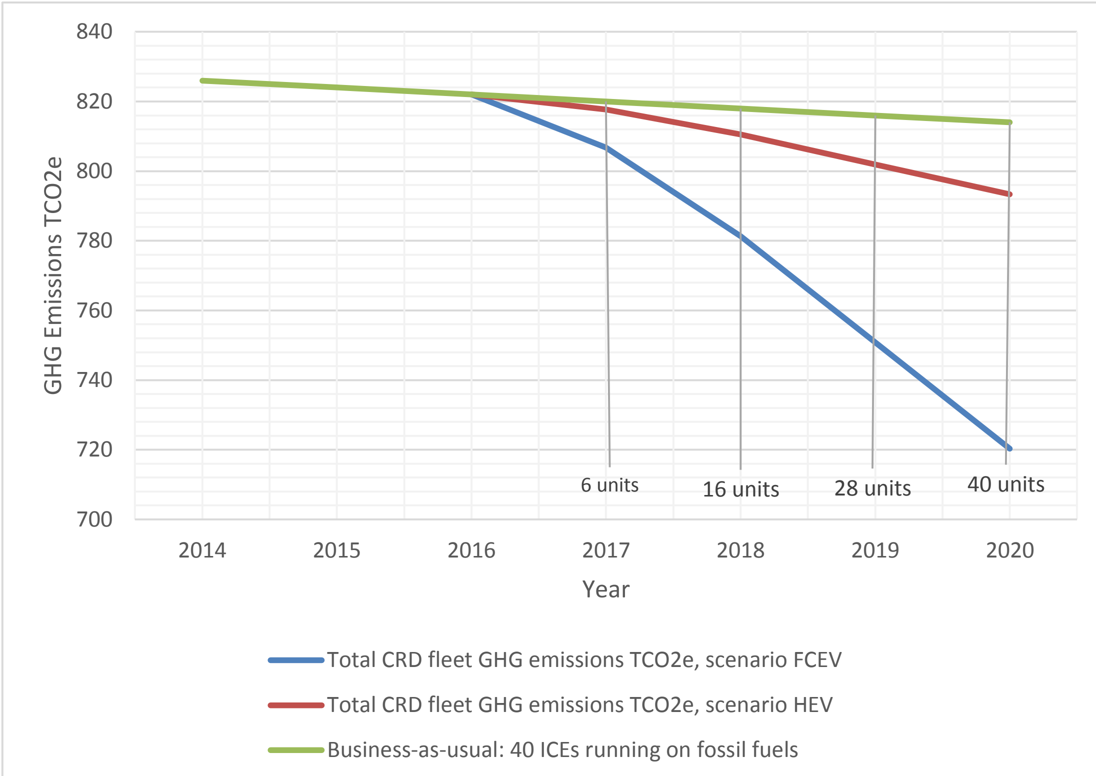


Figure 3 illustrates an estimate of the total GHG emissions avoided through a gradual replacement of 40 vehicles of the current CRD fleet. In the figure, Hyundai FCEVs and Toyota HEVs are compared with the business-as-usual scenario (replacement with units running on gasoline). It is assumed that the 40 vehicles are replaced gradually, as follows: 6 units in 2017; 10 units in 2018; 12 units in 2019 and finally 12 units in 2020.

It is assumed that the annual GHG emissions in 2016 are the same as in 2015. It is assumed as well, that the replaced units individually had the average of GHG emissions shown in **Error! Reference source not ound.**. As expected, the reductions reached by using FCEVs are much more significant than in the case of a fleet of HEVs. The business as usual scenario considers the reduction of the GHG emissions based on the custom renovation of the fleet with more efficient models.[56] By gradually replacing the current fleet with FCEVs as proposed in Figure 3, by 2020 the GHG emissions would be reduce roughly by 13% compare to the 2014 levels. This assessment is based on average approximations taken from the current fleet for replacement show in **Error! Reference source not found.**. The Smart Fleet analysis will consider the GHG missions in each unit (tank-to-wheel) and the dependence of the lifecycle emissions on the well-to-wheel emissions.

