



# Fuel Economy Benchmarking: Augmenting the Business Case for Low-Carbon Vehicle Adoption

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## Executive Summary

The following report outlines the methodology and results from the building of a Microsoft Excel tool to calculate fuel economy for all City of Vancouver fleet vehicles. A subset of 364 Ford pickup trucks were considered as a basis by which to build the tool and complete basic analysis. Data exports from GEOTAB, the Vehicle Interface Unit (VIU), and Fleetfocus M5 were used within the model with a variety of automated validation steps necessary to ensure clean data and accurate calculations. The two main calculations included are an overall fuel economy number for fleet vehicles and a fuel economy calculated every time a unit has fuel added. The overall fuel economy number allows for quick comparison between all units under consideration, while the fuel economy number at each fuel event allows for an analysis of vehicle performance over time.

Of the subset considered, dump body models from F350 to F750 accounted for six of the top ten highest fuel economy values by category and vehicle model. Seasonal trends were noted for some individual units, however further effort is required to utilize the tool to full potential and gain an in-depth understanding of fuel economy across the City of Vancouver fleet. Future work includes importing more vehicle data, and better understanding the data gaps that exist within the City of Vancouver's fleet vehicle data systems.

A full user guide with detailed calculation steps is included in the appendix of this document.

## Introduction

As part of the Greenest City Scholars program, the purpose of this project is to create a fuel economy dataset and Microsoft Excel tool for City of Vancouver (CoV) fleet vehicles with a focus on heavy and medium duty vehicles. This tool will be used to help support the business case to transition to more carbon friendly options such as vehicles running on full electric systems, compressed natural gas (CNG), or hybrid models.

Fuel economy is an important metric for any non-electric vehicle as it describes the fuel consumption per unit of distance which can be directly translated to emission calculations. It is also an indicator of overall vehicle performance and changes with conditions such as acceleration and braking patterns, climate conditions impacting vehicle power requirements, vehicle maintenance history, and vehicle usage patterns. This information is readily available for light duty vehicles through the Natural Resources Canada database (Natural Resources Canada, 2021), however there is currently no requirement for manufacturers to provide fuel economy estimations for heavy or medium duty vehicles. Without this data available, the CoV fleet must be analyzed on an individual vehicle level to understand fuel economy of heavy and medium duty vehicles which is ultimately the purpose of this project.

## Background

The City of Vancouver (CoV) has committed to 10 goal areas as part of the Greenest City Action Plan which aim to address the following three areas of focus to stay on the leading edge of sustainability:

- 1) Zero Carbon
- 2) Zero Waste
- 3) Healthy Ecosystems

Of the 10 goal areas developed, the following two are impacted as the fleet transitions to cleaner vehicles:

- 1) Climate and Renewables
  - a. Eliminate Vancouver's dependence on fossil fuels
- 2) Clean Air
  - a. Breathe the cleanest air of any major city in the world

In order to meet these goals, the CoV is focused on “walking the talk” and committing to greener operations, including a transition of fleet vehicles to more carbon friendly operations which is the main focus of this project.

In 2007, the CoV committed to the following emissions reductions from fleet vehicles compared to 2007 emissions levels (City of Vancouver, 2021):

- 30% reduction by 2020
- 50% reduction by 2030
- 100% reduction by 2050

As of 2018, the CoV fleet consisted of 1850 vehicles with the following average emissions per class of vehicle:

Vehicle Class	% of Total Fleet	Avg. Emissions per vehicle (tonnes CO2e)	% of Total Fleet Emissions
Heavy duty	12%	22.03	30%
Medium duty	17%	9.85	19%
Light duty	59%	4.63	31%

**Table 1: 2018 fleet vehicle emission profile (Dacey, 2019)**

As can be seen in Table 1, heavy and medium duty fleet vehicles contribute to almost half of fleet emissions but only account for 29% of fleet vehicles. This means that transitioning to cleaner heavy and medium duty vehicles is critical in reducing emissions for city operations and is thus the main focus for this project. It is important to note that significant progress has been made on the initial 2007 commitment to reducing emissions. In 2019 emissions dropped to 14,467 tonnes of CO2e from ~16,300 tonnes in 2018. By 2020, emissions were estimated at 10,207 tonnes of CO2e thanks in large part to the introduction of 100% renewable diesel to the fleet. This represented a 43% reduction in emissions as compared to 2007 levels which proves the CoV commitment to greener operations.

## Project Goals and Scope

The goal of the project was to create a tool in Microsoft Excel that can be used to evaluate fuel economy for all vehicles within the CoV fleet. The scope of the data evaluated was limited to Ford pickup trucks in the city fleet ranging from the F-150 to the F-750. By limiting the scope of data considered, the tool was able to be built, validated, and interesting insights were determined from a significant subset of vehicles. A total of 364 Ford units were considered with a breakdown by model that can be seen in the following table.

Model	Count
F-150	117
F-250	69
F-350	43
F-450	72
F-550	48
F-750	15

**Table 2: Ford units considered**

While the F-150 is considered a light-duty vehicle, it has been included in order to verify accuracy by comparing calculated numbers to publicly available data. It is important to note that although the data analyzed was limited to the above subset, the tool has been built to accommodate data for all vehicles within the CoV fleet.

## Data Sourcing

To calculate fuel economy, data was extracted from three individual sources in the form of .csv and .xlsx exports. A summary of these exports can be seen in the following table.

DATA SYSTEM	VARIABLE OF INTEREST	EXPORT FORM
GEOTAB	Distance travelled	Advanced Fill-Ups Report
Vehicle Interface Unit (VIU)	Fuel consumption	Fuel query
Fleetfocus M5	Unit parameters	Fleet export (name?)

**Table 3: Description of data sources**

## GEOTAB Data

The primary purpose of GEOTAB is to provide GPS and on-board diagnostic information for each vehicle within the CoV fleet. A screenshot of the report from GEOTAB can be seen in figure 1.

Vehicle	Vehicle Group	Driver	Driver Group	Date	Location	Fuel Economy	Fuel Added	Odometer
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Jan 03, 2019 13:54	National Yards - Fuel Stu		45.05	89.97
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Jan 10, 2019 10:55	National Yards - Fuel Stu		37.29	99.46
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Jan 21, 2019 7:18	National Yards - Fuel Stu		39.23	96.46
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Jan 25, 2019 14:22	National Yards - Fuel Stu		37.33	92.96
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Feb 04, 2019 7:30	711 Alexander St, Vancoc		37.65	89.97
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Feb 07, 2019 7:34	National Yards - Fuel Stu		32.00	48.48
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Feb 14, 2019 21:04	Man Yard - EQS Area: 2E		82.42	30.99
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Mar 06, 2019 7:38	National Yards - Fuel Stu		37.76	70.97
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Mar 08, 2019 13:19	371 Columbia St, Vancoc		39.70	56.98
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Mar 13, 2019 14:59	National Yards - Fuel Stu		35.38	51.48
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Apr 16, 2019 14:36	National Yards - Fuel Stu		42.27	65.97
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			Apr 26, 2019 14:37	National Yards - Fuel Stu		47.02	79.97
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			May 06, 2019 7:11	National Yards - Fuel Stu		37.35	99.46
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			May 10, 2019 14:48	National Yards - Fuel Stu		41.96	63.98
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In'			May 24, 2019 11:12	National Yards - Fuel Stu		39.91	100.96

Figure 1: Screenshot of GEOTAB Advanced Fill-Ups Report

The Advanced Fill-Ups Report from GEOTAB extracts vehicle data based on fuel event, meaning that the parameters included in the report are generated whenever fuel is added to the vehicle. Parameters in the report include fuel economy, fuel added, and odometer readings. For the purposes of this project, only odometer readings were utilized. The values for fuel volume added are generated by way of proprietary calculations within GEOTAB and are not typically as accurate as the raw fuel dispensed volumes captured by the VIU . The values provided for fuel economy are also rooted in proprietary calculations that cannot be confirmed therefore they have not been utilized in this project. An example subset of vehicles showing the discrepancy between VIU and GEOTAB fuel volumes can be seen in the following table. Both VIU and GEOTAB data in table 4 are for the same date range.

Unit	VIU Fuel (L)	GEOTAB Fuel (L)	% Difference
E7596	3226.5	3925.5	19.5%
A5828	7469.9	6874.0	8.3%
C1135	4423.5	4431.3	0.2%
C7652	8690.5	8135.5	6.6%
B1293	2353.7	2172.7	8.0%

Table 4: Fuel volume comparison between VIU and GEOTAB

## VIU Data

Due to uncertainty around fuel volume data in GEOTAB, a fuel query report was pulled from the VIU for fuel volumes. The fuel volumes in this report are the raw fuel dispensed numbers and are therefore the most accurate number within the CoV data systems. A screenshot of the report can be seen in figure 2.

