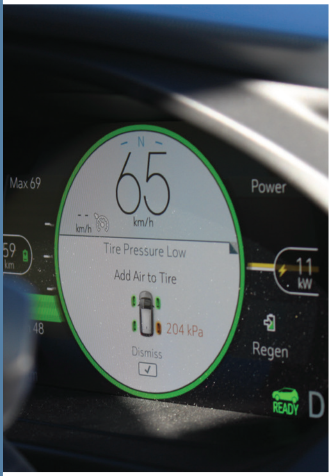
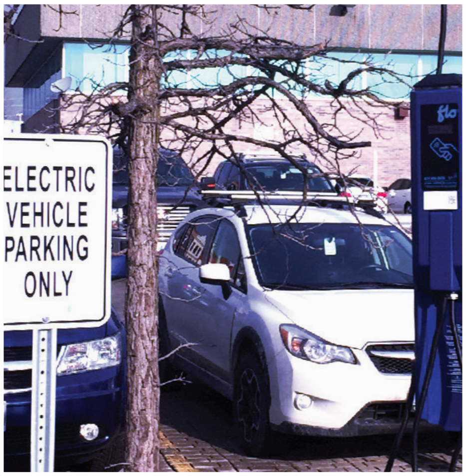
OxfordCounty

Growing stronger together

Green Fleet Plan

May 2021





Committed to

100% RE | Zero Waste | Zero Poverty

SIGNATURES

PREPARED BY

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May 17th, 2021

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Date

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ABBREVIATIONS LIST

Abbreviation	Definition
AC	Alternating Current
ASE	Automotive Service Excellence
ASTM	American Society for Testing and Materials
ATV	All-Terrain Vehicle
BEV	Battery Electric Vehicle
BNEF	Bloomberg New Energy Finance
CAD	Canadian dollars
CCS	Combined Charging System
CES	Change Energy Services
CNG	Compressed Natural Gas
CO_2e	carbon dioxide equivalent
CPI	Consumer Price Index
CSA	Canadian Standards Association
CTS	Custody Transfer Station
DC	Direct Current
DOE	Department of Energy
ECM	Engine Control Module
ECU	Engine Control Unit
EPA	Environmental Protection Agency
ERV	Emergency Response Vehicle
ESA	Electrical Safety Authority
ESD	Electro Static Discharge
ESS	Energy Storage System
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
GPS	Global Positioning System
HD	Heavy-Duty
HEV	Hybrid Electric Vehicle
hp	horsepower
HVAC	Heating, Ventilation and Air Conditioning
ICE	Internal Combustion Engine
IEA	International Energy Agency
kg	kilogram
km	kilometers
kW	kilowatt
kWh	kilowatt hour
L	litres

Abbreviation	Definition
lbs	pounds
LD	Light-Duty
Le	litre equivalent
LNG	Liquified Natural Gas
MD	Medium-Duty
MO	Missouri
mpg	miles per gallon
MSRP	Manufacturer Suggested Retail Price
MΩ	megaohm
NFPA	National Fire Protection Agency
NPV	Net Present Value
NRCan	Natural Resources Canada
OEM	Original Equipment Manufacturer
OESC	Ontario Electrical Safety Code
ON	Ontario
PHEV	Plug-in Hybrid Electric Vehicle
PPE	Personal Protective Equipment
PS	Paramedic Services
psig	pounds per square inch (gauge)
PTO	Power Take-off
PW	Public Works
RNG	Renewable Natural Gas
ROI	Return on Investment
SAE	Society of Automotive Engineers
SARTA	Stark Area Regional Transit Authority
scf	standard cubic feet
SUV	Sport Utility Vehicle
TAC	Transportation Association of Canada
tCO_2e	tonnes of carbon dioxide equivalent
TEQ	Transition l’énergie Quebec
TSSA	Technical Standards and Safety Authority
TWh	terrawatt hour
USD	American dollars
V	volts
VRR	Vehicle Replacement Rating
Wh	watt hour

EXECUTIVE SUMMARY

Background:

Oxford County currently operates and maintains a corporate fleet of approximately 184 assets across Public Works, Paramedic Services, and Corporate Services. The fleet composition includes light-duty vehicles (i.e. pickup trucks, SUVs, cars and cargo vans), heavy-duty trucks (i.e. snowplows, dump trucks and vacuum/sweeper trucks), construction equipment, tractors, ambulances, and emergency response vehicles (ERVs).

Purpose and Objectives:

In 2015, Oxford County Council endorsed the community-level goal of achieving 100% renewable energy (RE) by 2050. As shown in Figure 1, the County's **Green Fleet Plan** works in conjunction with the *Energy Management Plan* (2019) and the forthcoming *Facilities Long Term Renewable Energy Plan* (2021) to support and guide the contributions of the County organization towards the 100% RE goal. It is important to identify that the County organization is only one of multiple input entities that have a role in contributing to the 100% RE Plan.

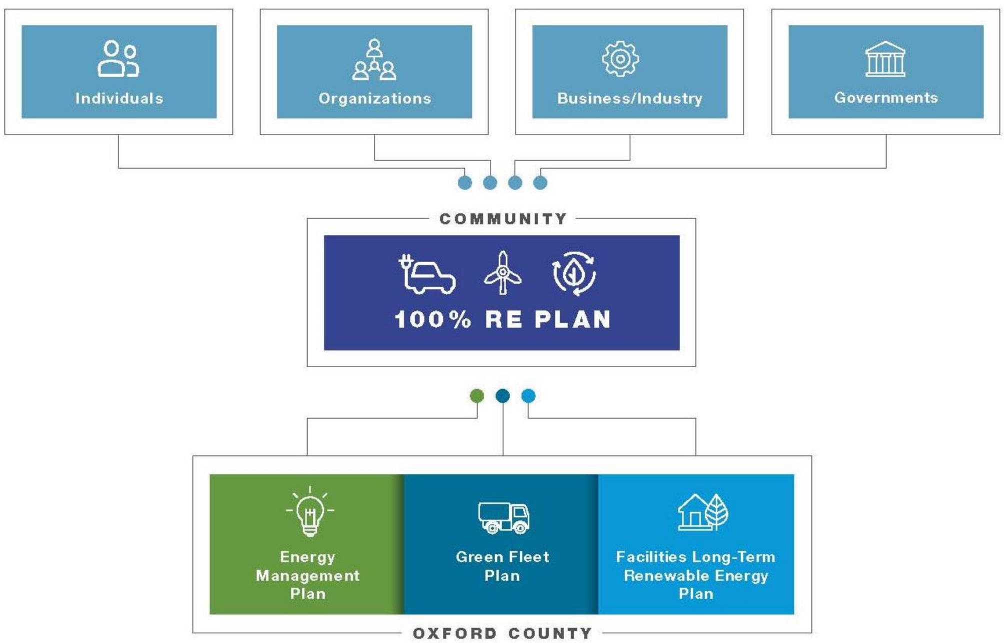


Figure 1 Oxford County's 100% RE document map

In the 100% RE Plan, a set of goals were established for energy reduction, greenhouse gas (GHG) emissions reduction, and renewable energy supply mix. Specifically, GHG emissions has a goal of reducing by 68.7% by 2050 from 2015 levels. To ensure progress towards the goal, the 100% RE Plan outlines incremental five year targets with 2025 set at 14% reduction from 2015 levels. In order to meet this target, fleet operations will need to significantly contribute to the County's overall reductions as it represents approximately 37% of the County's GHG emissions.

As of 2015, the County's fleet emissions were estimated at **2,239 tonnes of CO_2e.** To achieve the next target by 2025 (**14%, reference to 2015 level**), fleet emissions will need to be reduced by **316 tonnes of CO_2e/year**. The 2021 update to the Green Fleet Plan (2016) identifies actionable opportunities over the next 5-year period to meet this target and to support the County's aim of reducing dependence on fossil fuels over the long term.

Current State:

Oxford County has already implemented several green fleet initiatives towards meeting the 2025 emissions reduction target. These initiatives include the implementation of:

- Two (2) compressed natural gas (CNG) snowplows and an approved budget to purchase an additional two CNG snowplows in 2021,
- Establishing a fleet of nine (9) gas-hybrid ambulances and two (2) hybrid ERVs,
- A fleet of twenty (20) dual CNG/gasoline fueled light-duty vehicles,
- One (1) plug-in hybrid (PHEV) car, one (1) battery electric (BEV) car, and
- Installation of anti-idling technology on several vehicles.

With these completed initiatives, approximately 19% of the County fleet has been converted to alternative fuelled vehicles. Current fleet emissions are estimated at **2,200 tonnes of CO_2e/year**, demonstrating **40 tonnes of CO_2e reduction (reference to 2015 level).** An additional **276 tonnes of CO_2e/year** will need to be reduced by 2025 to meet the emissions reduction target of 14% from 2015 levels. Since 2018, there has been a downward trend in emissions from the corporate fleet as a result of the aforementioned initiatives.

Plan Development Methodology:

In addition to analysis of Oxford County's fleet data, stakeholders and vehicle user groups were consulted to help determine if there is a strong case for further rollout of vehicle technologies in this Green Fleet Plan.

Furthermore, a market scan of vehicle technology was conducted to determine the availability and maturity of new vehicles and technologies which could be factored into the plan.

Stakeholder Feedback:

User groups which were consulted include Paramedic Services, Roads, Water, Wastewater, Engineering Services and Asset Management. All groups acknowledged a need for the consideration of new technologies and vehicle types to aid in reducing fleet emissions. Key feedback specific to technology types included the following:

- **CNG Vehicles:** There is only one CNG fuel station in proximity located in Woodstock, causing logistical challenges for refueling.
- **Light-Duty Dual CNG/Gasoline Vehicles:** The CNG upfitting of light-duty vehicles (i.e. pickup trucks, cargo vans and SUVs) has not demonstrated significant GHG reduction due to the inconvenience of fueling at the CNG station in Woodstock and operator behaviour preferences towards gasoline utilization over CNG. As a result, vehicles have been operated primarily on gasoline. While the full potential of CNG vehicles has not been met, user feedback on CNG/gasoline vehicles indicated concerns with the fuel system, vehicle performance, storage space limited by CNG tanks, inconvenience of fueling and a safety concern of vehicles stalling on the road.

- **CNG Snowplows:** Performance and feedback for CNG snowplows has been more favourable. There have been some notes on the CNG snowplows having moderately less power, torque and operating range compared to their diesel counterparts. However, the CNG snowplows have performed well in terms of reducing GHG emissions (reducing up to 5 tonnes of CO2e per truck annually, refer to Section 6.2.5.1). Oxford County's approved 2021 budget does include upfitting two (2) additional CNG snowplows which will be allocated to the Woodstock yard, due to the site's proximity to the Rural Green Energy CNG fuel station.
- **Electric Vehicles:** There is some concern on an immediate transition to fully battery electric vehicles (BEVs) due to the availability of charging stations. However, hybrid (HEV) and plug-in hybrid (PHEVs) can allow users to gain familiarity with EV technology (i.e. regenerative braking and plug-in charging).
- **Hybrid Ambulances and ERVs:** Paramedic Services expressed positive feedback on their hybrid vehicles and plans to continue the rollout of hybrid vehicles across their fleet. As a side note, the City of Toronto is also proceeding to incorporate the same hybrid technology into their fleet following from Oxford County's successful demonstration as an early adopter.

Additionally, feedback indicated that decision-making should consider whole-of-life costs and support for options which balanced capital investments and operational cost savings. A vehicle lifecycle analysis has been used throughout this study to present the total lifecycle cost, payback period, and return on investment (ROI) calculations for each "green vehicle" option to promote financial sustainability.

Recommendations:

Oxford County's upcoming fleet replacement plan demonstrates that a majority of vehicle types being replaced over the next 5-years are light and medium-duty pickup trucks. Therefore, Oxford County should focus on evaluating green vehicle options which offer improved fuel economy for this class of vehicles. In addition, Oxford County has 16 heavy-duty diesel trucks scheduled for replacement over the next 5-years for which there are opportunities to cut GHG emissions.

The set of green fleet recommendations are summarized in Table 1 with financial and GHG reduction metrics. Note that a positive cost indicates an additional expenditure while a negative cost implies a cost savings. These recommendations propose a total reduction of **398 tonnes of CO_2e/year** which could be phased into the fleet by 2025, thereby demonstrating a viable path to meeting or exceeding the 2025 target. Recommendations are listed from most to least impactful based on the overall opportunity to lower GHG emissions, according to vehicle type/class.

Financial sustainability is also demonstrated as there is a positive or close to breakeven ROI and payback period achieved for several of the recommendations, including the hybrid pickup trucks, plug-in hybrid SUVs, CNG snowplows and anti-idling systems.

However, there are some recommendations where a positive ROI is not achieved. The more costly initiatives to implement include the BEV cargo vans, the BEV single axle truck, ambulances and ERVs requiring an aftermarket hybrid system conversion. These opportunities aim to be justified on the factors noted below:

- **BEV Fleet:** The BEV fleet provides the clearest path towards emissions reduction. However, the purchase price for BEVs is still quite high in comparison to conventional gasoline or diesel vehicles. This cost differential is the highest for the BEV single axle truck. In addition, there are additional costs at this time to setup EV charging infrastructure. The lifecycle and ROI analysis for each BEV assumes a $5,000 cost for a charging station.

- It is expected that this additional financial cost of the BEVs can be absorbed in order to start phasing in EVs and enabling users to gain familiarity with this technology before further rollout is implemented. Furthermore, there could be an opportunity to monitor and possibly extend the lifecycle of BEVs in order to improve their ROI.
- **PS Vehicles:** For the Paramedic Services fleet, although the hybrid ambulances and ERVs do not show a ROI and achieve payback over the vehicle lifecycle these technology initiatives are still an integral part of the green fleet plan. There are limited options available in the market for PS vehicles and fewer still in the area of green technology. From phasing in new hybrids these vehicles can collectively contribute a reduction of 50 tonnes of CO2e/year.

Table 1 Summary of Green Fleet Recommendations[1]

Opportunity	Vehicle Count	Total GHG Reduction (tCO_2e/year)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Net Life cycle Cost ($)	Payback Period (years)	ROI (%)
Hybrid Pickup Trucks	35	91	+$178,200	-$35,200	+$2,200	5.1	-1%
B20 Bio-diesel (20%) for Major Equipment[2]	N/A	76	N/A	+$8,800	N/A	N/A	N/A
BEV Pickup Trucks	7	67	+$140,000	-$26,700	+$6,500	5.2	-5%
BEV Cargo Vans	8	44	+$126,100	-$13,800	+$43,300	9.1	-34%
Hybrid Ambulances	5	38	+$164,500	-$7,500	+$104,500	19.9	-64%
Anti-Idle Technology[3]	16	31	+$107,200	-$10,800	-$800	9.9	1%
PHEV SUVs	3	14	+$24,600	-$4,200	-$600	5.9	2%
CNG Snowplows	2	10	+$104,200	-$11,000	-$5,800	9.5	6%
BEV Single Axle Truck	1	8	+$70,000	-$2,400	+$22,000	29.2	-31%
Dozer (with electric drive)	1	7	+$65,000	-$4,400	-$23,000	14.8	35%
Hybrid ERV (Asset 1317)	1	6	+$15,000	-$1,600	+$5,400	9.4	-36%
BEV ERV (Asset 1320)	1	4	+$12,500	-$1,000	+$6,500	12.5	-52%
Hybrid ERV (Asset 1318)	1	2	+$5,000	-$500	+$2,000	10.0	-40%
	Total:	**398**	**+$1.1 million**	**-$110,300**	**+$177,200**	**9.2**	**-18%**

CNG Infrastructure:

Oxford County has considered a slow fill CNG fuel station at the Water Operations Centre, located at 59 George Johnson Boulevard, Ingersoll. However, there are primarily light-duty

[1] The vehicles listed are scheduled for replacement within the period of this plan, as per Oxford County's Asset Replacement Plan. Capital cost will be implemented over the duration of the 5-year plan.

[2] Operating cost impact stated as total impact for all off-road vehicles and equipment dyed diesel fuel usage. Assumes B5 blend used in winter.

[3] Assumes a minimum 20% of total idling is non-productive for the 16 trucks listed in Section 6.2.6. Capital and operating budget impacts, lifecycle savings, payback and ROI are presented for the entire fleet of 16 trucks being outfitted with anti-idling systems.

vehicles stationed in proximity to this site. Given the outlook for greater GHG emissions reduction through the use of hybrid and battery electric light-duty vehicles, it is recommended to focus CNG adoption on heavy-duty vehicles.

As an alternative, an on-site slow fill CNG fuel station was considered in this study for the Springford Patrol Yard due to the number of heavy-duty trucks stationed at this site. However, the cost of an on-site CNG fueling station does not provide a justifiable business case. The fuel cost savings and cost of upfitting CNG heavy-duty trucks will not achieve a payback over the 20-year lifecycle of a CNG fuel station.

Investment in a CNG station can fixate Oxford County on this technology over the long-term and potentially impact reaching future GHG reduction targets when BEVs and other zero emission technologies (e.g. hydro fuel cell) are more viable.

EV Infrastructure:

The update to the Green Fleet Plan (2016) recommends twenty (20) plug-in EVs (includes PHEVs and BEVs) by 2025 phased into the fleet via end of life replacements. EV charging stations are recommended to be installed at the home sites for this fleet of EVs. The cost of EV charging stations is factored into the lifecycle cost at $5,000 (for a Level 2 charger).

In addition, there are 25 publicly available EV charging stations installed by the County in Woodstock, Tillsonburg, Thamesford, Ingersoll and Salford which can also be leveraged by Oxford County's fleet operations.

Target Future State (2025):

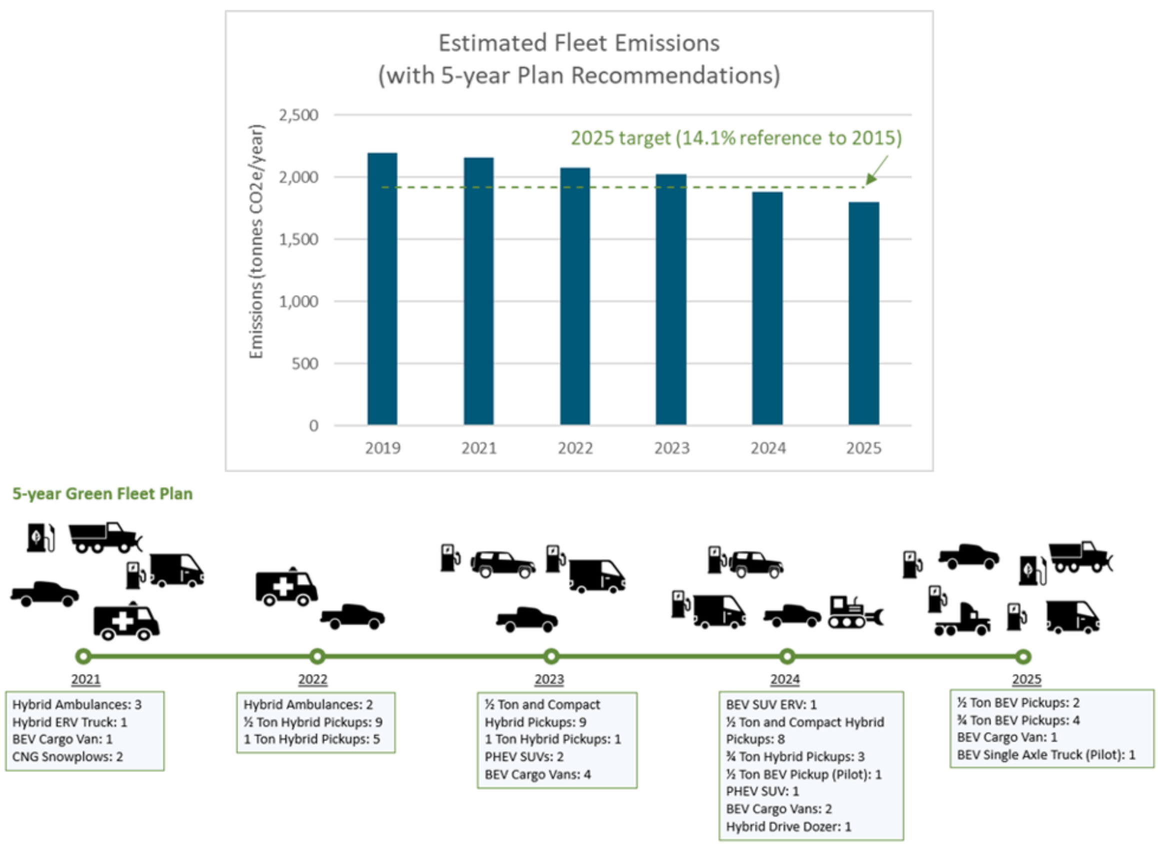


Figure 2 Green Fleet Transition

The transition pathway towards implementing the recommendations from the 5-year Green Fleet Plan is illustrated in Figure 2. The vehicles identified are to be phased in via lifecycle replacements, as per the replacement plan. Overall, Oxford County is in a strong position to hit or potentially exceed their 2025 target and stay on track for achieving future GHG reduction targets.

1 INTRODUCTION

1.1 OXFORD COUNTY COUNCIL APPROVAL

This report and 5-year Green Fleet Plan have been reviewed and are supported by approval from Oxford County Council.

1.2 BACKGROUND

Oxford County is a regional municipality located in Southwestern Ontario, with 8 area municipalities and a population of almost 120,000 residents. It is in close proximity to the 401 and 403 highways, and is central around the City of Woodstock, ON.

Figure 3 Oxford County Region

Oxford County is a progressive municipality which has recognized the need to address climate change by means of reducing greenhouse gas (GHG) emissions. In 2015, Oxford County Council endorsed a community goal of achieving use of 100% renewable energy by 2050 and subsequently the 100% RE Plan in 2018. To progress towards achieving this target Oxford County, as an organization, has developed an Energy Management Plan which looks at energy usage across the entire corporate activity of services which the County delivers. This Energy Management Plan is revised every five years to highlight areas of improvement and innovations to promote sustainability. Once complete, the Green Fleet Plan will support the County organization's roadmap for changes in energy consumption, reduction in GHG emissions, and increases in renewable energy mix.

The Green Fleet will work in conjunction with the Energy Management Plan (2019) and the forthcoming 2021 *Facilities* Long Term Renewable Energy Plan to guide the contributions of the County organization towards the 100% RE goal. It is important to identify that the County organization is only one of multiple input entities that have a role in contributing to the 100% RE Plan.

Oxford County's Fleet Services is an integral part of the Energy Management Plan, as fleet emissions are estimated to comprise approximately 37% of the County's overall emissions.

1.3 STUDY OBJECTIVES

The primary objective of this study is to identify actionable opportunities for the reduction of GHG emissions in Oxford County's fleet which can be incorporated in the next 5-year phase of Oxford County's Green Fleet Plan (2016). As noted previously, fleet emissions are a main component of the County's overall emissions. Therefore, the development of an actionable 5-year (2021-2025) update to the Green Fleet Plan (2016) will play a major role in achieving the County's broader objectives for environmental sustainability. Oxford County has a target set for a 14% reduction in fleet emissions by 2025 (relative to the baseline 2015 emissions). This goal aligns with the County's 100% renewable energy plan to achieve by 2050.

The County is also exploring the opportunity to install a County-owned on-site CNG fueling station at the Water Operations Centre (59 George Johnson Blvd, Ingersoll). The analysis in this 5-year Green Fleet Plan will help provide strategy direction on whether there will be sufficient future demand for CNG usage to warrant this fueling station project.

Furthermore, financial sustainability is also a key objective for the 5-year update to the County's Green Fleet Plan (2016). Green fleet opportunities in their entirety should be able to demonstrate a justifiable business case according to a net present value (NPV) with discounted payback period so that the Green Fleet Plan is reflective of budgetary considerations and can be viable over the long-term. The 5-year Green Fleet Plan shall help position Oxford County to achieve subsequent targets for GHG reduction, building towards the ultimate goal for 2050.

1.4 LIMITATIONS

The findings presented in this study are based on the information and data available at the time of writing. Furthermore, the analysis is based on the fleet and facilities data as well as stakeholder workshops held at the beginning of the study with Oxford County in 2020 and early 2021. It assumed that feedback gained during stakeholder workshops and the survey questionnaire provide an accurate portrayal of Oxford County's Fleet Services.

Furthermore, analysis is conducted on the assumption of Oxford County assuming the responsibility for the accuracy and quality of all data provided. Historical fleet data is used to help establish a baseline of Oxford County's current fleet operations in order to make comparisons against green vehicle alternatives. Fleet statistics such as fuel economy and fleet maintenance costs are referenced from historical data to help develop lifecycle cost assessments of vehicles and equipment.

Green fleet findings and analysis are subject to change due to the nature of continuing innovations in alternative propulsion technologies. The availability of market data on alternative vehicles is based on present conditions, providing a current snapshot of prices and specifications, and will likely change over time.

The plan herein will be subject to the County's annual Business Plan and Budget approval process. Recommended budgets highlighted throughout this plan are subject to change based on market conditions and will be assessed annually during budget preparation.

2 CURRENT STATE

2.1 FLEET ASSET INVENTORY

Oxford County operates and maintains a fleet of approximately 150 licensed vehicles and 44 major equipment assets (i.e. tractors and wheel loaders) utilized by Public Works, Paramedic Services, and Corporate Services.

Public Works provides a variety of services to the County including waste management, transportation services, facilities management, engineering and construction, water and wastewater treatment and distribution, forestry as well as summer and winter road operations (i.e. salt/sand and snow plowing). The Paramedic Services fleet is comprised of 14 ambulances as well as front-line emergency response vehicles (ERVs) which provide paramedic services (PS) across the County.

Figure 4 shows the breakdown of the asset inventory by classifications of vehicles and major equipment types. The major equipment category includes a variety of construction equipment such as backhoes, compactors, dozers, graders, loaders as well as tractors.

