ZERO-EMISSIONS FLEET INITIATIVE

Final Study Report

Making a difference...together

Capital Regional District | December 2021

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Introduction

The Capital Regional District's (CRD) Zero-Emissions Fleet Initiative (the Initiative) launched in February 2018 and completed in October 2021. The 'technology neutral' initiative focused on testing and comparing the use of zero-emissions vehicles, including battery electric vehicles (BEV), hydrogen fuel cell electric vehicles (FCEV), plug-in hybrid gas/electric vehicles (PHEV), and electric bicycles (e-bikes).

Project Objectives

The aim of the initiative was to embark on a process to eventually reduce greenhouse gas (GHG) emissions from the CRD fleet to almost zero. The Initiative supports the gradual replacement of internal combustion engine (ICE) vehicles with zero-emission models using hydrogen or electricity for fuel, as well as sizing vehicles for the appropriate use, reducing kms travelled, improving driver efficiency and, in some cases, using a modal shift with e-bikes replacing vehicles. The CRD has the potential to replace up to 100 existing ICE vehicles in the coming years as part of its ongoing fleet replacement process.

This project aimed to meet multiple objectives:

- Reduce GHG emissions in the CRD fleet by:
    - Conducting a field trial of FCEVs as part of the CRD fleet, with a view to broad adoption of this technology within the fleet
    - Testing and analyzing the use of additional zero-emission alternatives, including BEV and e-bikes where operationally appropriate
    - Conducting an in-depth "smart fleet" study to learn from and optimize these applications in terms of operating costs and GHG reduction
    - Investigating opportunities to use electric vehicles as an emergency power source
- Reduce GHG emissions from other vehicles on southern Vancouver Island by:
    - Sharing the results of the CRD pilot with local governments, businesses and interested individuals within the region and across British Columbia
    - Supporting fuel cell electric vehicle infrastructure deployment in coordination with the provincial government, the private sector and the host municipality
    - Supporting the uptake of FCEVs by other fleets and individuals on southern Vancouver Island
- Support economic development opportunities associated with hydrogen fueling infrastructure

Project Partners

The CRD was the lead partner for this initiative, supported by the Institute for Integrated Energy Solutions at the University of Victoria (IESVic) and the Province of British Columbia (through the Ministry of Energy and Mines).

Capital Regional District

The 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.

The CRD has clearly acknowledged and committed to taking action to address climate change within our operations as well as at the regional level, to reduce emissions and to prepare for the uncertainty a changing climate brings. This was highlighted in the CRD Board's declaration of a climate emergency in early 2019 and commitment to taking a leadership role to pursue regional carbon neutrality.

In response to the climate emergency, the CRD developed an updated five-year Climate Action Strategy in 2021, replacing two former strategies and integrating with existing local, provincial and federal climate action initiatives.

Developing and supporting low-carbon mobility within the capital region is a key pillar of the CRD's Climate Action Strategy. The CRD is technology neutral and is committed to exploring and using zero-emissions technology that can meet operational and duty-cycle needs in a cost-effective manner.

The Institute for Integrated Energy Systems at the University of Victoria

The mission of the IESVic is "To chart feasible paths to sustainable energy." IESVic 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.

Study of fuel cell technologies is part of IESVic's current research. Researchers are working to address most steps in a hydrogen energy system, 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 a key initiative at IESVic. The institute receives support from a number of government and industrial partners for its research into stack modelling 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 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 working on a Transportation Futures project focusing on electrification of transportation. This includes a wide range of vehicle classes, from e-bikes, through to personal vehicles, busses, 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 BC/AB to California grid with and without control over charging behaviour. 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.

IESVic undertook various aspects of research in this project, both during the developmental stages and analyzing the project implementation.

British Columbia Ministry of Energy and Mines

The Province of British Columbia has set legislated targets for reducing GHG emissions 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 BC's GHG emissions, respectively, making a transition to clean energy vehicles an important part of the Province's climate strategy.

Through the BC Ministry of Energy and Mines and the Clean Energy Vehicle Program, the Province supports the adoption of clean energy 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 BEV can qualify for up to $5,000 off the purchase price. The Province also supports the Fleet Champions Program, which assists fleets in British Columbia in their efforts toward deploying clean energy vehicles by offering technical and financial support for an electric vehicle business case, as well as providing incentives for the installation of charging infrastructure.

The Province provided funding towards the installation of a hydrogen fueling station for southern Vancouver Island. In addition, BC Ministry of Energy and Mines staff provided technical support to this project.

Part 1: Zero-Emission Vehicle Pilot Project

A key objective of the Initiative project was to test multiple types of zero-emissions vehicles, including hydrogen fuel cell vehicles, BEV, plug-in hybrid electric/gas vehicles, and e-bikes. This pilot project investigated matching zero-emission vehicles with operational requirements and what challenges and benefits they would provide.