	A	B	C	D	E	F	G	H	I	J	K
	UnitNum	DateWithdrawn	FuelDesc	PumpLoc	Litres	DeptCode	DeptDesc	ClassCode	ClassDesc	ClassCategory	Organization
2	A5934	2020-03-13 9:18	Gas E10	Manitoba Yard	109.86	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
3	A5934	2020-04-21 14:14	Gas E10	Manitoba Yard	0.33	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
4	A5934	2020-04-21 14:17	Gas E10	Manitoba Yard	83.98	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
5	A5934	2020-04-28 14:14	Gas E10	Manitoba Yard	0.42	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
6	A5934	2020-04-28 14:19	Gas E10	Manitoba Yard	96.33	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
7	A5934	2020-05-05 14:27	Gas E10	Manitoba Yard	96.9	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
8	A5934	2020-05-13 14:34	Gas E10	Manitoba Yard	105.16	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
9	A5934	2020-05-20 14:14	Gas E10	Manitoba Yard	79.1	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
10	A5934	2020-05-27 14:28	Gas E10	Manitoba Yard	101.58	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
11	A5934	2020-06-03 14:08	Gas E10	Manitoba Yard	95.97	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
12	A5934	2020-06-10 14:22	Gas E10	Manitoba Yard	86.66	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
13	A5934	2020-06-16 14:32	Gas E10	Manitoba Yard	84.71	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
14	A5934	2020-06-23 14:22	Gas E10	Manitoba Yard	97.24	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
15	A5934	2020-06-29 14:28	Gas E10	Manitoba Yard	88.39	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
16	A5934	2020-07-07 14:36	Gas E10	Manitoba Yard	86.96	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
17	A5934	2020-07-14 14:18	Gas E10	Manitoba Yard	95.47	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
18	A5934	2020-07-20 14:13	Gas E10	Manitoba Yard	73.41	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer

Figure 2: Screenshot of VIU Fuel Query report

Similar to the GEOTAB report, the VIU fuel query is based on fuel event. Vehicle parameters such as department description and class description are included in this report, however only fuel volumes were utilized.

## Fleetfocus M5

Fleetfocus is a fleet management system utilized by the CoV for maintenance tracking. The purposes of M5 for this project was solely to provide a database of vehicle parameters to aid in analysis. A screenshot of the export used can be seen in figure 3.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
	Using Dept.	Category Class	Category Description	Make	Model	Unit #	License Plate	Model Year	Last Repair Date (MM/DD/YYYY)	Shift (Usage: Hrs) (Usage: Day)	Contact	Status	Equip. Info	Acquisition Date	In Service Date	
1	ADMINISTRATION	LIGHT DUTY	VAN, CLASS 3, CUBE BODY, GAS	FORD	F550	C9218	LX3709	2017	05-03-2021	0000 2359 MTWTFSS	SEWA PANGALIA (604-654-0909)	IN	#DUF5GY0HEB126 86	07-11-2017	12-01-2017	
10	CEMETERY	HVY TRK	TRUCK, CLASS 4, REG CAB, DUMP BODY, SNOW, GAS	FORD	F450	A5858	ND8026	2018	05-03-2021	0730 1600 MTWTFXX	GLEN HODGES (604-325-2623)	IN	#DUF4HY6JEB7685 8	12-18-2018	12-21-2018	
51	CENTRAL STORES	HVY TRK	TRUCK, FLATDECK, LIGHT, GAS	FORD	F350	C1743	1877GA	2002	04-06-2021	0730 1600 MTWTFXX	GLENN GANJELAS (326-4746)	IN	#DWF36L32EC775 45	04-25-2002	08-26-2002	
127	COMMUNITY SERVICES	LIGHT DUTY	TRUCK, PICKUP, HEAVY, DIESEL	FORD	F350	B9206	2914GW	2004	02-04-2021	0000 2359 MTWTFSS	SEWA PANGALIA (604-654-0909)	IN	#FTWX32P54EC197 25	02-13-2004	03-12-2004	
202			TRUCK, PICKUP, HEAVY, FOUR WHEEL DRIVE, GAS	FORD	F350	C9206	PM1382	2020		0000 2359 MTWTFSS	SEWA PANGALIA (604-654-0909)	OUTF	#FTBWS3DN7LEE798 56	11-05-2020		
203			TRUCK, PICKUP, HEAVY, GAS	FORD	F250	D9259	JY8748	2016	02-18-2021	0000 2359 MTWTFSS	SEWA PANGALIA (604-654-0909)	IN	#FTX2A61GEA7643 1	10-21-2015	02-01-2016	
204	COMMUNITY SERVICES GROUP	HVY TRK	DO NOT USE - TRUCK, VAN, SINGLE AXLE, GAS	FORD	F350	A1206	AL7476	2003	03-22-2021	0700 1530 MTWTFXX	ALEXANDRIA LANE	IN	#FTSX3DL13EB67071	03-15-2003	03-15-2003	
208																

Figure 3: Screenshot of M5 vehicle detail report

The main parameters used in this project are category description, make, model, unit #, and model year.

### Data Quality and System Limitations

Data quality concerns and system limitations were a common theme throughout the course of the project. Validation steps have been built into the Excel tool in an effort to filter out data of suspect quality. Detailed descriptions of data validation steps can be seen in the Methodology section of this report. The main data quality concerns were as follows:

Data Concern	Result
Decreasing odometer readings with increasing time	Negative fuel economy
Less VIU fuel query events than GEOTAB events in same time period	Missing fuel volume, false fuel efficiency
Less GEOTAB fuel events than VIU fuel query events over same time period	Missing odometer readings, high fuel economy
Timestamp mismatch between GEOTAB and fuel query fuel events	Inconsistent unit data across systems, fuel economy calculation questionable

Table 5: Data quality concerns identified

Microsoft Excel was chosen as the program for this project for a variety of reasons. First, it offers the ability to create a custom solution from scratch without requiring specialized programming knowledge. It allows the building of a tool that can be modified and customized fairly easily meaning that future iterations of the tool will not be difficult to develop. Excel is also a very flexible tool allowing for the import and analysis of data in different forms which was critical for this project since multiple programs were utilized for data gathering.

In terms of system limitations, Microsoft Excel is generally not considered the best option for storing and analyzing large datasets. Due to restrictions around data access, data was supplied as .csv and .xlsx files and thus was directly built into the Excel tool. Complex calculations and data validation steps use significant computing power when considering these large datasets,

therefore limitations were reached and decisions around data analysis techniques were made to maximize tool function and usability.

## Methodology

For clarity purposes, instructions for using the excel tool will be included as an appendix to this report. The purpose of the methodology section is to provide detailed calculations and information on the intricate data validation steps taken to ensure data accuracy.

### Data Validation

The following data validation steps were taken when calculating the average fuel economy for vehicles over the time period where GEOTAB and fuel query data overlap. These validation steps have not been considered in the single event fuel economy calculations.

### Time Period Calculation

Since the Excel tool relies on user imported data, it is important to define the time frame considerations for the calculations performed. Date ranges are user defined when pulling exports from the VIU and GEOTAB, so only data with overlapping dates are considered in the analysis. Depending on how the user pulls data, it is possible that significant amounts of data is omitted if it is outside of the overlapping date range. For illustration purposes, three individual calendars for the month of July can be seen in figure 4. The yellow range represents the time frame of data pulled from GEOTAB, while purple is the time frame of data pulled in the VIU fuel query. The calendar with dates highlighted green shows the time period where GEOTAB data and VIU Fuel Query data overlap and is thus the date range considered for calculations.

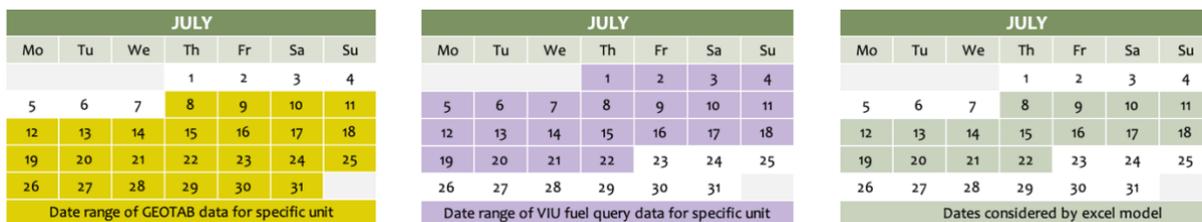


Figure 4: Example of date considerations

### Odometer Reading Decrease with Time

Of the 263 units with GEOTAB and Fuel Query data, 11 were found to have an inconsistency in GEOTAB odometer data where odometer readings decrease with time. This inconsistency was discovered to have two different forms:

- 1) Large magnitude
  - a. Final odometer reading less than initial odometer reading resulting in negative fuel economy number
  
- 2) Small magnitude
  - a. Odometer decrease occurs early in dataset and is of a magnitude such that the distance travelled by the end of the dataset offsets the decrease. Fuel economy calculations were positive but unreasonably high

Figure 5 shows a screenshot of the GEOTAB data with the odometer error highlighted in red text. This is an example of a small magnitude error that resulted in a fuel economy that was unreasonably high for this unit.

Vehicle	Vehicle Group	Date	Location	Fuel Economy	Fuel Added	Odometer
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Dec 16, 2019 7:33	National Yards - Fuel Sta	32.46	108.13	19170
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Dec 23, 2019 14:42	NY - Garbage and Rubbl	39.32	106.13	19441
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Jan 08, 2020 7:54	National Yards - Fuel Sta	30.91	28.03	19800
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Jan 14, 2020 13:23	National Yards - Fuel Sta	38.95	59.07	19932
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Jan 17, 2020 9:47	507 Malkin Ave, Vancou	44.66	92.61	20034
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Feb 05, 2020 7:17	National Yards - Fuel Sta	36.47	109.13	16979
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Feb 12, 2020 7:30	National Yards - Fuel Sta	34.99	69.59	17253
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Feb 21, 2020 14:47	535 Malkin Ave, Vancou	35.63	103.63	17475
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Mar 11, 2020 13:37	National Yards - Fuel Sta	46.50	28.53	17630
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Mar 18, 2020 7:52	National Yards - Fuel Sta	41.98	34.04	17694
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Mar 25, 2020 7:54	National Yards - Fuel Sta	30.67	111.64	17867
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Apr 14, 2020 12:32	National Yards - Fuel Sta	34.59	93.11	18102
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	Apr 29, 2020 14:39	National Yards - Fuel Sta	26.67	104.63	18481
A5755	Street Operations, BioDiesel, Truck - Class 4 - D	May 20, 2020 11:31	National Yards - Fuel Sta	27.22	109.13	18856

Figure 5: Screenshot of GEOTAB data showing odometer error

### Inconsistent Fuel Event Count

Of the 263 units with GEOTAB and Fuel Query data, 46 units were found to have an inconsistency in the number of fuel events over the same time period in GEOTAB as compared to the VIU fuel query. This data inconsistency was found in two different forms:

- 1) Less VIU Fuel Query events than GEOTAB events
  - a. When there are more GEOTAB events than Fuel Query events, there is the potential for missing fuel volumes. If fuel volumes are missing the overall average fuel economy will be unrealistically low.