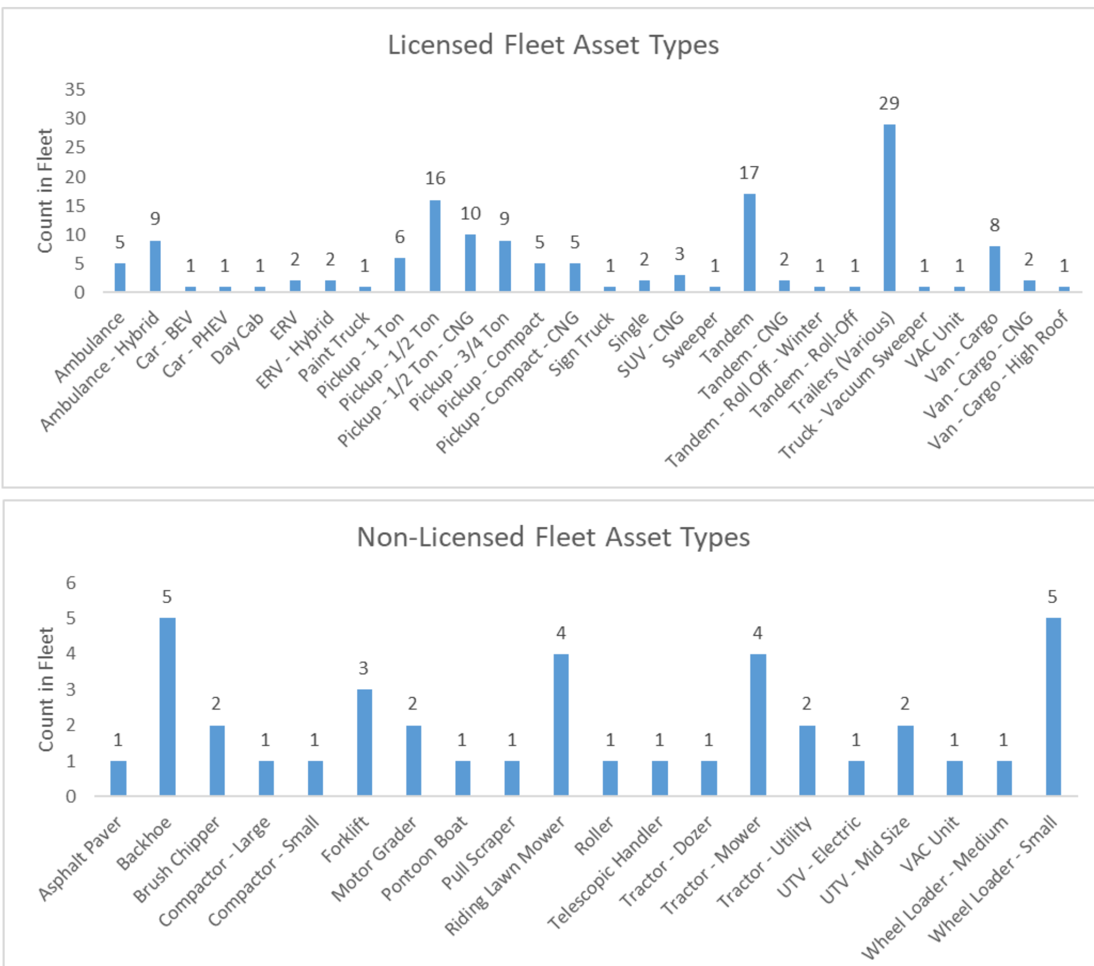
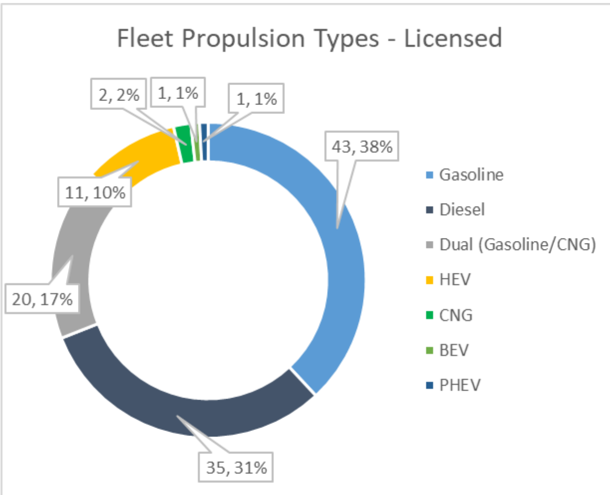


Figure 4 Oxford County Fleet Asset Inventory

The 5-year Green Fleet Plan focuses on GHG emission reduction strategies for the fleet. Assets without any fuel consumption (i.e. utility trailers) are excluded from the scope of this study. Oxford County has already started integration of several alternative propulsion technologies for vehicles in their fleet in order to reduce GHG emissions. The composition of the fleet by fuel types according to the vehicle and equipment count is shown in Figure 5.



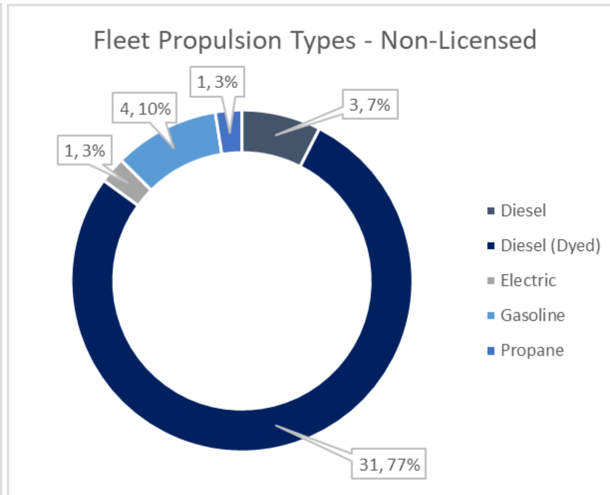


Figure 5 Oxford County Fleet Fuel Types

Oxford County has a sizable fleet of compressed natural gas (CNG) vehicles. In 2017, the County was the first Canadian municipality to bring CNG snowplows into service and in 2017 began upfitting the Public Works fleet with dual fuel CNG/gasoline powered pickups and vans.

The Public Works fleet also includes a Chevrolet Volt plug-in hybrid electric vehicle (PHEV) and a Chevrolet Bolt as a fully battery electric vehicle (BEV). In 2017, Oxford County was the first municipality in Canada to introduce gas-hybrid ambulances into service through a partnership with Crestline Coach and XL Fleet.

The major equipment is mainly fueled with diesel (clear and dyed) from on-site fueling tanks at Public Works yards owned by Oxford County. Gasoline powered equipment includes ride-on lawn tractors and all-terrain vehicles (ATVs). There is also one propane powered forklift in the asset inventory.

There are a variety of user groups which utilize this inventory of vehicles and equipment to deliver services for the County. Figure 6 shows the fleet allocation to each municipal user group and a brief overview of each fleet is included in Table 2.

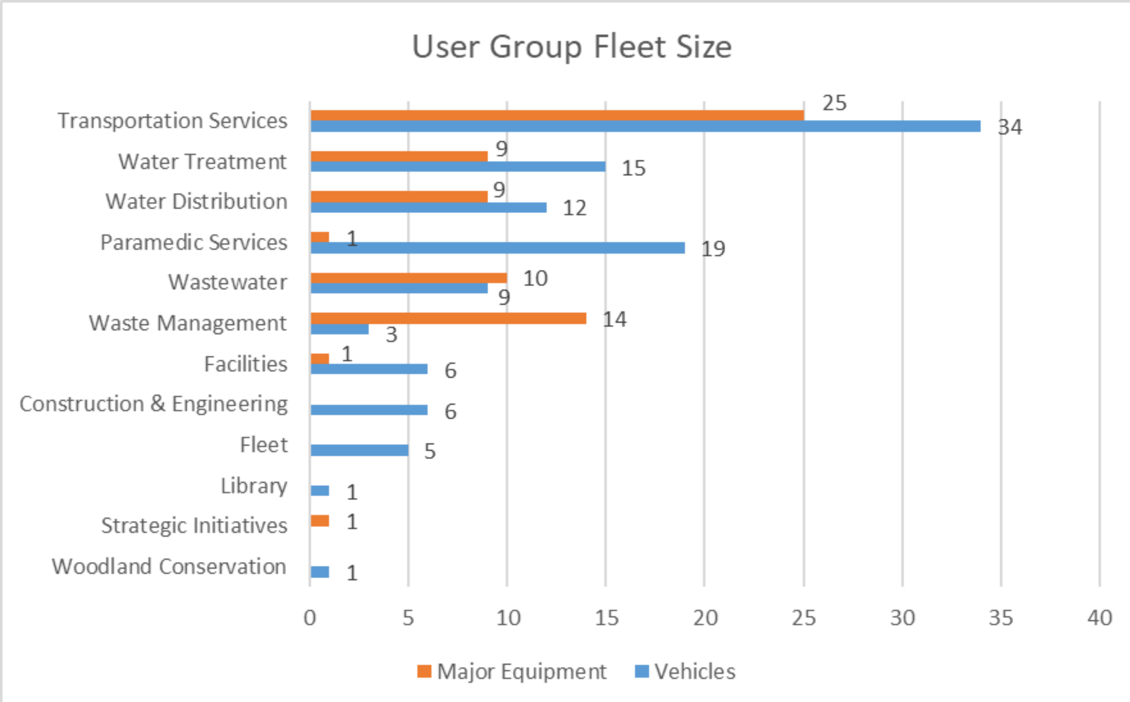


Figure 6 Oxford County Fleet User Groups

Table 2 Summary of User Group Fleets

User Group	Fleet Description
Transportation Services	• (9x) ½ ton and 1 ton pickup trucks (gasoline) • (3x) ½ ton and 1 ton pickup trucks (CNG/gasoline dual fuel) • (17x) tandem HD trucks (diesel) • (2x) Freightliner 114SD tandem snowplow trucks (CNG) • Freightliner M2 vacuum HD truck, Freightliner M2 paint and Ford F550 sign truck (diesel) • Various diesel major equipment
Water Treatment	• Sterling STE single axle truck (diesel) • (2x) Chevrolet Silverado 2500 pickup trucks (gasoline) • Mercedes Sprinter cargo van (diesel) • Chevrolet Express cargo van (CNG/gasoline dual fuel) • (3x) pickup trucks (CNG/gasoline dual fuel) • (7x) pickup trucks (gasoline) • (4x) John Deere wheel loaders (diesel)
Water Distribution	• International WorkStar 7600 tandem truck and Sterling L8513 single axle truck (diesel) • Chevrolet Equinox SUV (CNG/gasoline dual fuel) • RAM Promaster and Chevrolet Express cargo vans (gasoline) • (7x) pickup trucks (gasoline) • John Deere backhoe and Vermeer vac unit diesel major equipment
Paramedic Services	• Chevrolet Express cargo van (gasoline) • (9x) gas-hybrid ambulances Crestline (Chevrolet chassis)

User Group	Fleet Description
	• (5x) ambulances Crestline (Chevrolet chassis) • (4x) ERVs including Ford F250 pickup (hybrid), Chevrolet Silverado and Tahoe pickups (gasoline) and Toyota RAV4 (hybrid)
Wastewater	• Chevrolet Express cargo van (gasoline) • Freightliner tandem roll-off (diesel) • International WorkStar 7600 HD truck (diesel) • Chevrolet Silverado pickup truck (CNG/gasoline dual fuel) • (4x) Chevrolet Silverado 1500 and one (1x) 2500 pickup truck (gasoline)
Waste Management	• (1x) Freightliner day cab truck (diesel) • (2x) pickup trucks (gasoline) • (3x) John Deere ATVs (gas) • Various diesel major equipment (i.e. compactors, loaders and scraper)
Facilities	• Chevrolet Express cargo van (CNG/gasoline dual fuel) • Mercedes Sprinter cargo van (diesel) • One gasoline pickup truck, three (3x) CNG/gasoline dual fuel pickups
Construction & Engineering	• Chevrolet Equinox SUV (CNG/gasoline dual fuel) • (3x) pickup trucks (CNG/gasoline dual fuel) • (2x) pickup trucks (gasoline)
Fleet	• Chevrolet VOLT (PHEV) and Chevrolet BOLT (BEV) cars • Chevrolet Equinox SUV, Chevrolet Colorado pickup and RAM 1500 (all CNG/gasoline dual fuel)
Library	• Ford Transit van (gasoline)
Woodland Conservation	• Dodge RAM 1500 pickup (gasoline)

2.2 FLEET ASSET MANAGEMENT PLAN

Oxford County currently uses several systems including the Cartegraph work order management software system to track fleet data. CityWide is used to plan for asset management, including lifecycle replacements. Table 3 and Table 4 present the estimated useful life of fleet assets for licensed asset types and non-licensed asset types, respectively.

Table 3 Licensed Fleet Assets: Useful Life, Replacement Budget and Salvage Value

Asset	Useful Life	Proposed Replacement Budget	Salvage Value[4]
Cars (including PHEV and BEV)	5 years	$45,000	$3,000
Compact Pickup Trucks	5 years	$35,000 $45,000 (with CNG)	$3,000
½ ton Pickup Trucks	5 years	$45,000 $55,000 (with CNG)	$3,000
¾ ton Pickup Trucks	5 years	$47,000 $57,000 (with CNG)	$3,000

[4] Estimated salvage value provided by Oxford County Energy & Fleet Management.

Asset	Useful Life	Proposed Replacement Budget	Salvage Value[4]
1 ton Pickup Trucks	5 years	$70,000	$3,500
SUVs	6 years	$35,000 $48,000 (with CNG)	$3,000
Cargo Vans	6 years	$45,000 $55,000 (with CNG)	$3,000
ERVs (including hybrids)	6 years	$100,000 to $130,000	$9,000
Ambulances	6 years (325,000 to 350,000 km)	$186,000 (includes hybrid drivetrain and rooftop solar)	$9,000 $12,000 (hybrid)
Sign Truck	9 years	$150,000	$10,000
Single Axle	9 years	$280,000	$10,000
Day Cab Truck	10 years	$130,000	$10,000
Vac Truck	10 years	$240,000	$10,000
Sweeper Truck	10 years	$335,000	$10,000
Tandem Truck	9 years	$330,000 $380,000 (with CNG)	$35,000 (with plow)
Tandem Roll-Off	10 years	$250,000	$25,000
Tandem - Roll Off - Winter	9 years	$400,000	$35,000 (with plow)
Paint Truck	20 years	$400,000	$10,000

Table 4 Non-Licensed Fleet Assets: Useful Life, Replacement Budget and Salvage Value

Asset	Useful Life	Proposed Replacement Budget	Salvage Value[2]
ATV/UTV	5 years	$15,000 $17,000 (electric)	N/A
Riding Mower	15 years	$5,000	N/A
Tractor – Mower/Utility	10 years	$130,000	$20,000
Asphalt Paver	10 years	$130,000	$20,000
Roller	10 years	$75,000	$20,000
Pull Scraper	10 years	$130,000	$20,000
Compactor	10 years	$1,000,000 (small) $1,300,000 (large)	$100,000
Wheel Loader	15 years	$300,000 (small) $350,000 (medium)	$20,000
Dozer/Grader Tractor	20 years	$700,000	$20,000
Backhoe	20 years	$160,000	$20,000
Motor Grader	20 years	$330,000	$20,000

In addition to age, other factors to help prioritize replacement needs. A Vehicle Replacement Rating (VRR) is calculated annually for fleet assets with a weighted average formula based on the following factors:

1. Age (years)
2. Usage (cumulative mileage or hours)
3. Maintenance & Repair (cumulative maintenance cost relative to asset purchase cost)
4. Reliability (in-service versus out of service dates due to repair needs)
5. Condition

Oxford County has developed a capital replacement program for fleet vehicles and major equipment. Table 5 below lists the replacement counts by asset types, representative make/models of the assets being replaced, as well as the replacement budget. The replacement counts and proposed budget are also shown graphically in Figure 7.

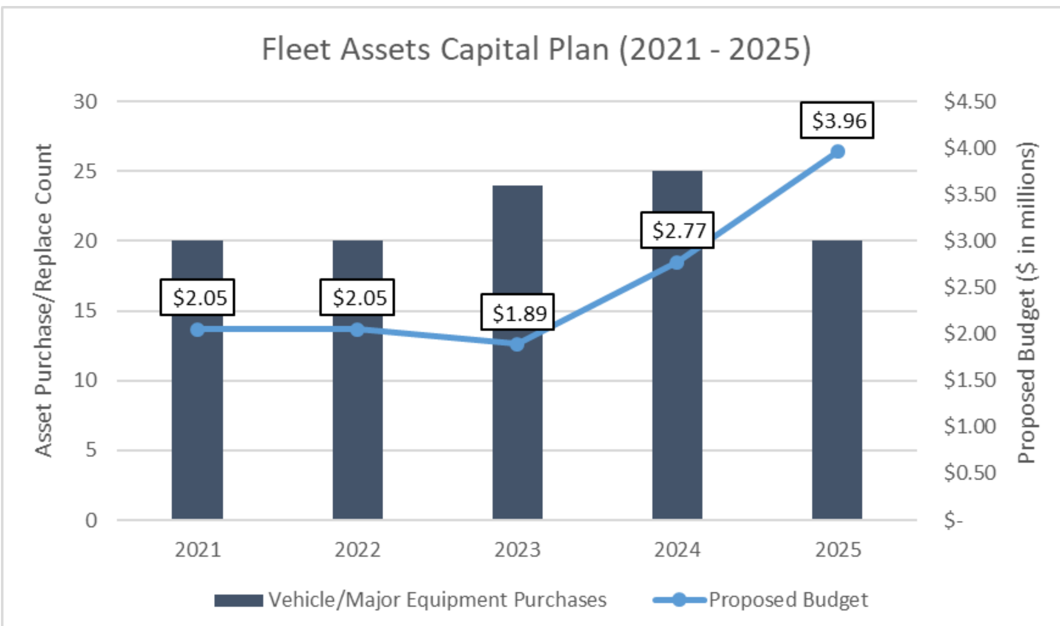


Figure 7 Fleet Assets Capital Plan (2021 – 2025)[5]

[5] Capital Replacement Plan as of 2020 year end

Table 5 Capital Replacement Program (2021 – 2025)

Vehicle Type	Total Purchase and Replace Count	2021 Count	2022 Count	2023 Count	2024 Count	2025 Count	Proposed Budget Total ($)
Ambulance	12	3	2	2	2	3	$ 2,232,000
Car	2			2			$ 90,000
Compactor - Small	1					1	$ 1,000,000
Day Cab	1		1				$ 130,000
ERV	3		1	1	1		$ 445,000
Paint Truck	1					1	$ 400,000
Pickup - Compact	10	5		3	2		$ 390,000
Pickup - 1/2 Ton	26	2	9	6	7	2	$ 1,274,000
Pickup - 3/4 Ton	9	2			3	4	$ 421,000
Pickup - 1 Ton	6		5	1			$ 420,000
Riding Lawn Mower	1					1	$ 5,000
Sign Truck	1					1	$ 150,000
Single	2					2	$ 560,000
SUV	3			2	1		$ 144,000
Tandem	9	3	2	1	1	2	$ 2,850,000
Tractor - Dozer	1				1		$ 700,000
Tractor - Mower	4	1			2	1	$ 520,000
Trailer	1	1					$ 10,500
Truck - Vacuum Sweeper	1				1		$ 240,000
UTV	3			1	2		$ 58,000
VAC Unit	2			1		1	$ 340,000
Van - Cargo	10	3		4	2	1	$ 461,000
Total	**109**	**20**	**20**	**24**	**25**	**20**	**$ 12,840,500**

Note that one hybrid ERV to replace Asset 1317 has already been purchased in 2020 but has yet to be received. In addition, one cargo van in 2021 is being purchased as an expansion fleet vehicle for a new staff. Oxford County Council has approved the budget for all 2021 fleet acquisitions through the 2021 Business Plan and Budget.

This schedule demonstrates that the majority of vehicle types being replaced over the next 5-years are light and medium-duty pickup trucks. Therefore, Oxford County should focus on evaluating green vehicle options which offer improved fuel economy for this class of vehicles. There are also a number of heavy-duty diesel trucks that will be up for replacement during this time period and can be assessed for more fuel efficient alternatives.

For the Paramedic Services fleet there is also a steady replacement cycle of two (2) to three (3) ambulances per year. The ambulance fleet is highly utilized and could therefore contribute to a notable emissions reduction for the overall fleet if fuel efficient systems are continually integrated for the fleet (i.e. rooftop solar, anti-idle technology, and hybrid drivetrains).

2.3 FLEET FACILITIES & MAINTENANCE PRACTICES

2.3.1 STAFF TRAINING & CERTIFICATIONS

Oxford County does not employ fleet maintenance technicians to manage preventative maintenance or corrective repairs for their fleet. All fleet maintenance and repair are done via local original equipment manufacturer (OEM) dealerships and repair shops.

Schulz Automotive, a local automotive shop located in Tavistock, ON has up-fitted the dual CNG/gasoline fuel systems for the passenger CNG vehicles in Oxford County's fleet. All maintenance and repair of this CNG fleet is managed through this shop.

With Oxford County's current setup of fleet sites used primarily for refueling and on-site parking it is unlikely that fleet maintenance work will be brought in-house within the timeframe of this 5-year Green Fleet Plan. Provisions would need to be made to further outfit on-site fleet maintenance shops and licensed mechanics would need to be hired. Therefore, rather than considering the skills gap, training and certifications for fleet maintenance on alternative propulsion technologies it will be more important to assess the capabilities of local shops to service such green vehicles.

Should Oxford County look to hire 310T diesel mechanics or 310S automotive mechanics licensed under the Ontario College of Trades they would also need to be aware of the specific safety training requirements for maintenance on alternative propulsion vehicles. For information purposes, Section 4.5 does provide an overview of safety, tools, and training for servicing alternative propulsion vehicles including CNG, battery electric, and hydrogen.

2.3.2 OVERVIEW OF FACILITIES

The following sections share an overview of Oxford County's sites which support their fleet operations. Most sites have a mix of indoor and outdoor vehicle storage including for CNG vehicles.

2.3.2.1 TRANSPORTATION SERVICES

The Road Operations user group operates out of four different yards located around Oxford County. Each site has a garage with overhead doors and parking bays. As listed in some indoor parking bays are reserved for Paramedic Services which have an ambulance station on-site. The remainder of indoor vehicle storage is prioritized for winter operations (i.e. snowplows) during winter months.

Table 6 lists the addresses of the Road yards and a brief description of what is located on-site. Each yard has their own on-site fueling stations for diesel, dyed-diesel and gasoline. Currently, no bio-diesel blends are used for fueling.

Table 6 Roads Supporting Fleet Sites

Facility Name	Address	Site Elements/Functions	Indoor Storage
Drumbo Patrol Yard	895939 Road 3, Drumbo, ON	Roads Patrol Yard with Shop, Salt Shed, Sand Dome and fueling station	Six (6) parking bays One bay dedicated to PS
Highland Patrol Yard	884135 Road 88, Embro, ON	Roads Patrol Yard with Shop, Salt Sheds, Sand Dome, Storage Barn and fueling station	Eight (8) parking bays One bay dedicated to PS
Springford Patrol Yard	432594 Zenda Line, Otterville, ON	Roads Patrol Yard with Sign Shop, Storage Sheds, Salt Shed, Sand Dome and fueling station	Eight (8) parking bays
Woodstock Patrol Yard	515165 11th Line, Woodstock, ON	Roads Patrol Yard with Main Building, Sign Shed, Storage Shed, Salt Shed, Sand Dome and fueling station	Four (4) parking bays

The fleet mix assigned to these yards include mostly pickup trucks including three (3) dual CNG/gasoline Ram 1500 pickups. There is also a diesel sign truck, paint truck and vac truck along with heavy-duty diesel construction equipment and tractors. The CNG pickup trucks are the most practical to be assigned to the Woodstock Patrol Yard due to the site's proximity to the Rural Green Energy CNG fueling station in Woodstock.

2.3.2.2 *WATER & WASTEWATER SERVICES*

The fleet of Water and Wastewater services are distributed to the various sites and shops listed in Table 7. This includes water treatment and distribution sites. Both fleets consist primarily of light-duty vans, pickups used as passenger vehicles to drive to sites.

The Wastewater group also has a vacuum truck and a tandem roll-off bin truck which is used to collect bio-solids. Wastewater recently instated a "right-sizing" initiative to replace three smaller dump trucks with one larger roll-off dump truck which can manage all bio-solids pickup in a more efficient single route, thereby reducing fleet kilometers travelled.

Table 7 Water and Wastewater Services Supporting Fleet Sites

Facility Name	Address	Site Elements/Functions
Ingersoll Wastewater Treatment Plant	56 McKeand Street, Ingersoll, ON	Blower Building, Control Buildings, Pumping Stations, Sludge Dewatering and Digesters
Tillsonburg Wastewater Treatment Plant	19 Van Street, Tillsonburg, ON	Blower Building, Control Buildings, Pumping Stations, Sludge Dewatering, Digesters and Storage Garages
Woodstock Wastewater Treatment Plant	195 Admiral Street, Woodstock, ON	Sewage Treatment Station, Biosolids, Blower Buildings, Pumping Stations, Sludge Dewatering and Digesters
Water Operations Centre	59 George Johnson Boulevard, Ingersoll, ON	Maintenance Shop and fueling station
Southside Water Treatment Facility	219 Victoria Street South, Woodstock, ON	Pumping Station, Storage Shed and Well

Vehicles return to base and are parked back at their respective shop each day. Each foreman has their own vehicle assigned or maintenance truck which is assigned to staff based on the scope of site work to be done.

2.3.2.3 *WASTE MANAGEMENT SERVICES*

Fleet assigned to Oxford County's Waste Management user group operate primarily from the County landfill at 384060 Salford Road. This site includes a waste transfer station, trailer office, administration building, storage sheds, fueling station, and a workshop. Vehicles and assortment of major equipment assets assigned to this site include the Freightliner M2 Day Cab diesel truck used for waste collection and two light-duty pickup trucks.

2.3.2.4 *PARAMEDIC SERVICES*

The Paramedic Services fleet of ambulances and emergency response vehicles (ERVs) are managed from the PS headquarters located at 377 Mill St. This site includes administrative offices, vehicle garage, and dispatching centre. In addition, the Drumbo, Highland and Springford Patrol Yards also serve as PS stations.

Table 8 Paramedic Services Supporting Fleet Sites

Facility Name	Address	Site Elements/Functions
Station 0 - Woodstock West & Administration	377 Mill Street, Woodstock, ON	PS administration, PS Station - 4 bays, Offices, and Dispatch
Station 1 - Woodstock East	208 Bysham Park, Woodstock, ON	PS Station - 2 bays
Station 2 - Ingersoll	162 Carnegie Street, Ingersoll, ON	PS Station - 2 bays
Station 3 - Tillsonburg	81 King Street, Tillsonburg, ON	PS Station - 4 bays
Station 4 - Norwich	6 Tidey Street, Norwich, ON	PS Station - 2 bays
Station 5 - Drumbo	895939 Road 3, Drumbo, ON	PS Station - 1 bay
Station 6 - Embro	884135 Road 8, Embro, ON	PS Station - 1 bay

2.3.2.5 *ENGINEERING SERVICES*

Oxford County's main administrative building is located at 21 Reeve Street. This location has an outdoor parking lot for employee and visitor parking. There is also a charging station installed for the County's Chevrolet Bolt and Chevrolet Volt vehicles in the basement parking area. There are also two Level 2 charging stations in the parking lot. The fleet assigned to Engineering Services includes light-duty gasoline and CNG/gasoline pickup trucks as well as a small fleet of cargo vans.