Program Design

The complete pilot project was designed as three separate vehicle tests:

Fuel Cell Electric Vehicles

The FCEV pilot was designed as the follows:

- Lease six FCEVs (ultimately reduced to two FCEVs due to supply issues from vehicle manufacturer).
- Provide training for staff on the use and fueling 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 Canadian Hydrogen and Fuel Cell Association to provide publicly available hydrogen fueling facilities in the CRD region.

E-bikes

The initial testing of e-bikes will be done by source control inspectors, who inspect businesses within a 5-km or less radius of CRD headquarters. The City of Victoria is continuously upgrading its system of cycling lanes, making cycling an even more desirable choice. The e-bikes were equipped with data loggers, and the benefits and challenges of this trial were monitored by IESVic, who provided an analysis of the program and recommendations for expanding this trial.

The pilot project included the following actions:

- Purchase two e-bikes and associated gear (helmets, lights, high-vis vests, locks, etc.);
- Coordinate safety training for inspectors using the bikes;
- Map the inspection territories to be visited by e-bike;
- Create standard operating procedures (and ensuring adherence to) to guide e-bike use and care (safety, parking, anti-theft, re-charging etc.);
- Define minimums for use (e.g., minimum twice per week dependent on safety/weather factors);
- Track the mileage and electric energy use and estimate GHG savings; and
- Provide final reporting out of number of trips, distances travelled, cost benefits, successes/challenges, observations and recommendations.

Battery Electric Vehicles

The BEV pilot project included the following:

- Purchasing two 'tester' BEVs
- Adding at least two more BEVs to the fleet, replacing ICE vehicles
- Adding telematics to 40 fleet vehicles
- Studying the opportunities for using EVs as an emergency or off-grid power source

The CRD purchased two BEVs that are additional to normal fleet requirements and made them available to staff to test their applicability. These BEVs did not replace existing vehicles, but were used in a series of different locations for a test period of two-six weeks so that staff could test them and provide feedback on the results. At the end of the two-year testing period, the "tester" BEVs were incorporated fully into the fleet as replacements for ICE vehicles.

Two additional PHEVs were added to the pilot instead of additional electric vehicles. The earlier fleet analysis indicated that all-wheel drive (AWD) and long driving distances were a requirement for some vehicle operation scenarios, and available EVs at the time could not meet these requirements.

Implementation

The procurement and testing of ZEVs stretched across a five-year period, and some changes in scope occurred. Details are described as follows.

Timeline

The ZEV pilot project began with the installation of an electric vehicle charger in September 2016, and ended with the return of the FCEVs in April 2021. A brief outline of the timeline is presented below:

2016	September	First Level 2 electric vehicle charger installed at CRD HQ
2017	January	Two Kia Soul electric vehicles purchased
	March	Twin Level 2 electric vehicle charger installed at Integrated Water Services building
2018	February	E-bikes were purchased and the four-month trial was completed
	November	First Mitsubishi Outlander AWD PHEV purchased
2019	February	Second Mitsubishi Outlander AWD PHEV purchased
2020	September	Two FCEVs leased
2021	January	Hydrogen fueling station completed; FCEV pilot beings
	April	FCEV pilot ends and vehicles returned

Changes in Scope

Over the three-year project timeline, some changes from the initial project plan occurred, as described below. While implementation details varied, the goals of the project remained the same.

Replacement of Two Electric Vehicles with Plug-in Hybrid Electric Vehicles

The project plan called for CRD to procure four EVs. Results of the telematics analysis found that PHEVs were better suited for CRD's uses (offering AWD), and would be used in electric mode for over 97% of trips taken, while providing greater range for the 3% of trips that were beyond the plug-in electric vehicle range. Consequently, CRD shifted procurement of two of the EVs to PHEVs. This change was confirmed with the Green Municipal Fund advisor. The change in environmental benefits is expected to be negligible.

Procurement of Additional E-bikes

The project plan anticipated piloting two e-bikes. However, bicycles come in various sizes and to accommodate all of the staff participating in the pilot, three bicycles (sized small, medium and large) were required. This change has no impact on the environmental benefits. Additional costs were covered by the CRD.

Delay in Procurement of Hydrogen Fuel Cell Electric Vehicles

The project plan anticipated piloting six FCEVs in the CRD fleet beginning in 2017, subject to the availability of hydrogen fueling in the capital region. Synergistically, but separate to the Initiative, a hydrogen fueling station is opening in the capital region, as part of the Province of BC's Hydrogen Fueling Infrastructure Program. The opening of the hydrogen fueling station was delayed until 2021. Consequently, CRD delayed procuring and piloting the FCEVs until January 2021. Due to the limits of the vehicle leases, the vehicles were returned in April 2021, resulting in a four-month trial period rather than the initial goal of three years.

Results

The pilot program looked for insight and feedback in the following categories. Summary of results are described in each.

Vehicle Performance

ZEVs were generally found to be acceptable for the use cases expected of them. Full BEVs with AWD were not available, so PHEV with AWD were substituted, resulting in higher emissions. The driving range of the Kia Soul EVs (approx. 150 km) was seen as sufficient for most intended trips, but too short for some, leading staff to select ICE or PHEV vehicles for these trips instead.