- 2) Less GEOTAB events than VIU Fuel Query events
  - a. When there are more fuel query events than GEOTAB events, there is the potential for inaccuracy in distance travelled. However, since only the starting and ending odometer readings are considered in the average fuel economy calculation, the error resulting from this inconsistency is typically negligible.

Table 6 shows the results of having less fuel query events as compared to GEOTAB events. Unit A1977, a Ford F-350, shows an average fuel economy of 4.46 L per 100km which is obviously unrealistically low.

<b>Unit A1977 (Ford F-350)</b>	
<b>Start Date:</b>	21-Feb-19
<b>End Date:</b>	30-Oct-20
<b>Fuel Query Events:</b>	8
<b>GEOTAB Events:</b>	69
<b>Fuel Volume (L):</b>	608.1
<b>Distance (km)</b>	13629.3
<b>Fuel Economy (L/100km)</b>	4.46

Table 6: Example of event count error

### Fuel Event Timestamp Mismatch

The purpose of this data validation step is as a double check to confirm that the GEOTAB and Fuel Query data is being generated properly for each individual unit. When a fuel event is registered in GEOTAB or the VIU, a timestamp is created with resolution down to the second. GEOTAB and the VIU operate on different communication systems so timestamps for fuel events are never exactly the same in both systems. The Excel tool is designed to match the start and end fuel events in GEOTAB and the Fuel Query based on the time stamp to ensure a proper range is gathered. In cases where the end date or start date differ by more than one day between GEOTAB and the Fuel Query the data is considered questionable and requires further investigation.

Of the 263 units with GEOTAB and Fuel Query data, 29 units were found to have this error. Table 7 shows the detailed parameters for unit D1267.

Unit D1267 (Ford F-450)	
<b>FQ Start:</b>	2019-06-21 14:46
<b>GEO Start:</b>	2019-06-21 14:43
<b>Difference (days)</b>	-0.002
<b>FQ End:</b>	2021-05-31 14:43
<b>GEO End:</b>	2021-06-02 7:20
<b>Difference</b>	1.692

Table 7: Example of timestamp mismatch

### Unreasonably Low Fuel Economy

In some cases units show an unreasonably low fuel economy despite passing all previous validation steps. In most instances of low fuel economy, the underlying reason is not immediately obvious so they will require further investigation. Regardless, the value of 13 L per 100km has been selected as a low benchmark as it represents the low end of expected fuel economy for a Ford F-150 (Natural Resources Canada, 2021). Of the 263 units with GEOTAB and Fuel Query data, 9 were found to have this error and have been omitted from the analysis.

### Calculations

Two main calculation methodologies were followed for considering individual unit fuel economy:

- 1) Overall Fuel Economy
  - a. The purpose of the overall fuel economy number is to provide an average number over the range of the data for easy comparison between categories and units.
- 2) Single Event Fuel Economy
  - a. The single event fuel economy is a calculation that occurs at every fuel event for an individual vehicle. The purpose of this series is to be able to trend over time and understand how vehicle performance changes with age and different weather or usage conditions.

### Overall Fuel Economy

The overall fuel economy for each unit is calculated by considering the total volume of fuel consumed within the date range under consideration and dividing it by the difference between the first and last odometer reading within the date range. This results in a fuel usage per km

number which is multiplied by 100 to get standard fuel economy units of litres per 100 km. Equation 1 demonstrates how these values are utilized.

$$FE = \frac{\sum_{i=1}^n FV}{OR_n - OR_0} \times 100$$

FE = Fuel Economy (L/100km)

FV = Fuel Volume per fueling event (L)

OR = Odometer Reading (km)

i = Fuel event number

As previously mentioned, data is analyzed by fuel event, thus it is important to consider fuel event numbers in this analysis. Fuel event 0 is considered to be the initial fuel event under consideration, while fuel event “n” is the final event under consideration. Distance travelled in this time period is calculated as the difference between the odometer reading at event n and the odometer reading at event 0. Fuel volume is the sum of all volumes between events. The fuel volume added at event 1 accounts for the distance travelled between event 0 and event 1 and is therefore included in the analysis. The fuel volume added at event 0 is for distance travelled prior to event 0 and is therefore outside of the data range.

A critical assumption being made in this calculation is that the fuel tank is being completely filled at each fuel event. This assumption is made due to data availability and limitations of Microsoft Excel as a database tool. Due to the large number of fuel events included in this calculation for each unit, any errors associated with this assumption being incorrect are negligible.

### Single Event Fuel Economy

To evaluate how vehicle performance changes over time, a fuel economy calculation can be performed at each fuel event and displayed on a plot for analysis.

$$FE = \frac{FV_n}{OR_n - OR_{n-1}} \times 100$$

FE = Fuel Economy (L/100km)

FV = Fuel Volume per fueling event (L)

OR = Odometer Reading (km)

i = Fuel event number

Similar to equation 1, the main assumption is that the fuel tank is being completely filled at each fuel event. The difference for this equation is it is only between two fuel events so errors associated with this assumption being incorrect are significant and obvious. It is also important to note that a fuel event for this equation is defined as a data point where both GEOTAB and VIU Fuel query data exists. In the case of gaps in GEOTAB data, all fuel volumes between fuel events are added together.

## Results

As of the writing of this report, 364 Ford trucks are in service in the city fleet. Of these units, 263 have both GEOTAB and VIU Fuel Query data imported into the Excel tool while 101 are missing from the data gathered. Based on the validation criteria discussed in the previous section, the following breakdown of validation codes was generated.

	F150	F250	F350	F450	F550	F750	Total
Valid	51	34	13	41	22	7	168
No Data	18	18	25	18	15	7	101
End Date Error	6	3	0	7	2	0	18
Event Count Error	31	8	1	0	5	1	46
Odometer Error	5	1	0	3	2	0	11
Start Date Error	2	3	3	1	2	0	11
Low FE	4	2	1	2	0	0	9
<b>Total</b>	<b>117</b>	<b>69</b>	<b>43</b>	<b>72</b>	<b>48</b>	<b>15</b>	<b>364</b>

Table 8: Ford unit summary by validation code

Of the 263 units that we have data for, 9 have been omitted due to unreasonably low fuel economy, 11 have been omitted due to odometer errors, and another 8 have been rejected based on other data inconsistencies. In the analysis of these units, over 80,000 lines of data from M5, the VIU, and GEOTAB were analyzed, validated, and ultimately summarized as vehicle fuel economy.

## Overall Fuel Economy

The overall fuel economy calculation is the easiest way to compare fuel economy across the fleet based on any parameter of interest. When considering category description and truck class, the following table of fuel economy is generated. Maximum and minimum values are included as indication of the range across vehicles of the same model and category description.

Row Labels	Count of Unit Number	Average of Fuel Economy (L/100km)	Max of Fuel Economy (L/100km)	Min of Fuel Economy (L/100km)
TRUCK, AERIAL, 34 FT BOOM, GAS				
F550	2	58.18	58.81	57.55
DO NOT USE - TRUCK, DUMP, 1 YARD, GAS				
F350	1	45.32	45.32	45.32
F450	2	63.69	71.19	56.19
TRUCK, CLASS 4, REG CAB, DUMP BODY, SNOW, GAS				
F450	3	53.96	83.97	38.22
TRUCK, CLASS 5, EXTENDED CAB, CHIP BOX				
F550	2	50.68	54.13	47.23
TRUCK, CLASS 7, CREW CAB, DUMP BODY, HYD BRAKE				
F750	2	46.82	50.85	42.80
R100 Biodiesel	2	46.82	50.85	42.80
TRUCK, AERIAL, 34 FT BOOM, DIESEL				
F550	1	46.80	46.80	46.80
TRUCK, CLASS 4, CREW CAB, DUMP BODY, GAS				
F450	7	45.84	57.23	38.33
TRUCK, FLATDECK, LIGHT, GAS				
F450	3	43.53	47.80	40.24
DO NOT USE - TRUCK, DUMP, 3 YARD				
F750	5	42.82	46.43	40.06
B5 Biodiesel	5	42.82	46.43	40.06
DO NOT USE - TRUCK, DUMP, 1 YARD, DIESEL				
F450	1	47.98	47.98	47.98
F550	4	40.77	49.88	34.35
DO NOT USE - TRUCK, FLATDECK, CRANE, LIGHT				
F750	1	40.89	40.89	40.89
B5 Biodiesel	1	40.89	40.89	40.89
TRUCK, CLASS 4, CREW CAB, DUMP BODY, DIESEL				
F450	22	36.19	65.71	26.96
F550	5	35.61	39.32	31.44
TRUCK, CLASS 4, CREW CAB, DUMP BODY, SNOW, GAS				
F550	3	35.92	41.29	30.82
TRUCK, CLASS 4, CREW CAB, DUMP BODY, SNOW, DSL				
F450	5	34.55	35.96	32.71
F550	13	34.95	39.96	23.62
TRUCK, PICKUP, HEAVY, GAS				
F150	2	26.79	32.14	21.43
F250	30	32.07	44.42	17.98
F350	1	25.88	25.88	25.88
TRUCK, PICKUP, HEAVY, FOUR WHEEL DRIVE, DIESEL				
F350	5	30.96	38.81	25.11
TRUCK, CLASS 4, REG CAB, DUMP BODY				
F450	3	30.91	34.68	27.64
TRUCK, PICKUP, HEAVY, FOUR WHEEL DRIVE, GAS				
F250	1	27.98	27.98	27.98
F350	5	31.15	46.29	21.34
TRUCK, CLASS 4, REG CAB, DUMP BODY, SNOW, DSL				
F450	2	29.36	29.72	29.01
TRUCK, PICKUP, LIGHT, FOUR WHEEL DRIVE, GAS				
F150	6	29.19	36.49	21.24
VAN, CLASS 3, CUBE BODY, GAS				
F350	1	23.43	23.43	23.43
TRUCK, PICKUP, HEAVY, DIESEL				
F250	15	22.28	36.06	15.30
F450	1	26.35	26.35	26.35
TRUCK, PICKUP, LIGHT				
F150	78	22.32	39.95	16.02
F350	1	29.16	29.16	29.16
TRUCK, PICKUP, COMPACT, FOUR WHEEL DRIVE				
F150	1	18.36	18.36	18.36
TRUCK, SERVICE, CLASS 5, FOUR WHEEL DRIVE				
F550	1	16.42	16.42	16.42

