# Lifecycle Costing Tool for Selecting New Fleet Vehicles

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## Disclaimer

## Acknowledgements

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# Executive Summary

## Introduction

The Township of Langley (TOL) has committed to electrifying 50% of their passenger fleet by 2026. A target of the Council-approved 2016 Strategic Energy Management Plan (SEMP), fleet electrification is the most effective way to decrease carbon emissions because fleet's fuel consumption accounts for almost half of all corporate greenhouse gas (GHG) emissions (38% of emissions). Since electric vehicles (EVs) have large capital costs compared to internal combustion engine vehicles (ICEVs), even after available incentives, a strong financial case is essential to obtaining budget approvals for these large capital investments.

The project is aimed to develop the Lifecycle Costing Tool (LCT), a model that takes historical expenses and projected future costs to estimate the true total cost of ownership for a vehicle over the lifetime the asset is in use. The LCT will assist TOL in selecting new vehicles and accelerate the adoption of low-emission vehicles. The tool will allow for complex comparison of lifecycle costs (LCC) between various vehicle models and will help to build the business case for selecting EVs over ICEVs.

## Methodology

The first stage of the project involved conducting a best practice research on other organizations in North America that were using a Lifecycle Costing Tool. It included general research on available software, examples of metrics the tool may need to comprise, and types of calculations and formulas used to determine the necessary metrics.

Project staff met with internal stakeholders from the Fleet and Finance departments to discuss the research findings and determine the necessary components and analysis logic for the tool. The recommendation was to develop an in-house tool using existing technology as a useful template.

The final result, the TOL Lifecycle Costing Tool (TOL LCT), consists of several components:

- *Inputs section* (in "Inputs & Dashboard" worksheet) where users choose the vehicle they are considering purchasing and may adjust some market and vehicle parameters,
- "Database" worksheet that has default inputs,
- *Financial model* that calculates LCC based on user-adjusted and default inputs ("Financial model"); and

- *Results section* (also in “Inputs & Dashboard” worksheet). The *Results section* consists of a dashboard demonstrating financial and environmental impact of vehicle use over their lifecycle. It includes graphs and tables showing annual energy consumption, carbon emissions, annual costs per kilometer, year-by-year cash flow comparison, etc.

The tool performs calculations based on data from official Canadian sources. Natural Resources Canada's 2019 Fuel Consumption Guide[1] and Plug In BC[2] are the source for information about vehicles available in British Columbia and their characteristics, including manufacturer's suggested retail price (MSRP) of EVs and plug-in hybrids (PHEVs). Atlas Policy Fleet Procurement Analysis Tool[3] provided the MSRPs of ICEVs. Project staff confirmed the federal and provincial incentives from Canada's Ministry of Transport[4] and the British Columbia official government website[5] and uploaded the general inflation rate from Bank of Canada annual targets[6]. Fuel Insights Inc.[7] and BC Hydro[8] provided the costs of fuel and electricity, respectively. Staff set the default cost of carbon from the Budget and fiscal plan 2018 of the Ministry of Finance and Corporate Relations of British Columbia and the Township’s Finance Department provided the standard fleet running costs.

## Summary

The TOL LCT shows that EV incentives currently play a significant role in making procurement choices in favour of EVs over ICEVs. However, including carbon costs, especially adding a more realistic figure like that of Metro Vancouver and City of Vancouver’s $150 per tonne of carbon dioxide ($CO_2$) emissions, would improve the business case for EVs even further.

## Next Steps

The final tool is going to be used by the Fleet Manager for analyzing potential vehicle procurements. The Tool User Guide explains how the tool works and how it was made and will

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[1] Fuel Consumption ratings: https://open.canada.ca/data/en/dataset/98f1a129-f628-4ce4-b24d-6f16bf24dd64

[2] https://pluginbc.ca/wp/wp-content/uploads/2019/05/Electric-Car-Handout_190523.pdf

[3] https://atlaspolicy.com/rand/fleet-procurement-analysis-tool/

[4] https://www.tc.gc.ca/en/services/road/innovative-technologies/list-eligible-vehicles-under-izev-program.html

[5] https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/clean-transportation-policies-programs/clean-energy-vehicle-program/cev-for-bc

[6] https://www.bankofcanada.ca/core-functions/monetary-policy/inflation/

[7] http://fuelinsights.gasbuddy.com/HeatMap

[8] https://app.bchydro.com/accounts-billing/rates-energy-use/electricity-rates/residential-rates/generation-rates-co2-comparison.html

serve the Fleet Manager as a resource for any future updates. Since the EV industry is new and very dynamic, the tool might require updates in the future such as adding new vehicles to the database and including new cost parameters or excluding the unnecessary ones. For example, the tool has an option to include carbon and battery replacement costs that are expected to be a considerable portion of vehicle lifecycle costs. Furthermore, the federal and provincial EV incentives programs are expected to be eliminated in several years, when the EV market becomes mature.

# 1.0 Introduction

The Township of Langley (TOL) has committed to developing a Lifecycle Costing Tool (LCT) for selecting new fleet vehicles as part of the Council-adopted 2016 Strategic Energy Management Plan (SEMP). This tool will help the Township reach its carbon reduction goals for fleet vehicles, which include:

- 50% of passenger vehicles to be electric by 2026
- 100% of gasoline trucks to be 50% more efficient due to right-sizing, electric, and fuel efficient purchasing by 2028

The Township's fleet fuel consumption accounts for 15% of corporate energy use and is the second largest source of its corporate GHG emissions, accounting for 38% of emissions. As part of the Township's commitment to supporting efficient, low carbon electrification, a LCT is planned for selecting new vehicles to accelerate the adoption of low-emission vehicles.

A LCT is essential for building the business case for selecting electric vehicles (EVs) over internal combustion engine vehicles (ICEVs). EVs have large capital costs compared to ICEVs, even after available incentives. Therefore, a strong financial case is essential to obtaining budget approvals for these large capital investments. The Township needs a tool that is designed for its specific fleet and financial parameters, allowing for comparisons between EV models and ICEV models, the tool will have to look at capital vehicle costs, available incentives, fuel costs, and maintenance costs.

This report is structured into nine sections, the first seven of which correspond to the stages of developing the appropriate LCT for the TOL. *Chapter two* demonstrates the overview of EV market trends in Canada and British Columbia. *Chapter three* summarizes the main findings from general research on available software and examples of frequently used metrics. *Chapter four* describes the main points of discussion of research findings with internal stakeholders from the Fleet and Finance departments, while *Chapter five* summarizes recommendations based on engagement with internal stakeholders and the research. *Chapter six* briefly describes the stages of tool development and issues arising in the process. *Chapter seven* describes the main components of final LCT and how the Tool can be accessed. *Chapter eight* contains instructions on how to use and edit the tool. *Chapter nine* and *Chapter ten* provide all the references used in the report and additional materials, respectively.

# 2.0 Background

### Electric Vehicle types

An electric vehicle or EV is the type of vehicle that contains a rechargeable battery that powers an electric motor for propulsion, instead of an internal combustion engine. The battery can be recharged by plugging into the electricity grid[9]. There are several types of EVs, according to Natural resources Canada[10]:

- Battery Electric Vehicles (BEV) that run entirely on electricity. BEVs use electricity to power an electric motor via a battery, which can be fully recharged by plugging into an external power source.
- Plug-in Hybrid Electric Vehicles (PHEV) use both an electric motor with battery and an internal combustion engine that can be used parallelly or separately.

### EV trends in British Columbia and Canada

The EV market in BC has been growing rapidly over the last 10 years. FleetCarma 2018 sales report[11] indicates that electric vehicle sales increased 158% by the end of September of 2018 compared to the same time the previous year. There was a total of nearly 35,000 EVs sold in Canada by the third quarter of 2018 of which 17,700 were PHEVs and 16,700 were BEVs. This represents 8.3% of total car sales in the third quarter of 2018 compared to 2.8% by Q3 in 2017. The reasons behind such an increase can be attributed to market maturity with more competitive EV models appearing in the market and growing consumer trust in EV technology.

Ontario, Quebec, and British Columbia experienced the greatest increase in EV sales in Canada (Figure 1). Notably, BC shows the highest EV adoption rates – 5.4% in 2018 compared to 5.0% in 2017 – even though BC's population as of 2018 was 4.8 million, which is significantly smaller than both Quebec (8 million) and Ontario (14 million). Nevertheless, the share of EVs in Canada is still small compared to other developed countries (e.g. Norway (39.2%) and Sweden (6.2%))[12].

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[9] EV101: https://pluginbc.ca/ev101/

[10] Natural Resources Canada: https://www.nrcan.gc.ca/energy/efficiency/transportation/21034

[11] Schmidt, E. (2018). Electric Vehicle Sales Update Q3 2018, Canada. Fleetcarma: https://www.fleetcarma.com/electric-vehicles-sales-update-q3-2018-canada/

[12] Benah K. Conongsby L. Clean Air Partnership. Building the corporate business case for electric vehicles. (2018): https://www.cleanairpartnership.org/wp-content/uploads/2018/11/CAP-EV-Business-Case.pdf

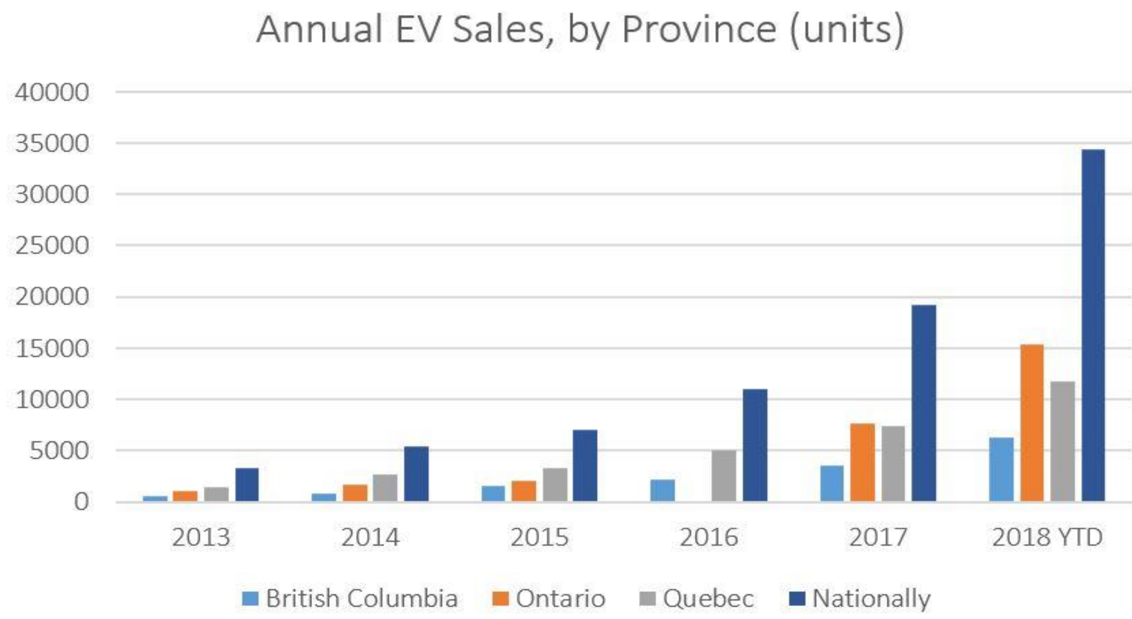


Figure 1. Source – FleetCarma. Electric vehicles sales update Q3 2018, Canada

**Are EVs economically competitive?**

Though EVs have a strong competitive advantage in terms of their lower ecological impact and overall driving experience compared to ICEVs, there are still concerns about the economic costs associated with purchasing EVs. These concerns can be addressed by providing the complex analysis of all the economic costs and benefits associated with EVs over their lifecycle.

The first stage of economic analysis should develop a costs breakdown. Though it is commonly known that the EVs have higher capital costs than majority of ICEVs due to high battery costs[13], there is a whole range of costs that should be considered. The majority of peer-reviewed research articles tend to agree on the following cost structure:

- Acquisition costs (including vehicle costs, charger costs, government invectives and taxes)
- Operating costs (including energy consumption costs, scheduled and unscheduled maintenance, battery or tire replacement, insurance)
- Disposal costs (including resale value)

[13] Kara, S., Li, W., & Sadjiva, N. Life Cycle Cost Analysis of Electrical Vehicles in Australia. (2017): https://www.sciencedirect.com/science/article/pii/S2212827116313397

Lifecycle vehicle costs also depend on the vehicle utilization (the number of trips, trips longevity, road quality, etc.) and market conditions (inflation, energy prices, taxes and incentives). Therefore, all the market projections should explicitly specify these usage parameters and preferably conduct sensitivity analysis under different market scenarios[14].

The second stage of economic analysis should consistently apply the developed approach to all vehicles. Different researchers sometimes do not consider all the parameters due to the lack of data or non-relevance to their case. Such inconsistencies in approach might become the reason for biased conclusions about economic advantage of some EVs.

The third stage of economic analysis should consider the economic side of such "non-financial" aspects of using vehicles such as ecological and infrastructural impacts.

To conclude, it is crucial for fleets to have a complex understanding of all the associated costs and benefits in order to have a full picture of EVs financial performance compared to ICEVs[15].

**Fleet key considerations for adopting EVs**

Fleets are the best candidates for EVs adoption. The main reasons for that are the availability of funding to cover the significant capital costs of EVs and charging infrastructure, as well as the access to data on usage patterns, including kilometers driven during the day, which allows for a scheduled charging strategy.

Fleets should be strategic in their adoption of EVs. The effectiveness of EV adoption in fleets depends on a number of parameters like availability of chargers, availability of suitable models, and the cost competitiveness between EVs and ICEVs. The latter parameter is very important to explore because EVs typically reveal cost savings over their lifecycle rather than upfront.

LCTs, which are designed to reflect all fleet management needs, can assist in analyzing fleet operations and allows fleet managers to derive the optimal time for replacement to optimize fleet costs. Moreover, LCTs can help fleet to monitor and adjust budgets, help with investment analysis, and maintenance strategy evaluation[16].

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[14] Breetz, H. L., & Salon, D. Do Electric Vehicles Need Subsidies? A Comparison of Ownership Costs for Conventional, Hybrid, and Electric Vehicles. (2018): https://trid.trb.org/view/1494605

[15] EVs Are Coming Faster Than You Think: https://www.chargepoint.com/files/EV_Research_Report_Rev5_12415.pdf

[16] Breault P., Felder M. Fleet challenge Ontario. Best practices manual (2011): http://www.fleetchallenge.ca/sites/all/themes/Fleet/pdfs/fcbpm2011.pdf

# 3.0 Literature review

This literature review summarizes key components and lessons learned from other organizations' LCTs. The research is based on fleet organizations' business cases and available tools and includes their brief overview and logic of the tool, fleet staff feedback on the tool (when available), and conclusions.

The review focuses on Canadian business cases since they apply costing tools that work with the same economic, environmental, and legal circumstances and therefore are most applicable. However, this review also explores several cases from the United States as they are more advanced in their EV adoption and have substantial experience working with EV fleets.

## 3.1 Business cases

### 3.1.1 Capital Regional District (BC, Canada)

**Overview**

The Capital Regional District (CRD), a district in British Columbia with a population of 383,400 people (2016), developed a Zero Emissions Fleet Initiative as a part of its Corporate Climate Action Strategy, which set the target to reduce GHGs by 33% from 2007 level by 2020[17]. In order to attain its target, CRD prepared a strategy that included (1) conducting a fleet trial with several types EVs and studying the travelling patterns using telematics and (2) a smart fleet analysis to calculate the EV potential of the fleet. As a result, according to Liz Ferris, the Climate Action Analyst of CRD, they discovered that 58% of their fleet had the potential for EV replacement.

In 2015, the CRD's fleet included 304 vehicles (with an average useful life of six years) that produced 54% of their $CO_2$ emissions. Before adoption of their zero emissions plan, the CRD had four PHEVs and one BEV. Wider adoption of BEVs was limited by the daily distances covered (that exceeded the EV ranges) and the lack of available SUV/ all-wheel drive BEV options[18].

[17] Ferris L. Capital Regional District. Zero Emissions Fleet Initiative. (2018, November 28): https://pluginbc.ca/wp/wp-content/uploads/2018/12/CRD-Liz-Ferris.pdf

[18] Feasibility Study. Zero Emissions Fleet Initiative Pilot Project. (2017, January): https://www.crd.bc.ca/docs/default-source/climate-action-pdf/zefi-feasibilitystudy.pdf?sfvrsn=5a11e0ca_2

As a result, the CRD expects to develop a mathematical tool to plan the replacement of the fleet units based on alternative fuel. According to fleet management of CRD, they decided to acquire the tool developed by E3 Fleet.

E3 Fleet is Canada's first fleet review and rating program, launched by the Fraser Basin Council in 2006, it offers organizations a variety of services in order to identify and achieve energy savings and emissions reductions in their fleets[19]. According to Roger Smith, Executive Director of the program and the President of Richmond Sustainability Initiatives[20], the tools are multifunctional and have real fleet databases (more than 50,000 vehicles from 100 municipalities). The tool provides recommendations on optimal vehicle replacement year, analyzes the effects of greening and replacement of the entire fleet, and produces a benchmark report.

**Tool features**

According to Roger Smith, E3 fleet has developed an expertise regarding lifecycle analysis (LCA) for vehicle fleets. They developed their simple 2016 LCT (Figure 2), which can be found on their website, into a more complex software. According to E3 fleet, the updated Fleet Analytics Tool (FAR) uses historical fleet data to model long term results (GHGs and costs, service levels such as availability and uptime) of different scenarios of fleet purchases ahead of actual implementation. Thus, the tool helps fleet management to reduce the risk while making important strategic decisions.

The tool consists of four modules:

1. Baseline analysis: GHGs and costs, service levels using FAR (discussed in more details further)
2. Life cycle analysis: identifying optimal economic lifecycles based on historical data via the new version of the LCA tool (discussed in more details further)
3. Best management practices review: optional, but recommended
4. Long-term capital budget planning: in the context of fleet modernization and carbon reduction within capital restraints

[19] E3 fleet information. Fraser Basin Council official website: https://www.fraserbasin.bc.ca/ccaq_e3_fleet.html

[20] His team is working on constructing medium vehicle tool for FBC

**Lifecycle Analysis Tool**

This tool is built to identify optimal economic lifecycles based on historical data. The tool includes inputs table, lifecycle costs analysis table, and visual representation of results. The tool accounts for both standard cost parameters as well as the cost effect of the decrease in productivity of workers due to vehicle aging, resale value, and the effect of idling. The tool calculates LCC of vehicles and then determines the optimal replacement year and savings associated with this replacement.