Table 9 Engineering Services Supporting Fleet Sites

Facility Name	Address	Site Elements/Functions
Oxford County Administration Building	21 Reeve Street, Woodstock, ON	Admin Building/Offices

2.3.2.6 *PROPOSED CNG FUEL STATION*

Oxford County is currently evaluating the business case for installation of their own slow fill CNG fueling station at the Water Operations Centre, located at 59 George Johnson Boulevard.

Figure 8 Aerial of CNG Fueling Station Proposed Site

The specifications for this station are proposed as follows.

- Ten (10) slow fill fueling nozzles
- Vehicle nominal fill pressure of 3,600 psig
- Two (2) Coltri MCH 14 compressors with 1st stage (90 psig), 2nd stage (325 psig) and 3rd stage (830 psig)
- 1,000 L for on-site storage
- Estimated capital cost $275,000

This 5-year Green Fleet Plan will supplement the business case for this fueling station by evaluating further options for CNG vehicles in the Public Works fleet and determining if there will be a sufficient demand for CNG fuel to make a return on investment (ROI) for the station as well to determine if CNG fuel use and its emissions reduction align with the green fleet strategy over the longer term (reference Section 6.2.11). The main target is to use vehicles stationed at the Water Operations Centre and Ingersoll Wastewater Treatment Plant. If the County were to proceed, they would also consult local area municipalities, particularly Town of Ingersoll and Township of Zorra based on their proximity to the proposed site.

Oxford County currently refuels the fleet of CNG snowplows and dual fuel CNG/gasoline vehicles at the Rural Green Energy fueling station located at 594676 Oxford Road 59 South of Woodstock. The proximity of this station to Oxford County's yards and common working sites can result in additional kilometers for vehicles to travel to/from Woodstock for refueling. Table

10 shows the approximate distance between the CNG fuel station and several of Oxford County's sites for Roads and Water/Wastewater fleets where vehicles are stationed.

The Southside Water Treatment Facility, Woodstock Wastewater Treatment Plant, Woodstock Patrol Yard and Oxford County Administration Building are the closest to the CNG station and thereby take priority for assignment of any CNG vehicles so as not to accumulate additional fleet kilometers traveling to/from the station.

Table 10 Proximity of Rural Green Energy CNG Station

Facility Name	Address	Distance to CNG Fuel Station
Southside Water Treatment Facility	219 Victoria Street South, Woodstock, ON	5 km
Woodstock Wastewater Treatment Plant	195 Admiral Street, Woodstock, ON	9 km
Woodstock Patrol Yard	515165 11th Line, Woodstock, ON	10 km
Ingersoll Wastewater Treatment Plant	56 McKeand Street, Ingersoll, ON	22 km
George Johnson Water Operations	59 George Johnson Boulevard, Ingersoll, ON	22 km
Springford Patrol Yard	432594 Zenda Line, Otterville, ON	25 km
Drumbo Patrol Yard	895939 Oxford Road 3, Drumbo, ON	26 km
Highland Patrol Yard	884135 Road 88, Embro, ON	32 km
Tillsonburg Wastewater Treatment Plant	19 Van Street	35 km

2.4 ENVIRONMENTAL INITIATIVES & ACHIEVEMENTS

To align with Oxford County's broader environmental initiatives set forth working towards 100% usage of renewable energy by 2050, Oxford County has established a set of milestone GHG reduction targets for their fleet. Table 11 lists Oxford County's GHG reduction targets, scheduled into 5-year milestones and relative to the baseline set in 2015 for emissions[6]. In 2015, total fleet emissions are estimated at 2,239 tonnes CO_2e/year with Public Works accounting for 85% and Paramedic Services accounting for 15% of fleet emissions. To achieve the 2025 target Oxford County will have to make a reduction of **316 tonnes of CO_2e/year**.

Table 11 Oxford County GHG Reduction Targets

Year	GHG Emissions Reduction	GHG Reduction (tonnes CO_2e/year)	Target GHG Emissions (tonnes CO_2e/year)
2015	N/A	N/A	2,239
2020	3.2%	72	2,167
2025	14.1%	316	1,923

[6] Reference from Oxford County – Energy Management Plan (July 2019)

Year	GHG Emissions Reduction	GHG Reduction (tonnes CO_2e/year)	Target GHG Emissions (tonnes CO_2e/year)
2030	25.0%	560	1,679
2035	36.0%	806	1,433
2040	46.9%	1,050	1,189
2045	57.8%	1,294	945
2050	68.7%	1,538	701

Oxford County has already started making progress to achieving these targets.

Table 13 outlines how the fleet has been tracking against the emissions targets and overall fuel consumption over the past 5-years. The emissions profile is based on the annual fuel consumption with the emission factors applied from Table 12.

Table 12 Oxford County Fuel Emission Factors

Fuel Type	Emissions Factor	Units
Diesel	2.738	kg CO_2e per L
Gasoline	2.326	kg CO_2e per L
CNG	2.965	kg CO_2e per kg

Table 13 Historical Tracking of Fleet Emissions Profile

Group	Fuel Type	Unit	2015	2017	2018	2019	2020
PW	Gasoline	L	251,446	269,727	268,969	220,914	198,779
PW	Diesel (Regular)	L	322,329	295,030	287,979	284,931	220,879
PW	Diesel (Dyed)	L	160,431	154,026	156,675	168,035	180,759
PW	CNG	kg	-	8,744	34,964	34,883	31,247
PW	Tailpipe Emissions:	tonnes CO_2e/year	1,907	1,883	1,947	1,857	1,655
PS	Gasoline	L	18,853	13,165	40,787	73,487	50,643
PS	Diesel (Regular)	L	105,195	123,192	104,426	66,083	88,455
PS	Tailpipe Emissions:	tonnes CO_2e/year	332	368	381	352	345
Oxford County (PW+PS)	**Total Tailpipe Emissions:**	**tonnes CO_2e/year**	**2,239**	**2,251**	**2,328**	**2,209**	**2,000**

*Data quality from 2016 has limited availability due to a transition in fuel management systems. From 2017 onwards records are managed in the Cartegraph system. Data was referenced from Oxford County's 2019 Energy Management Plan and Paramedic Services annual fueling records.

Take note that fleet emissions were significantly lower in 2020 due to the COVID-19 pandemic. In 2019, the most recent year not impacted by the COVID-19 pandemic and with complete fueling records for both fleets, Public Works accounted for 84% of emissions while Paramedic Services produced the remaining 16%. Overall, the majority of fleet emissions is sourced from the Public Works fleet. Figure 9 illustrates the trend in fleet emissions based on data available between 2015 and 2020.

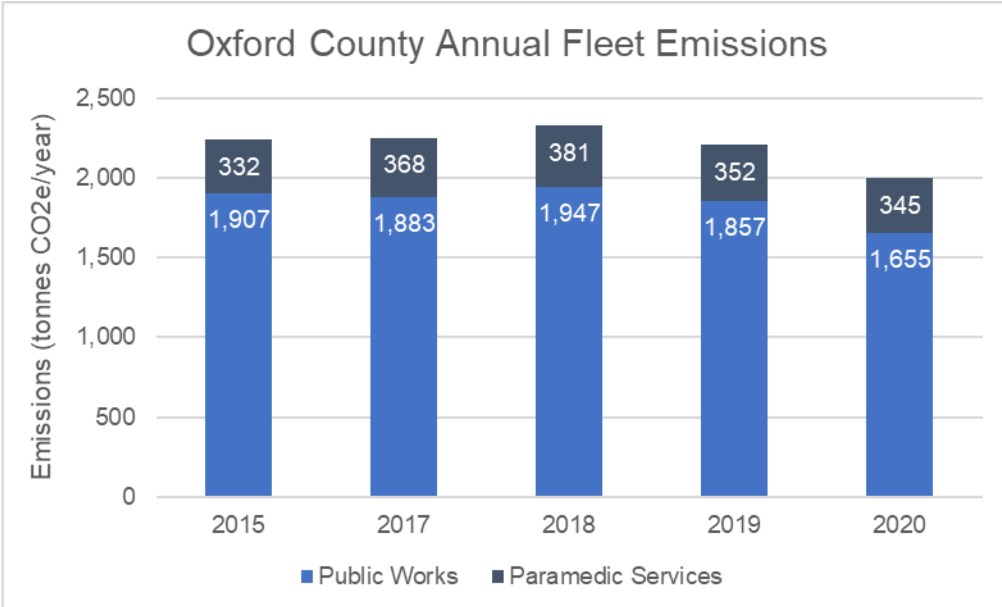


Figure 9 Oxford County Fleet Emissions Trend

Oxford County has already demonstrated a reduction of 30 tonnes of CO_2e/year by comparing 2019 to 2015 data. Furthermore, the emissions from the Public Works and Paramedic Services fleet has been trending downwards over recent years. Fleet emissions in 2020 is estimated at 2,200 tonnes CO_2e (using 2019 Public Works data as a proxy for 2020). Thereby, an estimated **40 tonnes CO_2e** has already been achieved, towards the next target in 2025.

Figure 10 shows the breakdown of 2019 fleet emissions of the Public Works fleet by vehicle type. The majority of fleet emissions can be attributed to the tandem trucks (34%), the pickup truck fleet (31%) and major equipment (25%).

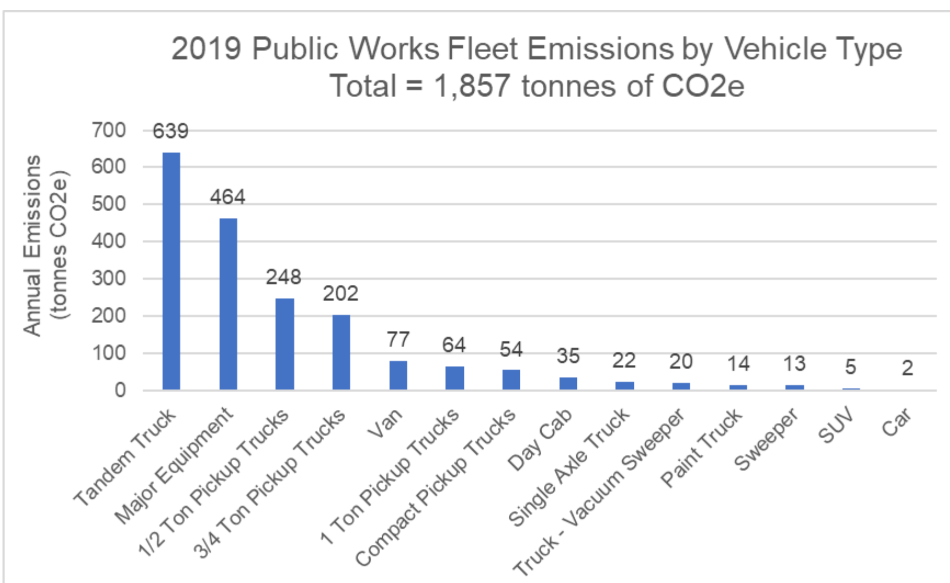


Figure 10 Public Works 2019 Fleet Emissions by Vehicle Type

Figure 11 shows fleet emissions by each user group. The largest contributor to annual emissions is Transportation Services (52%) due to their snowplows, heavy-duty diesel trucks and construction equipment.

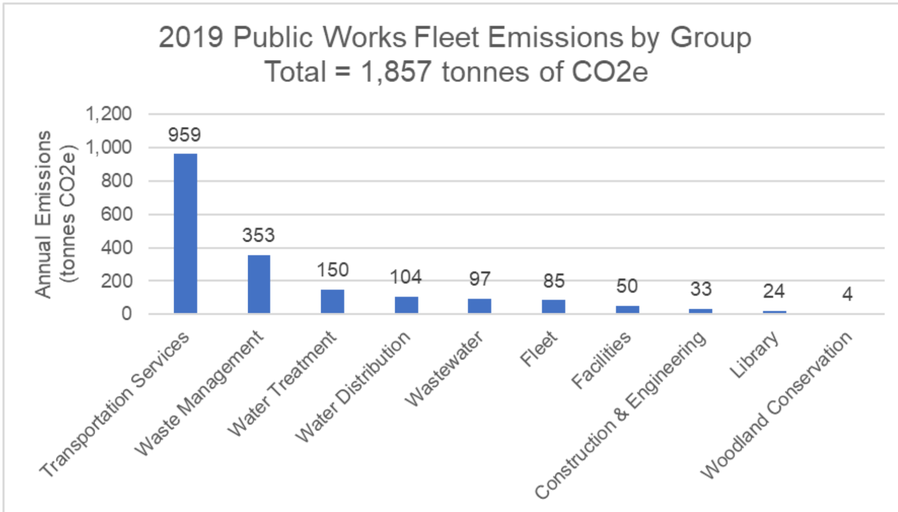


Figure 11 Public Works 2019 Fleet Emissions by User Group

Analyzing the breakdown of fleet emissions by these different groups and vehicles is important to understand some of the main drivers for overall fleet emissions and determine which can be targeted for more fuel efficient options or alternative fuels.

Some of the major changes that have occurred to Oxford County's fleet over the past 5-years as part of addressing environmental initiatives have been the introduction of CNG snowplows and dual fuel CNG/gasoline passenger vehicles in 2017 and 2018. As well, nine (9) gasoline hybrid ambulances and some hybrid ERVs have been introduced. A list of Oxford County's recent green fleet initiatives is included below.

Table 14 Oxford County Recent Green Fleet Initiatives

Implementation Year	Description of Initiative:
2016 - present	**Anti-Idling Ambulances –** Oxford County has implemented anti-idle technology in their ambulance fleet. The Eco-Run Anti-idling "Stop-start" shuts off the vehicle engine when the vehicle is stopped and in ideal operating conditions to save on fuel and idling emissions.
2017	**Passenger Hybrid and Battery Electric Vehicles –** Oxford County's Fleet division has one (1) Chevrolet Bolt as a fully battery electric vehicle (BEV) as well as one (1) Chevrolet Volt as a plug-in hybrid electric vehicle (PHEV).
2017	**CNG Snowplow Fleet** – The first implementation of CNG powered snowplows in a Canadian municipality. Public Works has two (2) upfitted Freightliner 114SD tandem trucks used for snowplowing and salt/sanding. The incremental capital cost for the CNG conversion was approximately $52,000 per vehicle minus an Ontario government incentive of $21,000 through the Green Commercial Vehicle Program for a net incremental cost of $31,000 per vehicle.

Implementation Year	Description of Initiative:
2017 - present	**Hybrid Ambulance Fleet –** The first implementation of gasoline-hybrid ambulances in Canada. Paramedic Services has nine (9) hybrid ambulances built by Crestline Coach on a Chevrolet 3500 chassis. These vehicles are non plug-in hybrids and recapture kinetic energy via braking to improve fuel economy. A hybrid drive system from XL Fleet is installed on these vehicles. The approximate cost of the hybrid drivetrain is $28,000.
2017 - present	**Rooftop Solar Units –** The installation of roof top solar panels for the nine (9) gas-hybrid ambulances currently in the fleet. These solar units help to power auxiliary electronic equipment needed in the ambulance and help reduce engine idling emissions that would otherwise power these systems. The approximate cost of the roof top solar system is $5,000 covering installation of two (2) panels and converter box.
2018	**Hybrid Pickup ERVs –** Paramedic Services has one Ford F250 pickup which has been outfitted with a hybrid drivetrain from XL Fleet and a Toyota Rav4 hybrid SUV. The non plug-in XL hybrid system offers the benefit of improved fuel economy through regenerative braking and acceleration assist. The cost of the hybrid drivetrain is approximately $28,000 per vehicle.
2017 - 2019	**Dual Fuel CNG/Gasoline Passenger Vehicles –** Public Works currently has a fleet of 20 upfitted CNG passenger vehicles. This fleet is distributed across all divisions of Public Works. The majority of CNG passenger vehicles have been introduced from 2017 to 2019. This fleet includes primarily light-duty pickup trucks as well as cargo vans and SUVs. The CNG fuel tanks and systems added to vehicles range from $9,000 to $13,000 depending on tank size.
2019	**Anti-Idling Technology –** Public Works has installed the GRIP anti-idling system on two diesel tandem trucks (Assets 362 and 367). This system shuts off the engine when the vehicle is left in park or in neutral and the power take-off (PTO) is not engaged.
2019 - present	**Fleet Utilization and Rationalization Implementation** - Oxford County underwent a significant review of its fleet in 2019 after postponing the acquisition of all passenger vehicles for the 2019 budget year. The review resulted in a number of changes, including, the removal of three tandem axles snowplows, six passenger vehicles, and three single axle trucks from the County's fleet. This review resulted in a 6.7% reduction of the County's overall fleet size. The County plans to continue the Fleet Utilization and Rationalization Review of all major equipment in 2022.
On-going	**Vehicle Right-Sizing –** Oxford County's Fleet Services has an on-going practice to review vehicle replacement needs for right-sizing opportunities. In addition, vehicle replacements are also assessed for CNG or electric vehicle options based on market availability. Oxford County has successfully "right-sized" several ¾ ton pickup trucks down to more fuel efficient ½ ton options to better suit their usage needs.

As part of this 5-year Green Fleet Plan it is important to engage for stakeholder and user feedback as well as analyze fleet data to help determine if there is a strong case for further rollout of these initiatives in the next phase of the Green Fleet Plan. The review of these initiatives is discussed further through the stakeholder feedback section of this report.

3 STAKEHOLDER ENGAGEMENT

3.1 PURPOSE

One of the key themes from consultations with Oxford County is that the strategic direction is for the fleet to achieve a 68.7% reduction in fleet GHG emissions relative to 2015 by 2050.

Recommendations of this 5-year Green Fleet Plan (2021 to 2025) should address the interim target of 14% reduction by 2025 and align to the ultimate goal of minimizing their dependence on fossil fuels over the long term to achieve the 2050 target.

As part of developing this Green Fleet Plan, staff from Oxford County were given the opportunity to provide feedback to help guide the direction of the plan. A survey was distributed to all extended management team members responsible for fleet assets. In addition, six groups were selected for a 30 minute interview. The six groups that provided feedback are:

1. Roads
2. Water
3. Wastewater
4. Paramedic Services
5. Asset Management
6. Energy Management & Fleet

Feedback was structured to identify key themes, these being:

1. Understanding the services provided from each user group and their operational demands for fleet vehicles.
2. Lessons learned from alternative fuel vehicles deployed to date (i.e. natural gas and hybrids).
3. Considerations for future green fleet adoption.

Feedback from the groups showed that staff hoped to see several benefits come out of the new Green Fleet Plan. These outcomes include:

1. A market scan of available vehicles and technologies,
2. A plan that allows the County to meet the emissions reduction target of 14%,
3. Adoption of reliable technology, piloting new vehicle technologies across user groups,
4. Appropriate right sizing of vehicles, and
5. Decision-making that considered whole-of-life costs, and support of options which balanced capital investments and operational cost savings.

The subsequent section summarizes the results of stakeholder feedback related to the green fleet, highlighting common themes documented during interviews, from correspondence, and from the online questionnaire.

3.2 STAKEHOLDER FEEDBACK

3.2.1 EXPERIENCES WITH CURRENT GREEN FLEET

Interviews with Roads, Asset Management, Water and Wastewater, and Paramedic Services yielded the following feedback related to the current green fleet initiatives.

3.2.1.1 *VEHICLE OPERATION*

The groups provided considerable feedback about experiences with operation of vehicles in the current green fleet, highlighting challenges that users have experienced:

- Light Duty dual fuel CNG/Gas vehicles have stalled during operation, creating a safety concern when turning into oncoming traffic and proceeding through intersections.
- The CNG fuel tank takes up valuable space in the truck bed, limiting storage capacity and utility of the space.
- Users have noted that the CNG fuel system has been known to freeze up during the winter.
- Mileage from a CNG tank on light-duty vehicles is considered low, most vehicles get less than 200 km on a full tank.
- The warranty on CNG vehicles is voided by the vehicle manufacturer on light-duty vehicles because the engine has been modified as an aftermarket conversion. This comment does not apply to the two CNG snowplows.
- Cold weather has impacted the range performance of the County's PHEV and BEV cars. In one instance the Chevrolet Bolt BEV was required to be towed back to the charging station during a cold snap.
- The experience has generally been positive with the XL Fleet hybrid systems. Hybrids are non-invasive in the sense that they do not need to be plugged in. The hybrid battery charges while driving via regenerative braking. Therefore, there are no delays in service due to vehicle charging, and vehicles can operate across a wide geographical area without need to plan logistics for visiting EV charging stations. Paramedic Services anticipates that, by the end of 2021, the group will have twelve (12) ambulances and three (3) emergency response vehicles (ERVs) that have been transitioned to hybrid powertrains.

3.2.1.2 *FUELING SOURCES*

Only one CNG fuel station is in proximity, located in Woodstock, causing logistical challenges for refueling (refer to Table 10 which lists the proximity of this fueling station to Oxford County sites). There are eleven (11) light-duty vehicles (i.e. pickup trucks and cargo vans) and four (4) heavy-duty tandem trucks at sites within 10 kilometers of this CNG fueling station (i.e. Woodstock Patrol Yard, Southside Water Treatment Facility and Woodstock Wastewater Treatment Plan). In addition, the following challenges were documented related to fueling:

- Considerable time is required to refuel. For example, if a vehicle is located at the southern edge of the county and needs to refuel, return travel time could be an hour or more.
- County services may be impacted if CNG pumps at the station are not functioning, or if there is a loss of power at the station.

For electric vehicles, both the PHEV and BEV cars have dedicated Level 2 EV chargers located in the basement of the County's administration building along with a network of charging stations located in Woodstock, Thamesford, Ingersoll, and Tillsonburg.

- Refueling has not been an issue for the hybrids in the PS fleet, as the hybrid are non plug-in and the battery can recharge during operation with regenerative braking.
- There is a rooftop solar panel system installed on the ambulances, which is used to charge auxiliary batteries. The system is not tied into the hybrid system for propulsion.

3.2.1.3 *MAINTENANCE & REPAIR*

Availability of repair shops was discussed, with users noting that repair facilities are generally limited. One facility located in Tavistock typically works on light-duty vehicles for the County, and a facility in London or Cambridge typically works on the tandem trucks and completes major repairs. In addition, there is a location in Woodstock for non-warranty repair work. There are only one or two qualified technicians available at either the London or Cambridge locations, but there have generally not been issues with quality of work or turn-around times.

It was noted by users that for passenger vehicles the distance of Tavsitock from fleet operations has created some challenges because travel to the repair facility requires a second vehicle and staff member for the return trip; leading to lost time travelling outside the City.

There have been no significant repairs required for the XL hybrid systems. Historically, minimal hybrid specific maintenance has been required. In cases when there is an issue, XL Fleet is capable of remote login to check diagnostics on the hybrid system. XL Fleet sends spare parts and repair instructions to Paramedic Services as needed.

Due to their reliability needs, ambulances and ERVs are maintained to a higher standard than typical fleet vehicles. They need to be able to respond to emergency calls, hospital visits, meetings, logistics and delivery of supplies.

3.2.1.4 *GREEN INITIATIVES FEEDBACK*

Users provided feedback regarding "green" initiatives that they felt have been successful, and those that could be improved upon. Changing driver behaviour by enacting an anti-idle policy was deemed to have worked well by most respondents, and many felt that CNG light-duty vehicle adoption has not yet met expectations.

3.2.2 CONSIDERATIONS FOR FUTURE GREEN FLEET ADOPTION

Green fleet users provided substantial feedback about key considerations for future green fleet adoption and the pros and cons of existing propulsion types.

- Vehicle operating range must be sufficient for daily travel and work requirements.
- The cost of the fleet transitioning to a new propulsion type is important. Increased capital investment should be offset by operational savings over the vehicle's lifecycle.

- Determine the availability of service stations, fueling infrastructure, and availability of vehicle parts.
- Review if annual contribution to the replacement reserve must be increased, and if that adjustment is sustainable for the existing reserve balance to handle the increased costs, or if additional charges would need to be assessed to departments.
- It was noted that there is a perception that the light vehicle market is moving to BEVs, and that CNG may be a short-term solution before transitioning to another technology.
- Users commented that, for the tandem trucks, if CNG remained an option, then fuel tank capacity should be increased to allow working through a shift without refueling. Additionally, the transmission could be changed to better harness the engine's power band for plowing and fuel economy.
- For heavy-duty vehicles, most users felt that hydrogen fuel cell vehicles are the most promising propulsion type.
- For light-duty vehicles, most users felt that PHEVs or BEVs are the most promising propulsion types.
- There are a limited number of vendors for ambulances and PS vehicles, due to strict ministry requirements to ensure reliability and specifications of vehicles.
- There can be difficulty with installing aftermarket add-ons. If weight is added to the vehicle, then it must pass through a new certification process.
- Reliability and repair turnaround time must be a priority. There cannot be on-call failure of ambulances or ERVs.

Users were questioned by an online survey about whether they felt each propulsion type would be a short-term or long-term solution in meeting GHG reduction targets (Table 15). In the Public Works group, most respondents felt that BEVs would be the most important propulsion type in the long-term. In the short-term most believed that PHEVs would be the most appropriate technology.

Paramedic Services provided feedback during interviews regarding perception of the role that various propulsion types may play in the short-term and the long-term. Hybrid vehicles are considered a reliable short-term solution before transition in the long-term to BEV technology that can meet the strict reliability standards of emergency response needs.

With a goal of reducing fleet emissions to zero, the vision from Paramedic Services is to set an example for the use of alternative propulsion systems to other municipalities; ultimately achieving this through adoption of BEV technology when it becomes cost effective and reliable.

Table 15 Role of Propulsion Types in Meeting GHG Reduction Targets

Propulsion Type	Role in GHG Reduction Objectives
Natural Gas (CNG)	Short-term role
Bio-diesel	Long-term role
Plug-in / Hybrid Electric Vehicles (PHEVs)	Short-term role

Propulsion Type	Role in GHG Reduction Objectives
Battery Electric Vehicles (BEVs)	Long-term role
Hydrogen Fuel Cell Electric Vehicles (FCEVs)	Long-term role

Public Works and Paramedic Services users provided feedback about their perception of each propulsion type as it relates to reducing GHG emissions, and the pros and cons of each. It was noted that cost of the new technology is important.