Table 9: Summary of average fuel economy by category and vehicle model

For clarity purposes, the top 10 highest fuel economy values by category description and model can be seen in table 10.

Category Description	Model	Unit Count	Fuel Economy (L/100km)
DO NOT USE - TRUCK, DUMP, 1 YARD, GAS	F450	2	63.69
TRUCK, AERIAL, 34 FT BOOM, GAS	F550	2	58.18
TRUCK, CLASS 4, REG CAB, DUMP BODY, SNOW, GAS	F450	3	53.96
TRUCK, CLASS 5, EXTENDED CAB, CHIP BOX	F550	2	50.68
DO NOT USE - TRUCK, DUMP, 1 YARD, DIESEL	F450	1	47.98
TRUCK, CLASS 7, CREW CAB, DUMP BODY, HYD BRAKE	F750	2	46.82
TRUCK, AERIAL, 34 FT BOOM, DIESEL	F550	1	46.80
TRUCK, CLASS 4, CREW CAB, DUMP BODY, GAS	F450	7	45.84
DO NOT USE - TRUCK, DUMP, 1 YARD, GAS	F350	1	45.32
TRUCK, FLATDECK, LIGHT, GAS	F450	3	43.53

Table 10: Top 10 highest fuel economy by category and model

Six of the top ten highest fuel economy values for Ford trucks are dump trucks ranging from F350 models to F750 which may represent an area of focus to transition to cleaner fuels. Figure 6 shows the distribution of overall fuel economy values. The right-skewed pattern is likely due to the subset of vehicles analyzed as the majority are F150s which are typically more fuel efficient than the heavier models.

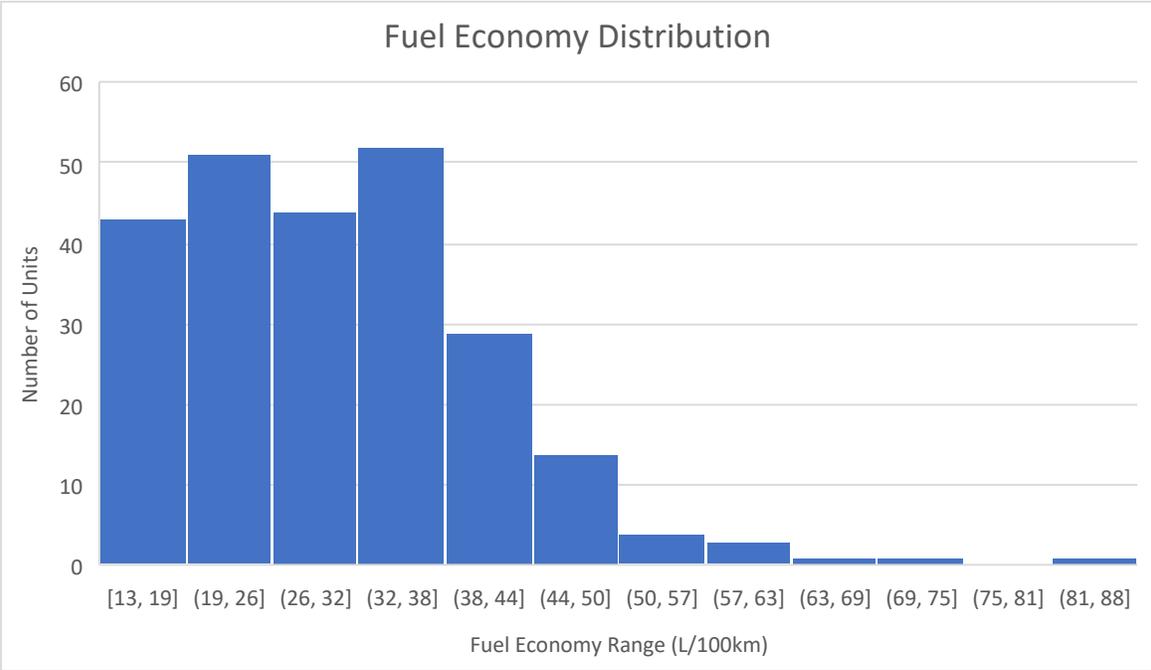


Figure 6: Distribution of fuel economy in Ford subset

## Fuel Economy vs Time

While the overall fuel economy values are beneficial for a quick analysis to understand which categories of fleet vehicles are using the most fuel, a more granular approach on an individual unit level is required to truly understand vehicle performance. Due to computing limitations, the Excel tool has been built to calculate fuel economy at each fuel event and display a chart for any one individual unit that the user wants to consider further.

As previously mentioned, this calculation assumes that the fuel tank is entirely filled at each fuel event and is accounting for all the fuel volume used since the last time the vehicle was filled. An example of the tool output can be seen in figure 7 below. The green dashed line represents the overall fuel economy value calculated in the previous section, while the blue data points are the fuel economy values calculated at the individual fuel events.

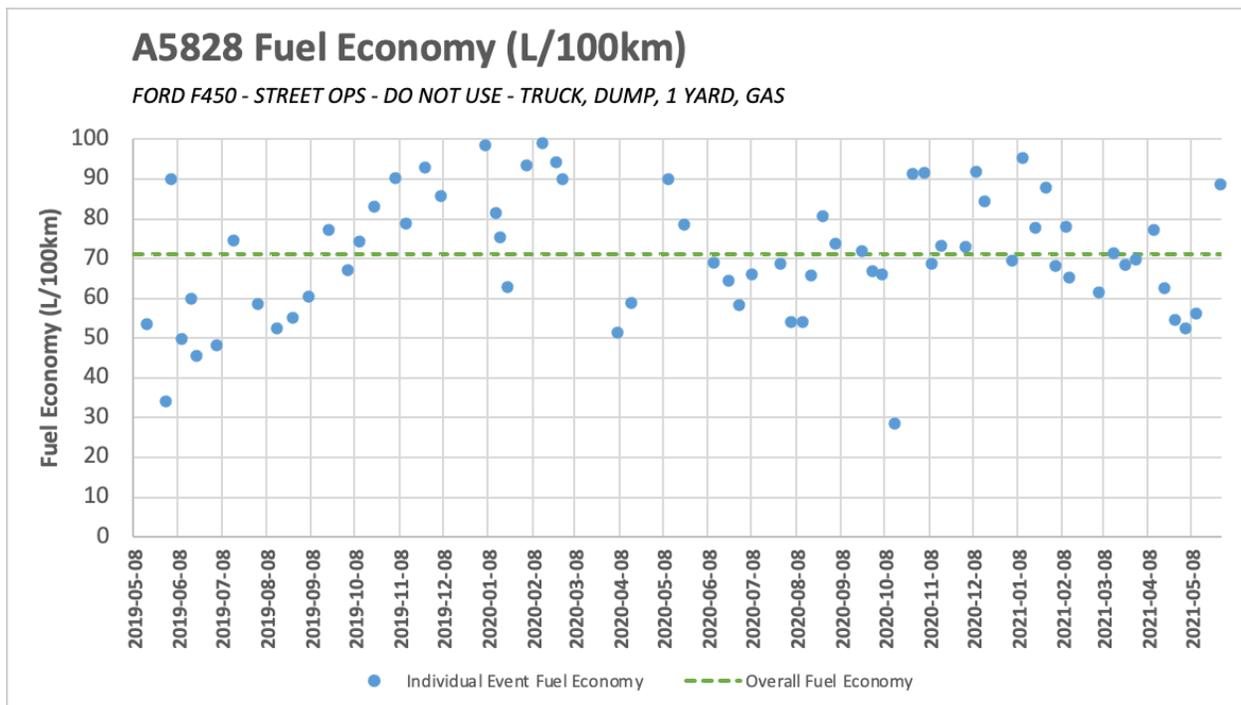


Figure 7: Fuel economy over time for unit A5828

It is not feasible to display charts for each unit here, however there are some interesting takeaways worth mentioning. First, as can be seen in the chart for unit A5828, there is significant variation in fuel economy over time. It appears that for this particular unit there is a seasonal impact where fuel economy trends higher in the winter months than the summer months. Unit A5827, a Ford F450 of the same category shows a similar trend as can be seen in the following figure.