Figure 3: Comparison between total GHG emissions (tCO_2e) reduction based on projected gradual replacement of units of the current CRD fleet



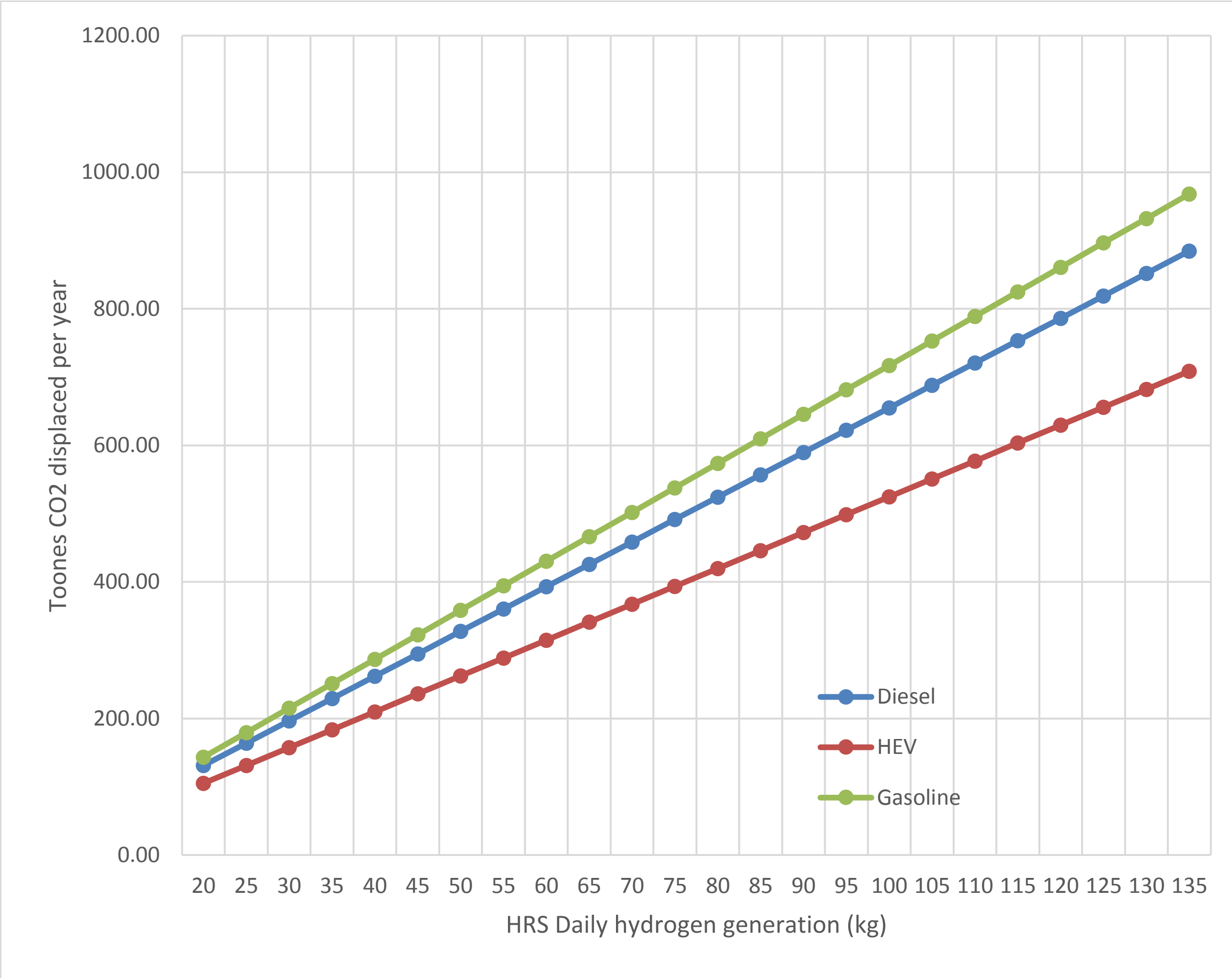
In blue, Hyundai FCEVs units (Blue) vs in red, Toyota HEVs units (Red) and in grey ICEs units running on gasoline.

Community GHG Emissions

Additional GHG emission reduction can come about in a number of ways. One of the largest opportunities is presented through opening the first public hydrogen refuelling station on Vancouver Island, which if properly leveraged to attract major auto manufacturers can lead to more ICE vehicles on the island being replaced with FCEVs. Every gasoline powered vehicle that is replaced by a FCEV will effectively drop the associated tank-to-wheel emissions to zero.