Table 16 User Perception of Propulsion Types

Propulsion Type	Pros	Cons
Hybrid (HEVs) and Plug-in Hybrid Electric Vehicles (PHEVs)	• Good fuel economy • HEVs can be charged anywhere, do not need specialized charging station infrastructure. • Likely the easiest propulsion type to transition to for Public Works from business and operations continuity. • Paramedic Services does not require additional investment in infrastructure for HEVs. Theses vehicles can be deployed to any location without need of planning for refueling.	• Potential capital cost • Time required for recharging the battery • Charging infrastructure is required for PHEVs.
Battery Electric Vehicles (BEVs)	• Excellent fuel economy • Quiet operation • Paramedic Services: BEVs considered to be the most viable long-term solution to achieving zero fleet emissions.	• Time required for recharging the battery • Uncertainties about battery life under higher loadings (i.e. auxiliary equipment running off the battery) • For Public Works, possibly the most difficult propulsion type to transition to from a business and operations continuity perspective. • Paramedic Services requires significant investment in charging infrastructure at all bases to ensure there is no service disruption due to lack of refueling locations. May require additional spare vehicles or a method to reliably swap out empty batteries with fully charged in order to maintain responsiveness.
Hydrogen Fuel Cell (FCEVs)	• Do not produce emissions, only water vapour	• High price of the technology • A lack of existing fueling stations
Natural Gas (CNG)	• The technology is available now	• Fuel tanks take up additional space • Reduced engine power • A limited number of fueling stations

Propulsion Type	Pros	Cons
Bio-diesel	• Fuel produced from renewable feedstock which absorbs CO_2 thereby lowering upstream emissions in fuel production • Benefits the environment compared to conventional diesel production	• Supply shortages may be possible

4 ALTERNATIVE PROPULSION TECHNOLOGY OVERVIEW

4.1 BIO-DIESEL AND RENEWABLE DIESEL

4.1.1 BIO-DIESEL

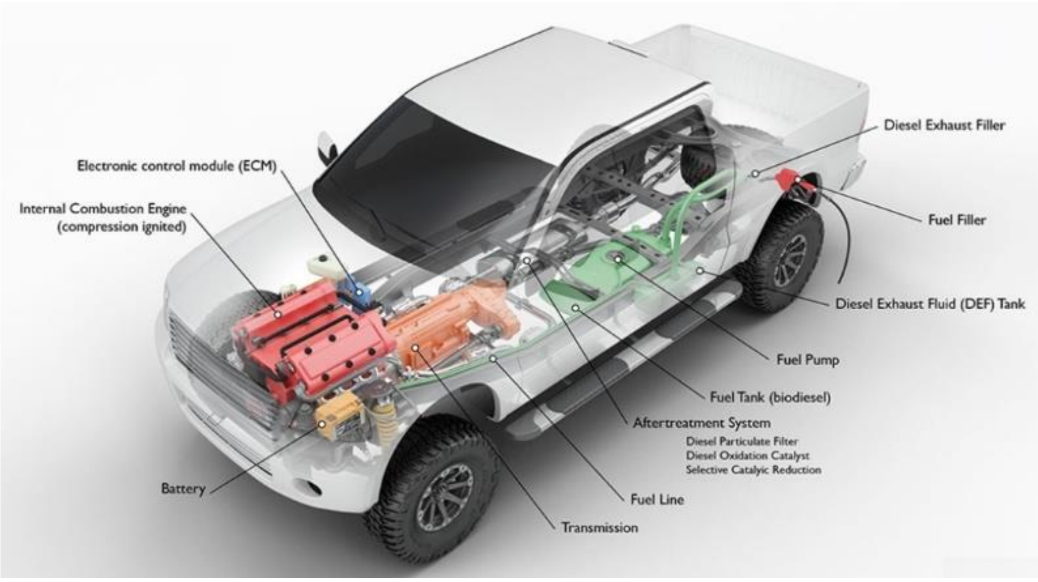


Figure 12 Bio-diesel Vehicle Components

Bio-diesel is a substitute for diesel fuel that has the potential to reduce GHG emissions. Bio-diesel is produced from renewable feedstock vegetable oils such as soy and corn. As the feedstock grows it absorbs carbon dioxide from the atmosphere thereby reducing upstream emissions contributed to the production of the diesel fuel.

In comparison to diesel produced from crude oil, the production process of bio-diesel involves recycling some waste products, which offers a more sustainable fuel source. These products go through a chemical reaction process called transesterification with alcohol and a catalyst in order to produce the fuel[7].

Bio-diesel can be blended with conventional diesel fuel. The blend is noted by a B-index (i.e. B20 is 20% bio-diesel blend). In North America, all major diesel engine manufacturers have approved the use of B5 bio-diesel[8].

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[7] Natural Resources Canada, Biodiesel, Available at: https://www.nrcan.gc.ca/energy/alternative-fuels/fuel-facts/biodiesel/3509

[8] Government of Canada, Bio-diesel Availability and Cost, Available at: https://www.nrcan.gc.ca/energy/alternative-fuels/fuel-facts/biodiesel/3523

Furthermore, bio-diesels up to a maximum blend of B20 can be used in any standard diesel engine without modifications. However, vehicle and engine warranty should still be consulted with the OEMs for use of a bio-diesel blend above B5. The National Bio-diesel Board is one reference which can be consulted for OEM statements on approved usage of various bio-diesel blends with their engines. For example, John Deere has stated all their diesel engines can be used with a B20 blend provided the ASTM 6751 standard is met. The ASTM 6751 standard governs quality acceptance for bio-diesel blends and ASTM D7467 standard prescribes quality standards specifically for the B20 blend.

Bio-diesel can offer a simple approach to lowering the GHG emissions of fleet vehicles where limited options are available. However, the bio-diesel should come from a reputable source as there is a risk of damage to engine components from particulate matter if not processed at a high standard.

Natural Resources Canada (NRCan) references the BQ-9000 certified list of producers and marketers in North America. BIOX Corporation located in Hamilton, ON is one company included on this list as a bio-diesel producer and vendor in Southern Ontario.

Emission factors published by NRCan's GHGenius modeling methodology for emissions can be used to demonstrate the impact of bio-diesel blends, as shown in Table 17.

There are some challenges with bio-diesel fuel in colder weather use. Due to the chemical process of transesterification used to produce bio-diesel, the fuel can retain higher moisture levels and thereby can be more subjective to gelling in colder weather. This can lead to problems in the fuel system such as filter clogging. However, these cold usage concerns can be overcome either by using fuel additives such as methyl hydrate or using a lower concentration bio-diesel blend in winter months.

Some peer municipal and transit fleet operations take the approach to use a lower blend such as B5 throughout the winter and revert to B20 throughout the rest of the year. This use case with emissions reduction is included in Table 17.

Table 17 Bio-diesel Blends Emissions Reduction

Bio-diesel Blend	Emissions (kg CO_2e per L)	Reduction (% per L)
B0 (Diesel)	2.738	N/A
B5 (5% blend)	2.583	5.6%
B20 (20% blend)	2.185	20.2%
Seasonal Use Case: B20 use with B5 use in winter (3 months)	2.285	16.6%

Bio-diesel can cost slightly more than regular diesel. The US Department of Energy states there can be an incremental cost of 20 cents per gallon for B20 fuel which is approximately an 8% premium.

4.1.2 RENEWABLE DIESEL

Renewable diesel is another alternative fuel which is made from waste agricultural products including natural fats, vegetable oils, and greases. The main difference between renewable and bio-diesel is the chemical process of producing the fuel. Renewable diesel is processed through hydrogenation making it more chemically similar to conventional diesel and is subject to the ASTM D975 standard for petroleum fuels.

Both renewable and bio-diesel offer similar GHG emission reduction benefits. However, one advantage of renewable diesel is that it can be used in higher concentrations and can directly replace conventional diesel. Renewable diesel does not have the same concerns as higher blend bio-diesel fuels in cold weather use.

One drawback it that renewable diesel is currently not as commercially available in Canada as bio-diesel. However, there has been recent interest and investment from the Canadian government to scale renewable diesel production in Southern Ontario to commercial levels.

In 2020, the Federal Economic Development Agency for Southern Ontario announced a $5 million investment to FORGE Hydrocarbons, located in Sombra, ON, for scaling their renewable diesel production from 200,000 litres up to commercial levels at 28 million litres per year[9].

This type of investment and similar developments could open the opportunity for renewable diesel fuel to be used in Oxford County's fleet when their existing fuel supply contract is up for renewal in 2024.

4.2 NATURAL GAS VEHICLE FUNCTIONALITY

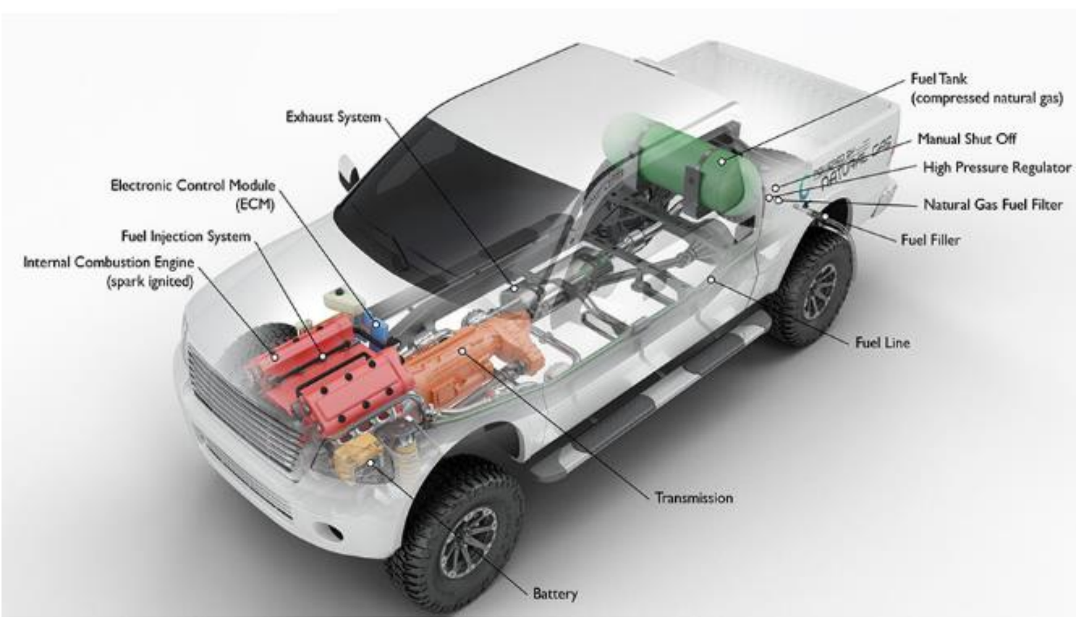

Figure 13 CNG Vehicle Major Components

Oxford County already has several dual fuel CNG/gasoline light-duty vehicles as well as heavy-duty retrofit CNG trucks.

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[9] Government of Canada "Two renewable fuel producers scale up to increase productivity and economic growth in rural southwestern Ontario". Available at: https://www.canada.ca/en/economic-development-southern-ontario/news/2020/07/two-renewable-fuel-producers-scale-up-to-increase-productivity-and-economic-growth-in-rural-southwestern-ontario.html

A CNG vehicle operates similar to a gasoline vehicle and they have a high degree of part commonality. Both types of vehicles use engines with spark ignition systems to generate power from injected fuel, however the main difference is the CNG fuel system. CNG fuel is contained in pressurized tanks which are reduced in pressure through a regulator to an acceptable level for the fuel system. It is then fed through a fuel filter and passed through fuel lines upon being injected into the engine. The mixture of fuel and air is ignited by a spark which releases energy and powers the vehicle. See Table 18 which lists the functional descriptions for the main components in a CNG vehicle powertrain.

Table 18 CNG Vehicle Components

Component:	Functionality:
CNG fuel tank	Stores pressurized CNG fuel until release into the fuel system
Manual shut off	Vehicle operator safety mechanism to shut-off the fuel supply
High pressure regulator	Reduces fuel pressure from the CNG tank to an acceptable level for passing through the fuel system
Natural gas fuel filter	Removes particulate, dirt and other contaminants that can harm the interior functioning of the engine
Fuel filler	Access point to replenish fuel stored in the fuel tank
Fuel line	Transfers fuel from the fuel tank to the engine
Internal Combustion Engine (ICE)	Produces mechanical power for the vehicle by spark ignition of injected fuel
Fuel Injection System	Vaporizes fuel that is injected into the engine for ignition
Electronic Control Module (ECM)	Engine computer that controls valve timing, fuel injection, monitors engine performance and fuel economy
Transmission	Transfers mechanical power produced by the ICE to drive the wheels
Battery	Power auxiliary vehicle electronics (lights, HVAC etc.) recharged by an alternator driven off the internal combustion engine (ICE)
Exhaust System	Channels exhaust gas from the engine out the vehicle tailpipe

4.2.1 RENEWABLE NATURAL GAS (RNG)

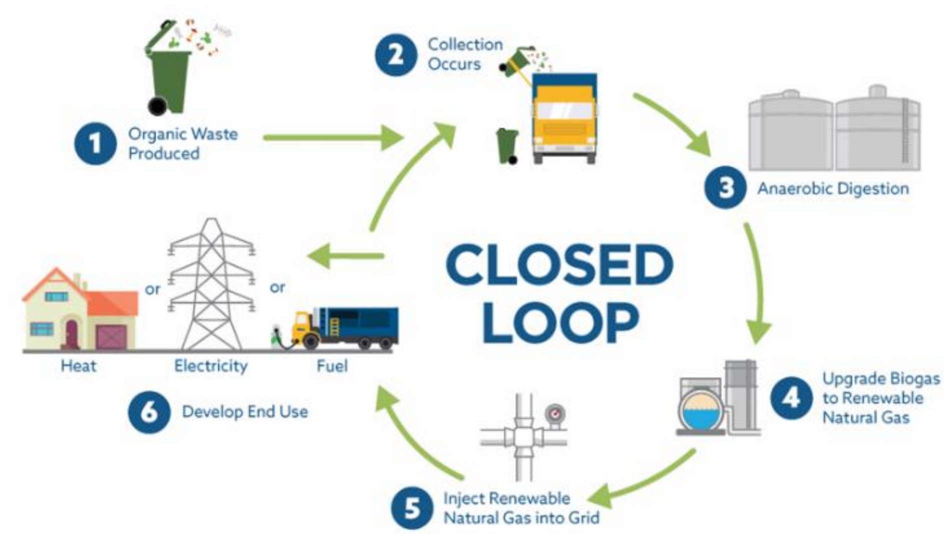

Figure 14 RNG Production Process

A renewable natural gas (RNG) vehicle operates similarly as a CNG vehicle, with the main difference being the sourcing of natural gas fuel. RNG is produced from biogas created by decomposing organic waste or bio-mass such as the ones found in landfills, farms and other industries. The traditional method of producing natural gas is from underground rock and shale deposits which require a large amount of energy/work to extract. In contrast, RNG offers a carbon-neutral GHG gas emissions impact by recycling and repurposing gas which would have been emitted into the atmosphere. Figure 14 illustrates the high-level process of producing RNG[10] while the impact of reducing emissions is demonstrated with the emission factors provided in Table 19.

Table 19 RNG Blends Emissions Reduction

RNG Blend	Emissions (kg CO_2e per kg)	Reduction (% per kg)
CNG (0% RNG)	2.965	N/A
20% RNG blend	2.372	20%
50% RNG blend	1.483	50%
100% RNG blend	0	100%

Although there are avenues to reduce GHG emissions for natural gas vehicle by replacing the CNG with renewable natural gas (RNG), the province of Ontario currently lacks a clear path towards deploying RNG at a large scale, whereas the province of Ontario currently relies on a clean electricity grid as an alternative.

4.2.2 NATURAL GAS FUELING STATIONS

Oxford County currently refuels the fleet of CNG vehicles at the Rural Green Energy fueling station located at 594676 Oxford Road 59 South of Woodstock. An overview of the major processes in a natural gas fueling station is shown in Figure 15. Natural gas fuel stations operate as natural gas is supplied from a distribution pipeline via a custody transfer station (CTS) that is incorporated into the CNG station footprint. A minimum and maximum contract pressure is set, and the outlet gas pressure at the CTS is regulated to a maximum pressure.

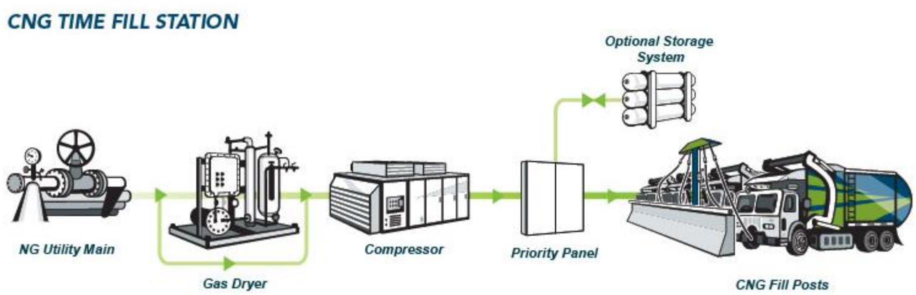

Figure 15 Schematic of CNG Fueling Station Components

[10] City of Toronto, Turning Waste into Renewable Natural Gas, Available at: https://www.toronto.ca/services-payments/recycling-organics-garbage/renewable-natural-gas/

The gas supply piping is connected from the CTS to the dryer. The drying of the gas and removal of any particulate provides extra protection to the compressors. The gas is connected through the gas desiccant vessel for drying. The moisture content of the outlet gas is monitored, and an alarm is sent to the Master Controller if it exceeds the set point. When an alarm is received, the dryer vessel is taken out of service and regenerated. When regeneration is completed, the dryer is placed back into service.

Gas from the dryer is then sent to the compressors. The Master Controller communicates with the gas control panel and the compressors to direct gas to the buffer storage, or the time fill posts, or the fast fill posts as needed.

Stations are equipped with enough compression to serve the load. The compressor arrangement is designed for a redundancy configuration. For example, with a 1+1 compressor arrangement, one (1) compressor will deliver the required station flows. The second compressor is available on standby in the event of a problem with the on-duty compressor. The station master controller automatically increments the lead / lag compressors for uniform run times on both compressors. The control logic will also include a “catch-up” mode whereby both compressors can be operated at the same time. The fill process is then triggered by connecting a “vehicle” to a fill post.

Overall, the cost estimate for a CNG fueling station can vary greatly depending on the availability of connection points to a natural gas utility main at the site as well as the number of fill posts, drying and compression requirements.

4.3 ELECTRIC VEHICLE FUNCTIONALITY

4.3.1 HYBRID & PLUG-IN HYBRID

Hybrid electric vehicles (HEVs) and plug-in electric vehicles (PHEVs) are quite similar. The biggest difference is the interaction between the electric and gas-powered drivetrains for each vehicle and the ability to charge a PHEV’s battery pack directly through its charge port.

A HEV mostly uses its gas-powered engine to generate power. Fuel is supplied from the fuel tank through the fuel system which is injected into the engine and spark ignited to produce power. This vehicle also utilizes an electric drivetrain to assist with acceleration and improve fuel economy. The vehicle is equipped with a battery pack which powers an electric traction motor used to drive the wheels. The traction motor also utilizes regenerative braking which recaptures energy during deceleration to charge the vehicle’s battery.

PHEVs run on electric energy from a battery pack which powers its electric traction motor. PHEVs are also capable of regenerative braking to recharge the vehicle’s battery during deceleration. The gas-powered drivetrain can be either run in parallel (same as a HEV) or in series (only after the vehicle’s battery pack has been depleted) which allows it to operate as a conventional gasoline vehicle. Further description on the main components of HEV and PHEV powertrains are provided in Table 20.

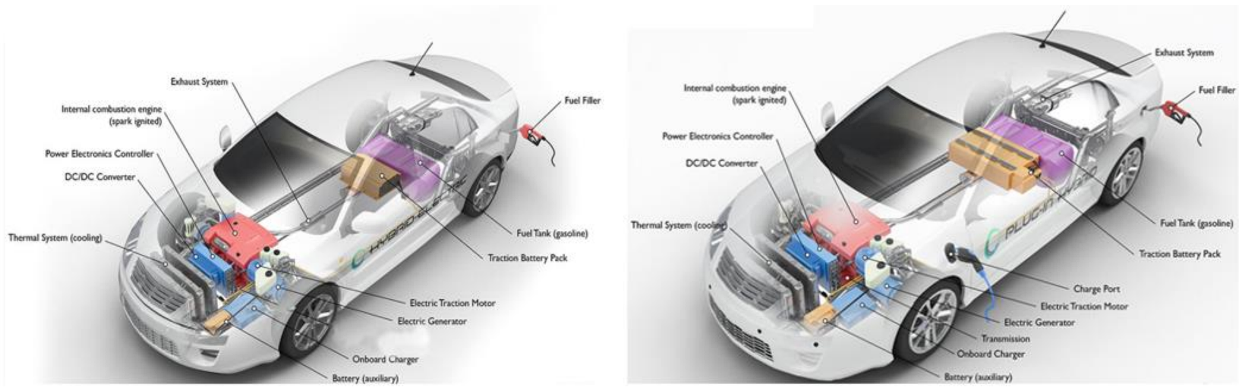

Figure 16 Major Components HEV (Left) and PHEV (Right)

Table 20 Hybrid (HEV and PHEV) Vehicle Components

Component:	**Functionality:**
Fuel filler	Access point to replenish fuel stored in the fuel tank
Fuel tank	Stores liquid fuel gasoline (diesel) until release into the fuel system
Fuel line	Transfers fuel from the fuel tank to the engine
Fuel Injection System	Vaporizes fuel that is injected into the engine for ignition
Internal Combustion Engine (ICE)	Produces mechanical power for the vehicle by spark ignition of injected fuel
Transmission	Transfers power produced by the ICE and/or traction motor to drive the wheels
Exhaust System	Channels exhaust gas from the engine out the vehicle tailpipe
Traction battery pack	Stores electric energy during charging and regenerative braking in order to power the traction motor
Electric traction motor	Drives the vehicles wheels and recharges the battery pack through regenerative braking
Electric generator	Generates electrical energy from braking (some traction motors incorporate this function)
Thermal System	Regulates the temperature of operating electrical components
Power electronics controller	Computer that controls the energy flow from the battery, traction motor speed and torque
DC/DC Converter	Converts high voltage from the traction battery pack to low voltage in order to power accessory vehicle electronics
Battery (auxiliary)	Low voltage to power auxiliary vehicle electronics (lights, HVAC etc.)
PHEV Only	
Charge Port	Access/interface point for external power supply in order to charge the vehicle battery
Onboard Charger	Converts external AC power supplied to DC for vehicle charging

4.3.2 BATTERY ELECTRIC

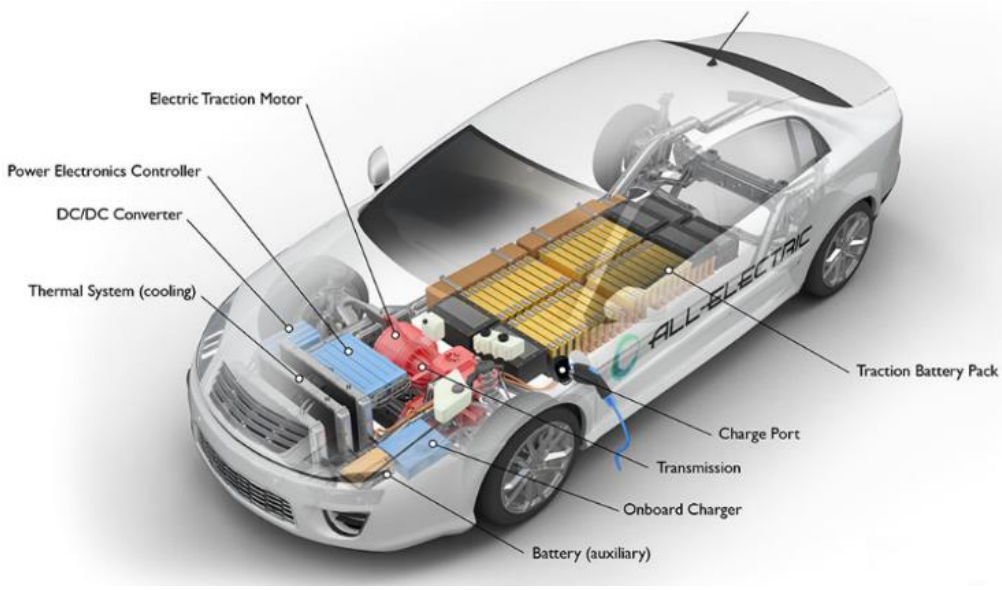

Figure 17 BEV Major Components

A battery electric vehicle (BEV) operates similar to the electric drivetrain components in a PHEV. A battery powers the electric traction motor which drives the wheels. The vehicle's battery is charged through plug-in coupling and by regenerative braking during operation. The main advantage of a BEV is the removal of the gas powered drivetrain. This results in the vehicle producing no emissions nor requires fuel system components or engine/transmission lubrication systems. Therefore, reducing complexity, increasing reliability and lowering maintenance costs. The main components of a BEV are stated in Table 21.

Table 21 BEV Vehicle Components

Component:	Functionality:
Traction battery pack	Vehicle power source, stores electric energy during charging and regenerative braking in order to power the traction motor
Charge port	Access/interface point for external power supply in order to charge the vehicle battery
Transmission	Transfers electrical power from the traction motor to the wheels
Onboard charger	Converts external AC power supplied to DC for vehicle charging
Battery (auxiliary)	Low voltage to power auxiliary vehicle electronics (lights, HVAC etc.)
Thermal system	Regulates the temperature of operating electrical components
DC/DC converter	Converts high voltage to low voltage from the traction battery
Power electronics controller	Computer that controls the energy flow from the battery, traction motor speed and torque
Electric traction motor	Drives the vehicles wheels and recharges the battery pack through regenerative braking

4.3.3 ELECTRIC VEHICLE CHARGING STATIONS

Both PHEVs and BEVs are charged by using a plug-in connector. In North America, the Society of Automotive Engineers (SAE) has established a standard of plug-in connector types: SAE J1772. By developing a standard, it ensures the interoperability of charging stations and EVs from different OEMs.

Typically, charging station designs in North America include a CHAdeMO plug-in connector due to the presence of certain Japanese vehicles in the North American market. The CHAdeMO is the standard for DC fast charging developed in Japan by their most prominent automakers, the association was initially formed by Nissan, Mitsubishi and Subaru. Toyota, Hitachi and Honda later followed suit.

There are two modes of charging, through alternating current (AC) and direct current (DC). The power supply from the electrical grid is in the form of AC and must be passed through a rectifier to be converted to DC. Moreover, there are different charging levels classified by the rate of power transfer for charging the vehicle’s battery. DC offers the fastest charge rates up to 350 kW.