**Fleet Analytics Review (FAR)**

FAR uses historical fleet data to model go-forward results (GHGs and costs, service levels such as availability/uptime) from changes to the fleet under consideration by management ahead of actual implementation, hence reducing risk. The changes that can be modeled by the tool include fleet modernization, carbon reduction, trips reductions, road planning, idling reductions. Apart from that, the tool also highlights vehicles that perform at least 50% worse than benchmark vehicles with similar characteristics (in terms of fuel consumption rate).

**User feedback**

The tool was implemented by various USA and Canadian municipalities, including Summerland (BC), Oxford (NS), Calgary (AB), and City of Vaughan (ON). According to E3 Fleet, fleet managers are pleased with the tool since they obtain the information on their actual economic lifecycles based on real data and the tool data supports fleet replacement and capital budget submissions in the long-term (five years).

**Advantages of tool**

a. Includes both direct and indirect costs of using the vehicles (e.g. the loss in productivity due to vehicle aging and idling).
b. Based on a rich database compiled of different real fleets.
c. FAR tells the economic impact of the new fleet policy (including training). FAR also provides the benchmarking analysis of fleet performance compared to other fleets (in form of reports or by messaging which vehicle in the fleet underperforms compared to the benchmark average).

**Drawbacks of the tool**

a. Both tools cost *[redacted for public report]* dollars (not including additional analytics services)

b. Tools include features that might not be necessary at this point
c. The database might not be relevant for TOL case (e.g. USA data, EV market is constantly changing with new models appearing in the market)
**d.** The functionality of the tool might be out of scope of TOL's current needs

**E3 fleet** — *Annual Lifecycle Cost Tool for Fleet Managers: Example*

**INPUTS**

| | | |
|---|---|---|
| Interest | | *Interest Costs for Capital Expenditures* |
| Inflation Rate | | *inflation rate for adjusting life-cycle maintenance and operating costs* |
| Depreciation Year 1 | | *Rate of vehicle depreciation in the first year of ownership* |
| Depreciation Year 2+ | | *Rate of vehicle depreciation in subsequent years of ownership* |
| Vehicle Purchase Cost | $ 30 000 | *Purchase Cost of Vehicle* |

EXAMPLE ONLY

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Estimated Maintenance Costs | $ 2 000 | $ 2 500 | $ 3 125 | $ 3 906 | $ 4 883 | $ 6 104 | $ 7 629 | $ 9 537 | $ 11 921 | $ 14 901 |
| Estimated Operating Costs (Fuel, Insurance, etc) | $ 5 000 | $ 5 250 | $ 5 513 | $ 5 788 | $ 6 078 | $ 6 381 | $ 6 700 | $ 7 036 | $ 7 387 | $ 7 757 |

**OUTPUTS**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Current Year Mtce & Operating Costs Total | $ 7 000 | $ 7 750 | $ 8 638 | $ 9 694 | $ 10 960 | $ 12 485 | $ 14 330 | $ 16 572 | $ 19 308 | $ 22 658 |
| Purchase Cost | $ 30 000 | $ 30 000 | $ 30 000 | $ 30 000 | $ 30 000 | $ 30 000 | $ 30 000 | $ 30 000 | $ 30 000 | $ 30 000 |
| Residual (% of Purchase Price) | 70% | 56% | 45% | 36% | 29% | 23% | 18% | 15% | 12% | 9% |
| Current Resale Value | $ 21 000 | $ 16 800 | $ 13 440 | $ 10 752 | $ 8 602 | $ 6 881 | $ 5 505 | $ 4 404 | $ 3 523 | $ 2 819 |
| Life to Date -- Maintenance (Future Value) | $ 2 000 | $ 4 600 | $ 7 955 | $ 12 259 | $ 17 755 | $ 24 746 | $ 33 613 | $ 44 830 | $ 58 993 | $ 76 843 |
| Life to Date -- Operating (Future Value) | $ 5 000 | $ 10 500 | $ 16 538 | $ 23 153 | $ 30 388 | $ 38 288 | $ 46 903 | $ 56 284 | $ 66 485 | $ 77 566 |
| Annual Lifecycle Cost -- Maintenance | $ 2 000 | $ 2 244 | $ 2 523 | $ 2 844 | $ 3 213 | $ 3 638 | $ 4 128 | $ 4 695 | $ 5 350 | $ 6 109 |
| Annual Lifecycle Cost -- Operating | $ 5 000 | $ 5 122 | $ 5 246 | $ 5 372 | $ 5 499 | $ 5 629 | $ 5 761 | $ 5 894 | $ 6 030 | $ 6 167 |
| Annual Lifecycle Cost -- Capital | $ 10 800 | $ 8 208 | $ 7 002 | $ 6 200 | $ 5 596 | $ 5 114 | $ 4 718 | $ 4 386 | $ 4 104 | $ 3 862 |
| Annual Lifecycle Cost -- Total | $ 17 800 | $ 15 574 | $ 14 771 | $ 14 416 | $ 14 309 | $ 14 382 | $ 14 607 | $ 14 975 | $ 15 484 | $ 16 138 |
| Optimum Replacement Point | | | | | X | | | | | |
| Current Maintenance and Operating Costs exceed Annual Lifecycle Cost | | | | | | | | X | X | X |



The Instructions | **The Example** | The Tool | The Graph

Figure 2. E3 Fleet Lifecycle Costing Tool – output worksheet (old version example)

## Contacts

- Nikki Elliott, Climate Action Program Coordinator, Capital Regional District, Office: 250 360 3048, email: nelliott@crd.bc.ca
- David Goddard, Fleet Manager, Capital Regional District, email: dgoddard@crd.bc.ca
- Roger Smith, Executive Director, Richmond Sustainability Initiatives, The E3 Fleet Standards Program, Office: 416 418 9931, email: rsmith@richmondsustainability.org

### 3.1.2 City of Seattle (WA, USA)

**Overview**

The City of Seattle has a population of 724,700 (2017) and its fleet is made up of 4,000 vehicles, 87 of which were BEVs by the time of 2015[21]. The fleet used cost of ownership analysis to demonstrate that, despite high upfront costs relative to ICEVs, BEVs were more cost effective in terms of operational costs in the long run, even without government EV incentives. As a result, by 2018, the overall fleet size has increased to 4,150 vehicles with over 200 PHEVs[22].

**Tool features**

According to Philip Saunders, Green Fleet Program Manager, the City of Seattle has designed its internal tool based on actual fleet data and included maintenance, electricity, fuel costs, salvage, etc. (Figure 3[23]). The tool was developed in collaboration with the states of New York, California and Oregon, which provided their tools as a template. The tool calculates the total cost of ownership of their actual vehicles that are up for replacement in comparison with more sustainable options over a 10-year lifecycle. The data for the tool was collected using telematics devices and the costing tool is updated based on current fleet features and staff needs. The Tool does not account for the costs of building the new gas/charging stations since they are considered a sunk cost. After the total costs are calculated, fleet managers choose more sustainable vehicles only if their lifecycle costs are within 10% above the cost of traditional vehicles. The data on fuel costs and environmental impact is taken from the U.S. Department of Energy[24].

**Upcoming updates of the tool**

Since the tool is going through the process of approval by all departments, it is going to be publicly available later in 2019.

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[21] West Coast Electric Fleets (WCEF). Partner Fleet Profile: EVs Save City of Seattle Fleet Money and Improve Overall Infrastructure. (2016): https://www.westcoastelectricfleets.com/portfolio-items/city-of-seattle-partner-fleet-profile/

[22] Durkan J. City of Seattle. Executive order. (2018, 24 September): http://durkan.seattle.gov/wp-content/uploads/2018/09/09.24.18-Fleet-EO.pdf

[23] Pratt A. Fleet electrification. Presentation: https://www.seattle.gov/documents/Departments/FAS/FleetManagement/Fleet-Electrification.pdf

[24] Official U.S. government source on fuel economy information: https://www.fueleconomy.gov/

### Advantages of the tool

Since the tool is not publicly available yet, the information about the advantages of the tool is going to be updated.

### Drawbacks of the tool

Since the tool is not publicly available yet, the information about the drawbacks of the tool is going to be updated.

$$\text{TCO} = \text{Acquisition} + \text{Life Fuel} + \text{Life Maint.} - \text{Salvage}$$

| Type | Description | Life | Acq. | Fuel | Maint. | Salvage | TCO |
|---|---|---|---|---|---|---|---|
| Gas | Ford Focus | 10 yrs | $21,284 | $8,000 | $11,790 | $2,128 | $38,946 |
| Hybrid | Ford CMAX | 10 yrs | $25,028 | $5,830 | $6,481 | $2,503 | $34,836 |
| BEV | Nissan Leaf | 10 yrs | $22,638 | $1,980 | $5,553 | $2,264 | $27,907 |

Fleet operating cost for 300 passenger sedans:

| | |
|---|---|
| Hybrids: | $10,450,860 |
| BEVs: | $ 8,372,160 |
| ***Savings*** | ***$ 2,078,700*** |

Figure 3. City of Seattle costs analysis

### Contacts

Philip Saunders, the Green Fleet Program Manager, City of Seattle Department of Finance and Administrative Services, Office: 206-684-0137, email: philip.saunders@seattle.gov

## 3.1.3 City of Vancouver (BC, Canada)

### Overview

From 2009 to 2018, the City of Vancouver, with a population of 675,200 people (2017), added more than 100 EVs to its fleet (electric motorcycles and passenger cars). Currently, their fleet consists of over 1,850 units, including 120 units of EVs and equipment. According to Amy Sidwell, Manager of Equipment Services Branch, the fleet's plan is to add even more EVs, focusing more on medium/ heavy duty electric trucks in 2019 in order to have 200 EVs in 2021 and reduce GHG by 30% from 2007 level by 2020[25]. In order to create a business case for successful purchases, the fleet is currently working on LCT for medium and heavy-duty vehicles.

According to Evan Dacey, the Fleet Manager, they do not have a LCT for light-duty vehicles. The procurement of new light-duty EVs is based on contracts signed with EV producers. The fleet prioritizes procurement of EVs unless there is a technical reason to use non-electric option (e.g. range, more space for people or cargo is needed). In this case, the fleet first looks at hybrid options before considering ICEVs. First, the Fleet departments determines characteristics of different models and then signs the vendor contract to standardize its procurement. For example, the last contract, which is now terminated, was with Ford for their Focus Electric model. City of Vancouver now works with other vendors that produce other models (like the Nissan Leaf).

**Tool features**

As mentioned earlier, the procurement process is more complex for medium- and heavy- duty fleet vehicles. The approach looks at the long-term fleet needs including capital needs, the replacement dates, and the location of usage. For example, dump trucks require a lot of power for long periods of time, therefore, currently switching to an EV would be very challenging. The City of Vancouver is currently collaborating with consultants to develop a LCT for these vehicles. Currently, they have data on 96 vehicles, including their mileage per year. The final tool will quantify every factor of vehicles usage including electrical usage, operating cost reductions, infrastructure costs, carbon pricing policy, the price for noise reduction, health impacts, etc. The tool is still in the process of testing.

**Upcoming updates of the tool**

Since the tool is going through the process of approval by all departments, there is no information on when it is going to be publicly available.

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[25] Dacey E., Green Fleet Plan, the City of Vancouver. Presentation (2018): https://www2.gov.bc.ca/assets/gov/environment/climate-change/cng/symposium/2018/cityvancouver-green-fleet-plan_evan-dacey_cng-symposium-2018.pdf

**Advantages of the tool**

Since the tool is not publicly available yet, the information about the advantages of the tool is going to be updated.

**Drawbacks of the tool**

Since the tool is not publicly available yet, the information about the drawbacks of the tool is going to be updated.

**Contacts**

- Evan Dacey, P. Eng, PMP, Equipment Manager, City of Vancouver, Office: 604 326 4786, email: Evan.Dacey@vancouver.ca

### 3.1.4 Fraser Basin Council (BC, Canada)

**Overview**

Fraser Basin Council (FBC) is a charitable non-profit society that focuses on climate change and air quality, watersheds and water resources, and local sustainability and resilience in the Fraser Basin and across BC. FBC also curates the BC Fleet Champions program, which has worked with 12 fleets in BC, helping them to electrify their fleet. The program initiators, in collaboration with FleetCarma consulting agency, analyzed 12 fleets from British Columbia for two years using telematics devices. As a result of their analysis, they recommended a combined total of 148 EVs to fleet managers, translating to about 61% of their total fleets, and calculated total potential cost of ownership reduction would be $3 million CAD [26]. The program has started another cycle and continues working with other fleets.

**Tool features**

As a part of its support of municipalities' green fleet initiatives, FBC collaborates with Atlas Policy Fleet Procurement Analysis Tool[27] (further – Atlas Policy Tool). This is a complex lifecycle costing tool that can compare two light-duty vehicles' economical and environmental costs (Figure 4). It

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[26] West Coast Electric Fleets (WCEF). BC Fleets Champion Program. Summary sheet (2018, June 26): https://pluginbc.ca/wp/wp-content/uploads/2018/06/FBC-Summary-Sheet-June-27-2018.pdf

[27] Atlas Policy Fleet Procurement Analysis Tool: https://atlaspolicy.com/rand/fleet-procurement-analysis-tool/

is updated quarterly and has its own user guide. The tool authors and FBC collaborated to create a Canadian version of the tool that uses Canadian data on fuel, electric costs, etc.

The tool uses the following types of inputs for making calculations:

- Market Inputs (the price of energy is adjusted automatically depending on the entered location), Vehicle Inputs (mileage, insurance costs, fuel economy, etc.)
- Vehicle Procurement Inputs (number of vehicles, vehicle prices, ownership structure, pricing approach, incentives or discounts)
- EV Infrastructure Inputs (if installation of EV charging stations is needed)

The output presents a dashboard report that includes a procurement summary:

- Nominal cost per distance traveled: the sum costs from charging infrastructure, social cost of carbon, taxes and fees, insurance, repairs, maintenance, fuel, financing, and depreciation)
- Procurement details: a breakdown of the major cost categories for both procurements and the total net present value (NPV) cost, which incorporates the time value of money

The tool also summarizes (1) the environmental impact calculations and allows the user to conduct (2) sensitivity analyses on up to four user inputs.

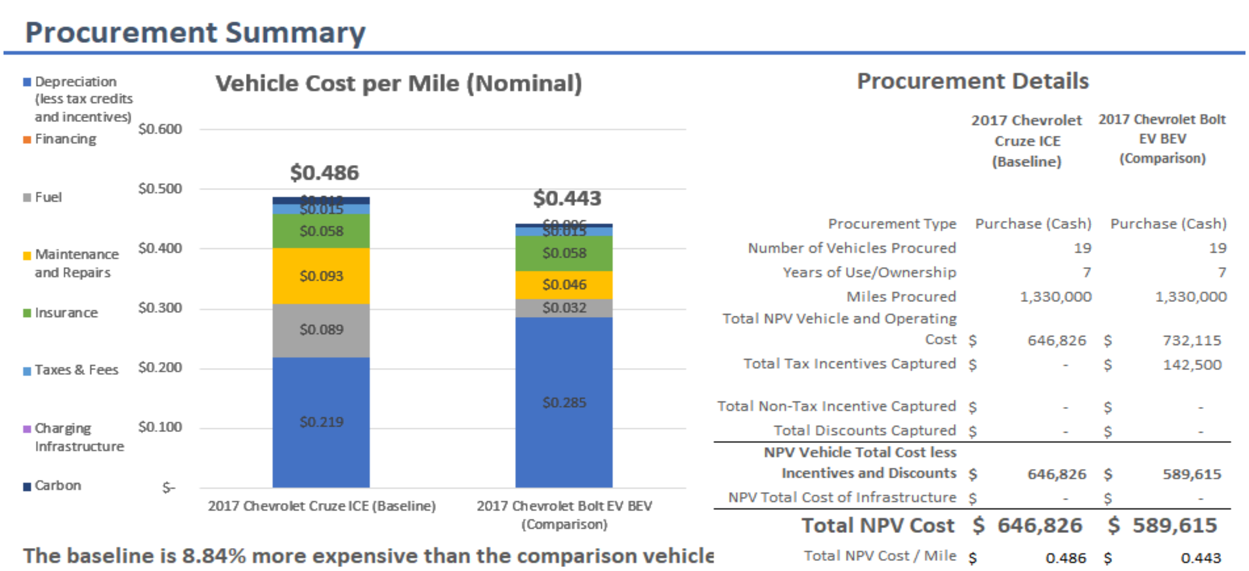


Figure 4. Atlas Policy Tool – Output worksheet

**User feedback**

Since Atlas policy tool authors do not track the tool's use, it is difficult to assess the fleet manager's feedback. However, according to author, the tool is in high demand since they receive many inquiries about it and the tool ranks high in search engine results. According to Pete Thimmaiah, FBC Transportation Analyst, the tool is very useful for fleet procurement. It accounts for a variety of different types of costs and provides visuals for a better understanding of costs savings on a kilometer basis. However, since it is not applicable for medium- and heavy-duty vehicles, FBC is working on their own internal LCT for these types of vehicles, which will be available in 2019.

**Upcoming updates of the tool**

The tool is usually updated every three months. This year, the tool makers are also planning to build out support for medium and heavy-duty vehicles.

**Advantages of the tool**

a. The tool authors frequently update its database with main background information about vehicles (sources include Natural Resources Canada, GH Genius, etc.)
b. The tool offers a complex approach to lifecycle cost (LCC) comparison including various cost categories
c. The tool provides visual comparison of total costs and dynamic comparative visuals
d. It also has additional features like sensitivity analysis, and environmental impact analysis

**Drawbacks of the tool**

a. Tool is inflexible: excluding some costs parameters, adding new cost parameters, or adding comparison of three or more vehicles is very likely to break the macros coding of the tool
b. The tool calculations are based on market average data, not actual fleet data
c. It allows for comparison of only two vehicles at the same time

**Contacts**

- Pete Thimmaiah Ph.D., Transportation Analyst, Plugin BC (a program of the Fraser Basin Council), email: pthimmaiah@pluginbc.ca
- Nick Nigro, Founder, Atlas Public Policy, email: nick.nigro@atlaspolicy.com

### 3.1.5 Fraser Valley Regional District (BC, Canada)

**Overview**

The Fraser Valley Regional District (FVRD), with a population size of 295,900 people (2016) and fleet size of 25 vehicles (2015)[28], signed onto the West Coast Electric Fleets initiative and committed to electrify at least 10% of their fleet[29].

In order to meet these requirements, FVRD conducted analysis of their fleet with help of E3 and collected trip data of their fleet using FleetCarma telematics devices. FVRD analyzed trip data of their fleet from October 2013 to August 2014 and concluded that 73% of all trips taken were less than 100km[30]. Since the average range of EVs is about 100 km, FVRD discovered the high potential for EV procurements. FVRD calculated five different scenarios of new vehicles usage based on differing estimates in service life, annual mileage, and energy prices over time.