It should be noted that range and AWD availability is improving with time. The average electric vehicle driving range on a single charge is now double that of the Kia Souls from 2017, thanks to technological improvements.

Driver Response

After the FCEV pilot, a qualitative survey was sent to staff who had operated the vehicle asking about what they enjoyed, disliked, their refueling experience, and overall opinion of the vehicles.

Driver feedback was generally positive, with some mixed feedback, particularly regarding refueling. Operators appreciated the smooth driving experience and knowing that the vehicle was greener to drive. Users mentioned the vehicle was a little different to drive compared to what they were used to, for example, the acceleration was "quiet".

There were concerns and hesitancy about refueling. Some had no issues, but some mentioned learning the new procedure was slow and one user called it frustrating. The single available location for refueling was seen as inconvenient by several users and it was not necessarily in a location that they were normally driving in.

One user was concerned about the safety of driving with compressed hydrogen on board.

Benefits and Challenges

Fueling of the FCEVs provided the benefit of the CRD not having to own and operate fueling infrastructure, as this was handled by the private company.

However, the lack of widespread fueling locations was seen as an inconvenience by FCEV operators and likely results in more distance being driven by the vehicles to reach the fueling station.

The new fueling method is more complicated than an electric vehicle charger, and required additional training for staff.

Public Response

The testing of FCEVs received some negative reaction from the public. On January 21, 2019, the Residents for Responsible Renewables lobby group sent a letter to the CRD Board Chair and Members, cc-ing municipal staff across the region. The group presented economic and environmental concerns related to the development of hydrogen fueling infrastructure in the capital region, and CRD's pilot of FCEVs within the CRD fleet.

Hydrogen Fueling Infrastructure

The external partners experienced some challenges in establishing a hydrogen fueling station in the region, resulting in a significant time delay to open the station. Other than the initial station, no other growth in hydrogen fueling for passenger vehicles has been seen in the capital region so far.

Part 2: Research and Analysis

The second objective of the Initiative was supporting vehicle trials with research into ways to substantially reduce energy use in the fleet through use of telematics and modelling; additional zero-emission transportation through BEVs and e-bikes replacing traditional vehicles; and exploring the potential for innovative ways to use electric vehicles as a power source in an emergency situation. These are described in detail below.

Fleet Telematics and Electric Vehicle Suitability Study

Partnering with Fleet Carma, a fleet management consultant, and student researchers at IESVic, the goal of this portion of the project was to conduct a smart fleet analysis and tools for fleet optimization.

Initial Program Design

The smart fleet analysis was designed to focus on the existing fleet and its usage. Analysis would be aided by the addition of telematics on about 30 ICE vehicles, to gather detailed information on vehicle usage. IESVic would analyze this data to answer the question of the adequacy of each alternative fuel technology or any combination of them that will lead to the lowest GHG emissions per year. The analysis would 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 operational cost and associated GHG emissions. Both evaluations would be bounded by the operational and corporate constraints.

Operational constraints include vehicle status/performance, weather conditions, fueling/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, would be essential for future policy decision making regarding GHG emissions.

The outcomes of this research were planned to 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 was planned to 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.

Implementation

Between February 2018 and February 2019, 43 telematics devices were installed within 62 fleet vehicles. Information was gathered on vehicle usage, with a focus on reducing GHG emissions, enhancing utilization and reducing operating costs. Before installing the devices, CRD undertook a privacy impact assessment, and rolled out an extensive internal communications campaign in conjunction with the device installment.

Results of the telematics study were presented in an Electric Vehicle Suitability Assessment (Appendix A) based on the telematics data, which recommended replacing 13 ICE vehicles with plug-in hybrid electric vehicles. An IESVic post-graduate student is currently conducting a more comprehensive analysis of the data, and trying to verify fuel consumption predictions through a micro-trip approach and assumed stoichiometric fuel rates from mass airflow sensors against data-logger fuel consumption predictions.

Summary of Results

From the Electric Vehicle Suitability Assessment, it was found that if 13 of the baseline vehicles were replaced with the plug-in hybrid vehicles, the fleet would see the following total savings over the service lives of the baseline vehicles:

- the fleet could save $147,446 in total savings over the service life. This represents 13% of the fleet budget.
- the fleet could realize an emission reduction of 49.2 tonnes per year over the service life, representing a 43% reduction in CO_2 emissions.
- the fleet could reduce gasoline and diesel consumption by a total of 16,067 L annually over the service life, representing a 43% reduction in fuel.

The study found that few vehicles are being used heavily, and a few were under-utilized. The threshold for an under-utilized vehicle is less than 25 kms per day, and less than one hour of engine on-time. Vehicles that meet this criteria could be replaced by a mileage reimbursement vehicle or a pool vehicle.

Evaluation of anonymized, averaged driver behaviour indicated possible opportunities within the fleet to review safe driving practices. Smooth braking and smooth acceleration can help reduce maintenance costs over the life of the vehicle. For an electric vehicle, smooth braking allows for more energy to be captured via the regenerative braking process.