Using some of the numbers from Figure 4, the potential tank-to-wheels emission reductions can be estimated for a given HRS size assuming it is at full capacity; a HRS that generates 85 kg of hydrogen per day can refuel 17 vehicles a day (5 kg per vehicle), and assuming that a vehicle needs to refuel once a week, the station has the potential to fuel 119 vehicles a week. With 119 vehicles a week being fueled with hydrogen, an estimated emissions reduction on a yearly basis for a variety of vehicle types being replaced is presented in Figure 4. The case of the gasoline vehicle was generated using the tank-to-wheel emissions of a BMW M5 sedan.[57]

Figure 4: Estimate of HRS GHG emission reduction potential for a variety of fuel types.



In addition to residential customers switching to FCEV, commercial vehicle operators are likely to be tempted by the opportunity to reduce their GHG emissions due to transport through converting their fleet to FCEV. A hydrogen refuelling station has the potential to be a catalyst for a dramatic increase in FCEV adoption rates and in turn reduce GHG emissions associated with transportation on southern Vancouver Island.

APPENDIX 7: Emergency Resilience and Clean Stationary Power

The CRD is planning to gradually replace its fleet of service vehicles with alternative fueled electric vehicles (AFEV).[58] As most currently available AFEVs have electric drivetrains (whether battery or fuel cell powered) large fleets of AFEV offer energy storage for grid support.[59] This topic, also known as Vehicle-to-Grid (V2G), has been widely addressed by the scientific community. It is also possible to use vehicles to power individual buildings (V2B), however its relevance during major events, such as earthquakes, is still a matter of recent research.[60]

Theoretically, in cases of emergency when the power system fails, a fleet of AFEV would have the potential to provide back-up power, with relatively small or no additional infrastructure.[61] This operational mode would could also cover stationary off-grid power operation, when the AFEV would be in idle mode and electricity is required for a specific task. During major disaster events, the emergency electric network infrastructure has proven to be more reliable than fossil fuel delivery infrastructure. A few days after the tragic events in Japan in 2011, the emergency electric infrastructure supporting city halls was already in operation, whereas the fossil fuel stations were out of service (also for security reasons). Plug-in Electric Vehicles were donated by Mitsubishi, Toyota and Nissan and deployed by city halls in order to support emergency operations.[62] This project would look into the technical and economic aspects of the utilization of a fleet of electric vehicles for emergency resilience considering the major risks of disaster that characterize Vancouver Island.

Outside of emergency situations, many day-to-day work tasks require the vehicles to be idling to provide power for equipment, or the use of on-vehicle generators. Beyond the electrical capabilities of the vehicles' own systems, there is an opportunity to replace idling and power requirements with portable power packs (battery or H2). These could be swapped between vehicles, and depending on the fleet usage characteristics provide large emissions reductions.

Research objective

This primary aim of this aspect of the project is to examine the feasibility of an emergency resilience strategy and policy involving the use of a fleet of AFEV for transportation and energy support during major disasters. In particular, two perspectives will be studied: what would be the optimal deployment of a fleet of AFEVs after major disaster events in order to reduce the impact on the community and, how could the fleet could be used under the concept of Fleet-to-Building, so that the basic need of electricity during emergencies might be provided? To achieve these goals, the following specific targets may be considered:

- Catalogue the different types of risks for the CRD and member municipalities;
- Characterize the fast response energy needs of the CRD during a major disaster;
- Model the minimum ranges needed to attend emergencies as a constraint for the acquisition of certain AFEV technology in each municipality;
- Estimate the capacity, in kWh, of a fleet of AFEV as a function of the AFEV's share regarding conventional internal combustion vehicles. Estimate, in addition, the individual capacity of each AFEV technology;

- Estimate the additional cost of utilizing the AFEV units as stationary back up power sources, taking into account the frequency of occurrence of major disaster. This item will need to address the extra cost due to battery/Fuel Cell stack degradation, drivetrain extra-utilization;
- Define deployment strategies of a fleet of AFEVs for the emergency-response plan.

The second part of the project will examine idling and electrical power requirements (instruments, welders, etc.) that might be serviced by battery or fuel cell 'power packs.'