In North America, some of the prominent manufacturers for EV charging stations include ABB, Siemens and Flo. Several of these providers have app based global positioning system (GPS) maps to show the locations of publicly available charging stations.

Around Oxford County there are currently 25 publicly available EV charging stations installed by Oxford County in Woodstock, Tillsonburg, Thamesford, Ingersoll and Salford.

Figure 18 CHAdeMO and SAE J1772 Chargers

There are two Level 3 charging stations located at 16 King St W, Ingersoll and 580 Bruin Blvd, Woodstock which comply to CHAdeMO and the SAE Combo CCS standards, charging up to 50 kW. The remaining chargers are all Level 2 SAE J1772. The cost for use of the Level 3 chargers is $15 per hour while the Level 2 chargers cost $2 per hour[11].

[11] Oxford County, EV Charger Summary.xlsx, AddEnergie pricing rates

4.4 HYDROGEN FUEL CELL VEHICLE FUNCTIONALITY

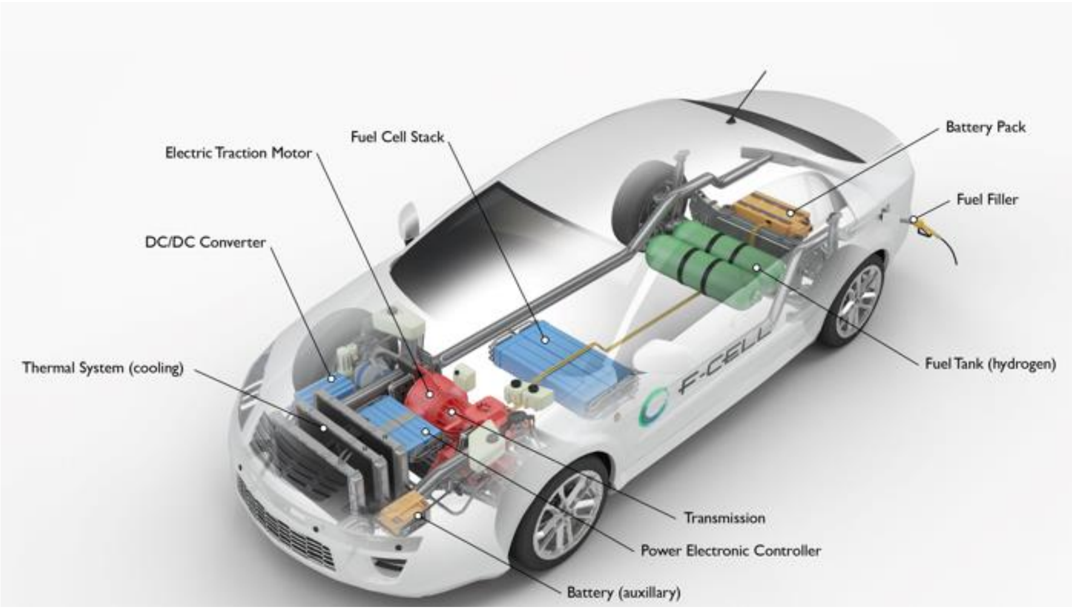

Figure 19 Hydrogen Fuel Cell Vehicle Components

A hydrogen powered fuel cell electric vehicle (FCEV) operates with the similar electrical powertrain principles as the BEV. However, the main difference is that the electricity used to power the vehicle is generated through a hydrogen fuel cell. The chemical reaction between hydrogen and oxygen in the cell produces an electrical current along with heat and water (H_20) as clean by-products. The fuel cell itself contains no moving components and the chemical process is essentially the reverse of the electrolytic reaction splitting water into hydrogen and oxygen (hydrogen as the cathode and oxygen as the anode). The on-board fuel tank contains the pressurized hydrogen until it is injected into the fuel cell (similar to a CNG storage tank). Hydrogen fuel cell vehicles require temporary refuelling at compressed hydrogen supply stations.

Overall, these vehicles are highly effective in lowering GHG emissions as their exhaust gas is primarily steam (H_20). The main challenges are the lack of refuelling infrastructure and potential safety concerns for carrying pressurized hydrogen tanks on-board. The main components of a FCEV are provided with explanation in Table 22.

Table 22 Hydrogen Fuel Cell Vehicle Major Components

Component:	Functionality:
Battery pack	Stores electrical energy produced through the fuel cell chemical reaction. Vehicle power source, stores electric energy during charging and regenerative braking in order to power the traction motor
Fuel Filler	Access point to replenish hydrogen stored in the pressurized on-board tanks
Fuel Tank (hydrogen)	Stores the pressurized hydrogen gas to be used in the fuel cell reaction to generate electricity

Component:	Functionality:
Fuel Cell Stack	The fuel cell which produces the electrochemical reaction between hydrogen (cathode) and oxygen (anode)
Fuel Cell Stack Auxiliaries	Includes the hydrogen and air humidifier, the injectors and the pumping system.
Transmission	Transfers electrical power from the traction motor to the wheels
Battery (auxiliary)	Low voltage to power auxiliary vehicle electronics (lights, HVAC etc.)
Thermal system	Regulates the temperature of operating electrical components
DC/DC converter	Converts high voltage to low voltage from the traction battery
Power electronics controller	Computer that controls the energy flow from the battery, traction motor speed and torque
Electric traction motor	Drives the vehicles wheels and recharges the battery pack through regenerative braking

4.4.1 HYDROGEN FUEL PRODUCTION

Figure 20 Shell Hydrogen Fueling Station

There are several methods to produce hydrogen fuel and the source of fuel production can greatly impact the effectiveness of reducing GHG emissions. Electrolysis is an electrochemical process involving an electrical current being used to split water into hydrogen and oxygen, from which the hydrogen (H_2) gas is then stored for use in fueling hydrogen fuel cell vehicles.

If the upstream electricity used in the electrolysis process is from a renewable source such as solar, hydro or wind this fuel production is classified as “green hydrogen”. However, the majority of hydrogen currently produced globally is from non-renewable fossil fuels. Hydrogen production from natural gas accounts for approximately 76% and production using coal accounts for 23%. These forms of non-renewable hydrogen fuel production are classified as “grey hydrogen” and “black hydrogen” respectively.

Canada currently produces approximately 3 million tonnes of hydrogen annually (4% of the global total). However, this is mostly for industrial applications as only 0.01% of hydrogen fuel production globally is used to fuel road vehicles[12]. The International Energy Agency (IEA) has forecasted "grey hydrogen" as the most cost-effective means for hydrogen fuel production until 2030. Thereafter, the benefits in GHG reduction from "green hydrogen" production can be expected to become more viable.

As a benchmark the price of hydrogen paid by the Stark Area Regional Transit Authority (SARTA) in Ohio is approximately $6.50 per kg. This hydrogen is produced from "grey/black" sources and is shipped from Sarnia, ON. There are currently no publicly available hydrogen fueling stations in Ontario.

Quebec currently has the only publicly available hydrogen fueling station in Canada. The capital cost of the station was $5.2 million with $1 million in funding received from Natural Resources Canada and another $2.9 million from Transition l'énergie Quebec (TEQ). The fueling station is located along the highway corridor at 5105 Wilfrid-Hamel Boulevard outside of Quebec City. In March 2020, the Quebec government announced investment plans for a second hydrogen fueling station[13].

4.4.2 HYDROGEN VEHICLE FUELING STATIONS

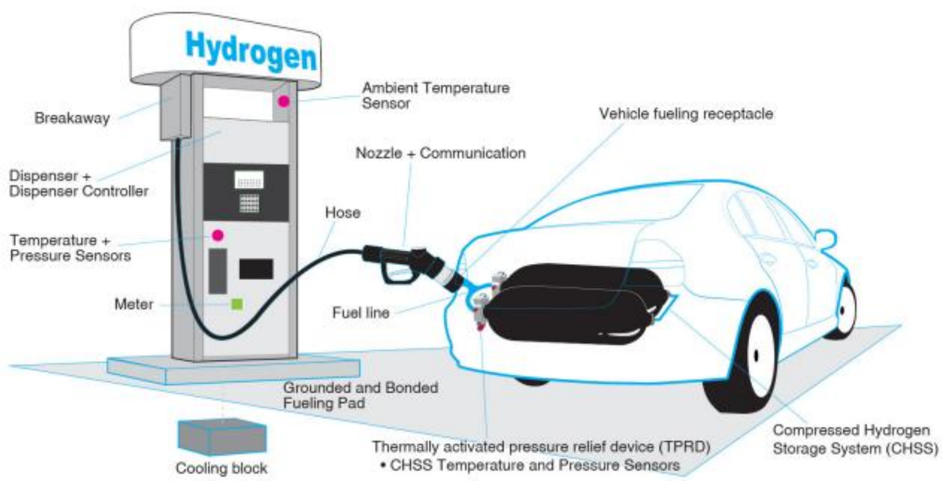

Figure 21 Hydrogen Fuel Station

Hydrogen fueling stations can either be an off-site delivery (i.e. hydrogen transported by tanker truck or pipeline to storage tanks located on-site) or on-site generation of hydrogen through electrolysis.

For on-site generation of hydrogen, a compressor system is used to pressurize the stored hydrogen to reduce volume and achieve an acceptable pressure for filling vehicle on-board storage tanks. The pressurized hydrogen gas can then be stored in an intermediate stage of

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[12] Clean Energy Canada, Hydrogen as part of Canada's Energy Transition, July 2020

[13] Fuel Cell Works, Second Hydrogen Station to be Built in Quebec, March 2020

storage tanks from which the hydrogen is ready to be dispensed through a filler hose and nozzle.

In certain applications, after the compressor stage, a chiller can be introduced in a closed-loop system to further chill the hydrogen prior to dispensing. Cooling and reduction of gas volume can enable faster fill times.

The filler nozzles for hydrogen are docked at fill stations like diesel, gasoline or natural gas applications. Different receptacle types (i.e. TN1 or TN5 specifically designed for high pressure hydrogen filling with low noise) interface between the fill nozzle and fill receptacle on the vehicle. The hydrogen is then stored in pressurized on-board storage tanks which regulate supply to the on-board fuel cell used to propel the vehicle through reversing the electrolysis reaction.

Currently in Ontario there is no readily available supply chain established for hydrogen fuel and there is a lack of infrastructure. When these issues are addressed, hydrogen may become a more viable alternative fuel source.

4.5 SAFETY, TOOLS & TRAINING

This section provides general information on the relevant codes and standards regarding the use of bio-diesel, natural gas, electric and hydrogen fuel cell vehicles. Furthermore, a discussion on specific tooling, training and safety measures is provided. As Oxford County does not currently perform in-house fleet maintenance the considerations on tools and training are intended to aid further understanding of vehicle technology, maintenance practices and considerations if in-house fleet maintenance technicians are part of a future business plan.

Applicable codes and standards for fueling stations and EV charging stations will be relevant should Oxford County consider these infrastructure installations to support fleet operations. Oxford County is currently evaluating the prospects for building a CNG fueling station at the Water Operations Centre located at 59 George Johnson Boulevard, Ingersoll.

4.5.1 BIO-DIESEL

In general terms, renewable diesel and biodiesel may be handled in a similar manner to conventional diesel. However, Natural Resources Canada (NRCan) lists the following considerations[14] for bio-diesel use:

1. Ensure the bio-diesel fuel blend meets the ASTM 6751 standard
2. Discuss vehicle and engine warranty with the OEM if a blend higher than 5% (B5) is going to be used
3. Confirm if BQ-9000 certified bio-diesel producers and marketers are available

For addition information regarding the requirements for working with bio-diesel, refer to the US Department of Energy's publication: Biodiesel Handling and Use Guide (Fifth Edition) DOE/GO-102016-4875 November 2016.

[14] Government of Canada, Bio-diesel Availability and Cost, Available at: https://www.nrcan.gc.ca/energy/alternative-fuels/fuel-facts/biodiesel/3523

4.5.2 NATURAL GAS

4.5.2.1 NATURAL GAS VEHICLES CODES & STANDARDS

Conversion and installation of facilities for the use of natural gas requires consideration of the following primary codes and standards listed in Table 23, each of which references several other applicable codes and standards.

Table 23 Natural Gas Applicable Codes & Standards

Code/Standard	Description
CAN/CSA B108-18	Natural Gas Fuelling Stations Installation Code, A National Standard of Canada. **Note:** An updated version of CSA B108 will be issued in 2021.
CAN/CSA B108-18	Natural Gas Fuelling Stations Installation Code, A National Standard of Canada. **Note:** An updated version of CSA B108 will be issued in 2021.
CSA B401-18	Vehicle Maintenance Facilities Code, First Edition. **Note:** An updated version of CSA B401 will be issued in 2021. The new edition will include requirements for Parking Structures.
NFPA 88A-2019	Standard for Parking Structures (see note above re CSA B401)

CSA B108 sets out the requirements for vehicle refuelling stations for vehicles powered by CNG or LNG.

CSA B401 was published in November of 2018 and is the first ever version of the Code. It sets out the requirements for existing and new vehicle maintenance facilities that “host” CNG and LNG vehicles for maintenance and repair.

NFPA 88A sets out the requirements for vehicle parking structures for vehicles of all fuel types. It is an American publication and has no official status in Canada. However, in the absence of a Canadian code/standard, it is used as reference material. The following guideline should also be referenced:

- Technical Guideline for the Design and Operation of Facilities Used for Indoor Repair, Storage and Cargo Handling for Vehicles Fuelled by Compressed Natural Gas and Liquefied Natural Gas (a Best Practices guideline)

This technical guideline aids fleet facility owners, architectural / engineering firms and building contractors in determining the requirements for existing or planned new facilities, to ensure they are safe for CNG vehicles maintenance, repair, storage, or cargo handling.

Furthermore, the Technical Standards and Safety Authority (TSSA) regulates the transportation, storage, handling and use of fuels in Ontario. The TSSA licenses fuel facilities, registers contractors and certifies tradespeople who install and service equipment. The key areas in which the TSSA is involved are:

1. Transmission, distribution and transportation
2. Storage and dispensing
3. Utilization

The main regulations to reference which are published by the TSSA for gaseous fuels, including CNG and hydrogen are the following Ontario Regulations:

- 219/01 – Operating Engineers
- 215/01 – Fuel Industry Certificates
- 214/01 – Compressed Gas
- 212/01 – Gaseous Fuels
- 210/01 – Oil and Gas Pipeline Systems

With regards to training, vehicle OEMs producing CNG models commonly provide standard training, operating, and maintenance manuals with the purchase of their vehicles or with vehicle retrofits. For a CNG vehicle, most of the vehicle maintenance activities will be similar to that of an equivalent diesel vehicle. However, there are notable differences regarding the fuel system.

Training should focus on the safe handling of pressurized gas tanks and inspection, as well as monitoring safe level of gas exposure with proper detection equipment. Necessary training can also include working at heights with lifts, scaffolding, and the use of fall arrest equipment in order to service CNG tanks which are commonly located on the roof or box collection/compaction body of a refuse truck, for example. Maintenance technicians servicing pressurized gas components onboard the vehicles will also require an appropriate gas fitters' certification. Furthermore, workers should be aware and service CNG vehicles in a facility equipped with proper ventilation and meeting applicable codes and standards.

In addition, emergency responders should have familiarity training with CNG so that they are aware of the potential hazards and have a mitigation plan in the event of responding to an incident involving a CNG vehicle.

CNG is becoming a widely adopted fuel alternative in transportation. As such, there are several institutions with specific training programs for maintenance workers. This includes The National Institute for Automotive Service Excellence (ASE) Certification for Light-/Medium-Duty CNG training program available in Canada and other programs offered by CNG engine OEMs such as Cummins Natural Gas Academy.

4.5.2.2 *NATURAL GAS TRAINING & TOOL REQUIREMENTS*

Although there is a large degree of part commonality with a diesel or gasoline vehicle, some specialized tools are required for the servicing and maintenance of a CNG vehicle. These tools are primarily related to the pressurized fuel system and CNG tanks. Figure 22 shows some of these tools (clockwise: gas detector, gas injector/extractor, torque wrench). Some specialized tools include:

- Gas leak detector worn by maintenance workers to monitor any gas leakage that could become a safety concern to workers and potential fire hazard
- Tools for the removal and inspection of CNG tanks (gas extractor, torque wrenches and tensioner straps)

Figure 22 CNG Special Tools

Vehicle OEMs producing CNG models commonly provide standard training, operating and maintenance manuals with the purchase of their vehicles or with vehicle retrofits. Training should focus on the safe handling of pressurized gas tanks and inspection as well as monitoring safe level of gas exposure with proper detection equipment. Furthermore, workers should be aware and service CNG vehicles in a facility equipped with proper ventilation and meeting applicable codes and standards.

In addition, emergency responders should have familiarity training with CNG so that they are aware of the potential hazards and have a mitigation plan in the event of responding to an incident involving a CNG bus or vehicle.

CNG is becoming a widely adopted fuel alternative in transportation. As such there are several institutions with specific training programs for maintenance workers. This includes The National Institute for Automotive Service Excellence (ASE) Certification for Light/Medium Duty CNG training program available in Canada. ASE tests can cost up to $130, and the cost of training will depend on the level of skill of the participant being tested. CNG engine OEMs offer other programs as well, much like the Cummins Natural Gas Academy. Those interested in the Cummins Natural Gas Academy are encouraged to contact their local Cummins distributor for more detail, including pricing information.

The TSSA also covers certification requirements for a fuels safety technician under Ontario Regulation 215/01 – Fuel Industry Certificates. A fuels safety technician is defined as a certified professional who performs tasks including installation, service and maintenance of equipment operating on gaseous fuels and compressed gas.

4.5.3 ELECTRIC VEHICLES

4.5.3.1 *ELECTRIC VEHICLES CODES & STANDARDS*

Conversion to alternative propulsion technologies requires consideration of the appropriate codes and standards. The regulatory instruments governing the use of electric vehicles include those listed in Table 24.

Table 24 Electric Vehicle Applicable Codes & Standards

Code/Standard	Description
CSA C22.1	Canadian Electrical Code, Section 86 – Electric Vehicle Charging Systems
NFPA 70-2017	National Electrical Code, Article 625 – Electric Vehicle Charging Systems

In Ontario, the Electrical Safety Authority (ESA) published the Ontario Electrical Safety Code (OESC), as Ontario Regulation 164/99, which describes the standards for electrical installations, products and equipment in the province. The OESC is based on the Canadian Electrical Code with specific amendments applicable for the provincial level.

The ESA has a mandate to improve electrical product safety for the public. The published Ontario Product Safety Regulation 438/07 specifies the ESA's roles to review safety risks of electrical products, issue alerts to the public, revoke or suspend product approvals and revoke the recognition of a certification body or field evaluation agency. Therefore, the ESA would have a role in the safety of electric vehicles and charging stations. Furthermore, the OESC would govern safety measures for the installation of electric vehicle charging infrastructure.

With regards to training requirements, OEMs typically provide training to their clients as part of the vehicle purchase price or pilot program along with including all related operating and maintenance manuals. Training requirements can be specified in the procurement process and contract negotiations. If additional training is necessary, it can be provided through a third-party institution.

Maintenance training shall focus primarily on the electrical systems of the vehicle, as most non-electrical components are similar to those on a diesel vehicle. While the amount of necessary training will depend on the particular vehicle and OEM it should cover the basics of working with electric propulsion (traction motors), inverters and batteries.

In the case of electric vehicles operating on a fuel cell (hydrogen), it should also cover the safe refuelling practices and maintenance around the fuel cell and storage tanks. Training should also include the required safety procedures for working with high voltage electrical components, correct usage of personal protective equipment (PPE) and specialized tools. Once a primary group of personnel have been trained, they can train additional mechanics and operators.

Furthermore, organizations such as the Society of Automotive Engineering (SAE) offer courses such as "High Voltage Vehicle Safety Systems and PPE", which is a one-day program focusing on the safety aspects of maintenance technicians working on electric and hybrid vehicles. It also covers electrical circuit design/diagnosis and isolation measures on DC and AC detection systems through high voltage controllers to mitigate the possibility of electrocution between a maintenance technician and the vehicle body/chassis.

Lastly, training should be provided for emergency responders and utility workers such that in the event of an accident involving an electric vehicle, these personnel are aware of the potential high voltage and chemical hazards associated with electrical vehicles. They should have mitigation strategies and a safe response procedure in place.

OEMs have been working with the National Fire Protection Association (NFPA) to publish an Emergency Field Guide and provide safety plans on how to respond to incidents involving their vehicles[15]. Schematics show the location of high voltage cables and how to disconnect the power supply. It is recommended to request a detailed safety response plan from vehicle OEMs.

4.5.3.2 *ELECTRIC VEHICLES SPECIALIZED TOOLING*

The maintenance of electric vehicles (EVs) can require specialized tools to fully service the more complex and high voltage electrical systems not present on a gasoline, CNG or diesel vehicle. These systems included battery packs, inverters and electric motors (traction motors). Some specialized tools include:

- High impedance multi-meters, diagnostic cable equipment, electrical safety equipment, battery protection tools, insulated screwdrivers etc.
- Special tools for electric accessories, which will be based on the specific vehicle model and OEM.
- Battery pack and inverter lifting jigs for maintenance work

Furthermore, PPE (Personal Protective Equipment) is a requirement for technicians working on electric vehicles. The American Society for Testing and Materials (ASTM) has published PPE usage specifications for items such as the required insulated glove class for safe use according to voltage level. Some of the common maintenance tools needed to service electric vehicles are further described below:

- **High Impedance Multimeter:** Used to measure the voltage and current across two points in an electrical circuit. Impedance is the amount of electrical resistance in the tool which governs the voltage limit in the circuit it can be applied to. Voltage/Multimeters are used to help troubleshoot electrical circuits and identify the power supply has been safely disconnected for further work. Most high impedance multimeters now have an electrical resistance greater than 1 megaohm (MΩ) and can cost upwards of $1,300.
- **Static-Free Tools:** Electro static discharge (ESD) safe tools are required to safely dissipate the static electricity charge that people can build-up naturally and then can be released through touching a conductive material (i.e. metallic vehicle frame). This discharge can also damage electrical circuits such as when working on sensitive components in a computer. Static-free tools are made from non-conductive materials or have protective coatings which mitigate this electrical discharge. Furthermore, anti-static wrist straps and floor mats can also be used as part of PPE for safely working on electrical components.
- **Specialized EV Tools:** Any tools required for specialized repairs of the EV (i.e. for the traction motor or battery pack installation/removal) are likely best left to the responsibility of the OEM.

Overall, static-free toolkits (i.e. ratchet set, torque wrench, screwdrivers, pliers) and electrician kits (i.e. multimeter, fluke meters) can collectively cost upwards of $10,000 per person to outfit a mechanic's tool set.

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[15] NFPA, Emergency Field Guide, Available at: https://catalog.nfpa.org/Emergency-Field-Guide-2015-Edition-P13872.aspx?icid=D762

4.5.4 HYDROGEN VEHICLES

4.5.4.1 HYDROGEN FUEL CELL VEHICLES CODES & STANDARDS

The transition to alternative propulsion technologies requires consideration of the appropriate codes and standards. The regulatory instruments governing the use of hydrogen vehicles include those listed in Table 25.

Table 25 Hydrogen Vehicles Applicable Codes & Standards

Code/Standard	Description
CAN/BNQ-1784-000	Canadian Hydrogen Installation Code
CSA FC 1	Stationary Fuel Cell Power Systems
CSA FC 3	Portable Fuel Cell Power Systems
CSA HPIT 2	Compressed Hydrogen Station and Components for Fueling Industrial Trucks
CSA HPIT 1	Compressed Hydrogen Powered Industrial Trucks On-board Fuel Storage & Handling Components
CSA HGV 2	Compressed Hydrogen Gas Vehicle Fuel Containers
CSA HGV 3.1	Fuel System Components for Compressed Hydrogen Gas Powered Vehicles
CSA HGV 4.1	Hydrogen Dispensing Systems
CSA HGV 4.2	Hoses for Compressed Hydrogen Fuel Stations, Dispensers, and Vehicle Fuel Systems
CSA HGV 4.3	Test Methods for Hydrogen Fueling Parameter Evaluation
CSA HGV 4.4	Breakaway Devices for Compressed Hydrogen Dispensing Hoses and Systems
CSA HGV 4.5	Priority and Sequencing Equipment for Hydrogen Vehicle Fueling
CSA HGV 4.6	Manually Operated Valves for Use in Gaseous Hydrogen Vehicle Fueling Stations
CSA HGV 4.7	Automatic Valves for Use in Gaseous Hydrogen Vehicle Fueling Stations
CSA HGV 4.8	Hydrogen Gas Vehicle Fueling Station Compressor Guidelines
CSA HGV 4.9	Hydrogen Fueling Station Guidelines
CSA HGV 4.10	Fittings for Compressed Hydrogen Gas and Hydrogen Rich Gas Mixtures
CSA HPRD 1	Thermally Activated Pressure Relief Devices for Compressed Hydrogen Vehicle Fuel Containers

Training should focus on the safe handling of pressurized gas tanks and inspection as well as monitoring safe level of gas exposure with proper detection equipment. Maintenance technicians servicing pressurized gas components onboard the vehicles will also require an appropriate gas fitters' certification. Furthermore, workers should be aware and service hydrogen vehicles in a facility equipped with proper ventilation and meeting applicable codes and standards.

In addition, emergency responders should have familiarity training with hydrogen to that they are aware of the potential hazards and have a mitigation plan in the event of responding to an incident involving a hydrogen vehicle.

At the provincial level and as stated in Section 4.5.2, the TSSA also covers hydrogen fuel. The main regulations to reference which are published by the TSSA for gaseous fuels, including CNG and hydrogen are the following Ontario Regulations:

- 219/01 – Operating Engineers
- 215/01 – Fuel Industry Certificates
- 214/01 – Compressed Gas
- 212/01 – Gaseous Fuels
- 210/01 – Oil and Gas Pipeline Systems

4.5.4.2 *HYDROGEN FUEL CELL VEHICLES SPECIALIZED TOOLING*

Some specialized tools are required for the servicing and maintenance of a hydrogen fuel cell vehicle. These tools are primarily related to the pressurized fuel system and hydrogen tanks. Some specialized tools include:

- Gas leak detector worn by maintenance workers to monitor any gas leakage that could become a safety concern to workers and potential fire hazard.
- Tools for the removal and inspection of hydrogen tanks (gas extractor, torque wrenches and tensioner straps).

Additionally, similar tools as the ones required for electric vehicles are needed as the electric powertrain has similar components and operates the same (batteries, motor, inverters, etc.).