Looking at the comparative data in the reports, two key areas were identified to consider in order to begin plug-in vehicle adoption:

1. Implementing PHEVs will ensure the vehicles are range capable and able to support the level of utilization observed in the fleet. To facilitate the implementation of an electric fleet, charging stations must be available and drivers must be encouraged to plug in the vehicles to maintain a high electric vehicle fraction. This will allow the fleet to realize the maximum level of savings.

2. There is a large opportunity to transition light duty trucks and/or SUVs to PHEV SUVs. At the time of the study, there were not many SUV EVs available. However, additional significant fuel and emission savings can be realized if the conventional light duty trucks and SUVs can be replaced with suitable PHEVs or newly available BEV.

E-bike Fleet Deployment Analysis

The CRD E-bike pilot was a joint project between IESVic and the CRD. The proposed research goals for the e-bike project were:

1. To make recommendations regarding the optimal use of e-bikes in urban commercial fleets
2. To compare the environmental, economic, and logistical performance of the operation of e-bikes in urban fleets to other vehicle modes
3. To make recommendations regarding the regulatory constraints placed on e-bike use with respect to motor power limits

Methodology

The research goals were answered through the deployment of three e-bikes outfitted with multiple sensors to capture a variety of data. The purpose of this work is to provide quantifiable, evidence-based results to inform the CRD as to the efficacy of the use of e-bikes in their corporate fleet. Additionally, this project was meant to inform other fleet operators as to the operational costs and benefits of e-bikes in commercial fleets. The project abstract is presented below and the complete project report is available Appendix B.

Abstract of Final Report

The deployment of three e-bikes into the CRD fleet resulted in over 600 km of recorded trip data. This data was used to inform several academic research projects, as well as determine typical operational capabilities of e-bikes for the CRD fleet. The collected data showed a reduction of emissions by 99% when compared to a typical car found in the CRD fleet. Even compared to battery electric cars, the e-bikes represent a 95% reduction in emissions. Compared to both of these modes, the e-bikes also represent an over 80% reduction in capital and operating costs.

Overall, the deployment of the e-bikes saved approximately 250 kg of CO_2, if they are considered to have replaced ICE car trips. The operating capabilities of e-bikes shows them as having half the pace of cars in urban environments. Where a car can cover 5 km in 8.5 minutes, an e-bike typically covered the same distance in only 20 minutes.

Fleet Vehicle Energy Consumption Software Prediction Project

In partnership with IESVic, CRD fleet logger data was used as a basis for development and verification of a data-driven, software-based tool for improved-accuracy predictions of fleet fuel and energy consumption. The resulting deliverable was a Master's thesis by student Autumn Umanetz. The thesis abstract is presented below and the complete thesis document is available in Appendix C.

Abstract of Final Thesis Project

This study proposes a data-driven model for prediction of the energy consumption of fleet vehicles in various missions, by characterization as the linear combination of a small set of exemplar travel segments. The model was

constructed with reference to a heterogeneous study group of 29 light municipal fleet vehicles, each performing a single mission, and each equipped with a commercial global positioning system logger. The logger data was cleaned and segmented into three-minute periods, each with 10 derived kinetic features and a power feature. These segments were used to define three essential model components as follows:

The segments were clustered into six exemplar travel types (called "eigentrips" for brevity). Each vehicle was defined by a vector of its average power in each eigentrip. Each mission was defined by a vector of annual seconds spent in each eigentrip. Ten percent of the eigentrip-labelled segments were selected into a training corpus (representing historical observations); with the remainder held back for testing (representing future operations to be predicted). A Light Gradient Boost Machine classifier was trained to predict the eigentrip labels with sole reference to the kinetic features, i.e., excluding the power observation. The classifier was applied to the held-back test data, and the vehicle's characteristic power values applied, resulting in an energy consumption prediction for each test segment. The predictions were then summed for each whole-study mission profile, and compared to the logger-derived estimate of actual energy consumption, exhibiting a mean absolute error of 9.4%. To show the technique's predictive value, this was compared to prediction with published L/100 km figures, which had an error of 22%. To show the level of avoidable error, it was compared with a Light Gradient Boost Machine direct regression model (distinct from the Light Gradient Boost Machine classifier), which reduced prediction error to 3.7%.

Earthquake Resiliency Implications of CRD Electric Vehicle Adoption

This sub-project of the Initiative was aimed at assessing the ramifications and potential roles of electric vehicles in a post-disaster scenario. A Cascadia earthquake has been chosen as the disaster framework to analyze as many of its disaster effects (e.g., damaged roads, landslides, disruption of power) are also experienced during other disaster concerns for Victoria, such as landslides and wildfires. The project summary is presented below and the complete report is available in Appendix D.