The outcomes of this research project may include:

- Feasibility study to determine the value of adopting a fleet of AFEV for the emergency-response scenarios
- Fast-response plan on how to manage AFEVs for support during major disasters
- Evaluation of on-vehicle stationary power sources for ancillary loads to reduce idling and generators, including fleet analysis and trial

Over the two years, one of the MASc. students will catalogue, characterize the risk associated with the region and the adequate fleet of AFEVs for fast emergency response plan. The work will also focus on the implementation of the Fleet-to-building adequacy taking into account capacity as a function of the size and diversity of the fleet and fundamental constraints such and battery / Fuel Cell stack degradation, drivetrain over-utilization. The second student will examine the fleet operational needs for stationary power currently serviced by idling vehicles or dedicated generators, and specific and trial battery and / or fuel cell power packs to service these requirements with reduced emissions.

APPENDIX 8: Project Budget

PROJECT COMPONENTS	BUDGET				SOURCES OF FUNDS						COMMENTS RE: GMF REQUEST	COMMENTS RE: OTHER FUND SOURCES
	CAPITAL	OPERATING	PST 7%	TOTAL CASH	CONFIRMED FROM CRD	REQUESTED FROM GMF	CONFIRMED FROM GOV. OF BC	CONFIRMED FROM IESVic	TOTAL COMMITTED	TOTAL CASH		
Vehicle/E-Bike Trials												
6 FCEV capital	$ 207,816		$ 14,547	$ 222,363	$ 82,047	$ 104,316	$ 36,000		$ 118,047	$ 222,363	Incremental cost of FCEV over ICE vehicle	CRD pays taxes, all operating, plus $11,250 per vehicle ($3750 per vehicle per year)
Operating FCEV		$ 88,000		$ 88,000	$ 88,000				$ 88,000	$ 88,000	$5500 per vehicle per year, includes insurance	CRD pays all operating
2 additional 'tester' BEV	$ 80,000		$ 5,600	$ 85,600	$ 38,910	$ 36,690	$ 10,000		$ 48,910	$ 85,600	Cost of 2 additional BEV for 3 years.	GMF pays 3/7 of capital cost and tax, plus all operating for 2 BEV for 3 years. CRD pays all capital and operating for BEVs bought in 2018 and 2019.
Operating 2 BEV		$ 7,500		$ 7,500		$ 7,500			$ -	$ 7,500		
2 BEV replacing ICE	$ 80,000		$ 5,600	$ 85,600	$ 75,600		$ 10,000		$ 85,600	$ 85,600		
Operating BEV replacing ICE		$ 3,750		$ 3,750	$ 3,750					$ 3,750		
2 E-bikes & gear	$ 20,000		$ 1,400	$ 21,400	$ 11,400	$ 10,000			$ 11,400	$ 21,400	Cost for one bike and gear	CRD pays taxes, cost of one bike and gear
Telematics (40)	$ 24,000		$ 1,680	$ 25,680			$ 25,680		$ 25,680	$ 25,680	Cost of licencing telematics for year 2	Fleet Carma pays cost of 40 telematics, plus first year of licencing, plus $15K EV suitability assessment
EV suitability study	$ 15,000			$ 15,000			$ 15,000		$ 15,000	$ 15,000		
Telematics operating		$ 40,400		$ 40,400		$ 20,200	$ 20,200		$ 20,200	$ 40,400		
4 BEV charging station	$ 12,000		$ 840	$ 12,840	$ 4,840	$ 4,000	$ 4,000		$ 8,840	$ 12,840	One third cost of the four stations	Fleet Champions pays $1K per station ($4K), CRD equipment replacement pays remaining 1/3 cost plus taxes
IESVic Analysis												
Smart Fleet		$ 90,000		$ 90,000		$ 49,000		$ 41,000	$ 41,000	$ 90,000	GMF contribution to student costs	UVic pays remaining student costs
E-bikes		$ 80,000		$ 80,000		$ 22,000		$ 58,000	$ 58,000	$ 80,000	GMF contribution to student costs	UVic pays remaining student costs
Emergency Power		$ 80,000		$ 80,000		$ 22,000		$ 58,000	$ 58,000	$ 80,000	GMF contribution to student costs	UVic pays remaining student costs
Support costs/computers		$ 97,440		$ 97,440				$ 73,000	$ 73,000	$ 73,000		UVic pays support costs (Computers), plus in kind faculty time
				$ -					$ -	$ -		
Project Support & Outreach												
Project development		$ 9,000		$ 9,000		$ 9,000			$ -	$ 9,000	GMF covers cost	
Feasibility study (CHFCA)		$ 15,000		$ 15,000			$ 15,000		$ 15,000	$ 15,000		Province (Communities and Transportation Alternative Energy Branch)
Project Mangagement		$ 94,700		$ 94,700					$ -	$ 94,700	~13.8 hours per week, 3 years, $44 per hour	CRD staff time 10 hours per week @$44 for 3 years
Symposium / Outreach		$ 65,000		$ 65,000		$ 65,000			$ -	$ 65,000	communications: $40K symposium, $25K outreach	
TOTALS	**$ 438,816**	**$ 670,790**	**$ 29,667**	**$ 1,139,273**	**$ 304,547**	**$ 349,706**	**$ 135,880**	**$ 230,000**	**$ 666,677**	**$1,020,133**		