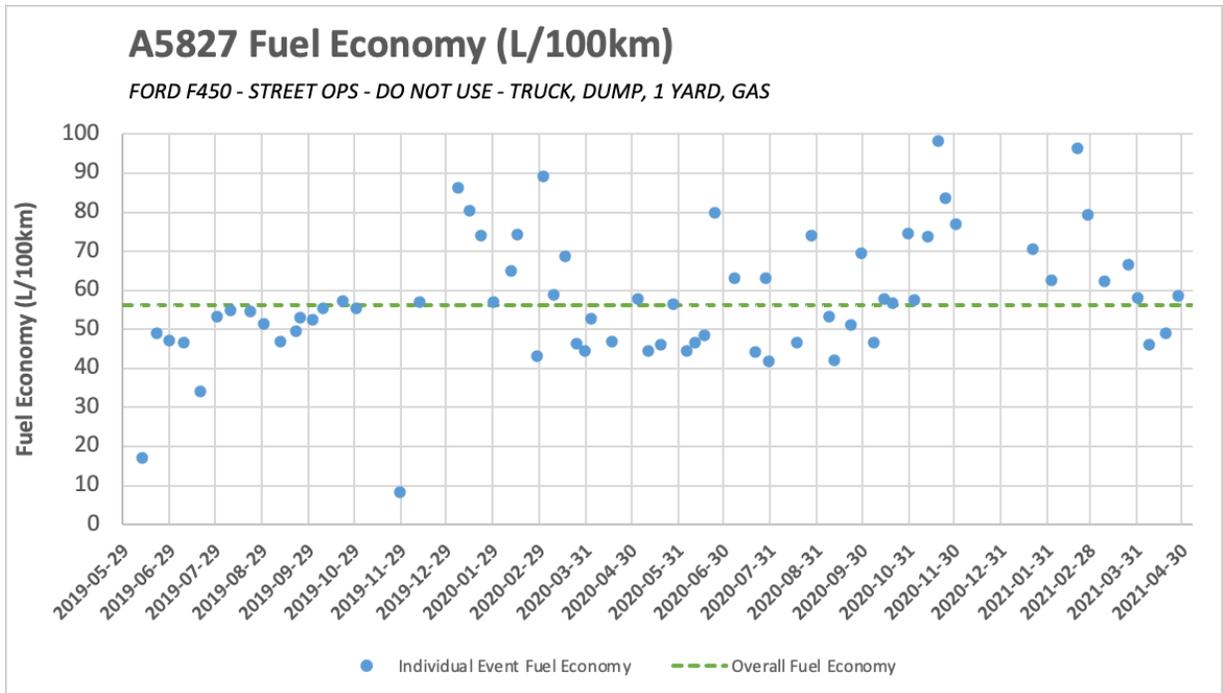


Figure 8: Fuel economy over time for unit A5827

In comparison to a light-duty Ford F150 pickup, there is no noticeable variation in fuel economy over time as can be seen in the following chart for unit C7552.

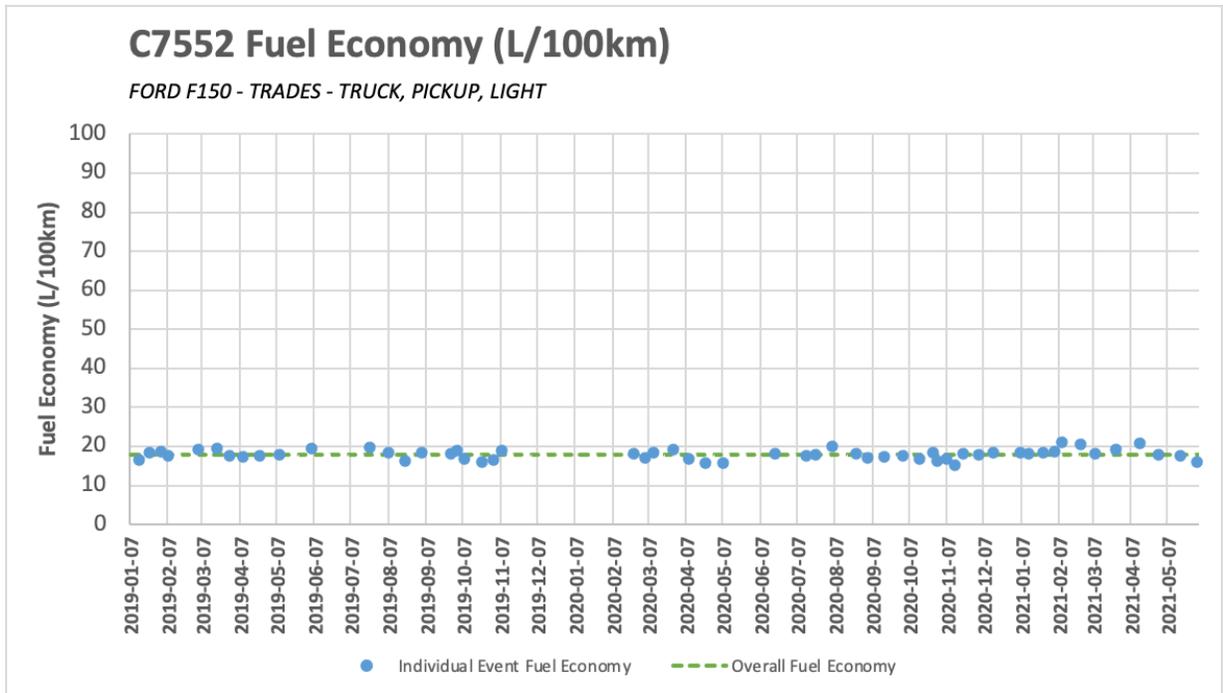


Figure 9: Fuel economy over time for unit C7552

Data can also be extracted from the individual unit charts to create comparisons of units across the same category. The following charts show three units (D7655, D7693, and D7698) and how their individual event fuel economy and overall fuel economy compare over the same time period.