As a result, the two out of five vehicles purchased by FVRD in 2015 were EVs (Nissan Leaf and Mitsubishi i-MiEV).

**Tool features**

In order to derive the economic and environmental impact of EV adoption, FVRD developed a simple Excel-based LCT where it included depreciation, energy costs, maintenance (the average of different municipalities), capital costs, manufacturer's retail costs, resale value, insurance[31], incentives, etc. (Figure 5). Assumptions used for the calculations were:

- Annual mileage (source – internal projections): 13,000 km
- Expected service life (source – FBC): 7 years
- Gasoline prices (source – BC Gas prices): $1.35/L ($1.74/L by 2021 based on historical data)

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[28] Finding the Business Case for EVs in Public Fleets. Presentation (2016): http://www.westcoastelectricfleets.com/wp-content/uploads/2016/03/Full-Slide-Deck-Feb-29-Compressed.pdf

[29] West Coast Electric Fleets Pledge. Plug-In BC website: https://pluginbc.ca/resource/pcc-zero-emission-vehicle-fleet-pledge/

[30] Fraser Valley Regional District (FVRD). Fraser Valley Regional District electric vehicle business case. (2015): http://www.westcoastelectricfleets.com/wp-content/uploads/2016/01/FVRD-Electric-Vehicle-Business-Case-Nov-2015.pdf

[31] According to FVRD, BCAA underestimated insurance rates: https://www.bcaa.com/insurance/

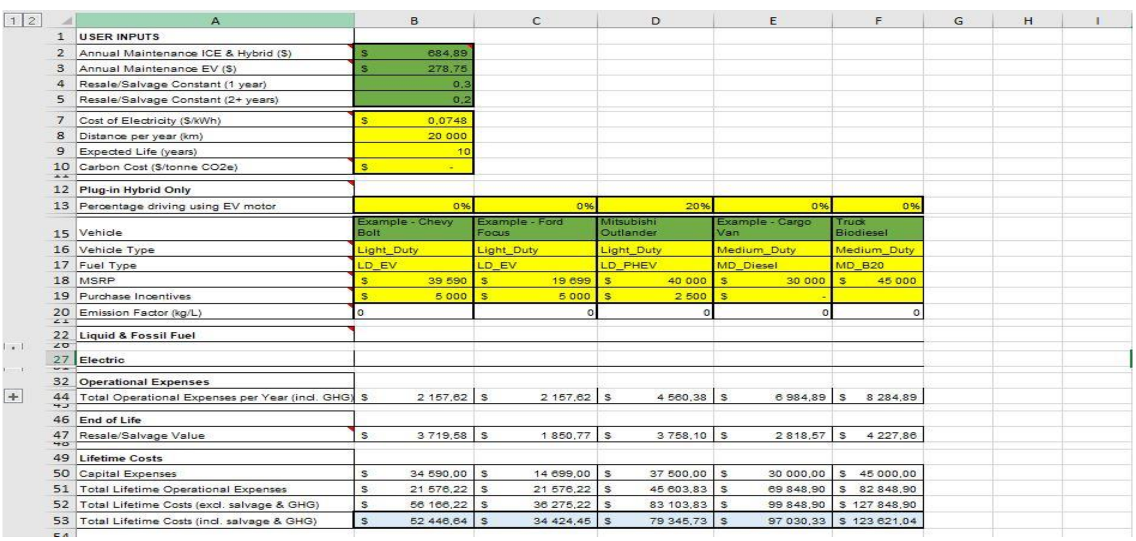
- Electricity prices (source – BC Hydro): $0.0748/kWh ($0.11/kWh by 2021 based on gasoline prices growth)
- Annual inflation (source – Bank of Canada): 2%
- Annual depreciation (source – internal projections): 30% in the first year, and 20% in each subsequent year
- Carbon tax rate (source – Government of BC): $30/tonne

### User feedback

Using this tool, FVRD specialists determined that purchasing EVs would save fuel and maintenance costs over the 10-year lifespan (not including incentives). Therefore, the tool proved to be effective in 2015. However, according to FVRD specialists, the tool has not been updated since. Moreover, they have not used the tool strategically for long term fleet management – currently, they replace vehicles as needed and prioritize EVs where possible[32]. Currently, FVRD has fours EVs in their fleet.

### Upcoming updates of the tool

The tool authors are not planning to update the tool.



| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | USER INPUTS | | | | | |
| 2 | Annual Maintenance ICE & Hybrid ($) | $ 684,89 | | | | |
| 3 | Annual Maintenance EV ($) | $ 278,75 | | | | |
| 4 | Resale/Salvage Constant (1 year) | 0,3 | | | | |
| 5 | Resale/Salvage Constant (2+ years) | 0,2 | | | | |
| 7 | Cost of Electricity ($/kWh) | $ 0,0748 | | | | |
| 8 | Distance per year (km) | 20 000 | | | | |
| 9 | Expected Life (years) | 10 | | | | |
| 10 | Carbon Cost ($/tonne CO2e) | $ - | | | | |
| 12 | Plug-in Hybrid Only | | | | | |
| 13 | Percentage driving using EV motor | 0% | 0% | 20% | 0% | 0% |
| 15 | Vehicle | Example - Chevy Bolt | Example - Ford Focus | Mitsubishi Outlander | Example - Cargo Van | Truck Biodiesel |
| 16 | Vehicle Type | Light_Duty | Light_Duty | Light_Duty | Medium_Duty | Medium_Duty |
| 17 | Fuel Type | LD_EV | LD_EV | LD_PHEV | MD_Diesel | MD_B20 |
| 18 | MSRP | $ 39 590 | $ 19 699 | $ 40 000 | $ 30 000 | $ 45 000 |
| 19 | Purchase Incentives | $ 5 000 | $ 5 000 | $ 2 500 | $ - | |
| 20 | Emission Factor (kg/L) | 0 | 0 | 0 | 0 | 0 |
| 22 | Liquid & Fossil Fuel | | | | | |
| 27 | Electric | | | | | |
| 32 | Operational Expenses | | | | | |
| 44 | Total Operational Expenses per Year (incl. GHG) | $ 2 157,62 | $ 2 157,62 | $ 4 560,38 | $ 6 984,89 | $ 8 284,89 |
| 46 | End of Life | | | | | |
| 47 | Resale/Salvage Value | $ 3 719,58 | $ 1 850,77 | $ 3 758,10 | $ 2 818,57 | $ 4 227,86 |
| 49 | Lifetime Costs | | | | | |
| 50 | Capital Expenses | $ 34 590,00 | $ 14 699,00 | $ 37 500,00 | $ 30 000,00 | $ 45 000,00 |
| 51 | Total Lifetime Operational Expenses | $ 21 576,22 | $ 21 576,22 | $ 45 603,83 | $ 69 848,90 | $ 82 848,90 |
| 52 | Total Lifetime Costs (excl. salvage & GHG) | $ 56 166,22 | $ 36 275,22 | $ 83 103,83 | $ 99 848,90 | $ 127 848,90 |
| 53 | Total Lifetime Costs (incl. salvage & GHG) | $ 52 446,64 | $ 34 424,45 | $ 79 345,73 | $ 97 030,33 | $ 123 621,04 |

Figure 5. Fraser Valley Regional District Lifecycle Costing Tool – output worksheet

32 Micha Gutmanis, Environmental Services Coordinator, Fraser Valley Regional District

**Advantages of the tool**

FVRD costing tool is very easy to use and modify. It proved to be effective in real life circumstances. Moreover, it is based on Canadian data.

**Drawbacks of the tool**

The tool has the following drawbacks:

- Based on non-updated information
- Does not have the breakdown of maintenance costs
- Does not account for government incentives (partial funding of EV)
- All the parameters should be typed manually (no built-in options)
- Does not have visualization

**Contacts**

Micha Gutmanis, Environmental Services Coordinator, Fraser Valley Regional District, email: mgutmanis@fvrd.ca

### 3.1.6 Metro Vancouver (BC, Canada)

**Overview**

Metro Vancouver is a regional district with a population over 2.46 million people (2016). It is governed by a Board of Directors that collaboratively plans for and delivers regional-scale services[33]. As part of its low emission policy, it focuses on increased EV acquisition by their fleet. One of its components is to develop a standard way to procure fleet assets, according to their operational requirements: low $CO_2$ emissions and cost effectiveness. They put together the emission vehicles standards and prioritize low emission vehicles. In order to do that, they conduct a LCA of potential fleet vehicles and set up the procurement plan.

**Tool features**

Fleet specialists use an internal economic prediction of market fuel price, reinvestment rate and calculate the present value of operational and environmental costs of different types of vehicles over their lifecycle (set to be 10 years). Apart from that, they include the capital costs and

[33] Metro Vancouver official website: http://www.metrovancouver.org/about/Pages/default.aspx

government incentives provided for EVs (Figure 3). Main assumptions used for the calculations are:

- Annual interest rate (source – internal projections): *[redacted for public report]*
- GHG emission price: *[redacted for public report]*
- Carbon tax rate: *[redacted for public report]*
- Gasoline prices (source – BC Gas prices): *[redacted for public report]*
- Electricity prices (source – internal projections): *[redacted for public report]*
- Annual mileage (source – internal projections): *[redacted for public report]*
- Expected service life (source – internal projections): *[redacted for public report]*

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | | Sedan | | | | SUV | | |
| 2 | | Conventional | Hybrid | PHEV | Electric | Conventional | Hybrid | PHEV |
| 3 | | Toyota Corolla | Toyota Prius | Chevrolet Volt | Chevrolet Bolt | Honda CRV | Toyota Rav4 Hybrid | Mitsubishi Outlander PHEV |
| 4 | Expected Fuel Economy (L or Le /100 km) | 7,5 | 4,5 | 2,2 | 2 | 8 | 7,3 | 3,2 |
| 5 | Expected Emission Factor (g/km) | 174 | 105 | 32 | 0 | 188 | 171 | 108 |
| 6 | Yearly Distance Driven (km) | 15 000 | 15 000 | 15 000 | 15 000 | 15 000 | 15 000 | 15 000 |
| 7 | Yearly Fuel Used (L or Le) | 1 125 | 675 | 330 | 300 | 1 200 | 1 095 | 480 |
| 8 | Yearly Emissions (Ton CO2e) | 2,6 | 1,6 | 0,5 | - | 2,8 | 2,6 | 1,6 |
| 9 | Lifetime Distance Driven (km) | 150 000 | 150 000 | 150 000 | 150 000 | 150 000 | 150 000 | 150 000 |
| 10 | Lifetime Fuel Used (L or Le) | 11 250 | 6 750 | 3 300 | 3 000 | 12 000 | 10 950 | 4 800 |
| 11 | Lifetime Emissions (Ton CO2e) | 26,1 | 15,8 | 4,8 | - | 28,2 | 25,7 | 16,2 |
| 12 | | | | | | | | |
| 13 | Purchase Cost | $ 21 995 | $ 29 320 | $ 38 341 | $ 42 378 | $ 31 842 | $ 34 790 | $ 42 248 |
| 14 | Government EV Incentives | $ - | $ - | $ (5 000) | $ (5 000) | $ - | $ - | $ (2 500) |
| 15 | Charging Cost | $ - | $ - | | | | | $ - |
| 16 | Lifetime Fuel Costs | $ 19 901 | $ 11 940 | $ 5 838 | $ 5 307 | $ 21 227 | $ 19 370 | $ 8 491 |
| 17 | Lifetime Carbon Costs | $ 3 915 | $ 2 363 | $ 720 | $ - | $ 4 230 | $ 3 848 | $ 2 430 |
| 18 | | | | | | | | |
| 19 | Life Cycle Cost | $ 45 811 | $ 43 623 | $ 39 899 | $ 42 685 | $ 57 299 | $ 58 007 | $ 50 669 |
| 20 | Yearly Saving (Premium) over Conventional | $ - | $ 219 | $ 591 | $ 313 | $ - | $ (71) | $ 663 |
| 21 | | | | | | | | |
| 22 | Net Present Value | $ (45 745) | $ (46 592) | $ (45 348) | $ (49 618) | $ (58 746) | $ (60 415) | $ (55 573) |
| 23 | Net Project Benefit (Undiscounted Sum of Net Revenue) | $ (49 880) | $ (49 582) | $ (47 409) | $ (51 715) | $ (63 421) | $ (64 861) | $ (58 295) |
| 24 | | | | | | | | |
| 25 | | | | | | | | |

Life Cycle Costs | Parameters | Gas Sedan | Hybrid Sedan | PHEV Sedan | EV Sedan | SUV | Hybrid SUV | PHEV SUV | Test | F ...

Figure 3. Metro Vancouver Lifecycle Costing Tool – output worksheet

### User feedback

The tool has proven to be useful for Metro Vancouver's fleet management. Metro Vancouver plans to have five replacements in 2019 and even more in the upcoming three years. Electrification of the fleet thus far led to a decrease in fuel costs and $CO_2$ emissions. Authors are working on collecting systemized fleet data and a fleet management system. They also have plans to create key performance indicators (KPIs) and metrics that they will be oriented to.

## Upcoming updates of the tool

Authors are working on updating the tool. In general, they want to make it applicable for making long term fleet procurement decisions for both light duty- and medium duty vehicles. The ability to compare different segments will enable Metro Vancouver to make more informed decisions about the type of vehicles they need. Since new EVs require more charging stations and power capacity, authors plan to include EV charging station costs in their tool in order to spread the upcoming costs more effectively.

In the short term, they plan to add maintenance, charging costs, depreciation, and resale value. They also plan to update all the 2016 parameters.

Metro Vancouver does not want to acquire outside software for their LCT because the main economic predictions and cost parameters lack fleet specific features. Their current tool comprises the work of different departments and uses projections that are consistent and have been refined for specific fleet needs.

## Advantages of the tool

Metro Vancouver LCT is very transparent and user friendly. It relies on economically confirmed predictions and assumptions. Moreover, it is based on Canadian data.

## Drawbacks of the tool

The tool has the following drawbacks:

- Based on non-updated information (operating costs)
- Uses some cost parameters that are not referred to any official sources (e.g. GHG emission price)
- Lacks important cost parameters like resale value, maintenance cost, depreciation, etc.
- Does not have assisting visualization

## Contacts

- Joshua Power, Climate Policy Analyst, Metro Vancouver, email: Joshua.Power@metrovancouver.org
- Shuh Chang, Equipment Management Engineer, Metro Vancouver, email: Shuh.Chan@metrovancouver.org

## 3.2 Ready tools

### 3.2.1 AFDC Vehicle cost calculator (USA)

**Overview**

Alternative Fuels Data Center's (AFDC) Vehicle Cost Calculator[34] was developed by the National Renewable Energy Laboratory (NREL) and the U.S. Department of Energy (DOE) (Figure 6). It is a high-level screening web calculator comparing total ownership costs and GHG emissions for different types of vehicles, including ICEVs and EVs on the market. Although the model is specifically made for individual users who consider purchasing a vehicle, the model's logic might be a useful template for fleet procurement.

**Tool features**

The tool allows users to choose several vehicles at the same time (features include model year, make, and model in the field "Choose vehicles to compare"). The calculator then automatically retrieves official city and highway fuel economy data[35] as well as purchasing price and energy (gasoline, electricity, etc.) price, which can be changed by the user. The prices are based on a national average, as reported in the quarterly Alternative Fuel Price Report. Then the user is offered to enter his/her average car usage behavior ("Tell us how you use your car" field).

Key cost categories used in the calculation include:

- Vehicles fuel use costs (energy price x fuel use x annual km driven)
- Maintenance and tires (source- study by the American Automobile Association (AAA)): 5.38 cents per mile
- Insurance, license, and registration (source – AAA): $1,616 per year
- Vehicle purchase cost (assumption that 90% of the price is payed out using five-year loan at 6% interest)

As a result, the tool provides the table and graph (field "Results") that demonstrate:

- NPV (sum of discounted TOC over the usage cycle)
- Annual Fuel Use (gal)
- Annual Electricity Use (kWh)

[34] AFDC Vehicle cost calculator official web-page: https://afdc.energy.gov/calc/

[35] fueleconomy.gov

- Annual Fuel/Electricity Cost (USD)
- Annual Operating Cost (USD)
- Cost Per Mile (USD/mile)
- Annual Emissions (lbs CO2)

### User feedback

Since NREL does not collect user data and does not store data from user inputs, it cannot provide information on feedback about the tool. According to the tool developers, majority of users that have contacted the Technical Response Service regarding the AFDC Vehicle Cost Calculator are based in the United States. Users include private individuals as well as individuals affiliated with academic or educational institutions, industry associations, private businesses, and state governments.

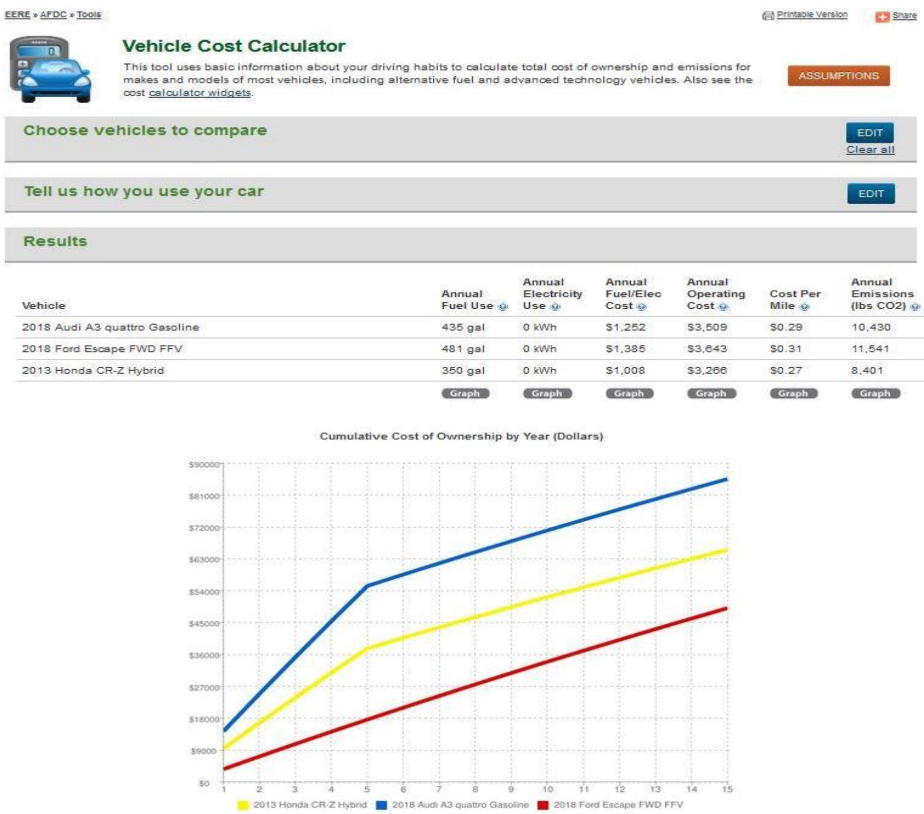



Figure 6. AFDC Vehicle cost calculator – website screenshot

### Upcoming updates of the tool

NREL does not have immediate plans to update the AFDC tool or change assumptions.