Background

The goal of the project was to provide a research paper for use cases tailored specifically to the CRD based on two key research question covered below:

1. What is the risk inherent in the adoption of an increasing share of electric vehicles in a local government fleet?
    a. To answer this question, research is being conducted into the resiliency of the liquid fuel vs. electrical supply infrastructure in a post-earthquake context. Initial research in this area has been conducted into what information is available for the Cascadia subduction zone of North America (extending from northern Vancouver Island to northern California), but the paper itself will focus Lower Mainland and the entirety of Vancouver Island, with more detail given to Vancouver Island.

    b. Research will also be conducted into the post-earthquake resiliency of electric vehicle charging infrastructure (electric vehicle charging stations for multiple vehicles, individual workplace charging ports, connectors).

2. What are the possible post-earthquake use scenarios for electric vehicles?
    a. How could electric vehicles act as individual nodes in an ad-hoc communication network in the case that the main 5G communication network has failed?
    b. Could electric vehicles provide power to emergency response shelters for people displaced in the earthquake?

Executive Summary

The following is the executive summary from the final research report, which can be found in its entirety in the appendices.

The adoption of electric vehicles has many benefits, such as reduced emissions, better performance, and economic savings on maintenance and fueling. The Greater Victoria area has one of the largest concentrations of electric vehicles in BC, and this concentration is only expected to grow with time. Greater Victoria is also located in a portion of BC with a high seismic hazard and would be profoundly affected by a Cascadia subduction zone earthquake. Until recently, maintaining vehicle use after an earthquake has depended on the resilience of the fuel infrastructure, but the increasing use of electric vehicles will transfer some of that dependence to the resilience of the electrical system.

Analyzing past earthquakes in Chile, Japan and New Zealand provides some insight into how to increase earthquake resilience. The 2010 Chile earthquake showed the importance of available excess generation capacity, private forms of communications, and utilizing small generators for recovery in isolated areas. The 2011 Japan earthquake illustrated the value of not locating too much generation capacity in tsunami zones, utilizing rolling blackouts for recovery, and the exceptional performance of microgrids. The 2011 New Zealand earthquake taught the danger of buried cables in liquefaction zones and how impactful spending money on resilience upgrades can be.

BC Hydro can improve the resilience of the electrical grid by adding generation capacity, relocating grid elements from tsunami and liquefaction zones, planning to have resources for repairs available, and establishing aid agreements with surrounding areas. Vancouver Island can improve its fuel resilience by retrofitting ports, increasing fuel storage, and planning for how fuel will be prioritized after an earthquake.

The CRD can improve their organizational earthquake resilience by establishing a local microgrid and utilizing the battery capacity of their electric vehicle fleet to provide mobile storage following an earthquake. The CRD can also plan for what their expected vehicle and generator fuel needs would be after an earthquake and establish sufficient storage.

Electric vehicles can be used after an earthquake to establish a communication network by acting as individual nodes in the network. Over 24 hours, an electric vehicle would use 0.533 kWh to provide this function, and a Nissan Leaf Plus could act in this capacity for about 116 days before battery depletion. In a 24-hour period, a Nissan Leaf Plus was found to able to donate 400 kWh of energy to a local shelter, assuming the vehicle had access to a fast charger and a microgrid with a 100 kW solar array. Given the Leaf's 363-km single-charge range, the same microgrid was able to provide power for eight Leafs to deliver supplies and people for a 24-hour period, assuming that each vehicle charged once per 24 hours.

Part 3: Project Outreach

A key focus of the Initiative project was community benefit through outreach and knowledge sharing. Final results and reports will be available on the CRD's public-facing website. Additionally, the project included the following direct outreach activities.

Zero-Emission Vehicle Symposium

The CRD hosted the Zero-Emission Vehicle Transportation Showcase on October 28, 2021, at the University of Victoria. This event enabled practitioners in government, non-profits and industry to connect, share best practices and identify potential collaborations.

Event Overview

The Showcase included:

- three themed sessions focused on local government best practices, academic research trends, and long-term community vision; and
- an evening networking event with local practitioner presentations.

Participation and Feedback

The event brought together 22 in-person participants, including 12 presenters and 11 online participants.

The CRD received positive feedback overall on the content, with guests noting that the event was a balance of detail and big-picture presentations, underscoring the value of knowledge sharing. Participants enjoyed the hybrid format, though the in-person attendees were particularly pleased to be able to discuss the topic in person, often for the first time since the COVID-19 pandemic began.

This event could be a useful model for regional knowledge sharing as more municipalities and organizations move forward on their path to decarbonized transportation. It also highlighted the importance of regional coordination and the role that the CRD can play in helping to connect key players and support the delivery of important initiatives.