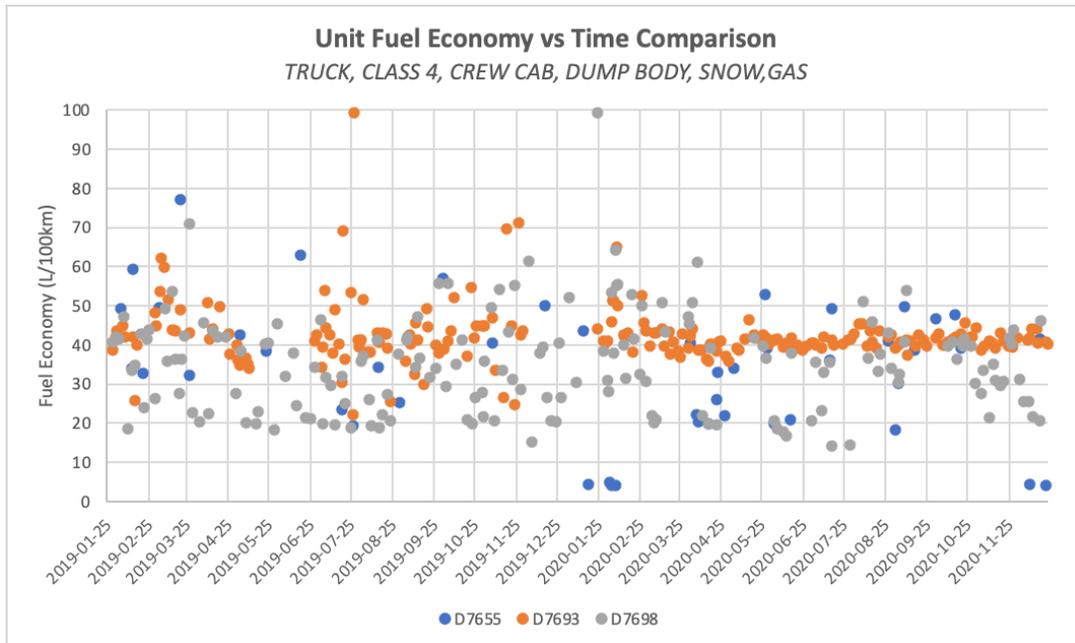


Figure 10: Fuel economy over time comparison for units D7655, D7693, and D7698

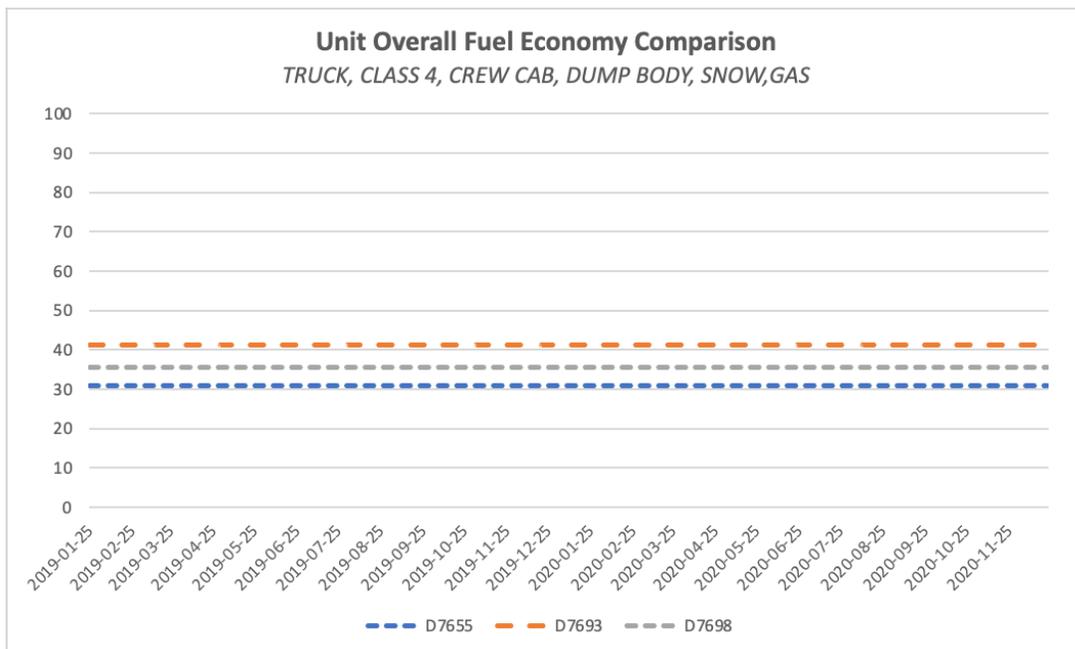


Figure 11: Overall fuel economy for units D7655, D7693, and D7698

All units show significant variance in fuel economy day by day with no significant indication of seasonal variation. Unit D7655 has significantly less data than the other units which suggests it is not being used as frequently which may explain the lower overall fuel economy as compared to D7693 and D7698. In individual event fuel economy, D7698 is consistently slightly lower than D7693. Vehicle usage patterns, age, and maintenance history would all be interesting to explore to see if there is anything that explains this discrepancy. When looking at overall fuel economy, the difference of ~5.64 L/100km between units is important to recognize considering on average these units travel ~ 15,120 km each year.

## Discussion

### Recommended Future Work

The following future work should be undertaken to continue to improve upon the tool and gain better insight around CoV fleet vehicles.

- 1) Import other unit data
  - a. Import data for other units of interest within city operations
  - b. Test limits of tool with large datasets
- 2) Build on the framework to provide more valuable visuals and insights
  - a. Other insights can be gained by modifying how data is viewed. The overall fuel economy pivot table can be manipulated to view data in a variety of interesting ways.
- 3) Understand GEOTAB data
  - a. If the inconsistencies within GEOTAB are fixed and the data is better understood the Excel tool accuracy will improve
  - b. GEOTAB dashboard reports can provide quicker and better visualizations side-by-side for improved comparisons
- 4) Link databases to analytics software
  - a. Whether working with just the GEOTAB database or multiple databases, analytics software such as Power BI, Spotfire, Tableau would be very powerful for fleet management

### Excel Tool Test

An additional dataset of 10 Freightliner units was added following the instructions in the appendix of this report to ensure functionality. Data was imported successfully, and the

automated fuel economy calculations were performed seamlessly. The tool was also opened on a Windows based operating system and MacOS to ensure cross-platform functionality. This test was also successful.

## **Conclusion**

At the writing of this report, only Ford units have been imported and considered in the GEOTAB and Fuel Query sections of the Excel tool, therefore they are the only units for which fuel economy has been calculated. The tool has been built with a M5 dataset that includes all fleet vehicles and is built to perform fuel economy calculations for all vehicles if GEOTAB and VIU data is provided. It should provide a user-friendly method of analysis of city vehicles based on the data systems that are currently being used and has been constructed to meet current needs and allow for easy modifications and additions as necessary. One of the main takeaways of this project is the data access and quality issues that exist within some of the systems involved. There are inconsistencies within GEOTAB that are even more evident when comparing to VIU data and should be addressed in order to have a proper understanding of fuel economy within city operations.

## Bibliography

City of Vancouver. (2021). *Green Fleets*. Retrieved from City of Vancouver Web Site:  
[https://vancouver.ca/green-vancouver/green-fleets?utm\\_campaign=green-fleet&utm\\_medium=Vanity&utm\\_source=green-fleet\\_Vanity](https://vancouver.ca/green-vancouver/green-fleets?utm_campaign=green-fleet&utm_medium=Vanity&utm_source=green-fleet_Vanity)

Dacey, E. (2019). *City of Vancouver Fleet Electrification: Infrastructure and Policy*. Vancouver: City of Vancouver.

Natural Resources Canada. (2021). *Fuel Consumption Ratings Search Tool*. Retrieved from Natural Resources Canada Web site: <https://fcr-ccc.nrcan-rncan.gc.ca/en>

## Appendix: Excel Tool User Guide

The following is a step-by-step guide for how to use and update the excel tool.

Disclaimer: By utilizing Microsoft Excel as a database and analysis tool, the file requires complex formulae which may cause some systems to run slowly. Patience will be necessary when opening the tool or updating the dataset.

The excel workbook is comprised of 9 different worksheets, each with a specific purpose.

WORKSHEET NAME	DESCRIPTION
GEOTAB Import	GEOTAB data is copied from the data export and pasted here for use in the tool
Fuel Query Import	VIU Fuel query data is copied from the data export and pasted here for use in the tool
M5 Import	M5 unit information is copied from the data export and pasted here for use in the tool
GEOTAB Formatted	A formatted version of the GEOTAB import necessary for calculations. No user input is required here
Fuel Query Formatted	A formatted version of the fuel query import necessary for calculations. No user input is required here
M5 Formatted	A formatted version of the M5 import necessary for functionality within the tool
Data Validation	Where all the validation checks and overall fuel economy calculations take place. No user input is required here
Unit Summary	A summary of specific unit parameters in table form. Main purpose is to allow for pivot table formation
Overall Fuel Economy	The pivot table summarizing overall fuel economy results in an easy to read format. User has the option of modifying the pivot table and selecting filters to view data in different forms
Fuel Economy vs Time	A calculator with chart for individual unit fuel economy over time. User must enter the unit number they wish to view, no other user input required

## Importing Data

Exports are required from Fleetfocus M5, GEOTAB, and the VIU for the tool to run successfully. To import data, select all data from export file, copy and paste it into the corresponding worksheet in the Excel tool. If the user wants to add on to the dataset already existing in the tool, they can paste it at the bottom of the existing dataset. Note, depending on processing power patience may be required when adding data to the tool.

### M5 Export – Unit Details

To be pasted in worksheet "M5 Import"

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
	Using Dept.	Category Class	Category Description	Make	Model	Unit #	License Plate	Model Year	Last Repair Date (MM/DD/YYYY)		Shift (Usage: Hrs) (Usage: Day)	Contact	Status	Equip. Info	Acquisition Date	In Service Date
1	ADMINISTRATION	LIGHT DUTY	VAN, CLASS 3, CUBE BODY, GAS	FORD	F550	C9218	LX3709	2017	05-03-2021		0000 2359 MTWTFSS	SEWA PANGALIA (604-654-0909)	IN	1FDUF5GY0HEB126	07-11-2017	12-01-2017
10	CEMETERY	HVY TRK	TRUCK, CLASS 4, REG CAB, DUMP BODY, SNOW, GAS	FORD	F450	A5858	ND8026	2018	05-03-2021		0730 1600 MTWTFXX	GLEN HODGES (604-325-2623)	IN	1FDUF4HY6JEB7685	12-18-2018	12-21-2018
51	CENTRAL STORES	HVY TRK	TRUCK, FLATDECK, LIGHT, GAS	FORD	F350	C1743	1877GA	2002	04-06-2021		0730 1600 MTWTFXX	GLENN GANJELAS (326-4746)	IN	1FDWF36L32EC775	04-25-2002	08-26-2002
127	COMMUNITY SERVICES	LIGHT DUTY	TRUCK, PICKUP, HEAVY, DIESEL	FORD	F350	B9206	2914GW	2004	02-04-2021		0000 2359 MTWTFSS	SEWA PANGALIA (604-654-0909)	IN	1FTWX32P54EC197	02-13-2004	03-12-2004
202			TRUCK, PICKUP, HEAVY, FOUR WHEEL DRIVE, GAS	FORD	F350	C9206	PM1382	2020			0000 2359 MTWTFSS	SEWA PANGALIA (604-654-0909)	OUTF	1FT8W3DN7LEE798	11-05-2020	
203			TRUCK, PICKUP, HEAVY, GAS	FORD	F250	D9259	JY8748	2016	02-18-2021		0000 2359 MTWTFSS	SEWA PANGALIA (604-654-0909)	IN	1FTX2A61GEA7643	10-21-2015	02-01-2016
204	COMMUNITY SERVICES GROUP	HVY TRK	DO NOT USE - TRUCK, VAN, SINGLE AXLE, GAS	FORD	F350	A1206	AL7476	2003	03-22-2021		0700 1530 MTWTFXX	ALEXANDRIA LANE	IN	1FTSX30L13EB67071	03-15-2003	03-15-2003

### GEOTAB Export – Advanced Fill-Ups Report

To be pasted in worksheet "GEOTAB Import"