**Advantages of the tool**

- The tool is easy to use
- It has a detailed description of all the assumptions and sources

**Drawbacks of the tool**

- The tool is in form of web calculator: it is inflexible and cannot be modified
- The tool is based on USA market data

**Contacts**

- Amy Snelling, Technical Response Service, U.S. Department of Energy and National Renewable Energy Laboratory, email: technicalresponse@icfi.com

### 3.2.2 AFLEET (USA)

**Overview**

Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool is the tool developed by Argonne National Laboratories (ANL)[36] aimed to measure both the environmental and economic costs and benefits of EVs. AFLEET Tool allows users to estimate petroleum use, GHG emissions, air pollutant emissions, and costs of ownership for light-duty and heavy-duty vehicles.

**Tool features**

AFLEET is an Excel-based tool (Figure 7) that examines acquisition and annual operating costs to calculate a simple payback for purchasing a new EV as compared to its ICEV counterpart, as well as average annual fuel use and GHG emissions. The tool compiles different options:

- Total cost of ownership (TCO) calculation
- Simple payback calculator
- Idle reduction calculator

[36] AFLEET tool official webpage: https://greet.es.anl.gov/afleet

The structure of the TCO calculations allows users to look at the operating and fixed costs on an annual basis for every year of planned ownership of a new vehicle and infrastructure purchase. The major cost categories used for TCO calculation are:

- Financing costs (depending on the purchase method)
- Depreciation
- Fuel costs
- Maintenance and repair
- Insurance
- License and registration
- Externality costs of petroleum use, GHG emissions, and air pollutant emissions

**User feedback**

It is a very popular tool, which is used by 8,000 predominantly American users, and has its own User Guide 2018[37]. Although there is no available feedback on the tool itself, the popularity of the tool speaks in favour of its reliability.

**Figure 20. TCO Outputs Sheet – Lifetime Costs Summary Table**

| | Gasoline | Diesel | Gasoline HEV | Gasoline PHEV | Gasoline EREV | EV | G.H2 FCV | Diesel HEV | Diesel HHV | B20 | B100 | E85 | LPG | CNG | LNG | LNG / Diesel Pilot Ignition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Light-Duty Passenger Car Fleet and Infrastructure** | | | | | | | | | | | | | | | | |
| Financing | $102,184 | | $117,512 | | $173,713 | $153,276 | $298,889 | | | | $114,957 | | $132,840 | $137,949 | | |
| Depreciation | $817,574 | | $940,210 | | $1,390,362 | $1,226,379 | $2,391,403 | | | | $919,771 | | $1,062,846 | $1,103,725 | | |
| Fuel | $649,636 | | $464,026 | | $375,042 | $628,176 | $804,483 | | | | $803,363 | | $796,953 | $472,525 | | |
| Diesel Exhaust Fluid | $0 | | $0 | | $0 | $0 | $0 | | | | $10,688 | | $0 | $0 | | |
| Maintenance and Repair | $945,364 | | $821,422 | | $897,446 | $832,997 | $832,997 | | | | $1,274,465 | | $945,364 | $945,364 | | |
| Insurance | $532,774 | | $532,774 | | $532,774 | $532,774 | $532,774 | | | | $532,774 | | $532,774 | $532,774 | | |
| License and Registration | $57,677 | | $57,677 | | $57,677 | $57,677 | $57,677 | | | | $57,677 | | $57,677 | $57,677 | | |
| Total Cost of Ownership | $3,105,209 | | $2,933,620 | | $3,427,014 | $3,431,279 | $4,918,223 | | | | $3,713,694 | | $3,528,453 | $3,250,013 | | |
| **Heavy-Duty Refuse Truck Fleet and Infrastructure** | | | | | | | | | | | | | | | | |
| Financing | | $1,072,935 | | | | $3,423,173 | | | $1,277,304 | | $1,072,935 | | | $1,328,396 | | |
| Depreciation | | $8,584,525 | | | | $27,389,516 | | | $10,219,673 | | $8,584,525 | | | $10,628,460 | | |
| Fuel | | $22,157,108 | | | | $16,470,132 | | | $18,241,779 | | $34,929,186 | | | $19,134,852 | | |
| Diesel Exhaust Fluid | | $464,704 | | | | $0 | | | $360,145 | | $464,704 | | | $0 | | |
| Maintenance and Repair | | $36,288,112 | | | | $35,509,715 | | | $35,748,256 | | $36,288,112 | | | $36,476,433 | | |
| Insurance | | $2,750,786 | | | | $2,750,786 | | | $2,750,786 | | $2,750,786 | | | $2,750,786 | | |
| License and Registration | | $289,726 | | | | $289,726 | | | $289,726 | | $289,726 | | | $289,726 | | |
| Total Cost of Ownership | | $71,607,894 | | | | $85,833,048 | | | $68,887,668 | | $84,379,972 | | | $70,608,652 | | |

Figure 7. AFLEET Lifecycle costing tool– output worksheet

[37] Burnham A. User Guide for AFLEET Tool 2018. (2018): https://greet.es.anl.gov/files/afleet-tool-2018-user-guide

**Upcoming updates of the tool**

The AFLEET tool is usually updated annually. Argonne National Laboratory, which is working on the tool, is funded by the US Department of Energy, so they are not planning to develop a Canadian version.

**Advantages of the tool**

- Sophisticated tool that considers various cost parameters
- Has additional features like idle reduction and simple payback calculator
- Has calculations visualization

**Drawbacks of the tool**

- Based on USA data
- Non-frequently updated
- The tool allows comparison of different types of vehicles, but not different models running on the same fuel
- The tool could be difficult for understanding and everyday usage

**Contacts**

- Andrew Burnham, Principal Environmental Scientist, Argonne National Laboratory. Office: 630-252-6606, email: aburnham@anl.gov

### 3.2.3 Alameda County Transportation (CA, USA)

**Overview**

Alameda County, a municipality based in California, USA, has a current fleet size of 800 light duty vehicles (out of 1200 total), 10% of which are currently electric[38]. Such statistics has been achieved by active fleet electrification for the last several years as a part of their climate action plan. The County has been collaborating with ChargePoint, to create an effective charging point management strategy, adaptable to changing fleet's needs and environmental goals.

[38] Charge Point. Alameda County Gets Smart About Growing Its EV Fleet. (2018): https://www.chargepoint.com/files/customerstories/cs-alameda.pdf

### Tool features

Alameda County developed their internal costing tool, which focuses on electricity costs and considers such parameters as the time of charging, purchase costs, incentives, and maintenance (Figure 8). It provides different scenarios of charging, from the most optimal to the least optimal, and enables the user to derive the optimal time for charging vehicles. It includes the following assumptions:

- Demand charges and energy rates (source: municipality electricity bills)
- Annual miles driven: 10 000 km
- Expected vehicle life: 10 years
- Cost of gasoline: USD 3,50 / Gal

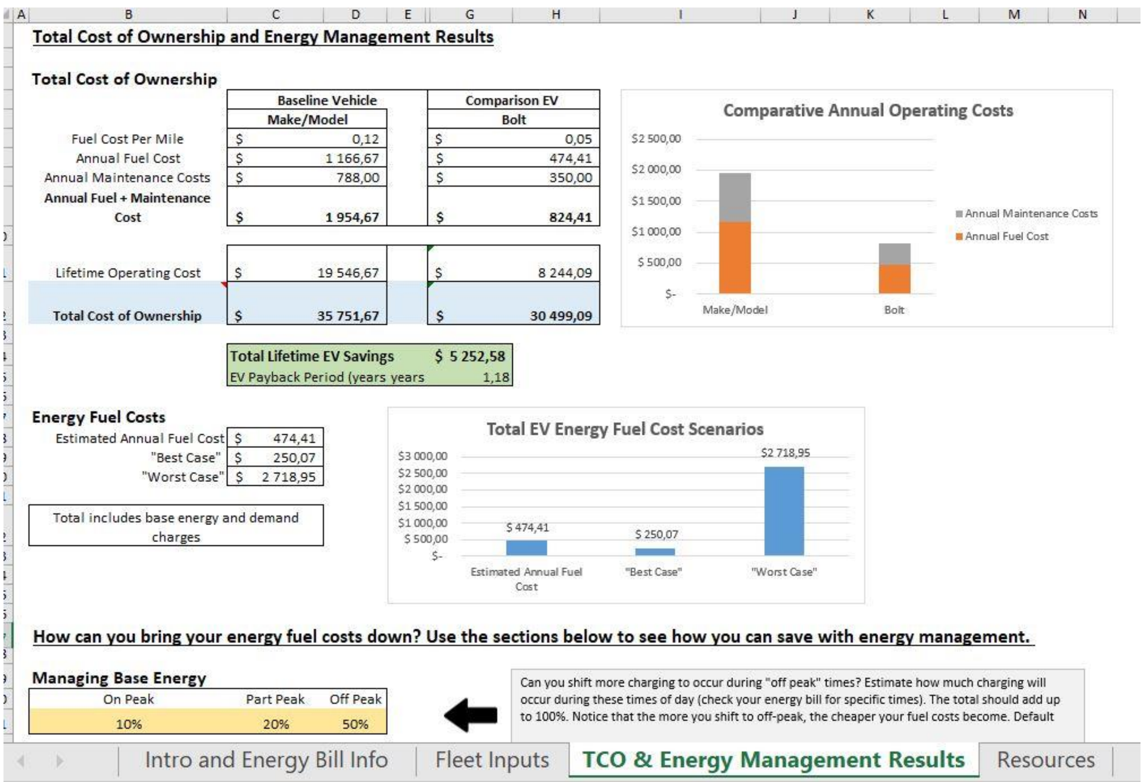



Figure 8. Alameda County Lifecycle costing tool– output worksheet

### Advantages of the tool

- The tool is very easy to use
- It allows the user to vary the time of charging

**Drawbacks of the tool**

- The tool does not include the costs carbon emission costs
- It lacks the breakdown of such important parameters like maintenance costs
- It uses American market data

**Contacts**

- NA, Alameda County Transportation Commission. Office: 510 208 7400, email: contact@alamedactc.org

### 3.2.4 FleetCarma (Canada)

**Overview**

FleetCarma is an Internet of things[39] (IOT) cleantech solution provider that is focused on collecting and analyzing telematics data of car usage in order to employ it for identifying EV potential of fleets. It has been working in partnership with different green initiatives (BC Fleet Championship program, E3 fleet, West Coast Electric vehicles). TOL also collaborated with FleetCarma in order to plan its EV fleet procurement. Part of this analysis included LCA of TCO of ICEV and EV. FleetCarma does not provide ready tool to fleet managers; however, it consults fleet owners on their best procurement strategy after gathering fleet vehicle utilization data by using its telematics devices[40].

**Contacts**

- Katrina Smallacombe, EV Program Manager, FleetCarma, a division of Geotab, Office: +1 800-975-2434, email: support@fleetcarma.com

[39] Internet of things- the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data (source: Wikipedia)

[40] FleetCarma. Electric vehicle sustainability assessment: https://www.fleetcarma.com/electric-vehicle-suitability-assessment/

## 4.0 Stakeholder Interview Summary

To further determine the necessary key features for the LCT, project staff also interviewed internal stakeholders: the Finance and Fleet departments (see the interview questionnaire in Appendix 10.1). The main purpose of these interviews was to understand the process of vehicle procurement, the existing issues with purchasing EVs, and expectations of the Fleet Department from the LCT.

### 4.1 Fleet Department

Staff interviewed Mike Parenteau, Fleet and Equipment Manager, and Noela McCall, Garage Service Technician, on May 30, 2019. They provided the following feedback on the research completed and their expectations about the LCT:

1. Mike and Noela believe that fuel costs and maintenance costs are the most important cost parameters for the tool. However, they understand the importance of electricity costs and environmental costs (in the form of carbon pricing), which are going to become a bigger concern in the future years.

2. Mike Parenteau does not have any major obstacles with negotiating the purchase of new EVs. However, Mike expresses his concerns about the lack of available infrastructure (charging stations) for future EVs. In addition, both Mike and Noela claim that the vehicle mileage might be highly dependent on weather and road conditions (e.g. traffic) and should be accounted for when considering an EV over ICEV.

3. The new tool should be simple, transparent, and should not require much time for managers to input data. Moreover, the tool should also serve educational purposes for the other departments and could contribute to fleet performance reports (e.g. maintenance and operating costs changes, changes in $CO_2$ emissions). Mike and Noela expect to see the following features for the tool:

   a) ability to compare more than two vehicle models
   b) dashboards with summary information about compared vehicles
   c) user manual

Based on the discussion of existing tools and fleet management needs, it was decided to compare the features of Metro Vancouver tool and Atlas Policy tool and prepare a recommendations memo for Fleet Services.

## 4.2 Finance Department

Project staff interviewed, Ryan Chapman, Financial Analyst in the Finance Department, on May 30, 2019. He provided the following feedback about available data for inputs for the tool:

1. All the costing and technical information about the fleet (500 units of equipment) is kept in an excel spreadsheet and can be aggregated for the tool purposes using pivot tables. However, year to year data on repairs and fuel consumption is significantly different due to annual maintenance and replacement plans, weather conditions, and insurance rates. Therefore, in order to calculate the weighted average by vehicle class, a Financial Analyst must clear the data from so-called outliers (i.e. vehicles that have non-representatively low / high operating costs).

2. The consistent format of data is available for 2016-2019.

3. Vehicle models are divided by vehicle class. Cars include the following class codes: V061, V062, V063 (EVs), while Sport utility vehicles (SUVs) are V046.

4. Commentaries about each parameter for calculating LCA:
    a. Electricity costs are not included since all vehicles are charged internally.
    b. Fuel consumption data per vehicle is not accurate because it includes a portion of inventoried fuel.
    c. Environmental costs are not accounted in the Finance Department since only tangible costs are considered.
    d. Maintenance costs are determined as the shop rate of $47 on top of staff's wage.
    e. Mileage data is collected regularly through manual entering of miles driven by vehicles drivers while fueling /charging their vehicles. However, according to Ryan Chapman, it might not be accurate because sometimes drivers put the wrong information.
    f. Overhead costs consist of ongoing day-to-day costs like shop overhead and GPS tracking.
    g. Vehicle useful life for most vehicles is 8 years.

h. Interest rate (investment rate) is usually assumed to be 3-4%. However, it is advised to use an estimate of 2%.
i. Straight-line depreciation method is used.

5. Including the cost of battery replacement might be problematic since there are few cases of the battery replacement (EVs have not existed more than their expected useful life). It was concluded, that the cost of battery replacement is not going to be included in the LCT since there is a sharp downward trend in the battery prices.

As a result, it was concluded that the best representative year, which will serve as the base year for calculations, is the closest year, 2018. In order to obtain the best statistically representative data on technical and cost characteristics of current vehicles in the fleet, the average vehicle *class* data will be derived, instead of vehicle *model* data.

Despite the loss in precision due to generalization (the main purpose of the LCT is to compare different models), the vehicle class data will be combined with vehicle model data from open sources. For example, the data on maintenance, operating, insurance, and mileage of vehicles types will be obtained and combined with vehicle or market specific cost parameters in order to obtain the most accurate data possible.

## 5.0 Recommendations

Based on multiple interviews with LCT holders and internal stakeholders, and various LCTs analysis, project staff presented the following summaries and recommendations to Noela McCall and Mike Parenteau on July 11, 2019, for their consideration. The summary below analyses advantages and disadvantages of two tools that are most suitable for Township Fleet needs – Atlas Policy tool and E3 fleet tools – and makes recommendations.

### Atlas Policy Tool

Atlas Policy tool is a complex LCT that can compare two light-duty vehicles in terms of their economic and environmental costs. The tool uses the market, vehicle, and EV infrastructure inputs for performing calculations of two vehicle lifecycle costs (see Section 3.2.2 for more details).

### Advantages

a. The tool automatically updates its database with main background information about vehicles (sources include Natural Resources Canada[41], GH Genius[42,] etc.)
b. The tool offers a complex approach to LCC comparison including almost all the LCC parameters
c. The tool provides visual comparison of total costs and dynamic comparative visuals
d. It also has additional features like sensitivity analysis, and environmental impact analysis
e. The tool is usually updated every three months

### Disadvantages

f. Tool is inflexible: excluding some costs parameters, adding new cost parameters, or adding comparison of three or more vehicles is very likely to break the macros coding of the tool
g. The tool calculations are based on market average data, not actual fleets data
h. It allows for comparison of only two vehicles at the same time
i. It lacks some important cost parameters like resale value

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[41] https://www.nrcan.gc.ca/home

[42] https://www.ghgenius.ca/

How can we address these concerns?

a. Rewrite the code of the tool: it will take considerable time to learn the coding of the tool and modify it
b. Complement the tool: add the new output worksheet providing the comparison of costs that the fleet is primarily interested in (fuel, maintenance). There is still a problem with adding more vehicles for the comparison

To conclude, the decision to use/not use Atlas Policy Tool mainly depends on the complexity of the expected tool. If management wants to see only the main categories- financing, cost of capital, maintenance, and fueling – then it should not be a problem to write a simple version of the tool using Atlas data sources. Otherwise, rewriting the tool could become quite challenging since it is highly sophisticated sheet with big database and there is a limited project time remaining (one and half months).

**Recommendation 1**

Basing on the knowledge of currently free available LCT, the recommendation is to use the Atlas Policy tool logic and database and simplify its template to the version similar to Metro Vancouver's , that makes it possible to obtain the output table comparing 3-5 vehicles at the same time. The main reason for not simply using the Atlas policy tool is because any modification in the tool might lead to the tool coding breaking.

**Sub-recommendations**

e. To follow the future release of the LCTs in the City of Seattle, Metro Vancouver, BCAA costing calculator. They can become a reliable source for market data and provide the updated costing methodology.
f. To follow the Canada website that regularly updates a rich database on fuel consumption and mileage of all the vehicle models available in the country ("Fuel consumption ratings"1).
g. It is also highly advised to consult with Fleet Champions Program1, which occasionally provides free fleet analytics and supports greening the fleet.
h. FBC and (probably) the City of Vancouver are currently collaborating with E3 Fleet to make their version of LCT, which might become public and therefore freely available soon.