Key Themes

Several key themes emerged from participant questions and comments, as well as from the various presentations:

Table 1: Key Themes of ZEV Symposium

Theme	Description
Beyond the commute	Many governments and organizations have made key steps towards supporting or requiring zero-emission passenger vehicles for commuting and other household travel. Showcase discussions highlighted interest in looking beyond the commute to broader ZEV opportunities, such as recreation, tourism, and emergency planning, and other emphasizing co-benefits like health metrics and economic development.
Beyond the car	Efforts to shift passenger vehicle kms to zero-emission are important. However, organizations are investigating how to reduce the total number of vehicle kms by shifting and electrifying other modes. Participants identified e-bikes, electric buses, and mode connectivity as increasingly important parts of the transportation system.
Knowledge sharing is vital	Municipalities across the region have different approaches and are at various stages of ZEV transportation implementation. It can be difficult to balance local interests in electric vehicle infrastructure and requirements. Integrating best practices and learnings from other organizations is highly valuable when tailored to the local municipal context. The CRD's efforts to connect and support municipalities play a key role in this exchange.
Measuring what matters	Data from zero-emission vehicle and infrastructure adoption is critical for tracking climate, transportation, and implementation metrics. Strong data can inform future designs, capture benefits, and mitigate negative impacts. Further, data availability can also foster research collaborations, as data availability can be a limiting factor in analysis.
A transition for everyone	Ensuring equitable access to zero-emission transportation is top of mind. Organizations are aiming to bring everyone along in the transition, but the 'how' continues to be explored and iterated. Pilot projects and dedicated funding for target groups are being explored to evaluate potential solutions.

E-Bike Fleet Webinar

On February 26, 2019, CRD staff shared results of the e-bike pilot as part of an 'E-Bikes in Fleets' webinar presented by West Coast Electric Fleets, an initiative of the Pacific Coast Collaborative, a joint initiative of California, Oregon, Washington, and BC to accelerate a vibrant, low-carbon economy on the West Coast. The presentation covered the following topics:

- Introduction to the CRD and the Initiative project as a whole
- E-Bike pilot project description
- Safe staff operating procedures
- Cost and procurement
- Storage and Security
- Results and GHG reductions
- Lessons learned and next steps

The complete presentation can be found Appendix E.

Final Project Results

The Initiative project aimed to take essential first steps toward reducing GHG emissions from the CRD fleet to almost zero. The project piloted zero-emission models using hydrogen or electricity for fuel, including FCEVs, EVs, PHEVs and e-bikes.

This project aimed to directly reduce GHG emissions in the CRD fleet, support the reduction of GHG emissions from other vehicles on southern Vancouver Island, and support economic development opportunities associated with hydrogen fueling infrastructure.

A summary of the project results is as follows.

Benefits and Drawbacks of ZEV Technologies

The Initiative examined a number of ZEV technologies and use cases. A brief summary of the benefits and drawbacks of these technologies identified by the project are outlined in the table below.

Table 2: Benefits and Drawbacks of ZEV Technologies

New Technology	Benefits	Drawbacks
Smart fleet analysis	Rigorous evidence-based comparative data on zero-emissions vehicles; new applied research findings for optimizing Smart Fleets. Microtrip modelling of vehicle duty cycles appears to be quite promising in terms of applying method to other fleets with varied duty cycles, as an alternative to trying to build bottom-up drivetrain models.	Data loggers do not capture data from heavy-duty fleet vehicles (however, a suitable electric vehicle or FCEV replacement does not exist at this time).
FCEVs	Reduced GHGs; support for emerging industry	Difficulty in providing fueling for new technology type; difficulty procuring vehicles; lack of models suitable for CRD needs capital cost of vehicles (without factoring in subsidies).
BEV	Reduced GHGs; reduced operational costs	Vehicle range; range anxiety; limited electric vehicle charging infrastructure; length of charge time; lack of models suitable for CRD needs (e.g., pickups, heavy duty, AWD SUV with range). *Continued on next page*

New Technology	Benefits	Drawbacks
Plug-in Hybrid Electric Vehicles	Longer ranges; more model types available (e.g., AWD); can refuel at gas stations; reduced GHGs compared to ICE vehicles	Can operate without being charged using fuel only and limiting their GHG reduction and operating cost savings; dual drive-train requires more maintenance than either EVs or ICEs
E-bikes	Reduced GHGs; reduced operational costs; employee health and fitness. E-bike modelling has been useful in showing implications of regulatory limitations and rider behaviour on GHG emissions impacts.	Mode of transport not suitable for all staff, or for all weather/climates; lack of cargo capacity; slower mode of transport, when compared to conventional vehicle.
Electric vehicles for emergency power	Potential to enhance emergency preparedness and resiliency.	Many external factors in post-disaster recovery are beyond the CRD's direct control (e.g., delivery of fuel or electricity).

Quantitative Results

From its initiation, the Initiative project defined several quantitative project parameters to track the effect of the program. These are outlined in the table below with commentary as follows.

Table 3: Quantitative results summary of complete project

Project Parameter	Units	Baseline Performance (before project)	Final Performance (in 2020)
Greenhouse gas emissions (target portion of fleet)	t CO_2e	158.4	116.6 (reduction of 41.8)
Vehicles in fleet	number	304	296 (in 2020)
Vehicle km travelled (total fleet)	km	1,443,828	1,791,500
Electric vehicles in fleet	number	1	9 permanently (11 during lease period of FCEV; 9 on order for 2022
E-bikes in fleet	number	0	9
Hydrogen fueling stations in region	number	0	1

t CO_2e = tonnes of carbon dioxide equivalent emissions

Greenhouse Gas Emissions

The vehicles purchased and tested as part of the Initiative project directly avoided 16.8 t of GHG emissions and indirectly avoided an additional 25 t thanks to additional electric vehicles purchased by the CRD after the success of the Initiative pilot. In total, 41.8 t of GHG emissions were avoided (see Table 4). For the FCEVs, this considers only the tank-to-wheel emissions and it assumes that hydrogen can be produced in a zero-emission method (e.g., hydro-power).