Vehicle	Vehicle Group	Driver	Driver Group	Date	Location	Fuel Economy	Fuel Added	Odometer
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Jan 03, 2019 13:54	National Yards - Fuel St		45.05	89.97
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Jan 10, 2019 10:55	National Yards - Fuel St		37.29	99.46
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Jan 21, 2019 7:18	National Yards - Fuel St		39.23	96.46
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Jan 25, 2019 14:22	National Yards - Fuel St		37.33	92.96
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Feb 04, 2019 7:30	711 Alexander St, Vanc		37.65	89.97
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Feb 07, 2019 7:34	National Yards - Fuel St		32.00	48.48
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Feb 14, 2019 21:04	Man Yard - EQS Area: 2f		82.42	30.99
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Mar 06, 2019 7:38	National Yards - Fuel St		37.76	70.97
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Mar 08, 2019 13:19	371 Columbia St, Vanc		39.70	56.98
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Mar 13, 2019 14:59	National Yards - Fuel St		35.38	51.48
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Apr 16, 2019 14:36	National Yards - Fuel St		42.27	65.97
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			Apr 26, 2019 14:37	National Yards - Fuel St		47.02	79.97
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			May 06, 2019 7:11	National Yards - Fuel St		37.35	99.46
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			May 10, 2019 14:48	National Yards - Fuel St		41.96	63.98
A1244	Street Operations, Gasoline E10, Dump 1 yrd, In			May 24, 2019 11:12	National Yards - Fuel St		39.91	100.96

## VIU Fuel Query

To be pasted in worksheet "Fuel Query Import"

	A	B	C	D	E	F	G	H	I	J	K
1	UnitNum	DateWithdrawn	FuelDesc	PumpLoc	Litres	DeptCode	DeptDesc	ClassCode	ClassDesc	ClassCategory	Organization
2	A5934	2020-03-13 9:18	Gas E10	Manitoba Yard	109.86	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
3	A5934	2020-04-21 14:14	Gas E10	Manitoba Yard	0.33	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
4	A5934	2020-04-21 14:17	Gas E10	Manitoba Yard	83.98	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
5	A5934	2020-04-28 14:14	Gas E10	Manitoba Yard	0.42	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
6	A5934	2020-04-28 14:19	Gas E10	Manitoba Yard	96.33	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
7	A5934	2020-05-05 14:27	Gas E10	Manitoba Yard	96.9	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
8	A5934	2020-05-13 14:34	Gas E10	Manitoba Yard	105.16	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
9	A5934	2020-05-20 14:14	Gas E10	Manitoba Yard	79.1	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
10	A5934	2020-05-27 14:28	Gas E10	Manitoba Yard	101.58	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
11	A5934	2020-06-03 14:08	Gas E10	Manitoba Yard	95.97	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
12	A5934	2020-06-10 14:22	Gas E10	Manitoba Yard	86.66	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
13	A5934	2020-06-16 14:32	Gas E10	Manitoba Yard	84.71	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
14	A5934	2020-06-23 14:22	Gas E10	Manitoba Yard	97.24	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
15	A5934	2020-06-29 14:28	Gas E10	Manitoba Yard	88.39	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
16	A5934	2020-07-07 14:36	Gas E10	Manitoba Yard	86.96	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
17	A5934	2020-07-14 14:18	Gas E10	Manitoba Yard	95.47	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer
18	A5934	2020-07-20 14:13	Gas E10	Manitoba Yard	73.41	E14	ENGINEERING SEWERS OPER.	B20ZZAZZZZ	TRUCK, PICKUP, LIGHT	LIGHT DUTY	Utilities - Sewer

Once all data has been added to the excel tool, all data validation steps and calculations should be performed automatically. **There is currently a limitation of 100,000 lines of data from the GEOTAB export and 60,000 lines of data from the fuel query export.**

If the user wishes to exceed these data range limitations, the following steps must be taken to ensure calculations work:

- 1) Take note of the row number of the last row of the imported fuel query data
  - a. If less than 60,000 – no action is required
  - b. If greater than 60,000 – move on to step 2
- 2) Unhide tab FQ Formatted and extend all formulae to whatever row your data in Fuel Query import ends at. I.e. If FQ import data ends at row 75,000, extend formulae to row 75,000
  - a. Note: this may take a significant amount of time depending on computing power, the author recommends going for a coffee and some fresh air
- 3) Open the Data Validation tab and navigate to cell K1
- 4) In the formula bar, replace every reference of "\$B\$60000" with "\$B\$" followed by the number of rows in the fuel query import tab.
  - a. For example, if the fuel query has 75,000 lines – all instances of \$B\$60000 will be replaced with \$B\$75000. An example of the formula can be seen below

```
=IFERROR(INDEX('FQ Formatted'!$C$2:$C$60000,MATCH(MIN(IF('FQ Formatted'!$B$2:$B$60000='Data Validation'!A2,ABS('FQ Formatted'!$C$2:$C$60000-'Data Validation'!J2))),IF('FQ Formatted'!$B$2:$B$60000='Data Validation'!A2,ABS('FQ Formatted'!$C$2:$C$60000-'Data Validation'!J2)),0)), "")
```

- 5) Repeat steps 2 and 3 for cell O2

Similarly for GEOTAB data, if the user wishes to exceed the current limit of 100,000 lines, the following steps must be taken:

- 1) Take note of the row number of the last row of imported GEOTAB data
  - a. If less than 100,000 – no action is required
  - b. If greater than 100,000 – move on to next step
- 2) Unhide tab GEO Formatted and extend all formulae to whatever row your data in Fuel Query import ends at. I.e. If GEOTAB import data ends at row 150,000, extend formulae to row 150,000
  - a. Note: this may take a significant amount of time depending on computing power
- 3) Open the Data Validation tab and navigate to cell L1
- 4) In the formula bar, replace every reference of “\$F\$100000” with “\$F\$” followed by the number of rows in the fuel query import tab.
  - a. For example, if the fuel query has 150,000 lines – all instances of \$F\$100000 will be replaced with \$F\$150000. An example of the formula can be seen below

```
=IFERROR(INDEX('GEO Formatted'!$F$10:$F$100000,MATCH(MIN(IF('GEO Formatted'!$B$10:$B$100000='Data Validation'!A2,ABS('GEO Formatted'!$F$10:$F$100000-'Data Validation'!J2))),IF('GEO Formatted'!$B$10:$B$100000='Data Validation'!A2,ABS('GEO Formatted'!$F$10:$F$100000-'Data Validation'!J2)),0)), "")
```

- 5) Repeat steps 2 and 3 for cell P2

## Overall Fuel Economy Results

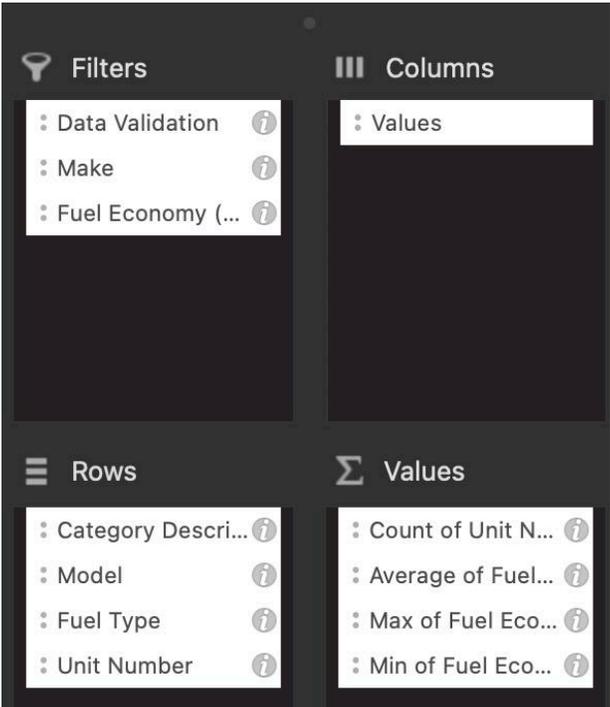
Once all data has been imported, the user must update the pivot table on worksheet “Fuel Economy Results. To do this, right-click anywhere in the table and select “Refresh”.

Row Labels	Count of Unit Number	Average of Fuel Economy (L/100km)	Max of Fuel Economy (L/100km)	Min of Fuel Economy (L/100km)
-TRUCK, AERIAL, 34 FT BOOM, GAS	2	58.18	58.81	57.55
-DO NOT USE - TRUCK, DUMP, 1 YARD, GAS	1	45.32	45.32	45.32
-TRUCK, CLASS 4, REG CAB, DUMP BODY, SNOW, GAS	2	63.69	71.19	56.19
-TRUCK, CLASS 5, EXTENDED CAB, CHP BOX	3	53.96	83.97	38.22
-TRUCK, CLASS 7, CREW CAB, DUMP BODY, HYD BRAKE	2	50.68		
-TRUCK, AERIAL, 34 FT BOOM, DIESEL	1	46.80		
-TRUCK, CLASS 4, CREW CAB, DUMP BODY, GAS	7	45.84		
-TRUCK, FLATDECK, LIGHT, GAS	3	43.53		
-DO NOT USE - TRUCK, DUMP, 3 YARD	5	42.82		
-DO NOT USE - TRUCK, DUMP, 1 YARD, DIESEL	1	47.98		
-DO NOT USE - TRUCK, FLATDECK, CRANE, LIGHT	4	40.77		
-TRUCK, CLASS 4, CREW CAB, DUMP BODY, DIESEL	1	40.89		
-TRUCK, CLASS 4, CREW CAB, DUMP BODY, GAS	22	36.19		
-TRUCK, CLASS 4, CREW CAB, DUMP BODY, SNOW, GAS	5	35.61		
-TRUCK, CLASS 4, CREW CAB, DUMP BODY, SNOW, DSL	3	35.92		
-TRUCK, CLASS 4, CREW CAB, DUMP BODY, SNOW, DSL	5	34.55		
-TRUCK, PICKUP, HEAVY, GAS	13	34.95		
-TRUCK, PICKUP, HEAVY, FOUR WHEEL DRIVE, DIESE	2	26.79		
-TRUCK, PICKUP, HEAVY, FOUR WHEEL DRIVE, DIESE	30	32.07		
-TRUCK, PICKUP, HEAVY, FOUR WHEEL DRIVE, DIESE	1	25.88		
-TRUCK, CLASS 4, REG CAB, DUMP BODY	5	30.96		
-TRUCK, CLASS 4, REG CAB, DUMP BODY	3	30.91		
-TRUCK, PICKUP, HEAVY, FOUR WHEEL DRIVE, GAS	1	27.98		
-TRUCK, CLASS 4, REG CAB, DUMP BODY, SNOW, DSL	5	31.15		
-TRUCK, PICKUP, LIGHT, FOUR WHEEL DRIVE, GAS	2	29.36	29.72	29.01
-TRUCK, PICKUP, LIGHT, FOUR WHEEL DRIVE, GAS	6	29.19	36.49	21.24