### Next Steps

Given the recommendation above, staff presented the following preliminary plan for the next 8 weeks:

a. Clearing the Atlas policy tool from the unnecessary features
b. Adding fleet database (and comparing it with offered data)
c. Adding output worksheet comparing different vehicles (with visuals)
d. Adding detailed commentaries to every single assumption and source used
e. Writing a manual corresponding to the necessary inputs and operations for working with the tool and updating the tool
f. Given there is time left, providing an example LCA of different vehicles, EVs and ICEVs, to show the effectiveness of the tool

### E3 Fleet tools

During the recommendation meeting staff presented an alternative option, E3 fleet tools: Fleet Analytics Review (FAR) and Lifecycle Analysis Tool. High-level analysis of these tools tells in favour of their usefulness in assisting the fleet in making long term strategic decisions. Moreover, TOL has worked with E3 fleet previously.

The tools are multifunctional, have real fleet databases and they provide recommendation on the optimal vehicle replacement year, the effects of greening and replacement on the entire fleet, and a benchmark report. Roger Smith also claimed that the tool was implemented by various USA and Canadian municipalities, including Summerland (BC), Oxford (NS), Calgary (AB), City of Vaughan (ON). Moreover, Roger offered to provide web or onsite presentation of the tool for fleet management to explain the features of the tool in more details and answer our questions.

### Lifecycle Analysis Tool

This tool is built to identify optimal economic lifecycles based on historical data. The tool includes inputs table, lifecycle costs analysis table, and visual representation of results. The tool accounts for both standard cost parameters as well as the cost effect of the decrease in productivity of workers due to vehicle aging, resale value, and the effect of idling. The tool calculates LCC of vehicle and then determines the optimal replacement year and savings associated with this replacement.

### Fleet Analytics Review (FAR)

FAR uses historical fleet data to model go-forward results (GHGs and costs, service levels such as availability/uptime) from changes to the fleet under consideration by management ahead of actual implementation, hence reducing risk. The changes that can be modeled by the tool include fleet modernization, carbon reduction, trips reductions, road planning, idling reductions. Apart from that, the tool also highlights vehicles that perform at least 50% worse than benchmark vehicles with similar characteristics (e.g. in terms of fuel consumption rate).

#### Advantages

a. They include both direct and indirect costs of using the vehicles (e.g. the loss in productivity due to vehicle aging and idling)
b. They are based on a big database compiled from different real fleets
c. FAR tells the economic impact of the new fleet policy (incl. trainings)
d. FAR also provides the benchmarking analysis of fleet performance compared to other fleets (in form of reports or by messaging which vehicle in the fleet underperforms compared to benchmark average)

#### Disadvantages

a. Both tools cost *[redacted for public report]* dollars (not including additional analytics services)
b. Tools include features that might not be necessary at this point (to be discussed with fleet management)
c. The database might not be relevant for TOL case (a lot of USA users, EV market is constantly changing with new models appearing on the market)
d. The functionality of the tool is out of scope of our current needs (to be discussed with fleet management)

**Recommendation 2**

The tool provides a lot of instruments for long term fleet planning. However, these functionalities are out of scope of the project and might not be relevant for the fleet manager at this point. Therefore, the recommendation is to arrange the meeting /video conference with Roger Smith and Fleet Department to learn more about the tool functionalities and consider it for future use. In the meantime, Recommendation 1 still stands.

After discussing the vision of the LCT with internal stakeholders, it was decided to follow Recommendation 1 and to use the Atlas Policy tool logic and database and simplify its template to obtain the tool comparing 3-5 vehicles at the same time and providing assisting visuals. Recommendation 2 will be considered for future next steps.

## 6.0 Tool Development

During the development of the tool, project staff consulted internal stakeholders and made changes to the tool based on questions or comments that were raised. During the overall process of the tool development staff completed the following key stages:

1. Compiled the tool with the main worksheets (like “Inputs”, “Database”, “Financial model”, “Results”) using Atlas policy tool template

2. Complemented the existing Canadian database with Fuel consumption ratings and some fleet market inputs

3. Created the dashboard worksheet comparing different vehicle characteristics, costs (with graphs), adding commentaries to the sources and inputs used

4. Confirmed key cost parameters with the Finance Department (Ryan Chapman) such as EV infrastructure inputs, non-tax incentives, taxes, procurement details, compliance costs, residual value, etc.

5. Compared LCT calculation results with existing policy tools like Atlas Policy Tool[43] and AFDC web calculator (USA)[44] in order to check the Tool’s calculations

6. Added the drop-down list for vehicle choice which allows different types of vehicles to be selected and notifies the user if a mistake in choosing the vehicle model was made

7. Lifecycle cost analysis was extrapolated to three more vehicles to allow for four vehicles comparison in total

The main difficulties while constructing the tool were the following:

1. Making the input entering simpler and “smarter” – it required additional analytics in hidden worksheets and making the user data entering process more rigid

[43] https://atlaspolicy.com/rand/fleet-procurement-analysis-tool/

[44] https://afdc.energy.gov/calc/

2. The current vehicle database did not have all the MSRP for ICEVs. This issue required the usage of USA database from the Atlas Policy Tool

3. Making the database update process more transparent – by writing detailed instructions for the Finance Department and by optimizing the database uploading process to the tool

## 7.0 Final Tool

The resulting tool, TOL Lifecycle Costing Tool (TOL LCT), consists of several components:

- *Inputs section* (in "Inputs & Dashboard" worksheet) where users choose the vehicle they consider purchasing and may adjust some market and vehicle parameters
- "Database" worksheet that has default inputs,
- *Financial model* that calculates LCC based on user-adjusted and default inputs ("Financial model"); and
- *Results section* (also in "Inputs & Dashboard" worksheet). The *Results section* consists of dashboard demonstrating financial and environmental impact of vehicle use over their lifecycle. It includes graphs and tables showing annual energy consumption, carbon emissions, annual costs per kilometer, year-by-year cash flow comparison, etc.

The tool file is saved to the Township's server and can accessed by contacting the Sustainability Department at energy@tol.ca.

# 8.0 Tool User Guide

## 8.1 About the tool

The final Township of Langley LCT helps users to obtain decision-relevant information (technical characteristics, financial and environmental impact) about light-duty vehicles. The tool is Microsoft Excel-based (macros-free) and can evaluate four different makes/models of vehicles at the same time using different criteria. The Township decided to develop a tool from scratch and not acquire one in order to have an easy-to-use and modifiable solution for financial and environmental comparison of various vehicles using actual fleet inputs.

The main advantages of the tool are that although it is easy to use, it offers a complex approach to lifecycle cost (LCC) comparison of four vehicles. TOL LCT also provides visual comparison of total costs with the help of interactive visuals. It is adapted to fleet needs and uses actual fleet costs provided by the Township's Finance Department.

The next steps in developing the tool would be automation of the uploading process of the main background information about vehicles (sources include Natural Resources Canada, GH Genius, etc.) in the database. Depending on the Fleet Department's needs the tool might require add-ins like sensitivity analysis, and environmental impact analysis, and including battery replacement impact on EV costs and useful life.

## 8.2 Structure of the tool

The Tool was built using Microsoft Excel without VBA coding. It is divided into four functional areas, as follows:

- Active worksheets- for users (Green worksheets)
- Data for the tool (Grey worksheets)
- Functional add-ins – hidden worksheets (Violet worksheets)
- Financial Model (Light blue worksheets)

User inputs cells color-coded as follows:

**Input Definitions (for "Vehicle comparison")**

Inputs that use vehicle database and shouldn't be altered

Inputs that upload market inputs but can be altered (preferable, in "Database")

Default assumptions that can be edited by user

Information in the *Inputs* section is used in the "Financial Model" worksheet, which is then aggregated in graph and table form in the *Results* section (Figure 9).

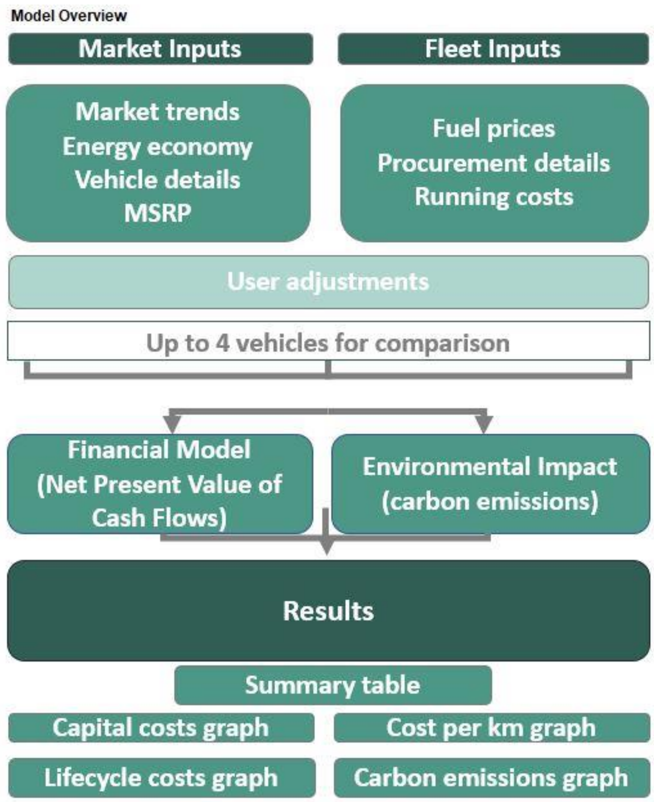



Figure 9. The Township of Langley Lifecycle Costing Tool overview

## 8.3 Using the tool

This chapter is aimed to provide users with instructions on how to obtain side-by-side comparison of vehicle lifecycle costs and $CO_2$ emissions.

### 8.3.1 Opening the tool

To open the tool, double click on the file entitled "TOL LCCT FINAL.xlsx". Please be aware that if you want to switch the tool from read-only mode and to be able to change any cells enter the password (password: *evehicle*).

### 8.3.2 Inputs section

In this section of "Inputs & Dashboard" worksheet, you can enter inputs for your financial analysis. Inputs are grouped in categories as follows:

- Market Inputs
  - Energy prices
  - EV infrastructure inputs
  - Carbon costs inclusion
  - Vehicle inputs (common for all the vehicles)
- Vehicle Inputs (vehicle specific)
  - Technical features
  - Fuel consumption & emissions
  - Purchase costs
  - Resale value
  - Incentives & taxes
  - Running & compliance costs

**Market inputs**

### Energy prices

In the *Market Inputs* section shown below you can start by entering the energy prices. Please be aware that default energy prices are already uploaded from "Database" worksheet. Therefore, it is preferable that you change energy prices in the database, and not in the dashboard cell directly. In order to overwrite the prices, just double-click the needed cell and you will be automatically transferred to the source "Database" worksheet, where you can enter the new price to reflect more recent or accurate information for your procurement.

### EV infrastructure inputs

This section allows the user to include or exclude EV charging infrastructure costs from the procurement cost comparison analysis. EV charging infrastructure costs consist of capital costs of installing the chosen amount of EV charging stations and their annual operating costs. This cost category is currently switched off because there is a separate budget for developing infrastructure, including the new stations' installation. Since the purchase of EVs budget and infrastructure budget are separate, including EV stations costs might be unnecessary for now. This gives the fleet flexibility in case the budget ever transfers to the Fleet Department. However, in case of adding infrastructure costs, it is highly advisable to analyze them with respect to the amount of EVs considered for the purchase: the more EV is planned to be purchased the lower the portion of infrastructure costs each EV should bear.

### Carbon costs inclusion

You can also include the cost of carbon in the financial analysis. Currently, the cost of carbon per CO2 kg is set to zero, since TOL Fleet fuel prices already include the cost of carbon. However, in case of additional environmental cost will be applied to vehicles, the zero parameter can be quickly set to an up-to-date number.

### Vehicle inputs (common for all the vehicles)

The section also includes common vehicles' inputs that can be adjusted manually. Since the tool is designed for passenger vehicles only (cars, SUVs, and passenger vans) and for the two main types of EVs (PHEV and BEV) with codes V041, V046, V061-063, the tool uses the Finance Department's standard useful life of eight years (Figure 10).

**Market inputs**

| Energy prices | | EV Infrastructure Inputs | |
|---|---|---|---|
| Gasoline Cost ($ / liter) | 1,31 | Procurement Includes EV Charging? | No |
| Electricity Cost ($ / kWh) | 0,1029 | Number of Level 2 EV Stations Needed (#) | 10 |
| Diesel, B5 ($ / liter) | 1,2 | | |

| Vehicle inputs (common for all the vehicles) | | | |
|---|---|---|---|
| *Annual Vehicle Mileage (VKT/Year)* | 24 135 | Include Cost of Carbon? | Yes |
| *Expected Years of Use/Ownership (Years)* | 8 | | |
| *% of Annual Kilometers City Driving* *(suggested by w/ the Finance department)* | 75% | | |

Figure 10. Market inputs

### Vehicle inputs

In this section, you can select vehicles to reveal and edit vehicle procurement costs. The tool automatically loads inputs for each vehicle. Any of the inputs in green cells can be edited. Vehicle costs (Insurance, Maintenance and repair, and Overheads) are currently populated based on data obtained from the Finance Department of the Township of Langley, depending on which vehicle class is chosen.

### Technical features

This section has four dropdown lists (green cells) that allow users to choose the preferred vehicle type, make, model, and year. After the vehicle from the database is chosen other technical characteristics like transmission, fuel type, engine size, range in electric mode (for EV only) are automatically uploaded. If certain characteristics are not applicable for certain vehicle types (e.g. electric range for ICE), then this field shows "N/A". If vehicle is not present in the database, then characteristics fields show "No vehicle in database" (Figure 11).

**Vehicle inputs**

| Technical features | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 |
|---|---|---|---|---|
| Description | 2018 MINI COOPER S E COUNTRYMAN ALL4 PHEV MID-SIZE | 2019 HYUNDAI SANTA FE AWD ICE SUV - SMALL | 2019 NISSAN LEAF S PLUS BEV MID-SIZE | 2019 TESLA MODEL S 100D BEV FULL-SIZE |
| Car type | PHEV | ICE | BEV | BEV |
| Make | MINI | HYUNDAI | NISSAN | TESLA |
| Model | PER S E COUNTRYMAN | SANTA FE AWD | LEAF S PLUS | MODEL S 100D |
| Year | 2018 | 2019 | 2019 | 2019 |
| Vehicle class | MID-SIZE | SUV - SMALL | MID-SIZE | FULL-SIZE |
| Vehicle Code | Cars - PHEV | SUVS | Cars - BEV | Cars - BEV |
| Transmission | AS6 | AS8 | A1 | A1 |
| Fuel type | B/Z* | X | B | B |
| Range electric (km) | 19 | N/A | 363 | 539 |
| Rechrage (hours) | N/A | N/A | 11 | 12 |
| Motor (kW) | 65 | N/A | A1 | A1 |
| Engine size (L) | 1,5 | 2 | N/A | N/A |
| Cylinders | 3 | 4 | N/A | N/A |
| Smog raiting | 3 | 5 | 10 | 10 |

Figure 11. Vehicle inputs – Technical features

### Fuel consumption & emissions

This section shows fuel consumption metrics (in litres/100 km for ICEVs and PHEVs in gas mode or kWh/100km for EVs and PHEVs in electric mode) for two types of driving – city and highway (Figure 12). Although the user can adjust the proportion of city and highway driving, note that for PHEV, electricity consumption is given for city and highway driving in proportions 55% and 45%, respectively. For PHEV and ICE, users can also see the carbon emission factor that is used for calculating lifecycle $CO_2$ emissions and their costs (if the user wants them to be included). For BEVs, the carbon emission factor is set to be zero.

| Fuel consumption & emissions | | | | |
|---|---|---|---|---|
| Fuel Consumption Gas City (L/100 km) | 8,40 | 12,30 | - | - |
| Fuel Consumption Gas Hwy (L/100 km) | 8,80 | 9,80 | - | - |
| Fuel Consumption Electric City (kWh/100 km) | 32,0 | - | 17,8 | 20,7 |
| Fuel Consumption Electric Hwy (kWh/100 km) | 32,0 | - | 21,5 | 20,5 |
| % of Annual Kilometers on Gasoline | 47% | 47% | 47% | 47% |
| Carbon emission (g/km) | 139,00 | 262,00 | - | - |

Figure 12. Vehicle inputs – Fuel consumption & emission

### Purchase costs and resale value

This section shows estimates of suggested Manufacturer Suggested Retail Price (MSRP) and residual value, which is assumed to be 5% of MSRP. Since the database does not have MSRPs for all the vehicles, and because the Township may receive proprietary pricing, there is an option to enter MSRP manually. It is highly advisable to treat these MSRPs as estimates and check up-to-date prices on official sources (Figure 13).

| Purchase costs | | | | |
|---|---|---|---|---|
| MSRP | 44 390 | MSRP not found | 40 698 | 116 190 |
| **Add MSRP manually?** | No | Yes | No | No |
| User's MSRP | 35 000 | 35 000 | 35 000 | 35 000 |
| **Resale value** | | | | |
| Residual value | 2 219,5 | 1 750,0 | 2 034,9 | 5 809,5 |
| Residual value (% of Base Price) | 5% | 5% | 5% | 5% |

Figure 13. Vehicle inputs – Purchase costs & resale value

### Incentives & taxes

This section uploads federal and provincial incentives for EVs that depend on vehicles' MSRP (Figure 14). According to the Finance Department, there are no initial taxes associated with vehicle purchases for municipalities. However, there is an empty cell allowing users to manually include any additional upfront fees or provincial sales taxes (PST).

| Incentives & taxes | | | | |
|---|---|---|---|---|
| Value of Federal EV Incentives ($/Vehicle) | 2 500 | - | 5 000 | - |
| Value of Provincial EV Incentives ($/Vehicle) | 1 500 | - | 3 000 | - |
| Provincial EV Incentive Cap ($) | 55 000 | 55 000 | 55 000 | 55 000 |
| Federal EV Incentive Cap ($) | 45 000 | 45 000 | 45 000 | 45 000 |
| Initial PST ($/Vehicle) | - | - | - | - |

Figure 14. Vehicle inputs – Incentive & taxes

### Running & compliance costs

This section summarizes maintenance, overhead, and insurance costs that are automatically uploaded from the "Database", depending on which vehicle class is chosen. These numbers are based on standard per vehicle costs provided by the Finance Department (Figure 15).