Table 4: Estimated GHG reductions from ZEV operations

ZEV	GHG reduction ($t\ CO_2e$)	Notes
2 FCEVs	0.4	44 total trips totaling 1,969 km of driving distance over four months; tank-to-wheel
2 BEV	11	Purchased as part of Initiative pilot project; 41,000 km driven
2 PHEV	3.9	Purchased as part of Initiative pilot project; 25,000 km driven
E-bikes	1.5	Extrapolated data from four-month trial: eight months per year for three years
Additional EVs	25	The CRD has purchased five additional electric vehicles since the Initiative pilot project; 94,000 km driven
TOTAL	**41.8**	

While significant, the program initially hoped for more GHG emissions to be avoided. However, several project setbacks reduced the final number. Due to lack of manufacturer availability, the FCEV pilot was reduced from six vehicles to only two. Additionally, due to the delay by external parties in opening the hydrogen fueling site on Vancouver Island, the FCEV pilot was reduced in scope from three years to four months. Furthermore, lacking available AWD electric vehicle models, two of the four vehicles in the electric vehicle pilot were swapped for PHEVs, which have improved fuel efficiency, but significantly more GHG emissions than an electric vehicle.

Advantageously for the future, most of these setbacks were solved by the end of the project. Because the electric vehicle pilot project was seen as successful, the CRD has purchased an additional five electric vehicles for its corporate fleet, resulting in further GHG reductions as a result of the Initiative. The CRD has nine electric vehicles on order for 2022 and further plans to purchase an additional 12.

Vehicles in Fleet

Over the course of the pilot project, the CRD corporate fleet reduced from 304 vehicles in 2017 to 296 vehicles in 2020. While not directly related to the Initiative, the project has significantly increased awareness of fleet usage and vehicle alternatives and undoubtedly informed fleet purchasing decision-making that has resulted in an approximate 3% reduction in fleet size.

Vehicle kms Travelled

The aim of the Initiative project was to analyze fleet usage and hopefully identify possibilities to reduce vehicle use. Unfortunately, vehicle use based on distance travelled has increased over the course of the project. Accurate data gathering was put in place in 2020, however, due the COVID-19 pandemic, it is likely that fleet behaviour changed in 2020 compared to the baseline year. For example, drivers were less likely to share vehicles and more likely to drive to sites individually, which would have resulted in increased kms driven.

Beneficially, the Initiative project was a contributing factor in the CRD developing accurate distance data monitoring that will support future efforts in fleet analysis.

Electric Vehicles in Fleet

One of the triumphs of the Initiative was the success in breaking electric vehicles into the CRD fleet. Over the course of the project, the CRD went from zero electric vehicles in operation to nine electric vehicles in 2021, with nine more already on order for 2022. This exceeded the expectations of the project. By overcoming the initial challenges of installing charging infrastructure, and giving staff experience with electric vehicles to ensure that they would fit existing work requirements, the Initiative program opened the door for widespread electric vehicle adoption at the CRD.

E-bikes in Fleet

E-bike adoption was another success for the project and the CRD. Due to popularity, additional e-bikes were purchased after the pilot program, bringing the total number of e-bikes to nine. They continue to be used regularly by CRD staff as shown in the figure below.