Pivot table data is linked to the worksheet “Unit Summary” where final data validation outcomes and overall fuel economy values are stored. A user with pivot table experience may wish to modify the table and view units in a variety of ways. Variables and parameters for considerations include:

- Unit Number
- Department
- Category Description
- Make
- Model
- Fuel Type
- Data Validation
- Fuel Consumption (L)
- Distance Travelled (km)
- Fuel Economy (L/100km)

Default pivot table parameters are as follows:

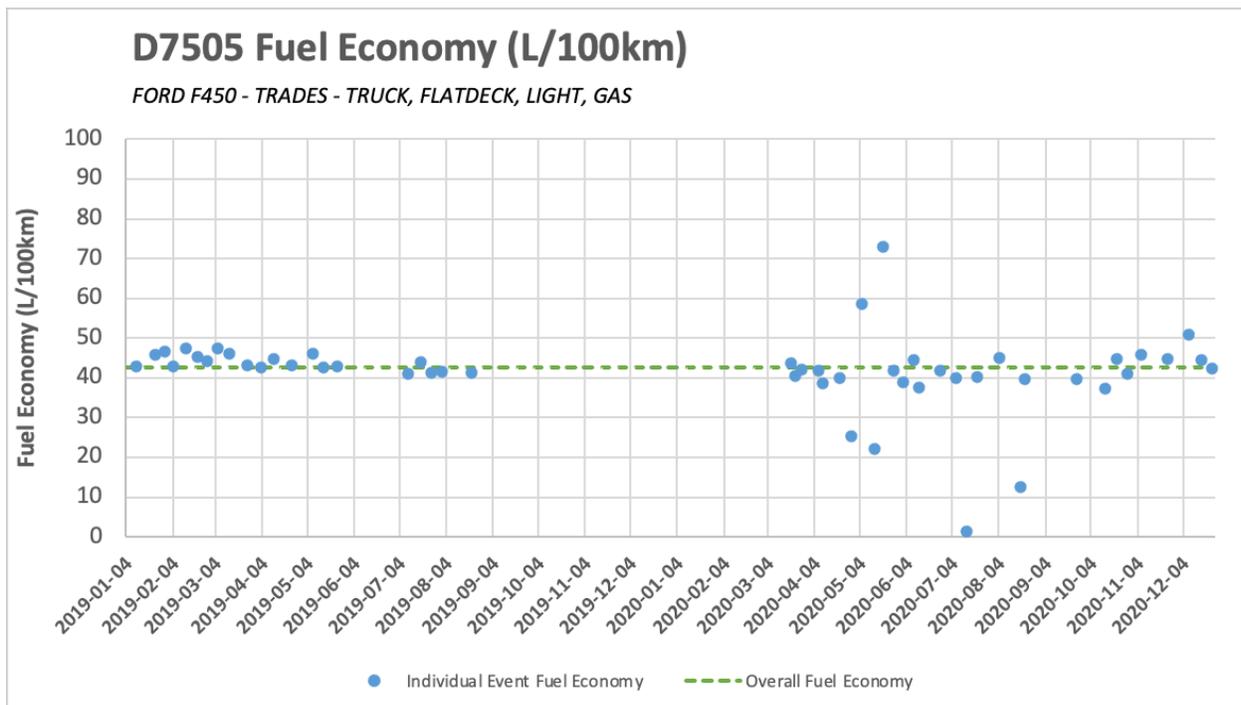


## Fuel Economy vs Time Results

Worksheet “Fuel Economy vs Time” is a calculator that generates a plot of fuel economy vs time for any one individual unit. Multiple units cannot be considered at the same time due to data and processing limitations.

To consider a unit, the user must enter the specific unit number in cell B2. All other information is automatically generated.

	A	B
1	<b>Unit Information</b>	
2	<b>Unit Number</b>	<b>D7505</b>
3	<b>Make:</b>	FORD
4	<b>Model:</b>	F450
5	<b>Fuel:</b>	Gas E10
6	<b>Department:</b>	TRADES
7	<b>Category:</b>	TRUCK, FLATDECK, LIGHT, GAS
8	<b>Overall Fuel Economy (L/100km)</b>	<b>42.55</b>
9	<b>Data Start</b>	04-Jan-19
10	<b>Data End</b>	23-Dec-20
11	<b>Data Validation</b>	<b>Valid</b>



When considering these charts, the user must be aware of the following:

- Data validation steps do not impact information displayed. Only an indication of the data validation code is provided in cell B11
- The value of overall fuel economy (green dashed line) is a weighted average based on distance travelled. If there are gaps in GEOTAB data, one fuel economy value will be attributed to a significant distance and may skew the overall fuel economy value away from the rest of the data points.
- Each data point is generated with the assumption that the fuel tank is completely filled at every fuelling event. Where this is not the case, a very low fuel economy number will be generated which will display as an obvious outlier
- Days where multiple fuel events occur have been omitted. These events are rare and have been excluded due to computing limitations. They are not believed to have a material impact on results.

### **Background Calculations**

The following is a summary of the background calculations necessary to produce fuel economy results. User input is not required for any of these calculations to take place aside from importing proper datasets.

#### **Data Validation Worksheet – Step-by-Step**

- 1) List of all units generated from worksheet “M5 Formatted”
- 2) Minimum and maximum dates of fuel events from GEOTAB data generated for each individual unit
- 3) Minimum and maximum dates of fuel events from VIU Fuel Query data generated for each individual unit
- 4) Minimum dates compared – the later value is chosen as the overall starting date for unit analysis – See column J – This is defined as “Start Date”
- 5) “Closest Fuel Start Date” generated by comparing all available fuel events in the VIU Fuel Query for specific unit to the calculated start date from step 4. The timestamp with the

minimum difference from the start date is selected

- 6) "Closest GEO Start Date" generated by comparing all available fuel events in the GEOTAB data for specific unit to the calculated start date from step 4. The timestamp with the minimum difference from the start date is selected
- 7) Timestamps from steps 5 and 6 are compared. If a difference of greater than 24 hours occurs, the data is coded with the validation code "Start Date Error"
- 8) Maximum dates compared – the earlier value is chosen as the overall end date for unit analysis – See column N – This is defined as "End Date"
- 9) "Closest Fuel End Date" generated by comparing all available fuel events in the VIU Fuel Query for specific unit to the calculated start date from step 7. The timestamp with the minimum difference from the end date is selected
- 10) "Closest GEO Start Date" generated by comparing all available fuel events in the GEOTAB data for specific unit to the calculated end date from step 7. The timestamp with the minimum difference from the end date is selected
- 11) Timestamps from steps 9 and 10 are compared. If a difference of greater than 24 hours occurs, the data is coded with the validation code "End Date Error"

\*\*Note: Timestamps and unit numbers are what drives the lookup functions for fuel economy calculations. These steps are only necessary because GEOTAB and VIU timestamps are different.

- 12) Column R calculates the number of fuel events in the VIU Fuel Query data for the specific unit within the calculated time period.
- 13) Column S calculates the number of fuel events in the GEOTAB data for the specific unit within the calculated time period.
- 14) If more GEOTAB fuel events exist than VIU Fuel Query events, the unit is assigned a validation code of "Event Count Error". This indicates that there may be missing fuel

volumes from the calculation which could result in unrealistically low fuel economy values

- 15) Column Y is a test of all odometer readings for a unit. If any one event occurs where the odometer reading decreases over subsequent fuel events, the unit is assigned a validation code of “Odometer Error”
- 16) Column AB is a sum of all fuel volumes for the individual unit in the calculated time period extracted from the VIU Fuel Query
- 17) Column AC is the difference of start and end odometer readings extracted from GEOTAB data
- 18) Column AD is the overall fuel economy calculation from the values obtained in steps 16 and 17. If this value is non-zero and less than 13 L per 100 km a validation code of “Low FE” is assigned to the unit

### **Fuel Economy vs Time – Step-by-Step**

- 1) User enters specific unit number in cell B2 which drives lookup functions in cells B3 to B11
- 2) Dates of available data generate date range in column A starting at row 16
- 3) Event serial numbers are generated as a combination of unit numbers and year/month/day of dates. The same serial numbers are generated in worksheets GEOTAB Formatted and Fuel Query Formatted
- 4) Fuel volumes and odometer readings are generated in columns H and I respectively by lookups of serial numbers in GEOTAB Formatted and Fuel Query Formatted worksheets
- 5) Scatter plot with line for overall fuel economy is automatically generated with date range and title updates. Fuel economy scale is locked as 0 to 100.