The tool also allows user to include battery replacement reserves, which are currently set to be zero. The reason behind setting it zero is that the tool allocates an eight-year Useful Life to all vehicles it is comparing[45]. This is exactly equal to the battery warranty of most EVs. Another reason is the high degree of uncertainty on when and whether a battery should be replaced. If a warranty claim is needed anytime in years 0-8 of owning the vehicle, then the new battery essentially resets the useful life of the car giving it another eight years before battery replacement needs to be considered again. Therefore, the uncertainty is still beyond the warranty time and useful life.

| Running & compliance costs | | | | |
|---|---|---|---|---|
| Maintenance and Repair Cost ($/Kilometer) | 1 011 | 819 | 206 | 206 |
| Overheads | 436 | 1 090 | 162 | 162 |
| Battery replacement costs (reserve $/year) | - | - | - | - |
| Relicensing (insurance license) | 12 | 12 | 12 | 12 |
| Cost to Insure ($/Year) | 1 381 | 1 481 | 1 921 | 1 921 |

Figure 15. Vehicle inputs – Running & compliance costs

### 8.3.3 Results section

This section presents a dashboard report that encompasses the results of calculations in "Financial Model" worksheet with user inputs. It is the visual presentation of tables compiled in the hidden "Result tables" worksheet.

### Procurement summary (nominal)

This section summarizes the lifecycle financial performance and fuel economy of considered vehicles (Figure 16). It provides information on annual energy economy, emissions, and costs. The figure below displays a dashboard with key financial metrics to easily assess the difference in procurements.

[45] https://www.energysage.com/electric-vehicles/buyers-guide/battery-life-for-top-evs/; https://www.plugincars.com/what-you-need-know-about-electric-car-battery-warranties-132884.html

Procurement summary (nominal)

| Vehicle | Capital costs | Annual Fuel use | Annual Electricity Use | Annual Fuel/Elec Cost | Annual Operating Cost | Annual Carbon costs | Foregone interest | Annual Emissions (kg CO2) |
|---|---|---|---|---|---|---|---|---|
| MINI COOPER S E COUNTRYMAN ALL4 | 44390 | 7714 | 4098 | 1694 | 2002 | 78 | 801 | 3355 |
| HYUNDAI SONATA HYBRID SE | 35000 | 11006 | 0 | 1777 | 3250 | 157 | 632 | 3186 |
| NISSAN LEAF S PLUS | 40698 | 0 | 4519 | 494 | 2518 | 0 | 734 | 0 |
| TESLA MODEL S 100D | 116190 | 0 | 4984 | 545 | 2518 | 0 | 2097 | 0 |

Figure 16. Results – procurement summary (nominal)

## Annual costs per km

This section presents a graph with financial metrics that shows a breakdown of the major cost categories as the sum costs from capital (with incentives, taxes and fees), forgone interest, fuel, maintenance and repairs, overhead, insurance, carbon, and charging infrastructure in dollars per kilometer (km) (Figure 17). The graph includes slicers that allow user to exclude/include any costs categories of choice. The section also shows a message cloud indicating the most and least expensive vehicle. It should be noted that working with slicers affects merely the graph and does not affect any calculations and the information in the message cloud.

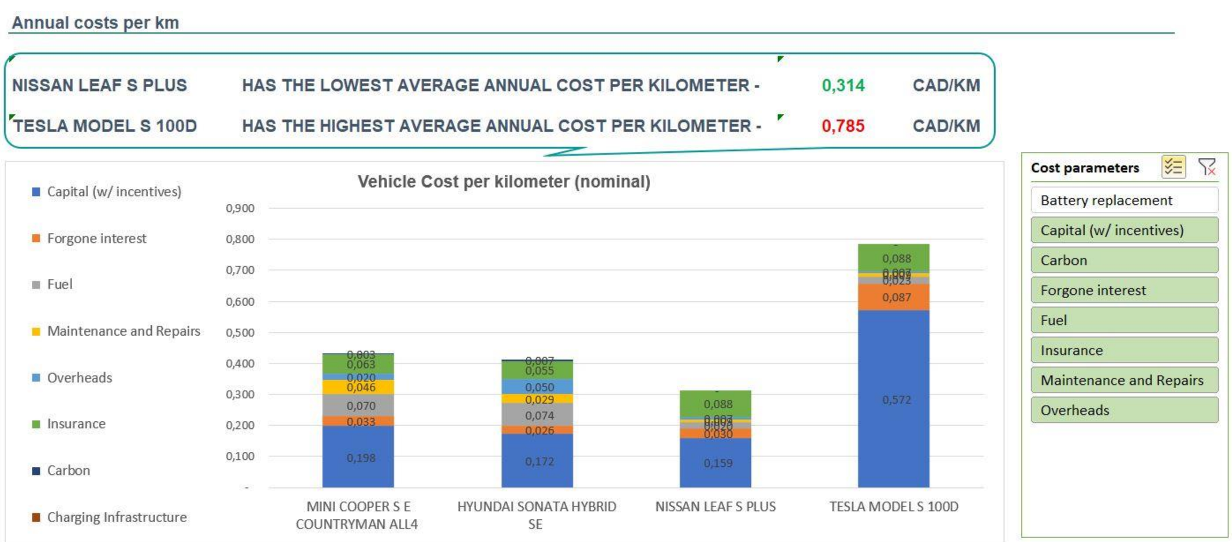



Figure 17. Results – Annual costs per km (nominal)

## CO2 emissions

This section summarizes the environmental impact calculations in terms of kilograms of annual $CO_2$ emissions. This metric is calculated using an emission factor in kg per km (from Fuel consumption & emissions section) and annual mileage (Figure 18). The section also shows a message cloud indicating the most and least environmentally friendly vehicle. Please note that if more than one vehicle has the same $CO_2$ emission factor, the message cloud shows only one vehicle (the example can be clearly seen in Figure 18, where both Nissan Leaf and Tesla Model S have no $CO_2$ emissions but the message cloud writes only about Nissan Leaf).

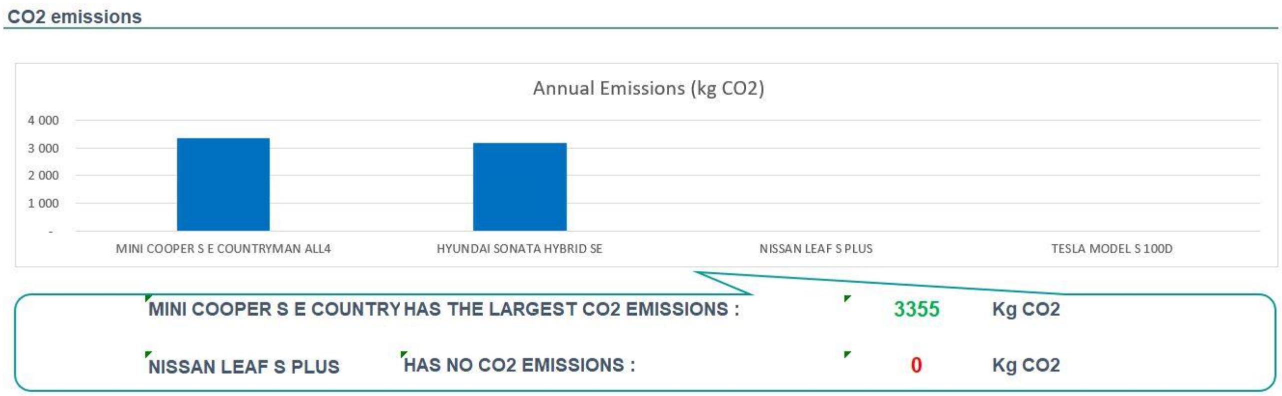



Figure 18. Results – Annual CO2 emissions

## Capital Costs

This Section presents a graphic comparison of MSRP of all four vehicles (Figure 19).

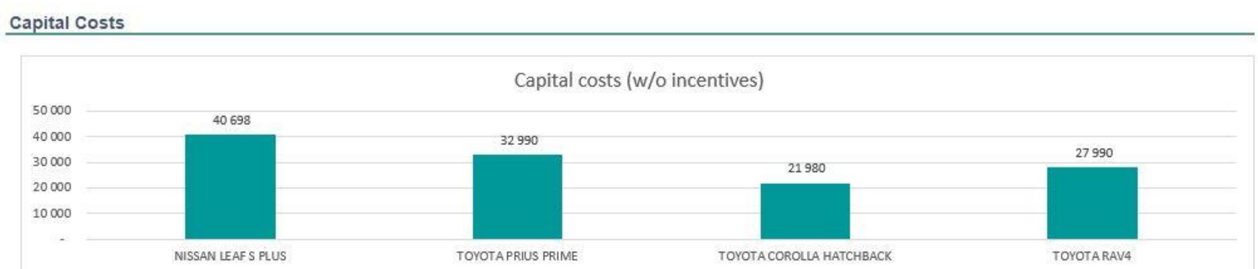
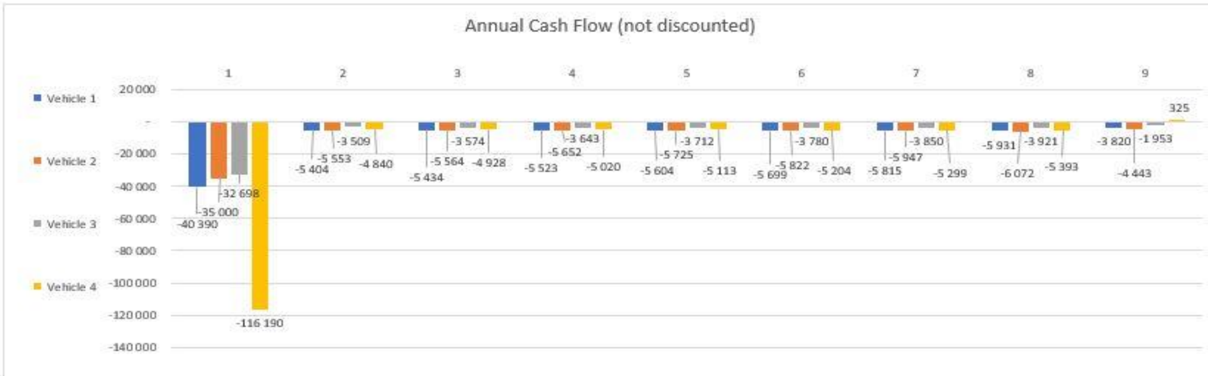



Figure 19. Results – Capital costs

## Year-by-year and Cumulative LCCC

The *Results* section also shows the cost comparison of the four procurements by summing incoming and outgoing cash flows over the life of the vehicles. A possible positive cash flow value at the end of the timeframe is the result of the sale of vehicles at the end of their useful lives at the price of their residual value. The graphs demonstrate comparison on annual and cumulative (Figure 20).

Year-by-year LCCC




Cumulative LCC

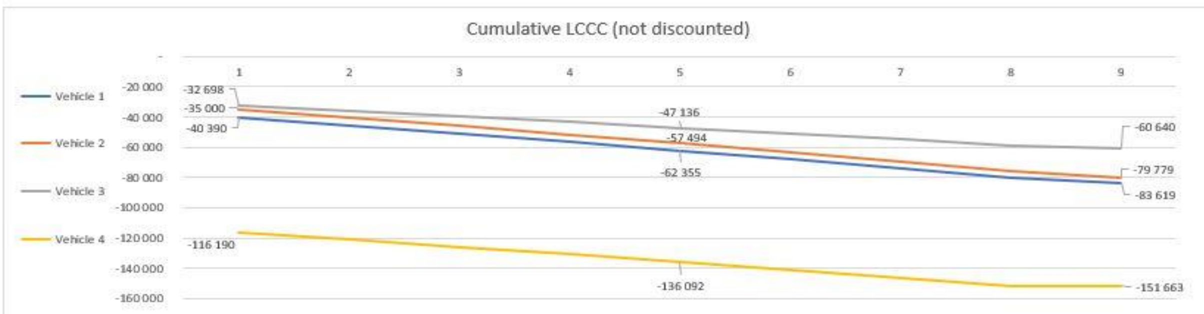



Figure 20. Results – Cash flow analysis (nominal)

### 8.3.4 Financial modelling

This worksheet shows the detailed financial analysis the results of which are presented in the *Results* section. This worksheet does not require user modification and is left visible to demonstrate the logic of year-by-year evaluations for four vehicles. The worksheet consists of four tables that summarize nominal and discounted costs, including depreciation, incentives, forgone interest, fuel, overhead, maintenance, insurance costs, etc. from the time of vehicle acquisition through a maximum of 12 years of use. The tables use both user inputs from “Inputs & Dashboard” and “Database” worksheets.

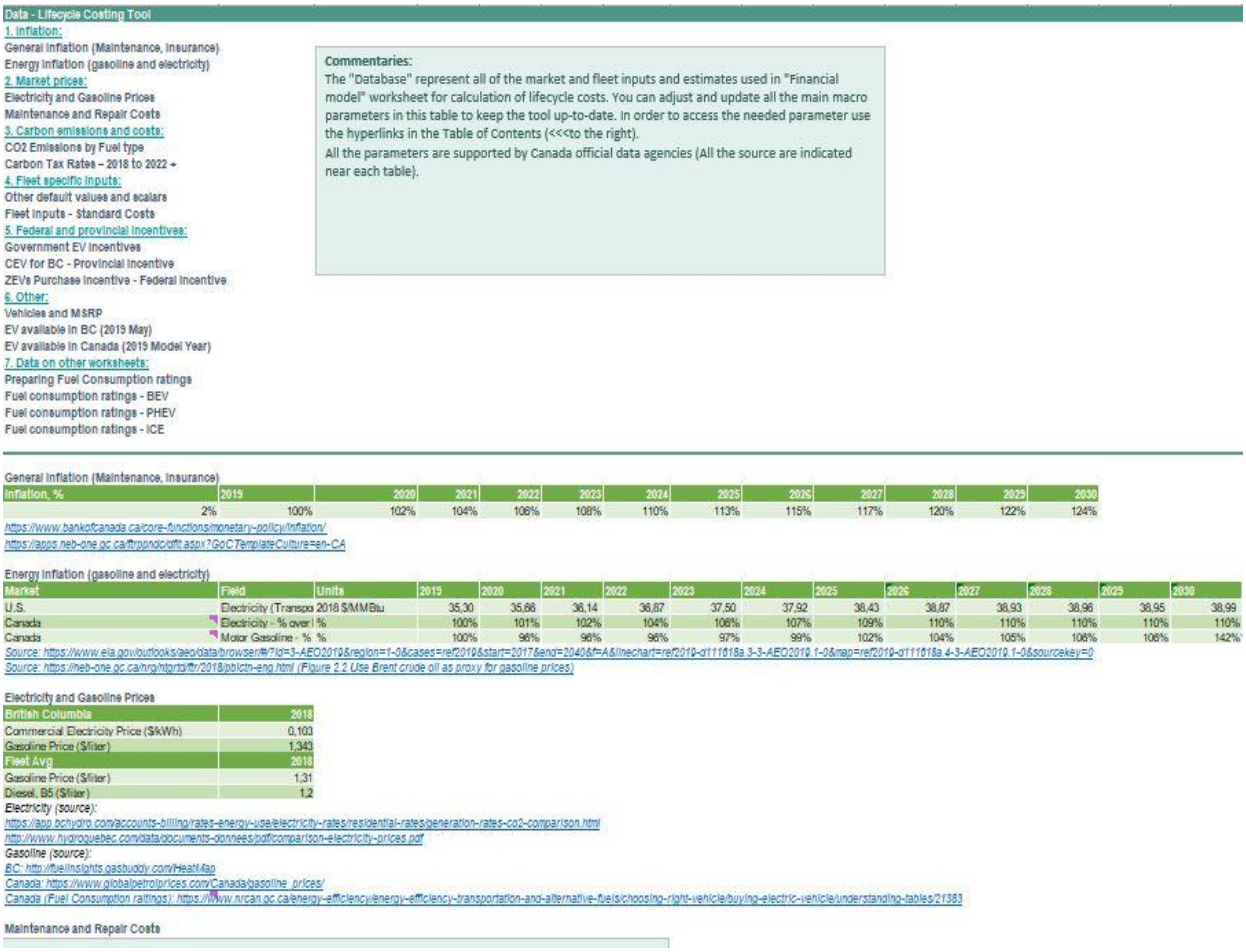
| Financial Models - Lifecycle Costing Tool | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Vehicle 1** | | | | | | | | | | | | | |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| ***Depreciation Calculations*** | | | | | | | | | | | | | |
| Fair Market Value | 44 390 | $ 39 119 | $ 33 847 | $ 28 576 | $ 23 305 | $ 18 033 | $ 12 762 | $ 7 491 | $ 2 220 | $ - | $ - | $ - | $ - |
| Depreciation | $ (5 271) | $ (5 271) | $ (5 271) | $ (5 271) | $ (5 271) | $ (5 271) | $ (5 271) | $ (5 271) | $ (2 220) | $ - | $ - | $ - | $ - |
| ***Capital and Financing Costs*** | | | | | | | | | | | | | |
| Cash Payment | $ (44 390) | | | | | | | | | | | | |
| EV incentives (prov + fed) | $ 4 000 | | | | | | | | | | | | |
| Tax or other fees | $ - | | | | | | | | | | | | |
| Capital plus interest | | $ (45 145) | $ (45 912) | $ (46 693) | $ (47 486) | $ (48 294) | $ (49 115) | $ (49 950) | $ (50 799) | $ (50 799) | $ (50 799) | $ (50 799) | $ (50 799) |
| *Interest Payments* | | $ *(755)* | $ *(767)* | $ *(781)* | $ *(794)* | $ *(807)* | $ *(821)* | $ *(835)* | $ *(849)* | $ - | $ - | $ - | $ - |
| Terminal value | | $ - | $ - | $ - | $ - | $ - | $ - | $ - | $ 2 220 | $ - | $ - | $ - | $ - |
| *Total Capital and Financing Costs* | ***$ (40 390)*** | ***$ (755)*** | ***$ (767)*** | ***$ (781)*** | ***$ (794)*** | ***$ (807)*** | ***$ (821)*** | ***$ (835)*** | ***$ 1 370*** | ***$ -*** | ***$ -*** | ***$ -*** | ***$ -*** |
| ***Fuel and Operating Costs*** | | | | | | | | | | | | | |
| Gas - fuel costs City | | $ (936) | $ (896) | $ (896) | $ (896) | $ (906) | $ (930) | $ (953) | $ (973) | $ - | $ - | $ - | $ - |
| Gas - fuel costs Hwy | | $ (327) | $ (313) | $ (313) | $ (313) | $ (317) | $ (325) | $ (333) | $ (340) | $ - | $ - | $ - | $ - |
| Electricity - fuel costs City | | $ (319,5) | $ (323,8) | $ (330,3) | $ (336,0) | $ (339,7) | $ (344,3) | $ (348,3) | $ (348,8) | $ - | $ - | $ - | $ - |
| Electricity - fuel costs Hwy | | $ (106) | $ (108) | $ (110) | $ (112) | $ (113) | $ (115) | $ (116) | $ (116) | $ - | $ - | $ - | $ - |
| *Fuel Cost* | | *$ (1 689)* | *$ (1 641)* | *$ (1 650)* | *$ (1 658)* | *$ (1 676)* | *$ (1 713)* | *$ (1 750)* | *$ (1 777)* | *$ -* | *$ -* | *$ -* | *$ -* |
| *Maintenance and Repair Cost* | | *$ (1 031)* | *$ (1 052)* | *$ (1 073)* | *$ (1 094)* | *$ (1 116)* | *$ (1 139)* | *$ (1 161)* | *$ (1 185)* | *$ -* | *$ -* | *$ -* | *$ -* |
| *Overheads* | | *$ (445)* | *$ (454)* | *$ (463)* | *$ (472)* | *$ (481)* | *$ (491)* | *$ (501)* | *$ (511)* | *$ -* | *$ -* | *$ -* | *$ -* |
| *Insurance Cost* | | *$ (1 421)* | *$ (1 449)* | *$ (1 478)* | *$ (1 508)* | *$ (1 538)* | *$ (1 569)* | *$ (1 600)* | *$ (1 632)* | *$ -* | *$ -* | *$ -* | *$ -* |
| *Battery replacement reserve* | | *$ -* | *$ -* | *$ -* | *$ -* | *$ -* | *$ -* | *$ -* | *$ -* | *$ -* | *$ -* | *$ -* | *$ -* |
| *Subtotal Fuel and Operating Costs* | ***$ -*** | ***$ (4 586)*** | ***$ (4 596)*** | ***$ (4 664)*** | ***$ (4 732)*** | ***$ (4 811)*** | ***$ (4 912)*** | ***$ (5 012)*** | ***$ (5 105)*** | ***$ -*** | ***$ -*** | ***$ -*** | ***$ -*** |
| ***Other Costs*** | | | | | | | | | | | | | |
| Cost of Carbon | | $ (63) | $ (71) | $ (79) | $ (79) | $ (80) | $ (82) | $ (84) | $ (85) | $ - | $ - | $ - | $ - |
| Subtotal Other Costs | **$ -** | **$ (63)** | **$ (71)** | **$ (79)** | **$ (79)** | **$ (80)** | **$ (82)** | **$ (84)** | **$ (85)** | **$ -** | **$ -** | **$ -** | **$ -** |
| ***Total Discounted Costs - Vehicle*** | | | | | | | | | | | | | |
| Total Annual Costs | $ (40 390) | $ (5 404) | $ (5 434) | $ (5 523) | $ (5 604) | $ (5 699) | $ (5 815) | $ (5 931) | $ (3 820) | $ - | $ - | $ - | $ - |
| Cumulative Total | **$ (40 390)** | **$ (45 794)** | **$ (51 228)** | **$ (56 751)** | **$ (62 355)** | **$ (68 054)** | **$ (73 869)** | **$ (79 800)** | **$ (83 619)** | **$ -** | **$ -** | **$ -** | **$ -** |
| Discount Factor *1,7%* | 100,0% | 98,3% | 96,7% | 95,1% | 93,5% | 91,9% | 90,4% | 88,9% | 87,4% | 85,9% | 84,5% | 83,1% | 81,7% |
| Discounted Total | $ (40 390) | $ (5 313) | $ (5 254) | $ (5 251) | $ (5 239) | $ (5 239) | $ (5 255) | $ (5 271) | $ (3 338) | $ - | $ - | $ - | $ - |