4.5.5 BATTERY AND HYDROGEN FUEL CELL VEHICLES TRAINING AND SAFETY

In Canada, the voltage threshold of 30V mandates maintenance personnel to have a high voltage qualified training for working on electrical components and circuitry and for using specific PPE. For reference, several OEMs use different battery pack voltages such as the Tesla 400 V (DC) battery and the Toyota Prius 201.6 V (DC).

An arc flash is a severe electrical hazard that is the result of a high voltage electrical discharge between conductors bridged by an air gap. This jump of electrical current at high voltage creates a large release of energy both thermal and as a light flash in the form of an electrical explosion which can be highly dangerous to maintenance technicians in the case that proper protective equipment (PPE) and preventative measures are not used while working on high voltage equipment such as the energy storage system (ESS) on either a battery electric vehicle or fuel cell electric vehicle (FCEV).

Working on any components at or above this 30V threshold requires the use of arc flash (minimum Category 1) PPE and establishing a work safe perimeter that only those who are high voltage qualified personnel wearing arc flash PPE can enter. For illustrative purposes, the PPE required according to the arc flash risk is presented in Figure 23.

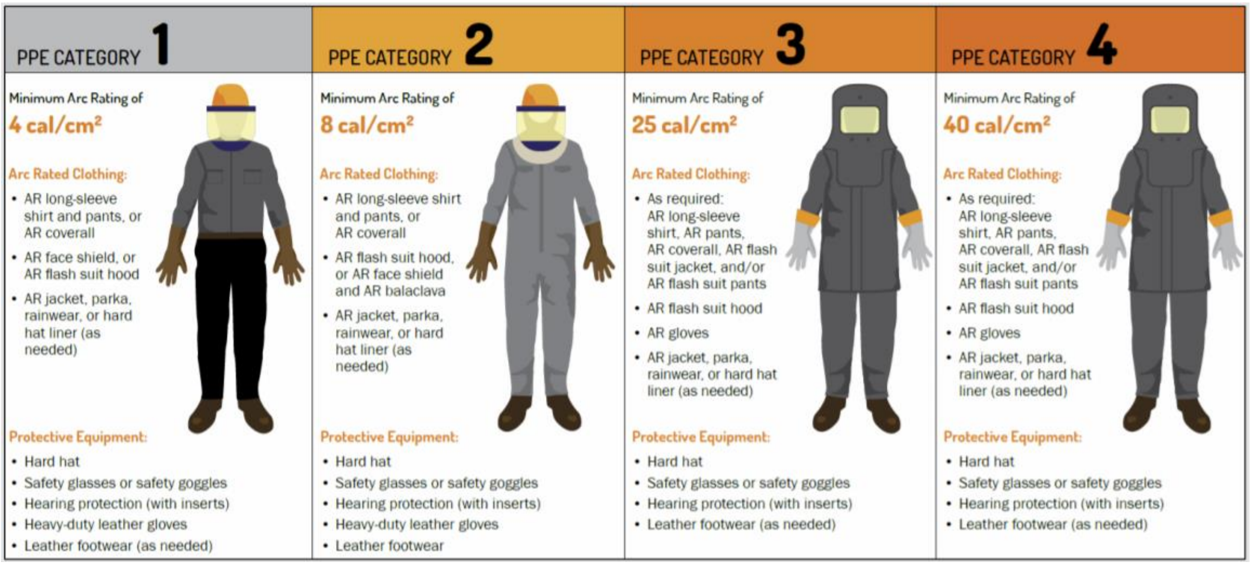


Figure 23 Arc Flash PPE Requirements

Figure 24 High Voltage Warning Label

Further detail on PPE requirements are published in the National Fire Protection Association (NFPA) 70E Standard for Electrical Safety in the Workplace.

Warning labels should be put on the exterior encasement where access to high voltage components are located to provide the technician clear information on the electrical risk as well as the required PPE to work on the components. An example warning label is shown in Figure 24 for illustrative purposes only.

Work on energized circuits of 30V or higher is not considered a routine activity. Personnel shall not work on such energized circuits unless they are qualified to do so, or they work under the direct supervision of a qualified person in an approved on-the-job training program. This type of repair work is best left to the OEM of the vehicle and component subsystems.

5 ALTERNATIVE PROPULSION VEHICLE MARKET SCAN

This section aims to provide a review of available models and industry trends. It should be noted that the information shared on the battery capacity, range and energy consumption was gathered from OEM technical specification sheets and can vary during operations.

5.1 INDUSTRY DIRECTION

A recent forecast was published on the sales volume according to the various propulsion technologies coming available in the market[16]. This forecast shown in Figure 25 highlights a notable shift towards electric and plug-in electric vehicles from 2020 onwards to reach 30% on average by 2030.

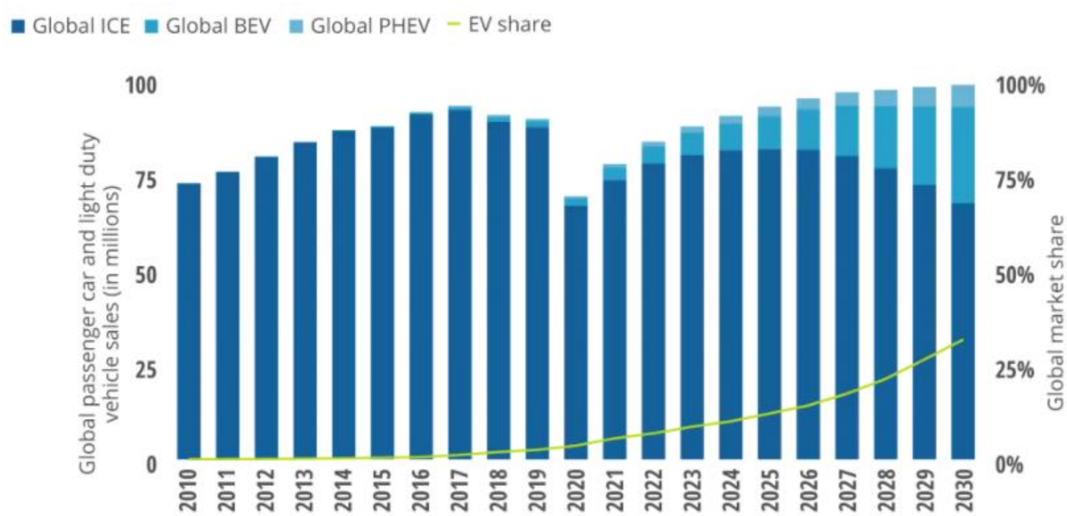


Figure 25 Global Sales Forecast by Propulsion Technology (millions of units)

The global market for lithium-ion batteries is expected to continue growing. In 2019, the market value for lithium-ion batteries was estimated at $36.7 billion USD and is forecasted to reach $129.3 billion USD by 2027[17]. The growth in this sector is fueled by large investments in research and development aiming to lower the price point and increase energy density (kWh per kg). There is also increased focus by governments on emissions reduction and continued strong demand worldwide for BEVs and other devices using lithium battery packs.

[16] Deloitte "Future of Mobility – Electric Vehicle Trends", Available at: https://www2.deloitte.com/uk/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html

[17] Allied Market Research "Global Lithium-ion Battery Market, Opportunities and Forecast 2020-2027".

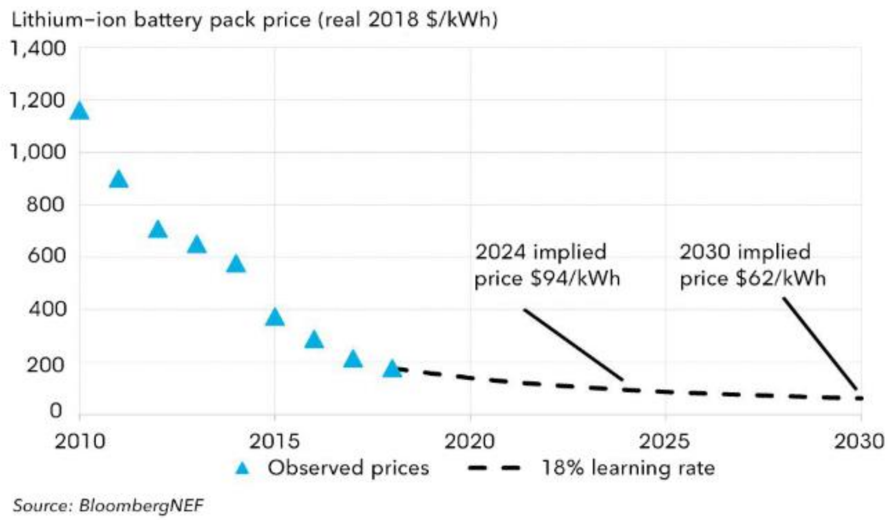


Figure 26 Lithium-ion Battery Price Outlook

According to a recent survey by Bloomberg New Energy Finance, battery prices for automotive and light duty vehicles, which were above $1,100/kWh (USD) in 2010, have fallen to reach $137/kWh (USD) in 2020[18]. This 89% reduction in cost was achieved due to the growth in battery electric vehicle sales and energy storage requirements, and the introduction of new electrode materials with higher energy densities.

It is expected that by 2023, average prices will reach $100/kWh (USD). As cumulative energy storage demand will surpass 2 TWh in 2024, prices will fall below $100/kWh (USD), making the energy cost and density of batteries on par with diesel and gasoline for conventional light-duty vehicles.

Various options for electric and hybrid vehicles are coming available. The range of battery electric vehicles has been improving and will continue to improve as more manufacturers continue to explore and develop new battery technologies. Electric vehicles are becoming a key focus for many traditional auto manufacturers such as Ford, General Motors and Toyota as well as new entrants focused exclusively on electric vehicles such as Tesla and Rivian.

There are currently a limited number of passenger hydrogen FCEVs available in Canada and North America. They are not as widely available as electric vehicles primarily due to the gap in availability of fueling infrastructure. As previously mentioned, there are currently no publicly available fueling stations in Ontario. However, hydrogen vehicles do offer several promising benefits should infrastructure and upstream production of hydrogen from cleaner sources improve. These benefits include zero tailpipe emissions, quick refueling and greater driving range in comparison to battery electric vehicles.

The following sections provide a market review of battery electric, hybrid, fuel cell vehicles coming available in the North American market. CNG alternatives are more focused on OEM approved conversions for light-duty vehicles and several heavy-duty truck OEMs offering CNG engine options.

[18] BNEF "Battery Pack Prices Cited Below 100 kWh" Available at: https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/

This is not an exhaustive list but instead is intended to serve as a representative same of the marketplace highlighting vehicle types and their capabilities which could be viable alternatives to Oxford County's current vehicles in development of the 5-year Green Fleet Plan and beyond.

5.2 CARBON TAX

The Federal Government of Canada passed the Greenhouse Gas Pollution Pricing Act in 2018 to implement a carbon pricing system and apply this "carbon tax" to provinces without a pricing system, this include the Province of Ontario. The objective is to promote the transition to cleaner technologies and move towards Canada's GHG reduction target of 30% (relative to 2005 baseline) by the year 2030.

The carbon tax initially started at $20 per tonne of CO_2e in 2019 and is set to increase by $10 per tonne until the tax reaches $50 per tonne in 2022. In December 2020, the government announced a gradual hike of this carbon tax to reach $170 per tonne by 2030.

This tax is factored into Provincial fuel prices, Table 26 lists the pricing impact for gasoline and diesel in Ontario[19] (assuming linear rate growth from $50 per tonne to $170 per tonne). The price impact for gasoline and diesel fuel is estimated based on emission factors provided in reference Table 12.

Table 26 Carbon Tax Impact on Fuel Price in Ontario

Year	Gasoline ($/L)	Diesel ($/L)	Natural Gas ($/kg)
2021	+$0.07	+$0.08	+$0.09
2022	+$0.11	+$0.13	+$0.12
2023	+$0.12	+$0.14	+$0.15
2024	+$0.16	+$0.18	+$0.20
2025	+$0.20	+$0.23	+$0.25

Note: the values presented are the incremental effect of the carbon tax on fuel prices (i.e. fuel price without versus with the carbon tax applied) based on the carbon tax rate forecasted.

The carbon tax is aimed to influence the business case for switching to cleaner fuels and technologies by impacting the operating cost of vehicles. This impact is explored in Section 6 with the cost assessment for green fleet opportunities for Oxford County's fleet.

5.3 HYBRID ELECTRIC CARS AND SUVS

In Canada, there are many hybrid vehicles available on the market for the light-duty passenger vehicle class. These 2020/2021 car and SUV models are listed below with estimated fuel economy and pricing details[20]. The manufacturer suggested retail price (MSRP) for these models ranges from $25,000 to $55,000. The Hyundai Ioniq offers the best advertised fuel economy for a car at 4.1 L/100 km while the Kia Niro offers the best fuel economy for an SUV at

[19] Canada Drives, Carbon Taxes & Rebates Explained (Province by Province), January 2021

[20] Plug N' Drive Canada, Electric Cars Available for Sale in Canada

4.7 L/100 km. Table 27 provides an overview of a models. See Appendix A for the complete list of available models and specifications.

Table 27 Hybrid Vehicle Models

Make	Model	Vehicle Type	Fuel Economy	Price (MSRP)
Toyota	Corolla Hybrid	Car	4.5 L/100km	$25,090
Kia	Optima Hybrid	Car	5.6 L/100km	$30,995
Honda	Insight Hybrid	Car	4.9 L/100km	$30,276
Hyundai	Ioniq Hybrid	Car	4.1 L/100km	$25,399
Ford	Fusion Hybrid	Car	5.5 L/100km	$29,375
Ford	Escape Titanium Hybrid	SUV	5.9 L/100km	$34,649
Kia	Niro	SUV	4.7 L/100km	$26,845
Toyota	RAV4 Hybrid	SUV	6 L/100km	$32,950

5.4 HYBRID PICKUP TRUCKS

Most of the recent focus and technology development from automakers has been in the area of battery electric pickup trucks (refer to Section 5.8.3). However, there is a market of non plug-in hybrid pickup trucks available in Canada. This category of alternative propulsion vehicles can be a very important component to Oxford County's Green Fleet Plan as there is a significant opportunity to cut emissions from current gasoline pickups. User groups have stated their preference for hybrid pickups over fully battery electric due to concerns of range limitation, availability and access to vehicle charging stations.

The Chevrolet Silverado was the first hybrid pickup truck introduced in 2012 but along with the GMC Sierra, both hybrid models have since been discontinued. However, Ford currently offers a hybrid version of the F-150 truck, and the RAM 1500 comes with an eTorque hybrid drive option to improve fuel economy. Vehicle specifications for both pickups are highlighted below, and OEM published spec sheets are included in Appendix A.

Both the Ford F-150 hybrid and RAM 1500 eTorque have a payload capacity up to 1 ton, thereby classifying them as possible replacement options for Oxford County's fleet of light and medium-duty pickups.

Table 28 Hybrid Pickup Truck Models

Make	Model	Vehicle Type	Payload	Towing	Fuel Economy EPA (L/100km) (city/highway/combined)	Price (MSRP)
Ford	F-150	Pickup	2,120 lbs	12,700 lbs	9.4/9.0/9.4 (2WD) 9.8/9.8/9.8 (4WD)	$42,840
RAM	1500 eTorque	Pickup	2,300 lbs	12,750 lbs	11.8/9.4/10.7	$34,240

Ford F-150 Hybrid

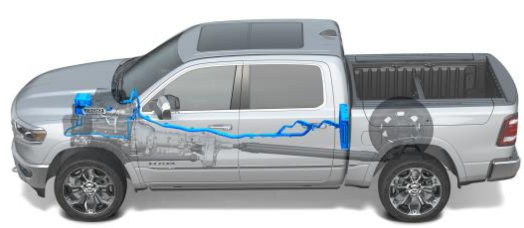
Ford offers a PowerBoost hybrid drive system for their best selling F-150 pickup. The HEV pickup offers a 20% improvement on fuel economy compared to the EcoBoost 3.5L V6 engine[21]. EPA testing publishes the fuel economy of the F-150 at 9.8 L/100km (combined).

The hybrid drive consists of an electric motor and 1.5 kWh lithium-ion battery. Following the concept of a non plug-in drivetrain explained in Section 4.3.1 the electrical system enables recapture of energy through regenerative braking and acceleration assist. The electrical system also offers 7.2 kW of power via outlets located in the truck bed.

The F-150 hybrid has a maximum payload of 2,120 lbs and towing capacity of 12,700 lbs. The hybrid option can be selected for any F-150 model with the incremental price ranging from $4,495 CAD on XL and XLT models to $3,300 CAD on the Lariat.

Note that Oxford County's Paramedic Services currently has one hybrid F-250 pickup. However, this truck was an aftermarket conversion with the hybrid drive system from XL Fleet.

RAM 1500 eTorque



The eTorque system was introduced in 2019 as an available option on RAM 1500 pickups for both 3.6-liter Pentastar V-6 upgrade and 5.7-liter HEMI V-8 engine configurations.

This hybrid drive system uses an electric motor in place of the alternator to improve the fuel economy of the truck. A 48V electrical system is used for the electric motor with a 430 Wh lithium-ion battery pack. This hybrid drive system assists in smoothing the acceleration profile, increasing torque and recaptures kinetic energy via regenerative braking[22]. The eTorque system also powers the electrical accessories of the vehicle and charges the conventional 12V starter battery on-board. The RAM 1500 eTorque offers an improvement on fuel economy at 20/25/22 mpg (city/highway/combined) according to

[21] Car and Driver, Tested: 2021 Ford F-150 Hybrid Proves to Be an Electrifying Workhorse

[22] Green Car Congress, 2019 RAM drops weight, gains 48V eTorque mild hybrid system

the EPA publication a 2 mpg benefit over the RAM 1500 V6 without the eTorque system, 17/25/20 mpg (city/highway/combined)[23].

The weight of the RAM 1500 has also been cut by 225 pounds to help improve fuel efficiency. The RAM 1500 eTorque has a 2,300 payload and towing capacity up to 12,750 lbs.

5.5 PLUG-IN HYBRID ELECTRIC VEHICLES

A variety of plug-in hybrid vehicle models are available on the market in Canada. These models for cars and SUVs are shown below with their estimated fuel economy and range according to gasoline and electric drivetrains[24]. The MSRP for these models ranges from $33,000 to $49,000. The Prius Prime is expected to have the best fuel economy for a plug-in hybrid car at 1.8 Le/100km. Table 29 shows some of the technical specifications for selected models. See Appendix A for detailed specifications and additional models.

Table 29 Plug-in Hybrid Vehicle Models

Make	Model	Vehicle Type	Fuel Economy (Gas)	Range (Gas)	Efficiency (Electric)	Range (Electric)	Price (MSRP)
Ford	Fusion PHEV	Car	2.4 Le/100km	940 km	19 kWh/100km	42 km	$33,930
Honda	Clarity PHEV	Car	2.1 Le/100km	475 km	22 kWh/100km	76 km	$46,306
Hyundai	Ioniq Electric Plus	Car	2.0 Le/100km	961 km	18 kWh/100km	47 km	$33,749
Kia	Optima PHEV	Car	2.3 Le/100km	937 km	18 kWh/100km	45 km	$43,995
Toyota	Prius Prime	Car	1.8 Le/100km	995 km	22 kWh/100km	40 km	$33,550
Chrysler	Pacifica Hybrid	Van	2.8 Le/100km	784 km	31 kWh/100km	51 km	$48,995
Kia	Niro PHEV	SUV	2.1 Le/100km	475 km	22 kWh/100km	42 km	$35,995
Mitsubishi	Outlander PHEV	SUV	3.2 Le/100km	463 km	34 kWh/100km	35 km	$43,998

[23] Autoblog, 2019 Ram 1500 eTorque fuel mileage numbers released

[24] Plug N' Drive Canada, Electric Cars Available for Sale in Canada

5.6 HYBRID DRIVE CONVERSIONS (XL FLEET)

XL Fleet was founded in 2009 to offer aftermarket hybrid drive systems on Class 2 to 6 municipal and commercial fleet vehicles. XL Fleet offers two drivetrain options, a plug-in and non plug-in, which are designed for compatibility with a range of different vehicle makes and models. Details on these drivetrains are listed below.

Oxford County currently has the XLH™ non plug-in hybrid drivetrain outfitted on one Ford F-250 ERV and their ambulances built on GM/Chevrolet chassis.

Table 30 XL Fleet Hybrid Drivetrains

Drivetrain Details	**Hybrid (XLM™)**	**Plug-in Hybrid (XLP™)**
Est. Fuel Economy Improvement[25]	up to 25%	up to 50%
Battery Pack	1.8 kWh	15 kWh
Charging	Regenerative Braking	SAE Level 1 (~12 hours charge time) SAE Level 2 (~5 hours charge time)
System Weight	350 to 385 lbs	750 lbs
Available Vehicle Make/Models	Chevrolet Silverado GMC Sierra 2500 / 3500 HD Ford F-250 pickup Ford Transit vans Chevrolet Express and GMC Savana vans Ford E350/450 Cutaways GM 3500/4500 Cutaways Ford F-59 Super Duty Reach™ Van from Isuzu and Utilimaster	Ford F-150 pickup Chevrolet Silverado and GMC Sierra 2500 HD pickups Chevrolet Silverado and GMC Sierra 3500 HD pickups Ford F-250 pickup

XL Fleet has strong partnerships with vehicle OEMs including Ford, GM, Chevrolet and Isuzu to certify aftermarket work and ensure the OEM's vehicle warranty remains valid. In addition, XL Fleet offers a 3-year (75,000 mile) warranty on all of their hybrid drivetrains.

[25] Fuel economy improvement stated from XL Fleet. Refer to Section 6 for analysis on XL Fleet hybrids currently used in Oxford County's fleet (i.e. Paramedic Services Ford F-250 pickup and ambulances).

The cost of the XLM hybrid system on Oxford County's ambulance and ERVs has trended down from $35,000 (2017) to now $27,850 per vehicle. XL Fleet has commented that they have yet to repurpose/reinstall a hybrid system from a retiring vehicle to a new vehicle because the system is configured based on the specific model year.

5.7 HYBRID DRIVE CONVERSIONS (HYLIION AXLE)

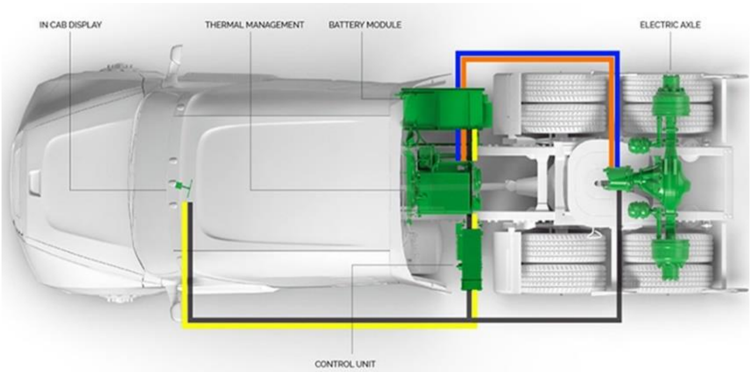


Figure 27 Hyliion Hybrid Axle System

Hyliion is a company based in Cedar Park, Texas which offers a hybrid drive axle for Class 8 tandem axle trucks. This hybrid drive system can be installed at approved modification centers for diesel and CNG trucks from OEMs including Peterbilt, Freightliner, Volvo, Kenworth and Navistar.

Hiller Truck Tech, located in Ayr, ON, is a truck supplier to Oxford County and they offer the Hyliion hybrid axle option. The unit costs approximately $40,000 including installation.

The Hyliion axle system adds about 800 lbs and consists of a battery pack, control unit, thermal management system and regenerative braking.

The improvement on fuel economy is stated to be typically around 7% to 10% and as high as 15% on hilly terrain. In addition, the hybrid axle system can provide a boost of up to 115 hp and 1,500 lbs in torque.

5.8 BATTERY ELECTRIC VEHICLES

5.8.1 CARS AND SUVS

Battery electric car options for the light-duty vehicles currently available in Canada are described below. Note that luxury and performance vehicles are excluded from the market scan (i.e. Porsche Taycan, Tesla Model S etc.) due to cost considerations for municipal fleet applications. Table 31 shows specifications for a few selected models. For additional vehicle information and models, see Appendix A.

Table 31 Battery Electric Vehicle Models

Make	Model	Vehicle Type	Battery size	Fuel Economy (L equivalent)	Range (All-electric)	Efficiency (Electric)	Price (MSRP)
Chevrolet	BOLT	Car	60 kWh	2.0 Le/100km	417 km	0.14 kWh/km	$44,998
Hyundai	Ioniq	Car	38.3 kWh	1.8 Le/100km	274 km	0.14 kWh/km	$41,499
Nissan	Leaf	Car	40 or 62 kWh	2.1 Le/100km	363 km	0.17 kWh/km	$44,299
Volkswagen	eGolf	Car	35.8 kWh	2.1 Le/100km	198 km	0.18 kWh/km	$37,895
Tesla	Model 3	Car	75 kWh	0.18 Le/100km	423 km	18 kWh/100km	$53,000
Ford	Mustang Mach-E	SUV	75 kWh	0.19 Le/100km	475 km	22 kWh/100km	$50,500
Hyundai	Kona	SUV	64 kWh	0.15 Le/100km	415 km	18 kWh/100km	$45,000
Kia	Soul EV	SUV	39.2 kWh	0.16 Le/100km	248 km	20 kWh/100km	$43,000
Chevrolet	Bolt EUV	SUV	65 kWh	0.13 Le/100km	417 km	16 kWh/100km	$38,200

5.8.2 CARGO VANS

Figure 28 GM Brightdrop Van

Recently, GM has announced that it will begin production of the Brightdrop EV 600 electric van at its CAMI plant in Ingersoll, Ontario beginning 2021. This venture will be the first Canadian automotive assembly plant to produce electric vehicles at a commercial scale.

This cargo van is a purpose-built commercial electric vehicle for delivery of goods and services over long ranges and can travel up to 400 km on a full charge. With 120 kW DC fast charging, an hour of charging can restore up to 70% of battery capacity, about 270 km of range. The vehicle has a GVWR of 10,000 lbs with up to 2,200 lbs available payload.

In addition to the GM announcement, Table 32 shows technical specifications for a few selected cargo van models. The Ford eTransit van is available today, while others are expected to be more commercially available in 2022. For additional vehicle information and models, see Appendix A.