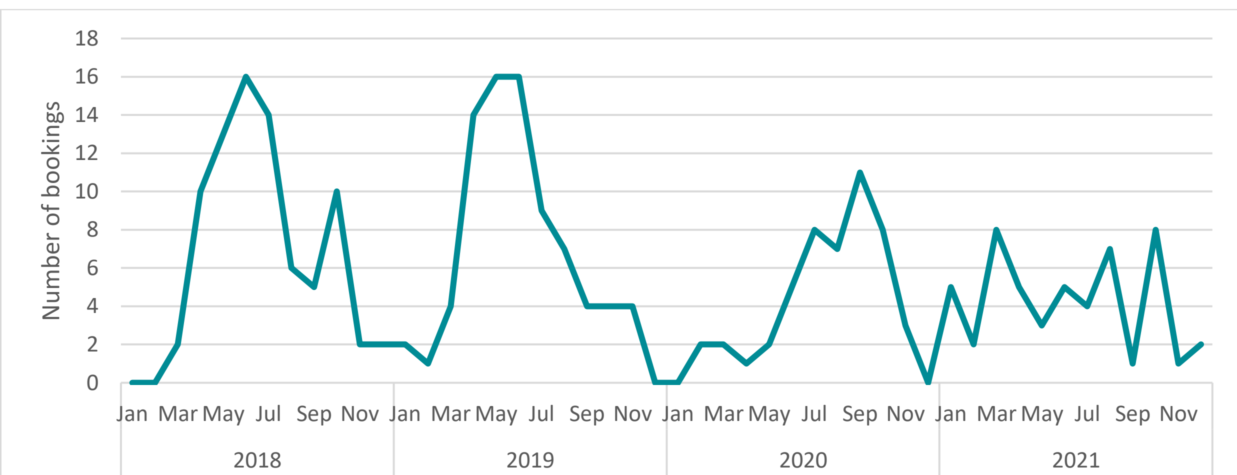

Figure 1: CRD E-bike usage by month

Hydrogen Fueling Stations in Region

While there were some delays in timeline, the support of the Initiative program helped bring about the development of a hydrogen fueling station in the Greater Victoria area. The hydrogen infrastructure safety study (Appendix F) completed in support of this project provided valuable information about the feasibility of the fueling station and addressed common concerns. This project provides new opportunity for future use and development of hydrogen fuel cell technologies in the region.

Socio-Economic Impacts

In addition to the environmental benefits of reducing GHG emissions, the Initiative project also had a variety of social and economic benefits.

Social

Some of the social benefits of the program included the following:

- Improved air quality in CRD service areas, including neighbourhoods and parks.
- Reduced noise pollution in CRD service areas, including neighbourhoods and parks.
- Increased visibility of ZEVs throughout the capital region to draw public attention, instill curiosity, and generate impromptu opportunities for engaging with the public.
- Significant organizational experience with ZEVs will provide significant knowledge to be shared as part of outreach programs.
- Hydrogen fueling infrastructure made available to Vancouver Island residents.
- Notable opportunity for civic pride about being early adopters and significant adopters of ZEV technology.
- Significant increase in electric vehicles, and resulting increased opportunity for electric vehicles to be used as a power source in emergency events.

Economic

Economic benefits of the program included the following:

- Reduction in fleet operational costs in fuel purchases and maintenance.
- Multiple hydrogen fueling stations in the region would result in business growth and local employment opportunities, and accelerate the development of a clean hydrogen industry in BC and Canada.
- Widespread availability of hydrogen fueling infrastructure would support new supporting business, such as hydrogen vehicle and infrastructure maintenance. Businesses that benefit from the availability of hydrogen would be attracted.

Conclusion

From 2017 to 2021, the Initiative provided a zero-emission vehicle jump-start for the capital region. It supported and funded academic research regarding ZEVs. It gave the opportunity for the CRD to purchase and test its first ZEVs and install the required infrastructure. The opportunity to understand ZEV applicability led to a further five electric vehicle purchases for the CRD corporate fleet and a growing rate of adoption (nine more purchases on order for 2022, with potential for 12 more), as well as efforts to expand the corporate charging infrastructure. The program supported the development of the first hydrogen fueling station for vehicles on Vancouver Island, opening up business and economic opportunities that may use this infrastructure. Overall, the program contributed to increasing rate of ZEV adoption both at the CRD and regionally.

The Initiative project was essential in CRD policy development around transportation emissions. It supported and informed the development of CRD's corporate Green Fleet Strategy, ensuring ZEVs are considered in all fleet purchases. Furthermore, the findings and experience gained from the Initiative was key in the development of the CRD's Climate Action Strategy, with goals for reducing emissions from vehicle use in the capital region and the CRD corporate fleet as well.

The project encountered some challenges; however, the hydrogen fueling station was delayed and FCEVs were not available from the manufacturer in the quantity expected. The project overall timeline increased, while the FCEV pilot duration was significantly shortened. Finding AWD electric vehicles was challenging, requiring PHEVs to be selected as alternatives, which are lower-emission but not zero-emission vehicles. Encountering and overcoming these challenges was valuable organizational learning and provided a basis for future ZEV decisions.

In summary, the Initiative was integral in developing new information and experience for the CRD around ZEVs. With strong future goals for electric vehicle adoption and GHG emission reduction, the Initiative project was a key stepping-stone on the CRD's path to its climate goals.

Making a difference...together

List of Abbreviations

AWD	All-wheel drive
BEV	Battery electric vehicle
CO_2	Carbon dioxide
FCEV	(hydrogen) fuel cell electric vehicle
GHG	Greenhouse gas
HQ	Headquarters
ICE	Internal combustion engine
IESVic	Institute for Integrated Energy Systems at the University of Victoria
PHEV	Plug-in hybrid gas/electric vehicles
SUV	Sport utility vehicle
t CO_2e	Tonnes of carbon dioxide equivalent

List of Appendices

Appendix A: Electric Vehicle Suitability Assessment Report
Appendix B: CRD-UVic E-Bike Fleet Deployment Report
Appendix C: Predicting Fleet-Vehicle Energy Consumption With Trip Segmentation Thesis Paper
Appendix D: Earthquake Resiliency Implications of CRD EV Adoption Report
Appendix E: Incorporating Electric Bikes into a Regional Government Fleet CRD Webinar Presentation
Appendix F: CRD Feasibility Study-Zero Emissions Fleet Initiative-Infrastructure Safety Study