Figure 21. Financial model

### 8.3.5 Database management

#### Database

The “Database” worksheet contains the source data for all fields populated in the tool. None of this data is updated automatically. Therefore, users should be cautious while editing this data. In order to easily access the needed data inputs, use hyperlinks in the table of contents at the beginning of the worksheet. Please note that the tables in blue are given for informational purposes only and not used in the tool (for example, different type of emission gases that might be included in the tool). All the web-sources for inputs are given in blue italics below each input table. For your information, there are also green text boxes with commentaries on how the information was gathered, the duration of this information relevance, etc. (Figure 22).



Data - Lifecycle Costing Tool

1. Inflation:
General Inflation (Maintenance, Insurance)
Energy Inflation (gasoline and electricity)
2. Market prices:
Electricity and Gasoline Prices
Maintenance and Repair Costs
3. Carbon emissions and costs:
CO2 Emissions by Fuel type
Carbon Tax Rates – 2018 to 2022 +
4. Fleet specific inputs:
Other default values and scalars
Fleet Inputs - Standard Costs
5. Federal and provincial incentives:
Government EV Incentives
CEV for BC - Provincial Incentive
ZEVs Purchase Incentive - Federal Incentive
6. Other:
Vehicles and MSRP
EV available in BC (2019 May)
EV available in Canada (2019 Model Year)
7. Data on other worksheets:
Preparing Fuel Consumption ratings
Fuel consumption ratings - BEV
Fuel consumption ratings - PHEV
Fuel consumption ratings - ICE

Commentaries:
The "Database" represent all of the market and fleet inputs and estimates used in "Financial model" worksheet for calculation of lifecycle costs. You can adjust and update all the main macro parameters in this table to keep the tool up-to-date. In order to access the needed parameter use the hyperlinks in the Table of Contents (<<<to the right).
All the parameters are supported by Canada official data agencies (All the source are indicated near each table).

General Inflation (Maintenance, Insurance)

| Inflation, % | 2019 | | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2% | 100% | | 102% | 104% | 106% | 108% | 110% | 113% | 115% | 117% | 120% | 122% | 124% |

https://www.bankofcanada.ca/core-functions/monetary-policy/inflation/
https://apps.neb-one.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA

Energy Inflation (gasoline and electricity)

| Market | Field | Units | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U.S. | Electricity (Transpo | 2018 $/MMBtu | 35,30 | 35,66 | 36,14 | 36,87 | 37,50 | 37,92 | 38,43 | 38,87 | 38,93 | 38,96 | 38,95 | 38,99 |
| Canada | Electricity - % over | % | 100% | 101% | 102% | 104% | 106% | 107% | 109% | 110% | 110% | 110% | 110% | 110% |
| Canada | Motor Gasoline - % | % | 100% | 96% | 96% | 96% | 97% | 99% | 102% | 104% | 105% | 106% | 106% | 142% |

Source: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2019&region=1-0&cases=ref2019&start=2017&end=2040&f=A&linechart=ref2019-d111618a.3-3-AEO2019.1-0&map=ref2019-d111618a.4-3-AEO2019.1-0&sourcekey=0
Source: https://neb-one.gc.ca/nrg/ntgrtd/ftr/2018/pblctn-eng.html (Figure 2.2 Use Brent crude oil as proxy for gasoline prices)

Electricity and Gasoline Prices

| British Columbia | 2018 |
|---|---|
| Commercial Electricity Price ($/kWh) | 0,103 |
| Gasoline Price ($/liter) | 1,343 |
| **Fleet Avg** | **2018** |
| Gasoline Price ($/liter) | 1,31 |
| Diesel, B5 ($/liter) | 1,2 |

Electricity (source):
https://app.bchydro.com/accounts-billing/rates-energy-use/electricity-rates/residential-rates/generation-rates-co2-comparison.html
http://www.hydroquebec.com/data/documents-donnees/pdf/comparison-electricity-prices.pdf
Gasoline (source):
BC: http://fuelinsights.gasbuddy.com/HeatMap
Canada: https://www.globalpetrolprices.com/Canada/gasoline_prices/
Canada (Fuel Consumption raitings): https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation-and-alternative-fuels/choosing-right-vehicle/buying-electric-vehicle/understanding-tables/21383

Maintenance and Repair Costs

Figure 22. Database worksheet

## Fuel consumption ratings (BEV, PHEV, ICE)

These three worksheets ("17-19 BEV", "17-19 PHEV", "17-19 ICE".) are uploads from Natural Resources Canada website[46]. Datasets in the worksheets provide model-specific fuel consumption ratings, estimated carbon dioxide emissions, and other technical characteristics for new vehicles for retail sale in Canada. In order to adjust the data for easy access in the tool, only light-duty vehicles available in British Columbia were picked (see Section 8.4 for the detailed description of how the database was modified) and MSRPs from publicly available sources[47] were uploaded for vehicles (Figure 23). The final table presents a unique list of vehicles the

[46] https://open.canada.ca/data/en/dataset/98f1a129-f628-4ce4-b24d-6f16bf24dd64

[47] https://carcostcanada.com/Canada/Prices/2012-Mitsubishi-i_MiEV/24982

characteristics of which are automatically uploaded in “Inputs & Dashboard” worksheet when a certain vehicle from the database is chosen in the dropdown list.

Legend

Manually created columns

Columns uploaded from Natural Resources Canada

Fuel consumption ratings - BEV

| | | | | | | | | CONSUMPTION | | | | | | | | | | | needed for vehicle search | | needed for ru |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Selection Name | YE | MAKE | MODEL | VEHICLE CL | MOTO (kW | TRANSMIS | FU TY | CITY (kWh/1 km) | HWY (kWh/ km | COMB (kWh/1 km) | CITY (Le/1 km | HWY (Le/ kr | COMB (Le/ kn | RA (I | CO2 EMISSI (g/kr | CO2 R/ | SMO RATI | RECHA TIME | Drivetr Type | MSI | Drivetr Type |
| 2019 BMW i3 (120 Ah) BEV | 2019 | BMW | i3 (120 Ah) | SUBCOMPACT | 125 | A1 | B | 16,8 | 20,6 | 18,5 | 1,9 | 2,3 | 2,1 | 246 | 0 | 10 | 10 | 7 | BEV | 51568 | Cars - BEV |
| 2019 BMW i3s (120 Ah) BEV | 2019 | BMW | i3s (120 Ah) | SUBCOMPACT | 135 | A1 | B | 16,8 | 20,6 | 18,5 | 1,9 | 2,3 | 2,1 | 246 | 0 | 10 | 10 | 7 | BEV | 55168 | Cars - BEV |
| 2019 CHEVROLET BOLT EV BEV | 2019 | CHEVROLET | BOLT EV | STATION WAGON | 150 | A1 | B | 16,4 | 19 | 17,6 | 1,8 | 2,1 | 2 | 383 | 0 | 10 | 10 | 9,3 | BEV | 44095 | Cars - BEV |
| 2019 HYUNDAI IONIQ ELECTRIC BEV | 2019 | HYUNDAI | IONIQ ELECTRIC | MID-SIZE | 88 | A1 | B | 13,7 | 17,4 | 15,5 | 1,6 | 1,9 | 1,7 | 200 | 0 | 10 | 10 | 4 | BEV | 37449 | Cars - BEV |
| 2019 HYUNDAI KONA ELECTRIC BEV | 2019 | HYUNDAI | KONA ELECTRIC | SUV - SMALL | 150 | A1 | B | 16,2 | 19,3 | 17,4 | 1,8 | 2,2 | 2 | 415 | 0 | 10 | 10 | 9 | BEV | 44999 | Cars - BEV |
| 2019 JAGUAR I-PACE BEV | 2019 | JAGUAR | I-PACE | SUV - SMALL | 294 | A1 | B | 26,2 | 29,1 | 27,5 | 2,9 | 3,3 | 3,1 | 377 | 0 | 10 | 10 | 13 | BEV | 89800 | Cars - BEV |
| 2019 KIA SOUL EV BEV | 2019 | KIA | SOUL EV | STATION WAGON | 81 | A1 | B | 16,8 | 22,4 | 19,3 | 1,9 | 2,5 | 2,2 | 179 | 0 | 10 | 10 | 5 | BEV | 35895 | Cars - BEV |
| 2019 NISSAN LEAF (40 kWh) BEV | 2019 | NISSAN | LEAF (40 kWh) | MID-SIZE | 110 | A1 | B | 16,8 | 21 | 18,7 | 1,9 | 2,4 | 2,1 | 243 | 0 | 10 | 10 | 8 | BEV | 36398 | Cars - BEV |
| 2019 NISSAN LEAF S PLUS BEV | 2019 | NISSAN | LEAF S PLUS | MID-SIZE | 160 | A1 | B | 17,8 | 21,5 | 19,5 | 2 | 2,4 | 2,2 | 363 | 0 | 10 | 10 | 11 | BEV | 40698 | Cars - BEV |
| 2019 NISSAN LEAF SV/SL PLUS BEV | 2019 | NISSAN | LEAF SV/SL PLUS | MID-SIZE | 160 | A1 | B | 18,3 | 22,1 | 20 | 2,1 | 2,5 | 2,2 | 349 | 0 | 10 | 10 | 11 | BEV | 40698 | Cars - BEV |
| 2019 SMART EQ FORTWO CABRIOLE | 2019 | SMART EQ | FORTWO CABRIOLE | TWO-SEATER | 60 | A1 | B | 18,7 | 23,1 | 20,7 | 2,1 | 2,6 | 2,3 | 92 | 0 | 10 | 10 | 3 | BEV | 29050 | Cars - BEV |
| 2019 SMART EQ FORTWO COUPE BE | 2019 | SMART EQ | FORTWO COUPE | TWO-SEATER | 60 | A1 | B | 16,9 | 22,3 | 19,3 | 1,9 | 2,5 | 2,2 | 93 | 0 | 10 | 10 | 3 | BEV | 32050 | Cars - BEV |
| 2019 TESLA MODEL 3 Mid Range BEV | 2019 | TESLA | MODEL 3 Mid Range | MID-SIZE | 202 | A1 | B | 16,4 | 17,9 | 17,1 | 1,8 | 2 | 1,9 | 425 | 0 | 10 | 10 | 10 | BEV | 61740 | Cars - BEV |
| 2019 TESLA MODEL 3 Long Range BE | 2019 | TESLA | MODEL 3 Long Rang | MID-SIZE | 202 | A1 | B | 15,3 | 17 | 16,1 | 1,7 | 1,9 | 1,8 | 499 | 0 | 10 | 10 | 10 | BEV | 68490 | Cars - BEV |
| 2019 TESLA MODEL 3 Long Range AW | 2019 | TESLA | MODEL 3 Long Rang | MID-SIZE | 335 | A1 | B | 17,4 | 18,7 | 18 | 2 | 2,1 | 2 | 499 | 0 | 10 | 10 | 10 | BEV | 68490 | Cars - BEV |
| 2019 TESLA MODEL 3 Long Range AW | 2019 | TESLA | MODEL 3 Long Rang | MID-SIZE | 358 | A1 | B | 17,4 | 18,7 | 18 | 2 | 2,1 | 2 | 499 | 0 | 10 | 10 | 10 | BEV | 81990 | Cars - BEV |
| 2019 TESLA MODEL S 75D BEV | 2019 | TESLA | MODEL S 75D | FULL-SIZE | 386 | A1 | B | 20,6 | 19,9 | 20,3 | 2,3 | 2,2 | 2,3 | 417 | 0 | 10 | 10 | 12 | BEV | 106890 | Cars - BEV |
| 2019 TESLA MODEL S 100D BEV | 2019 | TESLA | MODEL S 100D | FULL-SIZE | 386 | A1 | B | 20,7 | 20,5 | 20,6 | 2,3 | 2,3 | 2,3 | 539 | 0 | 10 | 10 | 12 | BEV | 116190 | Cars - BEV |
| 2019 TESLA MODEL S P100D BEV | 2019 | TESLA | MODEL S P100D | FULL-SIZE | 568 | A1 | B | 22,6 | 20 | 21,5 | 2,5 | 2,3 | 2,4 | 507 | 0 | 10 | 10 | 12 | BEV | 110000 | Cars - BEV |
| 2019 TESLA MODEL X 75D BEV | 2019 | TESLA | MODEL X 75D | SUV - STANDARD | 386 | A1 | B | 23 | 21,9 | 22,5 | 2,6 | 2,5 | 2,5 | 383 | 0 | 10 | 10 | 12 | BEV | 113590 | Cars - BEV |
| 2019 TESLA MODEL X 100D BEV | 2019 | TESLA | MODEL X 100D | SUV - STANDARD | 386 | A1 | B | 24,3 | 23,7 | 24 | 2,7 | 2,7 | 2,7 | 475 | 0 | 10 | 10 | 12 | BEV | 141690 | Cars - BEV |
| 2019 TESLA MODEL X P100D BEV | 2019 | TESLA | MODEL X P100D | SUV - STANDARD | 568 | A1 | B | 25,4 | 23,6 | 24,6 | 2,8 | 2,7 | 2,8 | 465 | 0 | 10 | 10 | 12 | BEV | 130000 | Cars - BEV |
| 2019 VOLKSWAGEN e-GOLF BEV | 2019 | VOLKSWAGEN | e-GOLF | COMPACT | 100 | A1 | B | 16,8 | 18,6 | 17,4 | 1,9 | 2,1 | 2 | 201 | 0 | 10 | 10 | 5,3 | BEV | 36720 | Cars - BEV |
| 2018 BMW i3 BEV | 2018 | BMW | i3 | SUBCOMPACT | 125 | A1 | B | 16,2 | 19,7 | 17,8 | 1,8 | 2,2 | 2 | 183 | 0 | 10 | 10 | 5 | BEV | 49000 | Cars - BEV |
| 2018 CHEVROLET BOLT EV BEV | 2018 | CHEVROLET | BOLT EV | STATION WAGON | 150 | A1 | B | 16,4 | 19 | 17,6 | 1,8 | 2,1 | 2 | 383 | 0 | 10 | 10 | 9,3 | BEV | 44095 | Cars - BEV |
| 2018 FORD FOCUS ELECTRIC BEV | 2018 | FORD | FOCUS ELECTRIC | COMPACT | 107 | A1 | B | 17,7 | 21,8 | 19,6 | 2 | 2,5 | 2,2 | 185 | 0 | 10 | 10 | 5,5 | BEV | 33698 | Cars - BEV |

Figure 23. Fuel Consumption Ratings (Battery Electric Vehicles)

## 8.4 Updating & modifying the tool

The tool is highly dependant on user and default inputs that are automatically uploaded from the database. Therefore, in order to keep the tool updated and receive actual information about vehicle performance users need to:

1. Be careful while changing the parameters
2. Make sure to check that ALL worksheets are adjusted to these changes

The following sections are going to explain how to update the main worksheets.

### 8.4.1 Database update

The tables in the “Database” predicting prices, costs, and their dynamics are manually uploaded from open statistical sources for many years (more than eight years). Therefore, there should not be the need to expand the tables. However, it is highly advisable to periodically check that the tables’ content is using the up-to-date sources.