List of Abbreviations

AFEV- alternatively fuelled electric vehicle

BEV- Battery Electric Vehicle

CRD- Capital Regional District

FCEV- Fuel Cell Electric Vehicle

GHG- Greenhouse Gas

IESVic- Institute for Integrated Energy Systems at University of Victoria

MEM- Ministry of Energy and Mines

V2G- Vehicle to Grid

ZEV- Zero Emissions Vehicle

ZEFI- Zero Emissions Fleet Initiative

ZEFIPP- Zero Emissions Fleet Initiative Pilot Project

Endnotes

---

1 http://www.motoring.com.au/act-government-orders-20-hyundai-fuel-cell-vehicles-103615/
2 http://www.ecowatch.com/hydrogen-fuel-cell-vs-electric-cars-which-will-drive-us-into-the-futur-1882109487.html
3 https://electrek.co/2017/01/04/automotive-execs-battery-powered-cars-vs-fuel-cells/
4 CRD Corporate Plan 2015–2018 (p.11)
5 CRD Corporate Climate Action Strategy, 2016
6 CRD Corporate Climate Action Strategy, 2016, p. 32
7 http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/transportation/cev_phase_1_review_final_2.pdf
8 https://www.cevforbc.ca/clean-energy-vehicle-program
9 https://www.cevforbc.ca/eligible-cevforbc%E2%84%A2-vehicles
10 http://pluginbc.ca/charging-program/incentives-for-fleets/
11 http://www.uvic.ca/research/centres/iesvic/index.php
12 http://www.chfca.ca/
13 Canadian Hydrogen and Fuel Cell Sector Profile 2015, June 2016
14 A National Hydrogen and Fuel Cell Strategy for Canada. Submitted by: Canadian Hydrogen and Fuel Cell Association. Date: June 28th, 2016
15 http://www.chfca.ca/say-h2i/cars-and-buses/bc-transit-fuel-cell-bus-fleet
16 CRD Corporate Climate Action Strategy, 2016 (p. 16)
17 https://www.hyundaiusa.com/tucsonfuelcell/index.aspx
18 Documented use of hydrogen-powered Tucsons in Vancouver.

[19] Electric cargo bikes. Images http://www.busybike.com/en/shop/brands/urban-arrow; http://bullitt-berlin.de/; http://www.butchersandbicycles.com/; http://www.thebicycleworks.org/cargo--electric-shop.html
[20] CRD Corporate Climate Action Strategy, 2016, page 34
[21] http://crd.ca.legistar.com/gateway.aspx?M=F&ID=d1e24d6c-b650-4901-841d-0907548fee46.pdf
[22] http://www.westcoastelectricfleets.com/fleet-pledge/
[23] CRD Corporate Climate Action Strategy, 2016, page 37
[24] CRD Corporate Climate Action Strategy, 2016, page 3
[25] http://www.hydrogencarsnow.com/index.php/chevy-equinox/
[26] Information quoted from https://www.fleetmatics.com/what-is-telematics
[27] http://www.timescolonist.com/news/local/crd-has-high-hopes-for-hydrogen-fuel-cells-1.2359349
[28] http://www.chfca.ca/education-centre/hydrogen-safety/
[29] NREL, "Hydrogen Production and Delivery," National Renewable Energy Laboratory, 2016. http://www.nrel.gov/hydrogen/proj_production_delivery.html. [Access Sept. 1, 2016].
[30] Canadian Hydrogen and Fuel Cell Sector Profile 2015, June 2016
[31] Canadian Hydrogen and Fuel Cell Sector Profile 2015, June 2016
[32] A National Hydrogen and Fuel Cell Strategy for Canada. Submitted by: Canadian Hydrogen and Fuel Cell Association, Date: June 28th, 2016
[33] http://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/transportation/cev_economic_opportunities_final_report.pdf Section 5, p. 42-43, 32
[34] http://www.hyundaihydrogen.ca/faq.html