Table 32 Electric Cargo Van Models

Make	Model	Vehicle Type	Battery Size	Range (All-electric)	Efficiency (Electric)	Price (MSRP)
Ford	eTransit	Cargo Van	67 kWh	203 km	33 kWh/100km	$58,000
Navistar Inc.	eStar	Cargo Van	80 kWh	160 km	50 kWh/100km	N/A
Workhorse	C1000	Cargo Van	70 kWh	160 km	44 kWh/100km	N/A
BYD	Class 6	Cargo Van	221 kWh	200 km	110 kWh/100km	N/A

5.8.3 PICKUP TRUCKS

Several start-up companies such as Tesla and Havelaar are approaching the market to develop fully electric pickup trucks in competition with established companies like GMC and Ford. The Tesla Cybertruck is the only model available today and has limited availability. Other models are expected to be available for purchase starting in 2021 and 2022. Although information is limited on some of these newer models, below are vehicles anticipated to enter the market soon. For additional information on the electric pickups mentioned here refer to Appendix A.

Table 33 Electric Pickup Truck Models

Make	Model	Vehicle Type	Battery Size	Range (All-electric)	Efficiency (Electric)	Price (MSRP)
Chevrolet	Silverado	Pickup	Not Available (Scheduled Launch 2025)	Not Available (Scheduled Launch 2025)	Not Available (Scheduled Launch 2025)	Not Available (Scheduled Launch 2025)
Ford	F-150	Pickup	Not Available (Scheduled Launch 2022)	Not Available (Scheduled Launch 2022)	Not Available (Scheduled Launch 2022)	$55,000 (est.)[26]
Tesla	Cybertruck	Pickup	100 kWh	386 km	25 kWh/100km	$50,000 (est.)[24]
GMC	Electric Hummer	Pickup	350 kWh	Up to 650 km	54 kWh/100km	$70,000

[26] Market Watch "When does the electric Ford F-150 pickup go on sale, and how much will it cost?"

Make	Model	Vehicle Type	Battery Size	Range (All-electric)	Efficiency (Electric)	Price (MSRP)
Rivian	R1T	Pickup	Up to 180 kWh	643 km	28 kWh/100km	$69,000
Havelaar	Bison e-Pickup	Pickup	N/A	300 kWh	110 kWh/100km	N/A
Bolinger	B2	Pickup	120 kWh	322 km	37 kWh/100km	$158,000

5.8.4 HEAVY-DUTY TRUCKS & CHASSIS

The marketplace for heavy-duty battery electric trucks is mixed between new entrants and well-established OEMs in the heavy-duty truck industry expanding their product line. A brief overview of these OEMs and their vehicle specifications are provided in the table below. It should be noted that one of the key challenges for heavy duty truck application today remains the reduced payload. According to a recent interview from Volvo, "an electric truck with four batteries carries about one tonne less payload than its diesel-driven counterpart" [27]. Further details on vehicle specifications are provided in Appendix A.

Mack also has a battery electric model of their Class 8 LR truck. However, available specifications on this model are limited at this time.

Table 34 Examples of All-Electric Class 8 and Class 8 Heavy-Duty Truck Models

Make	Model	Vehicle Type	Battery size	Range (All-electric)	GVWR (lbs)
BYD	N/A	Class 6	221 kWh	136 km	26,000
Lion Electric	Lion6 – Single Axle	Class 6	252 kWh	290 km	26,000
Lion Electric	Lion8 – Tandem	Class 8	336 kWh	270 km	60,000
Volvo	FL Electric	Class 8	300 kWh	300 km	32,000
Peterbilt	220 EV	Class 7	282 kWh	Up to 320 km	33,000
Freightliner	eM2 106	Class 8	315 kWh	Up to 370 km	33,000
Mack	LR Electric	Class 8	N/A	N/A	66,000

[27] Volvo "Quick Facts Electric Trucks". Available at: https://www.volvotrucks.com/en-en/news-stories/magazine-online/2018/jun/quick-facts-electric-trucks.html

5.9 NATURAL GAS VEHICLES

The market for light-duty CNG vehicles is typically focused on aftermarket vendors partnering with vehicle OEMs to offer a certified CNG option for their vehicles. Selection of an OEM certified option is important as Oxford County has experienced void warranty from RAM and Chevrolet vehicles due to aftermarket CNG conversions.

Schulz Automotive located in Tavistock, ON has been used by Oxford County for the upfitting of all the dual CNG/gasoline fuel systems for passenger CNG vehicles in Oxford County's fleet. All maintenance and repair of this CNG fleet is managed through this shop. Some additional vendors for CNG conversions include the following.

- **Landi Renzo Group** has recently received certification from the environmental protection agency (EPA)[28] for use of their Eco Ready CNG fuel system on Ford F150 pickups. This upgrade can be outfitted through approved regional installers or specified with the truck build at the Ford plant in Kansas City, MO.
- **Alternative Fuel Systems Inc.** is a subsidiary of Westport Power Inc. who manufactures Cummins Westport CNG engines (including the Cummins ISL-G 280). AFS designs, develops and produces engine control units (ECUs) as well as providing aftermarket fleet conversion in the area of natural gas-powered vehicles.
- **Frontier CNG Inc.** are fleet specialists offering CNG fleet conversions of vehicles from light to heavy-duty vehicles. They also offer fuel pricing programs and strategies along with installation of CNG fuelling stations. Frontier CNG Inc. has their head office located in Mississauga, ON.

Several of the major medium and heavy-duty truck OEMs offer the option to outfit their trucks with a natural gas powertrain. Cummins Westport is the primary OEM manufacturing natural gas engines for these vehicles. Current models include the Cummins ISX12N which can deliver up to 400 hp and the Cummins L9N with 250 to 350 hp.

Traditional heavy-duty truck chassis OEMs include Freightliner, Autocar, Mack and Peterbilt with Class 8 vehicle make/models. Examples of heavy-duty CNG trucks available in the market today are discussed below with vehicle specifications for each provided in Appendix A.

Table 35 Examples of Natural Gas Heavy Duty Vehicles

Make	Model	Vehicle Type	Natural Gas Tank Size	Range	Payload
Freightliner*	114SD	Class 8	227 L	550 km	N/A
Autocar**	ACMD 4X2	Class 8	Up to 378 L	N/A	5,443 kg

* Currently, Oxford County already uses the Freightliner 114SD CNG Truck as part of their snowplow fleet.

[28] Automotive Fleet "EPA Certifies Landi Renzo's CNG F-150". Available at: https://www.automotive-fleet.com/343788/epa-certifies-landi-renzos-cng-f-150

** Autocar offers the option for CNG powertrains on six of their current truck models (ACMD 4X2, ACMD 4X2, ACMD 6X4, ACX 4X2, ACX 6X4 and ACX 8X4).

5.10 HYDROGEN VEHICLES

The hydrogen FCEVs currently available in North America are listed below, all are from major Japanese auto manufacturers. Currently, only the Toyota Mirai and Hyundai Nexo are available in Canada. Examples of light-duty fuel cell vehicles available in the market today are discussed below with vehicle specifications for each provided in Appendix A.

Table 36 Examples of Fuel Cell Vehicles

Make	Model	Vehicle Type	Hydrogen Tank Size	Range	Price (MSRP)
Toyota	Mirai	Car	122 L	500 km	$73,870
Hyundai	Nexo	Car	157 L	570 km	$73,000

5.11 MAJOR EQUIPMENT

Traditional heavy equipment and tractor manufacturers have also been making progress in the space of battery electric drivetrains. This section provides an overview of some recent advancements which can be of interest.

Proterra and Komatsu Partnership

Proterra is a commercial electric vehicle technology manufacturer and Komatsu is a manufacturer and supplier of construction and mining equipment. In January of 2021, the two entities announced that they would be partnering to develop all-electric construction equipment, beginning with a Komatsu battery-electric middle class hydraulic excavator.

Figure 29 Rendering of Komatsu Battery Electric Backhoe

The first joint-development is slated to undergo proof of concept in 2021, with anticipated commercial availability being 2023 or 2024. The electric-battery system is expected to incorporate high energy density and fast charging technology and will be merged within the existing body of the excavator to act as a counterweight used to balance the excavator's hydraulic arm movements.

John Deere All-Electric Backhoe

John Deere has developed a proof-of-concept electric backhoe and is testing the vehicle on work sites in the North Eastern USA. The backhoe is targeted to achieve the same operation and performance levels of its diesel-powered counterpart, the John Deere 100 horsepower 310L backhoe.

John Deere aims to produce an electric backhoe that will lower operating costs, reduce noise pollution, improve machine reliability, and eliminate operations emissions. The backhoe is in early development phases and a date for commercial release has not been given yet.

Case 580 EV

Introduced in 2020, this fully electric backhoe loader is currently available in North America. It is equipped with a 480V, 90 kWh lithium-ion battery that provides enough power for at least 8-hours of typical operation and can be charged by a 220V three phase connection.

The loader is stated to potentially save up to 90% in annual vehicle service and maintenance costs when considering reduction and elimination of diesel, engine oil, diesel exhaust fluid, and regular preventative maintenance activities.

Caterpillar D6XE Electric Drive Dozer

In addition, to the movement of manufacturers investing in the development of battery electric tractors and construction equipment.

Figure 30 CAT D6XE Dozer

One model of interest is the D6XE medium-duty dozer from Caterpillar. From its release in 2018, the D6XE dozer is the first of its kind with an electric drive transmission which is stated to reduce fuel consumption by up to 35% and can reduce maintenance costs by up to 12% from reducing the complexity of a mechanical drivetrain[29]. Some of the key factors cited by Caterpillar for the maintenance cost reduction are:

- Simplified electric drivetrain,

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[29] CAT D6XE specifications, Source: https://www.cat.com/en_US/products/new/equipment/dozers/medium-dozers/2145358496516889.html

- Elevated sprocket allows power train to slide out from the back of the dozer like traditional machine,
- Cab air filter replacements extended to every 500 hours,
- Standard reversing fan extends the time between core clean-outs,
- Generator accessible via 30-minute cab removal, and
- Power train oil life extended from 1,000 to 2,000 hours

There have also been improvements in the fuel efficiency of newer model diesel powered equipment now available in the market.

Oxford County currently has a 2006 model Caterpillar D7R11 dozer (Asset ID 742) scheduled for replacement in 2024 for which the D6XE dozer could be a viable replacement option. The D6XE dozer is slightly smaller but can offer improvements on fuel consumption and emissions. Table 37 highlights a comparison on some of the key specifications of these dozer models, while more details are included in Appendix A.

Table 37 Medium Duty Dozer Specifications

Make	Model	Engine	Power Train	Power	Operating Weight	Fuel Tank	Estimated Price[30]
CAT	D6XE	CAT C9.3B	Electric Drive	215 hp	51,333 lbs	90 gal	$765,000
CAT	D7	CAT C9.3B	Fully Automatic 4-speed	265 hp	65,644 lbs	122.8 gal	$700,000

[30] CAT D6XE price listed at $529,802 USD (exclusive of tax), Source: https://ironsearch.com/equipment/for-sale/caterpillar-d6xe-xwvp-dozer/4067497

6 GREEN FLEET PLAN

6.1 GREEN FLEET OPPORTUNITIES

From the process of reviewing Oxford County's current green fleet initiatives, stakeholder engagement with user groups and a market scan of alternative propulsion technology there are several opportunities to consider for further reduction of fleet emissions and incorporating these recommendations into the 2021 update to the Green Fleet Plan (2016). Table 38 provides a list of these opportunities under consideration.

There is a need to further evaluate each of these opportunities through an assessment of capital and operating costs, return on investment (ROI), and estimate of potential emissions reduction. Section 6.2 further details this analysis and presents the implications for the 5-year Green Fleet Plan.

Through the evaluation process, each of these opportunities can be assessed against ease of implementation, cost impact (capital and operating budgets), and magnitude of GHG reduction.

Table 38 Green Fleet Opportunities for Assessment

No.	Opportunity	Description
1	Pickup Trucks	Evaluate the option of replacing gasoline and CNG/gasoline pickup trucks with more fuel efficient hybrid options and the possibility to pilot a fleet of battery electric trucks. There are 51 pickup trucks scheduled for replacement over the next 5-years which offers a large potential for emissions reduction. This total includes compact, ½ ton, ¾ ton and 1 ton pickups. However, note that the 2021 budget has already been approved for the replacement of nine (9) pickup trucks in 2021. Therefore, this opportunity will focus on the trucks being replaced from 2022 onwards.
2	Cargo Vans	Evaluate the replacement of diesel, gasoline and CNG/gasoline vans currently in the fleet with more fuel efficient options such as battery electric. There are nine (9) cargo vans are coming up for replacement over the next 5-years which can be assessed.
3	Cars	Evaluate replacement of the one PHEV car assigned to Engineering Services with a BEV model.
4	SUVs	Evaluate replacement of three (3) CNG/gasoline SUVs for replacement with more fuel efficient hybrid or BEV options. Assets 665 and 917 (in 2023) and asset 803 (in 2024).
5	Heavy-Duty Trucks	There are several heavy-duty diesel trucks (i.e. tandems and single axle trucks) which could be evaluated for emission reduction opportunities. • Total of 14 diesel trucks scheduled for replacement over the next 5-years. • Two (2) diesel snowplows stationed at the Woodstock Yard which could be considered for CNG conversion due to proximity to the

No.	Opportunity	Description
		CNG fueling station. Oxford County has committed to purchasing two CNG snowplows in 2021 as per their approved fleet budget. • A small pilot of a BEV or a hybrid drive system, such as the Hyliion Axle, could be a viable alternative for other single axle or tandem trucks. The focus for a BEV should be on a lower mileage truck without winter critical operations in order to mitigate range anxiety.
6	Anti-Idle Technology	Evaluate the implementation of anti-idling systems across the wider fleet, focusing on vehicles with high idling time. Public Works has installed anti-idling systems on two diesel tandem trucks (Asset 362 and 367). This system shuts off the engine when the vehicle is left in park or in neutral and the power take-off (PTO) is not engaged.
7	Waste Management Equipment (Dozer)	Evaluate "right-sizing" for a more fuel efficient option for replacement of the diesel dozer currently used by the Waste Management group. Oxford County currently has a 2006 model Caterpillar D7R11 dozer (Asset ID 742) scheduled for replacement in 2024. This dozer has averaged 10,000 L/year (diesel) producing 27.5 tonnes of CO_2e. One option is the Caterpillar D6XE dozer with an electric transmission. It is slightly smaller but can offer improvements on fuel consumption and emissions (reference Section 5.11).
8	Hybrid Ambulance Program	Evaluate the replacement of the diesel ambulance fleet with gas-hybrid ambulances. There are currently nine (9) hybrid ambulances in the fleet. From 2021 to 2022 there will be an opportunity to continue this replacement program and complete the entire fleet transition to hybrids as another five (5) diesel ambulances are set for retirement[31].
9	Hybrid ERV Program	Evaluate the replacement of gasoline and diesel ERVs with hybrid vehicles. There are currently two ERVs, assets 1317 (diesel) and 1318 (gasoline) set for replacement in 2021 and 2022 respectively which could adopt hybrid technology.
10	Bio-diesel	Dyed diesel fuel consumption totaled 168,000 L in 2019. There is an opportunity to consider the use of bio-diesel fuel blends B5 (5%) up to B20 (20%) to reduce emissions for these diesel vehicles where limited alternatives exist for other fuels or electric options. Note that a lower B5 blend will be considered for winter operations to mitigate concerns of fuel gelling. Section 5.11 does highlight some recent advancements in battery electric technology. However, there are currently no options available in the market which would be suitable "like-for-like" replacements with the tractors Oxford County has in their 5-year replacement plan.

[31] Scheduled retirement plan for assets 1003, 1006 and 1007 (in 2021), 1192 and 1193 (in 2022)

No.	Opportunity	Description
11	CNG Infrastructure Assessment	The current fleet of Public Works vehicles can be assessed for further CNG adoption. Based on the estimated fuel demand of CNG vehicles this could make a case for Oxford County to invest in its own on-site CNG fuel station and minimize unnecessary travel time to/from the existing public fuel station. The emissions reduction of the CNG fleet and payback period of the fueling station will need to be assessed for alignment against not only the interim 5-year GHG reduction target but also longer term targets working towards 2050.

6.2 COST ASSESSMENT & EMISSIONS MODELING

Table 39 lists the common financial inputs, fuel pricing and emission factor assumptions which are used in all the vehicle lifecycle cost comparisons of the green fleet opportunities. Additional lifecycle inputs by vehicle type are based on historical fleet data from Oxford County and OEM published data for vehicle and technologies not in the current fleet.

Table 39 Financial and Fuel Emission Factor Inputs

Input/Assumption	Value	Source
Financials		
Inflation Rate	2.1%	Statistics Canada, Consumer Price Index (CPI) Ontario, Historical Summary
Discount Rate	1.19%	Bank of Canada Government Long Term Bond Yield (proxy for risk-free rate)
Fuel Costs		
Diesel Base Fuel Price	0.98 $/L	Oxford County Fuel Records
Diesel (Dyed) Base Fuel Price	0.828 $/L	Oxford County Fuel Records
Gasoline Base Fuel Price	1.002 $/L	Oxford County Fuel Records
CNG Base Fuel Price	0.92 $/kg	Oxford County Fuel Records
Electricity Base Price	0.13 $/kWh	Oxford County Facility Data Request
Ontario Carbon Tax Estimated Impact on Fuel Prices	Refer to Section 5.2	Carbon Taxes & Rebates Explained (Province by Province), January 2021
Emission Factors		
Diesel Emissions	2.738 kg CO_2e/L	Oxford County Emissions Factor
Gasoline Emissions	2.326 kg CO_2e/L	Oxford County Emissions Factor
CNG Emissions	2.965 kg CO_2e/kg	Oxford County Emissions Factor

Note that the increment of carbon tax impact relative to base fuel price is not applied to 5% of the fuel cost for B5 and correspondingly not applied to 20% of the fuel cost for B20 blend. For example, the 2.7 cent/L increase would only be applied as 2.2 cents/L for B20 fuel.

6.2.1 PICKUP TRUCKS

Oxford County's fleet replacement plan is heavily centred on pickup trucks over the next 5-years. From 2021 to 2025 there are 51 vehicles scheduled for replacement. Therefore, there is an opportunity to consider more fuel efficient technologies over the gasoline and CNG/gas pickups currently in the fleet.

The lifecycle analysis comparing different propulsion types of pickups is presented below. Modeling inputs used for the analysis of the light-duty and medium-duty pickups are noted in Appendix B. Note that currently OEM hybrid options are available for compact and ½ ton pickups whereas an aftermarket system, such as the XL Fleet system, would need to be considered for hybrid ¾ ton and 1 ton pickups. Some variations may occur in emissions reduction based on different vehicle usage profiles of fleet user groups, refer to Appendix C.

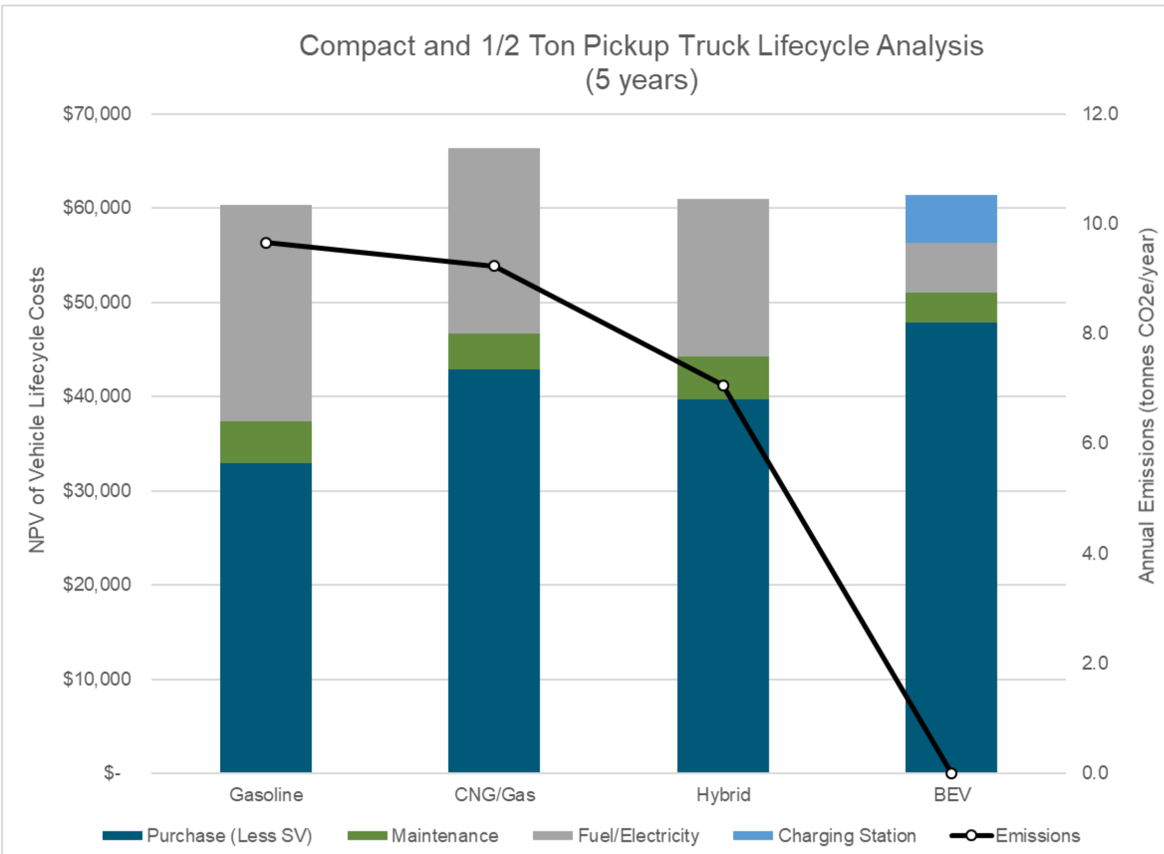

Figure 31 Compact and ½ Ton Pickup Truck Lifecycle Analysis

This lifecycle comparison shows that the dual fuel CNG/gasoline pickups cost more than hybrid or battery electric alternatives. This is largely due to the capital upfitting cost for CNG systems which can range from $9,000 up to $13,000. There is a moderate cost savings from CNG fuel over the life of the vehicle however, this fuel savings is not as great in comparison to hybrid or battery electric options. Furthermore, the Transport Canada EV purchase incentive of $5,000 helps lower the purchase cost of BEV pickups.

A gasoline pickup truck is likely to contribute almost 10 tonnes/year in CO_2e emissions. The CNG upfitting option can reduce this to 9 tonnes/year (10% reduction)[32]. However, hybrid and battery electric options are more favourable in cutting emissions.

For light-duty compact and ½ ton pickup trucks there are OEM available hybrid options, such as the hybrid Ford F-150. However, for ¾ ton and 1 ton pickup trucks an aftermarket conversion, similar to the XL Fleet hybrid system, is likely required. There are aftermarket hybrid options available for Chevrolet Silverado 2500 and 3500 pickups. The analysis for ¾ ton and 1 ton pickups is shown in Figure 32 and Figure 33 respectively.

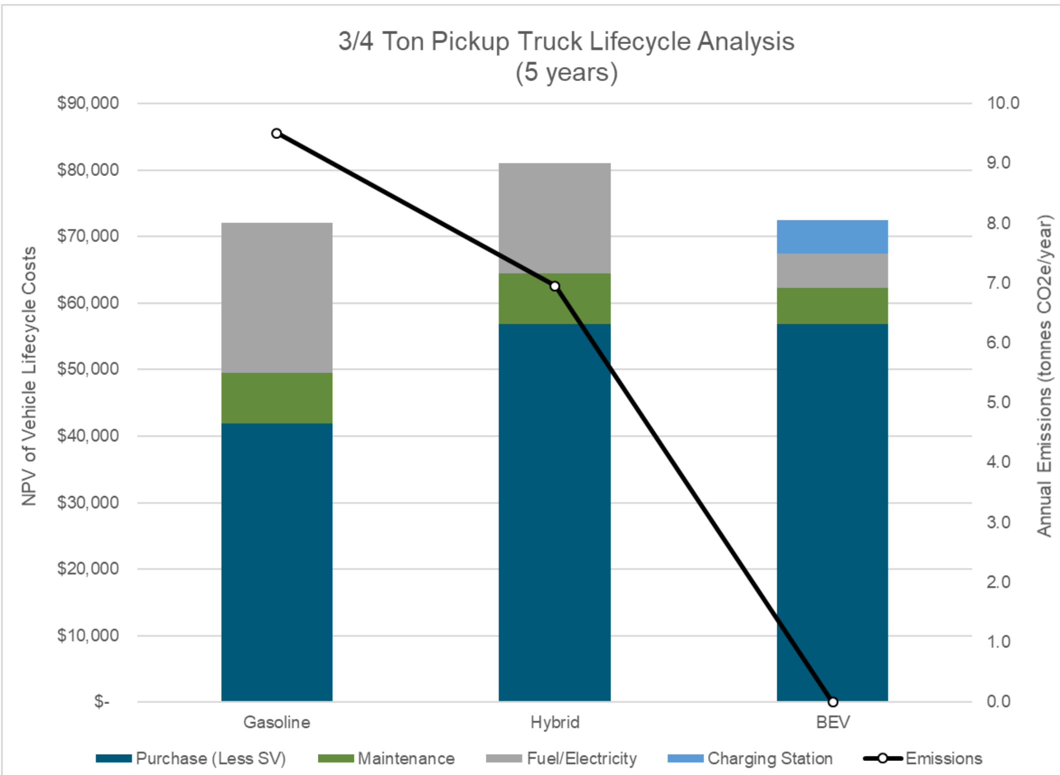

Figure 32 3/4 Ton Pickup Truck Lifecycle Analysis

[32] Based on Oxford County 2019 Fuel Records for CNG Pickups 33% of total fuel use (measured in gLe) is CNG.