Tables with incentives are using generally accepted price caps that might change because of federal or provincial legislation. For example, according to BC Canada, provincial incentives will be available until March 31st, 2020 or until available funding is depleted, whichever comes first. The table of ICEVs taken from Atlas Policy tool[48] is needed for uploading MSRP for ICE. Since Atlas

[48] https://atlaspolicy.com/rand/fleet-procurement-analysis-tool/

Policy is usually uploaded quarterly, it is preferable to check whether this table is updated in their "Data" worksheet.

### 8.4.2 Fuel consumption ratings update

This LCT uses data from Fuel Consumption Ratings for uploading vehicle technical characteristics. The database of EVs, PHEVs, and ICEVs was downloaded from Natural Resources Canada website (Fuel Consumption ratings[49]). These datasets are annually uploaded and in order to access them you should download the following csv files:

- BEV: Battery-electric vehicles 2012-2019 (English) – 1 file
- PHEV: Plug-in hybrid electric vehicles 2012-2019 (English) – 1 file
- ICE: 2017-2019 Fuel Consumption Ratings (English) – 3 files

Datasets provide model-specific fuel consumption ratings and estimated carbon dioxide emissions for new light-duty vehicles for retail sale in Canada.

In order to adjust the data for the easy access in the tool, the tables were edited using these steps.

1. Delete items with these characteristics:

a) Luxury made (Figure 24)

b) Years 2012-2016

c) Non-relevant vehicle classes (Figure 24)

| Deleted luxury mades |
|---|
| ALFA ROMEO |
| ASTON MARTIN |
| BENTLEY |
| BUICK |
| CADILLAC |
| INFINITI |
| LAMBORGHINI |
| LAND ROVER |
| LEXUS |
| LINCOLN |
| MASERATI |
| MERCEDES-BENZ |
| PORSCHE |
| RAM |
| ROLLS-ROYCE |
| BUGATTI |

| Deleted vehicle classes |
|---|
| PICKUP TRUCK - SMALL |
| PICKUP TRUCK - STANDARD |
| SPECIAL PURPOSE VEHICLE |

Figure 24. The list of deleted vehicles made and classes

[49] https://open.canada.ca/data/en/dataset/98f1a129-f628-4ce4-b24d-6f16bf24dd64

2. For ICEVs list, delete items that used N (Natural gas), E (Ethanol E85) and delete vehicles with repeating characteristics (transmission, engine size etc.)

3. MSRP for EVs were uploaded manually from the lists of vehicles available in BC / Canada (the tables can be found in "Database")

4. MSRP for ICEVs were taken from Atlas Policy LCT database and uploaded for all the tables using VLOOKUP command (Vehicle and MSRP table)

5. Since not all the models have MSRP available, in case of an error, some MSRP should be typed manually using open data sources[50]

6. For PHEV, in order to pick out total electricity consumption in kWh/100km and not mixed units of measurement, divide *CONSUMPTION COMBINED Le/100 km* column into 3 columns:
   - Total COMB (Le/100km)
   - Electricity COMB (kWh/100km)
   - Fuel COMB (L/100km)

   Use the formula *Total COMB (Le/100km) x 8,9(kWh/Le)* as an ESTIMATE for electricity consumption in electricity mode. The derived value is an ESTIMATE of real energy consumption in electricity mode because it relies on assumptions that (1) PHEV is used for 55% city and 45% highway driving (2) PHEV uses negligible amount of gasoline (which is true, according to Fuel Consumption Ratings for BC models) in electricity mode so that the price of this gasoline can be substituted with the electricity price.

The final tables can be found on separate worksheets "17-19 BEV", "17-19 PHEV", "17-19 ICE".

### 8.4.3 Drop down lists update

Dependent dropdown lists for choosing vehicles allow user to choose VEHICLE TYPE, VEHICLE MAKE, VEHICLE MODEL, VEHICLE YEAR in the section *Vehicle inputs* from unique lists in hidden worksheets "Vehicle Filter (Vf) V1" (Figure 25). The following section is going to explain how these unique lists are created. Since the tool compares four vehicles, four identical worksheets ("Vehicle Filter (Vf) V1", "Vf V2", "Vf V3", "Vf V4") were made so that there is no confusion with

[50] Examples could be https://carcostcanada.com/Canada/Prices/2012-Mitsubishi-i_MiEV/24982

the choice of vehicle (if the same worksheet is used for all the four vehicles the tool does not work).

**Vehicle inputs**

| Technical features | Vehicle 1 | Vehicle 2 | Vehicle 3 | Vehicle 4 |
|---|---|---|---|---|
| Description | 2018 MINI COOPER S E COUNTRYMAN ALL4 PHEV MID-SIZE | 2019 HYUNDAI SONATA HYBRID SE ICE MID-SIZE | 2019 NISSAN LEAF S PLUS BEV MID-SIZE | 2019 TESLA MODEL S 100D BEV FULL-SIZE |
| Car type | PHEV | ICE | BEV | BEV |
| Make | MINI | HYUNDAI | NISSAN | TESLA |
| Model | PER S E COUNTRYMAN | SONATA HYBRID SE | LEAF S PLUS | MODEL S 100D |
| Year | 2018 | 2019 | 2019 | 2019 |
| Vehicle class | MID-SIZE | MID-SIZE | MID-SIZE | FULL-SIZE |

Figure 25. Dropdown lists for choosing vehicle (bright-green cells)

In order to create these dependable dropdown lists, the following tutorials[51] were used and three tables were created: *Table 1, Table 2, Table 3* (Figure 26). The first table in the worksheet represents all the vehicle items of all the types. They are manually copied from worksheets "17-19 BEV", "17-19 PHEV", "17-19 ICE". Helpers 1-3 help to drag all the items of the chosen type (ICE/PHEV/BEV) on the second table (*Table_Div*). The *Table 2* also has helpers that drag down all the items of the chosen vehicle make, (BMW/ CHEVROLET/ AUDI/ NISSAN/ KIA/...) on the *Table 3* (*Table_Div2*).

As a result, *Table 2.1* and *Table 3.1* are made; *Table 2.1* contains unique list of vehicles make of chosen vehicle type from *Table 2*; *Table 3.1* contains unique list of vehicle models of chosen vehicle make from *Table 3*. These unique lists serve as a source for our dropdown lists in "Inputs & Dashboard" worksheet.

*Table 1 - uploaded manually by copying all the vehicle items from "17-19*

| MAKE | MODEL | YEAR | TYPE | Helper 1 | Helper 2 | Helper 3 |
|---|---|---|---|---|---|---|
| BMW | i3 (120 Ah) | 2019 | BEV | 1 | | 64 |
| BMW | i3s (120 Ah) | 2019 | BEV | 2 | | 65 |
| CHEVROL | BOLT EV | 2019 | BEV | 3 | | 66 |
| HYUNDAI | IONIQ ELECTR | 2019 | BEV | 4 | | 67 |
| HYUNDAI | KONA ELECTRI | 2019 | BEV | 5 | | 68 |
| JAGUAR | I-PACE | 2019 | BEV | 6 | | 69 |
| KIA | SOUL EV | 2019 | BEV | 7 | | 70 |
| NISSAN | LEAF (40 kWh) | 2019 | BEV | 8 | | 71 |
| NISSAN | LEAF S PLUS | 2019 | BEV | 9 | | 72 |
| NISSAN | LEAF SV/SL PLU | 2019 | BEV | 10 | | 73 |
| SMART E( | FORTWO CABR | 2019 | BEV | 11 | | 74 |
| SMART E( | FORTWO COU | 2019 | BEV | 12 | | 75 |
| TESLA | MODEL 3 Mid I | 2019 | BEV | 13 | | 76 |

**Table 2**

| MAKE | MODEL | YEAR | Helper 1 | Helper 2 | Helper 3 |
|---|---|---|---|---|---|
| BMW | 530e xDRIVE | 2019 | 1 | | 12 |
| BMW | 740e xDRIVE | 2019 | 2 | | 28 |
| BMW | i8 COUPE | 2019 | 3 | | |
| BMW | i8 ROADSTE | 2019 | 4 | | |
| CHRYSLER | PACIFICA HY | 2019 | 5 | | |
| FORD | FUSION ENE | 2019 | 6 | | |
| HONDA | CLARITY PLU | 2019 | 7 | | |
| HYUNDAI | IONIQ ELEC | 2019 | 8 | | |
| HYUNDAI | SONATA PLU | 2019 | 9 | | |
| KIA | NIRO PLUG- | 2019 | 10 | | |
| KIA | OPTIMA PLU | 2019 | 11 | | |
| MINI | COOPER S E | 2019 | 12 | 12 | |
| MITSUBISHI | OUTLANDER | 2019 | 13 | | |

**Table 3**

| MAKE | MODEL | YEAR |
|---|---|---|
| MINI | COOPER S E CO | 2019 |
| MINI | COOPER S E CO | 2018 |

| Table 1.1 Unique List - type | Table 2.1 Unique List - make | Table 3.1 Unique List - model | Table 3.2 Unique List - year |
|---|---|---|---|
| BEV | BMW | COOPER S E COU | 2019 |
| PHEV | CHRYSLER | | 2018 |
| ICE | FORD | | |
| | HONDA | | |
| | HYUNDAI | | |
| | KIA | | |
| | MINI | | |
| | MITSUBISHI | | |
| | TOYOTA | | |
| | VOLVO | | |
| | AUDI | | |

Figure 26. Creating Unique lists for dependent dropdown lists

[51] https://www.xelplus.com/extract-unique-items-for-dynamic-data-validation-drop-down-list/
https://trumpexcel.com/extract-data-from-drop-down-list/

Consequently, if there is a necessity to change the dropdown list because of change in the vehicle database, the editor should follow these steps:

1. Copy and paste the list of VEHICLE TYPE, VEHICLE MAKE, VEHICLE MODEL, VEHICLE YEAR from three source worksheets to Table 1 (first four columns)

2. Make sure that if there are (1) more vehicles than before then all the formulas should be dragged down to the list end and if there are (2) less vehicles than before then the unnecessary formulas should be deleted

3. Repeat the actions above for the rest three worksheets- otherwise new vehicles will not appear in the dropdown list

### 8.4.4 Financial model and Results table

If you make changes in the "Financial model" (adding more years, adding or deleting cost parameters) then make sure to review Checks ("TRUE" / "FALSE") in the "Results tables" worksheet and make corrections if Checks are red. Otherwise, the results of the calculations will be mispresented in the *Results* section.

### 8.4.5 Other changes

Depending on the fleet requirements and EV market changes, there could be other changes in the tool required. Such updates might include:

1. Increasing the length of vehicle useful life (more than 12 years)

2. Increasing the number of vehicles compared

3. Adding cost parameters

4. Adding/eliminating inputs

5. Creating additional visuals

Different measures require different update approaches. Therefore, *Appendix A.1* offers a checklist serving as a high-level guidance for user to make sure that the tool works properly after the changes are made. This checklist does not claim to fix all the possible bugs but might provide support in case some tool elements do not work properly.

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# 10.0 Appendices

## 10.1 Questions for internal stakeholders (Finance department, Fleet department)

**Data for the tool**

1. These are the parameters that are frequently used in LCT. Which parameters in this list are most important to you? How often do you update this data? What is the format of data collection? Who are the data holders? What obstacles might come up with collecting this data?
    a. Electricity costs
    b. Fuel costs
    c. Maintenance costs
    d. Environmental costs
    e. Interest rates
    f. Depreciation rates
    g. Mileage
    h. Expected life
    i. GHG emissions

2. What other parameters of importance would you like to be included in the tool? What obstacles might come up with obtaining this data?

**Decision-making process**

3. What is your current decision-making process for choosing EVs over ICVs? Which decision-making points are most important to you (e.g. costs, mileage, available infrastructure, capacity, performance during the cold weather)?
4. What are the main obstacles in this decision-making process?

**Your feedback on available LCT**

5. Which of the costing tools discussed above do you see as the most applicable for TOL fleet? Why?
6. What difficulties do you see with using the tool?

7. What drawbacks in the costing tools discussed do you see (e.g. unrealistic assumptions, not accounting for important trends in vehicles industry, not accounting for certain cost parameters)? How would you suggest us to deal with these problems?
8. What additional features (e.g. different economic scenario analysis, sensitivity analysis with respect to change in fuel\energy costs, etc.) would you like to see in the tool?
9. What are the main obstacles do you see in making the tool?

## 10.2 Table – Comparison of Lifecycle Costing Tools

| # | Tool name (if there is no name then location is entered) | Type (excel/web) | Available now? | Location | Fleet Size | Costs considered | Additional features | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|---|
| *Business cases* | | | | | | | | | |
| 1 | E3 Fleet | Excel | ✗ | Capital regional district, Canada | 304 vehicles (2015) | FAR and LCA tools:<br>• Ownership costs<br>• Maintenance costs<br>• Deriver productivity decrease (due to vehicle aging / idling)<br>• Fuel costs | • Best management practices review (BMPR)<br>• Long-term capital budget planning (LTCP) | • Includes both direct and indirect costs of using the vehicles<br>• They are based on a big database compiled from different real fleets<br>• FAR tells the economic impact of the new fleet policy (incl. trainings)<br>• FAR also provides the benchmarking analysis of fleet performance | • Both tools cost *[redacted for public report]* dollars each<br>• Tools include features that might not be necessary at this point<br>• The database might not be relevant for TOL case<br>• The functionality of the tool is out of scope of our current needs |
| 2 | City of Seattle | Excel | ✗ | Seattle, USA | 4,150 vehicles, incl. >200 PHEVs (2018) | • Acquisition costs<br>• Maintenance costs<br>• Salvage costs<br>• Fuel costs | NA | Since the tool is not publicly available yet, the information about the advantages of the tool is going to be updated | |
| 3 | City of Vancouver | NA | ✗ | BC, Canada | 1,850 vehicles, incl. 120 Evs | • Acquisition costs<br>• Maintenance<br>• Fuel costs<br>• Operating cost reductions<br>• Infrastructure costs<br>• Carbon costs<br>• Noise reduction costs<br>• Health impacts costs | NA | Since the tool is not publicly available yet, the information about the advantages of the tool is going to be updated | |

| # | Tool name (if there is no name then location is entered) | Type (excel/web) | Available now? | Location | Fleet Size | Costs considered | Additional features | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|---|
| 4 | Atlas Policy Tool | Excel (w/ macros) | ✔ | Fraser Basin Council, Canada | NA | • Acquisition costs<br>• Charging infrastructure<br>• Social cost of carbon<br>• Taxes and fees<br>• Insurance<br>• Repairs<br>• Maintenance<br>• Fuel<br>• Depreciation | • Environmental impact calculator<br>• Sensitivity analysis calculator | • Automatically updated big database (based on Natural Resources Canada, GH Genius, etc.)<br>• Complex approach to lifecycle cost (LCC) comparison<br>• Visual comparison of total costs and dynamic<br>• Supporting visuals<br>• Additional features<br>• Frequently updated (every three months) | • Tool is inflexible<br>• Calculations are based on market average data, not actual fleets data<br>• Allows for comparison of only two vehicles at the same time<br>• Lacks some cost parameters like resale value |
| 5 | Fraser Valley Regional District | Excel | ✔ | BC, Canada | NA | • Acquisition costs<br>• Annual maintenance<br>• Operation costs<br>• Resale/salvage value<br>• Fuel/electricity costs<br>• Depreciation<br>• Carbon costs | NA | • Easy to use and modify. The tool proved to be effective in real life circumstances.<br>• Based on Canadian data | • Based on non-updated information<br>• Doesn't have the breakdown of maintenance costs<br>• Doesn't account for government incentives (partial funding of EV)<br>• All the parameters should be typed manually (no built-in options)<br>• Doesn't have visuals |

| # | Tool name (if there is no name then location is entered) | Type (excel/web) | Available now? | Location | Fleet Size | Costs considered | Additional features | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|---|
| **6** | Metro Vancouver | Excel | ✓ | BC, Canada | NA | • Carbon costs<br>• Fuel costs<br>• Electricity costs (zero)<br>• Acquisition costs<br>• Depreciation | NA | • Transparent and user friendly<br>• Relies on economically confirmed predictions and assumptions<br>• Based on Canadian data | • Based on non-updated information<br>• Uses some cost parameters that are not referred to any official sources<br>• Lacks important cost parameters<br>• All the parameters should be typed manually (no built-in options)<br>• Doesn't allow to for scenarios comparison<br>• Doesn't have visuals |
| *Ready LCT* | | | | | | | | | |
| 1 | AFDC | Web-calculator | ✓ | USA | NA | • Fuel costs<br>• Maintenance and tires<br>• Insurance, license, and registration<br>• Acquisition costs | NA | • The tool is easy to use and automatic<br>• It has a detailed description of all the assumptions and sources | • The tool is inflexible, and the calculations cannot be proofread<br>• The tool is based on USA market data |
| 2 | AFLEET | Excel | ✓ | USA | NA | • Financing costs (depending on the purchase method)<br>• Depreciation<br>• Fuel costs<br>• Maintenance and repair<br>• Insurance<br>• License and registration<br>• Externality costs (environmental) | • Simple payback calculator<br>• Idle reduction calculator | • Sophisticated tool that considers various cost parameters<br>• Has calculations visualization | • Based on USA data<br>• Non-frequently updated<br>• The tool allows comparison of different types of vehicles, but not different models running on the same fuel<br>• The tool could be difficult for understanding and everyday usage |
| 3 | Alameda County | Excel | ✓ | USA | 800 light-duty vehicles (incl. 80 EVs) | • Electricity costs (depending on the time of charging) Acquisition costs<br>• Government incentives<br>• Maintenance costs | • The tool is very easy to use<br>• It allows the user to vary the time of charging | • The tool does not include the costs carbon emission costs<br>• It lacks the breakdown of such important parameters like maintenance costs<br>• It uses USA market data | |
| **4** | FleetCarma | NA | ✗ | Canada | FleetCarma only provide LCCA services | | | | |

## 10.3 Checklist for tool updating (provides guidance on finding bugs in tool in case of changes in the tool were made)

Inputs section:

- ☐ Make sure that all the vehicle inputs do not report “No vehicle in the database” or “#N/A”
- ☐ Check that given the changes are made in inputs section; they are captured in “Financial model”

Financial model:

- ☐ Check that formula cells in “Financial model” do not report any mistake
- ☐ Check that if changes are made in “Financial model” they are captured in “Results tables”

Results table:

- ☐ Make sure that checks (“TRUE” / ”FALSE”) in “Results tables” are green – it means that graphs reflect correct calculation numbers

Database:

- ☐ Please note that changes in the “Database” instantly reflect “Financial model”