[35] https://www.hyundaiusa.com/tucsonfuelcell/index.aspx
[36] http://www.greencarreports.com/news/1105869_u-s-army-chevy-to-unveil-hydrogen-fuel-cell-colorado-truck-in-october
[37] http://www.greencarreports.com/news/1105873_nikola-unveils-how-its-electric-truck-works-custom-hydrogen-fuel-cell
[38] https://www.driveclean.ca.gov/Search_and_Explore/Technologies_and_Fuel_Types/Hydrogen_Fuel_Cell.php
[39] http://www.prnewswire.com/news-releases/hydrogen-fuel-cell-vehicles-are-future-of-the-automobile-says-information-trends-300323754.html
[40] http://www.carpe-fc.ca/
[41] http://www.prnewswire.com/news-releases/hydrogen-fuel-cell-vehicles-are-future-of-the-automobile-says-information-trends-300323754.html
[42] http://www.motoring.com.au/act-government-orders-20-hyundai-fuel-cell-vehicles-103615/
[43] http://www.motoring.com.au/hyundai-locks-in-hydrogen-future-54046
[44] http://www.petrolplaza.com/news/industry/MiZlbiYyMDQyNyYmMSYzMCYx
[45] http://www.petrolplaza.com/news/industry/MiZlbiYyMDQyNyYmMSYzMCYx
[46] http://paultan.org/2016/08/30/toyota-aims-to-sell-30k-fuel-cell-cars-per-year-by-2020/
[47] https://www.hyundaiusa.com/tucsonfuelcell/index.aspx
[48] https://www.hyundaiusa.com/tucsonfuelcell/index.aspx
[49] CHII paper (unpublished)
[50] National Renewable Energy Laboratory NREL, «New Horizons for Hydrogen» Research Review, pp. 4-9, April, 2004.
[51] US DOE, "Hydrogen production: Electrolysis," US Department of Energy, 2016. [Online]. Available: http://energy.gov/eere/fuelcells/hydrogen-production-electrolysis. [Accessed 1th Sept. 2016].
[52] BC Hydro, «It's about water: 92% of BC Hydro's power generation is hydroelectric» BC Hydro, 2016. [On line]. Available: https://www.bchydro.com/energy-in-bc/our_system/generation/our_facilities.html. [Access le 27 Aug. 2016].
[53] Ministry of Environment, « 2016/17 B.C. Best practices methodology for quantifying greenhouse gas emissions,» Ministry of Environment, , Victoria, B.C., 2016
[54]http://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/renewable-low-carbon-fuels

[55] US DOE «HYDROGEN PRODUCTION» US DOE, 2016. http://energy.gov/eere/fuelcells/hydrogen-production.
[56] E3 Fleet review.
[57] BMW «BMW M5 Sedan Technical Data» BMW, 2016. [On line]. Available: http://www.bmw.com/com/en/newvehicles/mseries/m5sedan/2013/showroom/technical_data/index.html
[58] E3Fleet, "Capital Regional District E3 Fleet Review for 2014," Capital Regional District E3 Fleet, Victoria, Canada, 2015
[59] J. Tomić and W. Kempton, "Using fleets of electric-drive vehicles for grid support," Journal of Power Sources, vol. 168, no. 2, pp. 459-468, 2007
[60] K. Tanguya, M. R. Duboisb, K. Lina-Lopeza and C. Gagné, "Optimization model and economic assessment of collaborative charging using Vehicle-to-Building," Sustainable Cities and Society, vol. 26, p. 496–506, 2016
[61] T. Gómez San-Román, I. Momber, M. Rivier-Abbad and Á. Sánchez-Miralles, "Regulatory framework and business models for charging plug-in electric vehicles: Infrastructure, agents, and commercial relationships," Energy Policy, vol. 39, no. 10, p. 6360–6375, 2011
[62] K. Belson, "After Disaster Hit Japan, Electric Cars Stepped Up," The New York Times, 6th May 2011. [Online]. Available: http://www.nytimes.com/2011/05/08/automobiles/08JAPAN.html?_r=0