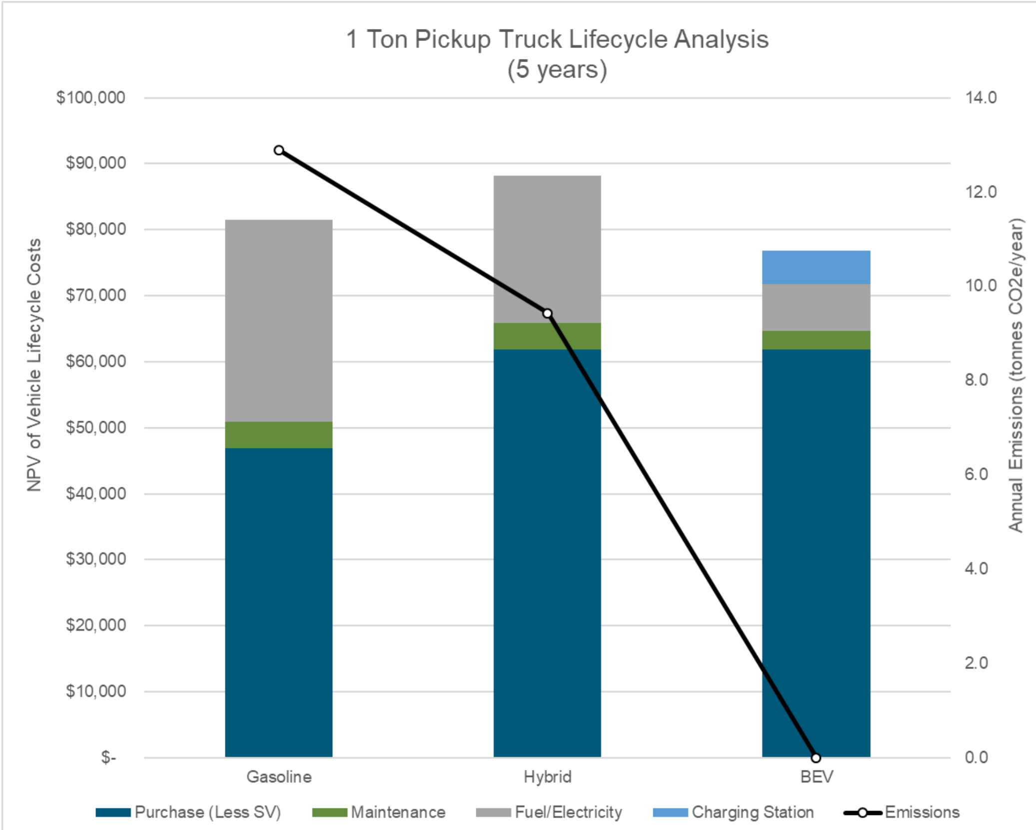

Figure 33 1 Ton Pickup Truck Lifecycle Analysis

Overall, the hybrid options for both ¾ ton and 1 ton pickup trucks are more costly, in comparison to hybrid ½ ton pickups which have OEM hybrid options available. However, there can are still notable emissions reduction for transitioning ¾ and 1 ton pickups to hybrids in the interim and bridge the technology gap until OEM hybrids or fully battery electric options are more available.

Table 40 outlines a replacement strategy for the pickup truck fleet. It shows the number of pickup trucks to be replaced each year by their respective propulsion type. Potential annual emissions reduction is achieved by replacing these trucks with the proposed replacement technology; gasoline, hybrid, or BEV. This strategy also aligns with the market availability of hybrid and battery electric trucks by allowing time for technology to mature and allows adequate time for Council approval and procurement processes for new hybrid and BEVs. For this reasoning 2021 pickup truck replacements are recommended to be gasoline.

Table 40 Pickup Truck Replacement Strategy

Year	Pickup	Gasoline	CNG/Gasoline	Proposed Replacement Technology	Potential Annual Emissions Reduction (tonnes CO_2e/year)
2022	Compact and ½ Ton	6	3	Gas (Hybrid)	33.3
2022	1 Ton	5	N/A	Gas (Hybrid)	17.3
2023	Compact and ½ Ton	5	4	Gas (Hybrid)	16.2
2023	1 Ton	1	N/A	Gas (Hybrid)	3.5

Year	Pickup	Gasoline	CNG/Gasoline	Proposed Replacement Technology	Potential Annual Emissions Reduction (tonnes CO_2e/year)
2024	Compact and ½ Ton	1	7	Gas (Hybrid)	12.9
2024	¾ Ton	3	N/A	Gas (Hybrid)	7.7
2024	Compact and ½ Ton	1	N/A	BEV (pilot)	6.9
2025	Compact and ½ Ton	2	N/A	BEV	21.8
2025	¾ Ton	4	N/A	BEV	38.0
				Total:	**157.5**

Overall, there is potential to reduce fleet emissions by almost 158 tonnes per year by replacing all retiring pickup trucks from 2022 to 2024 with hybrid options, purchasing an initial BEV pickup truck in 2024 and continuing all pickup truck replacements in 2025 with BEVs.

The following table shows the cost and emissions impact for replacing pickup trucks with hybrid and BEV alternatives. A positive capital budget impact means that the proposed new technology is more expensive than the old vehicle. A negative operating cost impact means the new technology has an annual cost savings.

Table 41 Financial & GHG Reduction Summary of Pickup Trucks

Vehicle Type	Est. Annual GHG Reduction (tCO_2e/year)	Lifecycle GHG Reduction (tCO_2e)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Lifecycle Operational Savings ($)	Payback Period (years)	Return on Investment, ROI (%)
Compact and ½ Ton Hybrids (replacing Gasoline)	2.4	12.1	+$6,800	-$1,200	$6,000	5.7	-12%
Compact and ½ Ton Hybrids(1) (replacing CNG/Gas)	2.0	10.1	-$3,200	-$400	$2,000	< 1 year	> 100%
¾ Ton Hybrids (replacing Gasoline)	2.6	12.8	+$15,000	-$1,200	$6,000	12.5	-60%
1 Ton Hybrids (replacing Gasoline)	3.5	17.3	+$15,000	-$1,600	$8,000	9.4	-47%
Hybrid Pickup Trucks(2) (compact, ½, ¾ and 1 ton)	**90.7**	**453.7**	**+$178,200**	**-$35,200**	**$176,000**	**5.1**	**-1%**
Compact and ½ Ton BEVs (replacing Gasoline)	9.0	45.2	+$20,000	-$3,500	$17,500	5.7	-13%
¾ Ton BEVs (replacing Gasoline)	9.5	47.5	+$20,000	-$3,900	$19,500	5.1	-3%
BEV Pickup Trucks(2) (compact, ½ and ¾ ton)	**66.7**	**333.5**	**+$140,000**	**-$26,700**	**$133,500**	**5.2**	**-5%**

(1) A payback period of less than 1 year and a ROI exceeding 100% means that the capital cost for the hybrid pickup truck is less than the CNG/Gas outfitted truck. As well, there are annual operating savings from reduced fuel consumption. There is no incremental investment in capital cost.

(2) Calculated as a weighted average total based on the total number of replacements of each type (i.e. 13x hybrid ½ ton pickups replacing gasoline pickups, 14x hybrid ½ ton pickups replacing CNG/gas pickups, 3x ¾ ton hybrid and 6x 1 ton hybrid pickups replacing ¾ ton and 1 ton gasoline pickups respectively).

6.2.2 CARGO VANS

There are nine (9) cargo vans scheduled for replacement over the next 5-years and one cargo van being added to the fleet in 2021 as an expansion vehicle. These cargo vans include diesel, gasoline and dual fuel CNG/gasoline vehicles. There is an opportunity to assess which of these propulsion types is the most favourable in terms of lifecycle cost and emissions as well as considering BEV options. Appendix B cites the inputs used for this analysis with the lifecycle comparison shown in Figure 34.

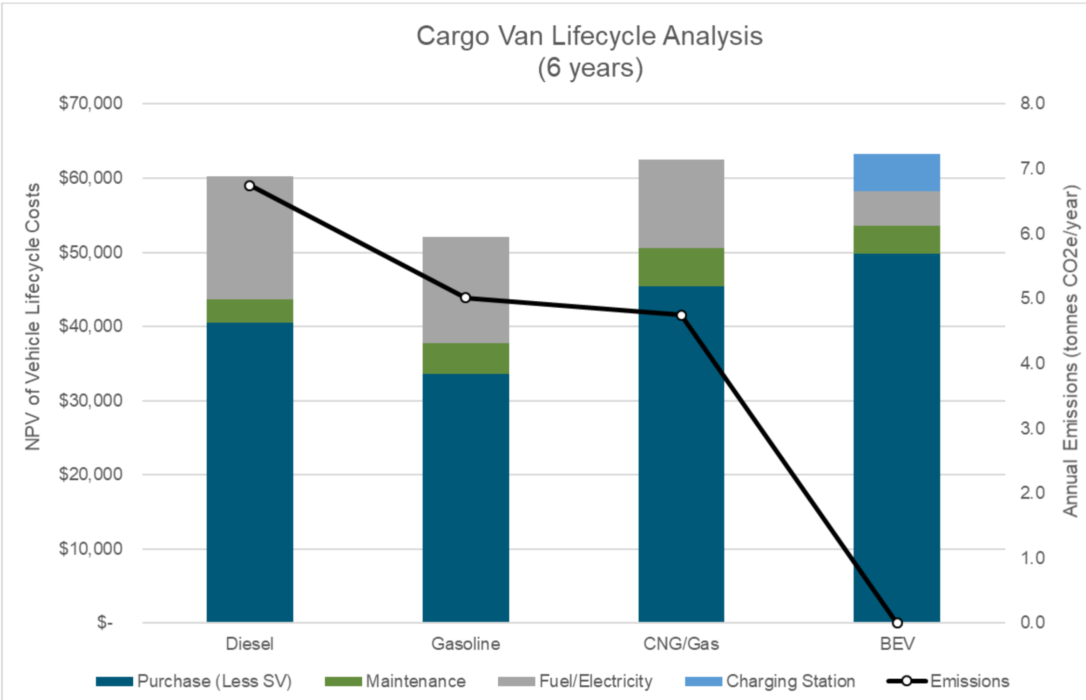

Figure 34 Cargo Van Lifecycle Analysis

The lifecycle comparison shows that gasoline is the most favourable fuel type for cargo vans currently in the fleet. Gasoline vans have the lowest lifecycle cost as well as lower emissions compared to the diesel vans. There is minimal GHG reduction between a straight gasoline and a CNG/gasoline van due to limited CNG fuel consumption. This can be sourced back to the inconvenience of CNG fueling for the fleet.

The total lifecycle cost of a BEV cargo van is comparable to diesel and CNG/gasoline vans. Table 42 proposes a replacement strategy for the cargo van fleet, centred on the idea of ultimately transitioning to BEVs and bridging this gap with the most fuel efficient gasoline option in the interim.

Paramedic Services has expressed interest in replacing their cargo van with a BEV. Note that this replacement would be subject to Council budget approval as the replacement would occur in 2021.

Table 42 Cargo Van Replacement Strategy

Asset ID	Make/Model	Replace Year	Current Fuel	Proposed Technology	Potential Emissions Reduction (tonnes CO_2e/year)[33]
573	TBD	Expansion (2021)	Gasoline	Gasoline	+4.6 (added)
574	Chevrolet Express	2021	Gasoline	Gasoline	0
OXF	Chevrolet Express	2021	Gasoline	BEV	4.6
110	Mercedes Sprinter	2023	Diesel	BEV	3.7
570	Mercedes Sprinter	2023	Diesel	BEV	6.1
680	Chevrolet Express	2023	CNG/Gasoline	BEV	4.3
682	Mercedes Sprinter	2023	Diesel	BEV	6.1
104	Chevrolet Express	2024	CNG/Gasoline	BEV	2.6
905	Ford Transit	2024	Gasoline	BEV	11.6
664	Chevrolet Express	2025	Gasoline	BEV	4.6
				Total:	**39**

Overall, there is potential to reduce fleet emissions by 39 tonnes per year following this plan to replace all cargo vans until 2023 with more fuel efficient gasoline vans. This is the net effect also accounting for additional fleet emissions from the expansion purchase of a gasoline cargo van in 2021. Note that some variations may occur in emissions reduction based on different vehicle usage profiles of fleet user groups, refer to Appendix C.

To align with market maturity in this category from 2023 onwards all replacements could be considered as BEVs starting with a pilot BEV cargo van in 2021 for the Paramedic Services fleet, subject to budget approval from Council. Table 43 presents the financial and environmental implications for this replacement strategy.

A positive capital budget impact means that the proposed new technology is more expensive than the old vehicle. A negative operating cost impact means the new technology has an annual cost savings. The capital cost of the BEV cargo van includes a plug-in charging station for the vehicle (refer to Appendix B).

Table 43 Financial & GHG Reduction Summary of Cargo Vans

Vehicle Type	Est. Annual GHG Reduction (tCO_2e/year)	Lifecycle GHG Reduction (tCO_2e)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Lifecycle Operational Savings ($)	Payback Period (years)	Return on Investment, ROI (%)
BEV Van (replacing Diesel)	6.7	40.2	+$14,400	-$1,900	$11,400	7.6	-21%
BEV Van (replacing Gasoline)	5.0	30.0	+$21,300	-$1,700	$10,200	12.5	-52%
BEV Van (replacing CNG/Gas)	4.8	28.8	+$9,500	-$1,500	$9,000	6.3	-5%
BEV Vans(1)	**43.7**	**261.7**	**+$126,100**	**-$13,800**	**$82,800**	**9.1**	**-34%**

[33] Additional emissions with the expansion cargo van being added to the fleet in 2021 are estimated based on the typical utilization, fuel economy and emissions of gasoline cargo vans currently in the fleet.

(1) Calculated as a weighted average total based on the total number of replacements of each type (i.e. 3x BEV cargo vans replacing diesel, 3x BEV replacing gasoline vans and 2x BEV replacing CNG/gas)

6.2.3 CARS

Oxford County plans on replacing its one Chevrolet VOLT PHEV with a fully battery electric car. Appendix B provides the inputs for the lifecycle comparison of Oxford County's PHEV and BEV cars with the result shown in Figure 35.

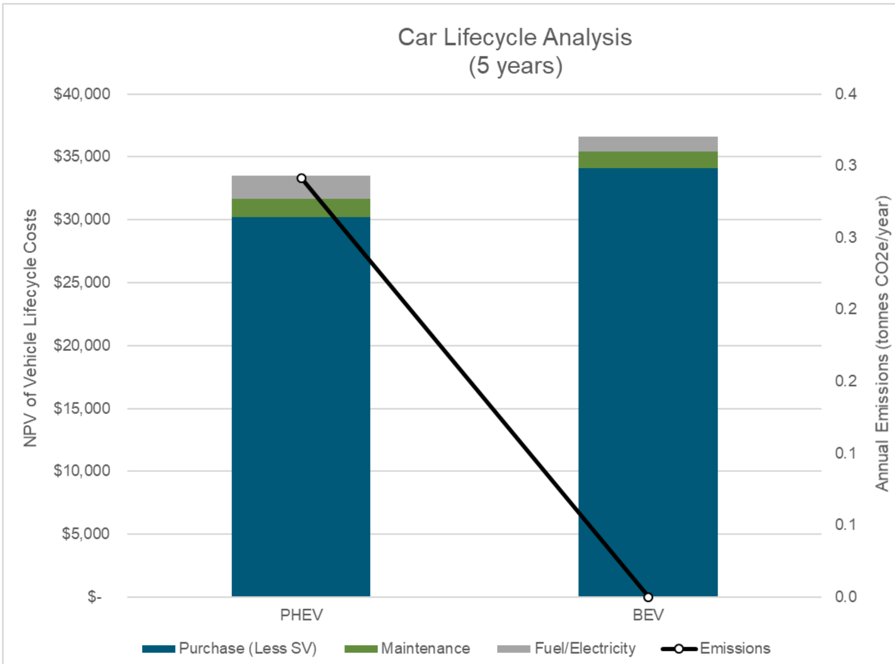

Figure 35 Car Lifecycle Analysis

Overall, there is minimal GHG reduction for a BEV over PHEV. Based on Oxford County's historical fueling records the PHEV was driven on gasoline approximately 20% of the time. Transport Canada rebates apply for both long-range PHEVs and BEVs. However, the MSRP for BEV models is still notably higher than PHEVs.

The financial business case alone does not suggest that a BEV is a better alternative. Furthermore, a PHEV can also offer more flexibility in terms of range in case travel outside Oxford County is required for meetings or training. The recommendation would be to stay with a PHEV and evaluate the next lifecycle replacement as BEV prices are likely to continue trending down. Table 44 summarizes the financial figures and emissions reduction if the BEV option is pursued.

Table 44 Financial & GHG Reduction Summary of BEV Car

Vehicle Type	Est. Annual GHG Reduction (tCO_2e/year)	Lifecycle GHG Reduction (tCO_2e)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Lifecycle Operational Savings ($)	Payback Period (years)	Return on Investment, ROI (%)
BEV Car (replacing PHEV)	0.3	1.5	+$3,900	-$200	$1,000	19.5	-74%

6.2.4 SUVS

There are three dual fuel CNG/gasoline SUVs in the fleet, which are scheduled for replacement within the next 5-years. Appendix B lists the inputs used in developing the lifecycle comparison of these SUVs against more fuel efficient hybrid, PHEV and BEV alternatives. Note utilization can vary by user group, refer to Appendix C.

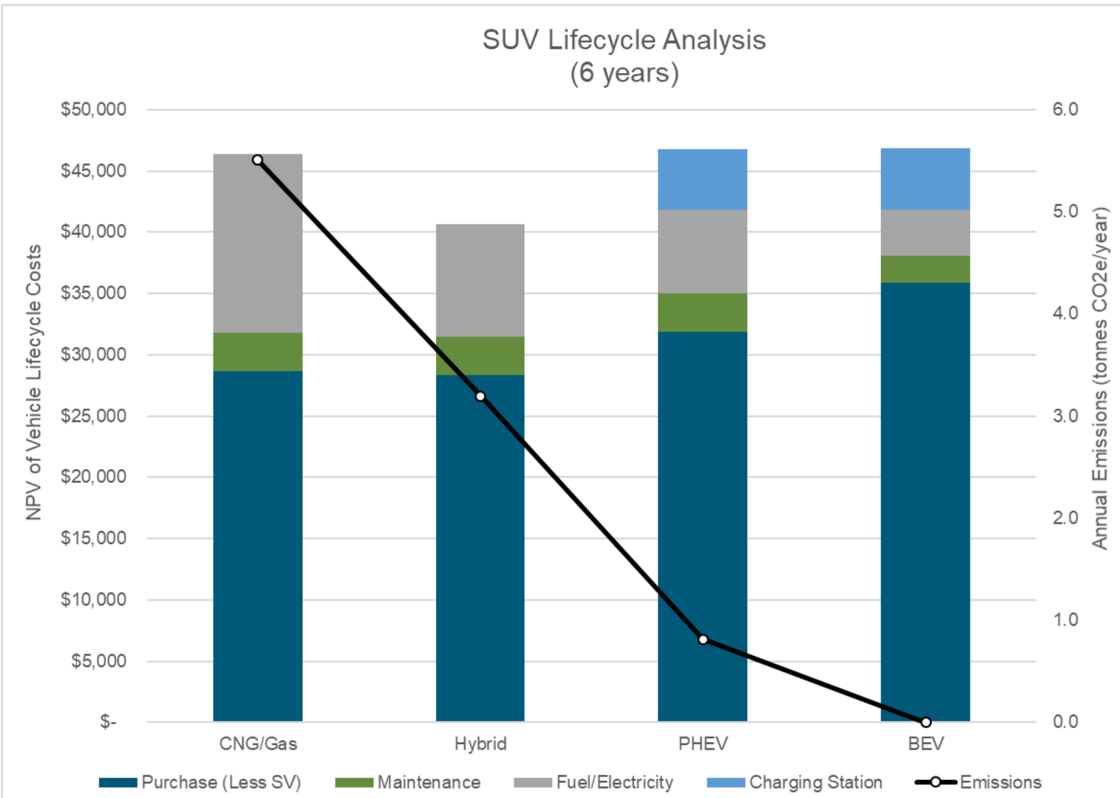

Figure 36 SUV Lifecycle Analysis

The current fleet of SUVs, although outfitted with CNG fuel system, only run on CNG fuel about 15% of the time. Thereby, the CNG system does not contribute greatly to emissions reduction.

The total lifecycle cost of both PHEV and BEV options are less than the cost of CNG/gasoline SUVs currently in the fleet. Furthermore, both PHEVs and BEVs offer significant reduction in tailpipe emissions.

From user group feedback the strategic direction will be to pursue PHEVs for the SUV fleet. This will enable users to get familiar with the operational needs of plug-in charging before transitioning completely to battery electric alternatives. PHEVs also help address concerns of range anxiety in case users need to travel outside Oxford County. The replacement timeline of this fleet is provided in Table 45.

Table 45 SUV Replacement Strategy

Asset ID	Make/Model	Replace Year	Current Fuel	Proposed Replacement Technology	Potential Emissions Reduction (tonnes CO_2e/year)
665	Chevrolet Equinox	2023	CNG/Gasoline	PHEV	2.8
917	Chevrolet Equinox	2023	CNG/Gasoline	PHEV	8.6
803	Chevrolet Equinox	2024	CNG/Gasoline	PHEV	2.8
				Total:	**14.3**

The PHEVs will also achieve payback over the vehicle lifecycle. There is cost savings of foregoing the CNG fuel system upgrade as well as savings on annual fuel cost. Table 46 provides these financial measures and emissions reduction. Overall, PHEVs can produce a positive ROI and cut approximately 5 tonnes CO_2e per vehicle in comparison to CNG/Gasoline SUVs.

Table 46 Financial & GHG Reduction Summary of PHEV SUVs

Vehicle Type	Est. Annual GHG Reduction (tCO_2e/year)	Lifecycle GHG Reduction (tCO_2e)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Lifecycle Operational Savings ($)	Payback Period (years)	Return on Investment, ROI (%)
PHEV SUV (replacing CNG/Gas)	4.6	27.6	+$8,200	-$1,400	$8,400	5.9	2%

6.2.5 HEAVY-DUTY TRUCKS

Oxford County has 16 heavy-duty diesel trucks scheduled for replacement over the next 5-years. The market for heavy-duty battery electric trucks is maturing however CNG is also an option. Section 6.2.11 investigates the potential for CNG adoption in addition to investment in a CNG fueling station. However, the following are some considerations for this fleet which would be feasible without the investment for on-site CNG station:

1. **CNG Snowplows:** to evaluate the CNG conversions for two more snowplows being purchased in 2021 which are to be stationed in Woodstock, due to the site's proximity to the publicly available CNG fueling station.
2. **Pilot Hybrid Tandem Truck:** there is an opportunity to consider a pilot of the Hyliion hybrid axle technology on a tandem truck to improve fuel economy and reduce GHG emissions.
3. **Pilot BEV Trucks:** there can be an opportunity to pilot a BEV truck in the later part of the 5-year plan, in order to better align with market availability of BEV truck models. Trucks with lower daily utilization demands and which are less operations critical (i.e. non plow trucks) can be targeted first to mitigate risk of the pilot. One likely candidate is replacement of a Sterling L8513 single axle (Assets 684 or 685) use by the Water Treatment or Distribution groups. A Class 7 or 8 BEV truck can be selected for this pilot.

   Currently, there is no market availability for a BEV tandem snowplow. Furthermore, the cold weather operations and long operating range required for these trucks would introduce a large element of risk into fleet operations. The potential for BEV snowplows can be revisited as part of future updates to Oxford County's green fleet plans as technology progresses. However, at this time there are likely better suited heavy-duty fleet trucks to begin the transition to BEVs in the fleet, as mentioned above.

6.2.5.1 *SNOWPLOW TANDEM TRUCKS*

A lifecycle analysis of diesel versus CNG snowplows has already been prepared from Oxford County in their 2018 TAC Award submission. This report was referenced along with Oxford County's historical fleet maintenance records to present the updated lifecycle comparison below. Data on the Hyliion hybrid axle was obtained from Hiller Truck Tech and published information from Hyliion.

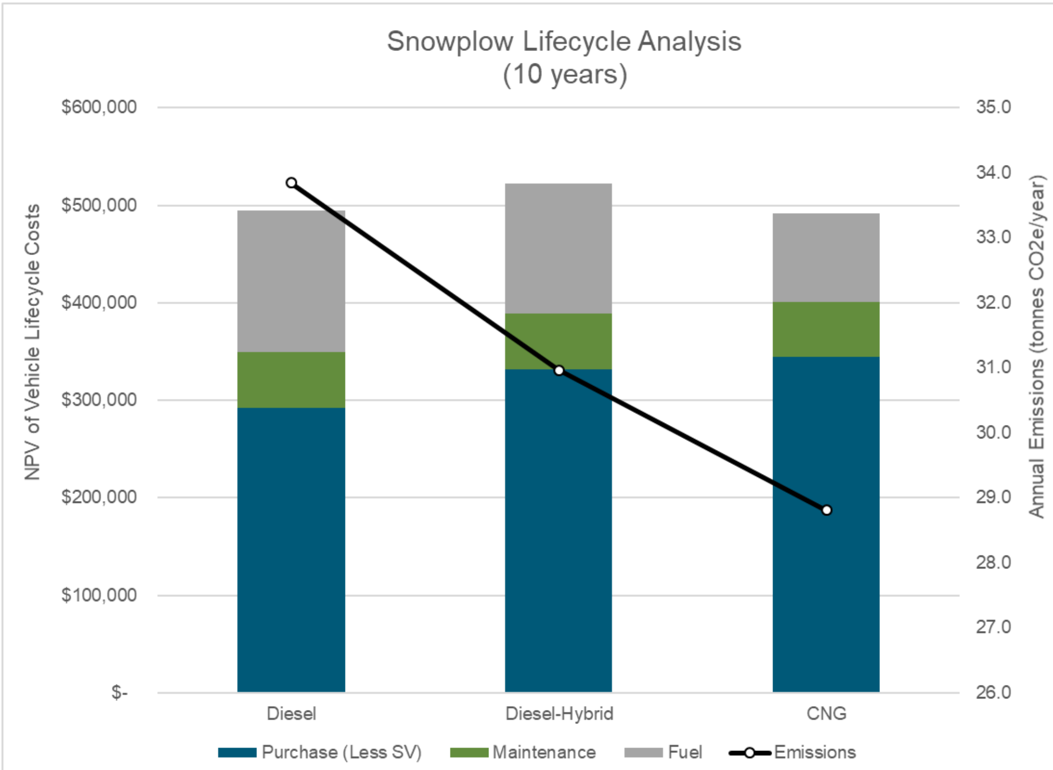

Figure 37 Snowplow Lifecycle Analysis

The economics of CNG snowplows is presented against diesel in Table 47. Note that the grant funding from the Green Commercial Vehicle Program (GCVP) to cover approximately $30,000 of the CNG upfitting costs for the two CNG snowplows currently in the fleet has now expired.

Further adoption of CNG snowplows does offer the potential for reducing 5 tonnes of CO_2e/year per truck and there are savings from fuel cost to recover investment of CNG upfitting over the 10-year lifecycle of the truck. The revised Federal Carbon Tax in 2020 will have a greater impact on diesel fuel versus CNG fuel thereby, yielding more cost savings over the truck lifecycle.

Table 47 Financial & GHG Reduction Summary of CNG Snowplows

Vehicle Type	Est. Annual GHG Reduction (tCO_2e/year)	Lifecycle GHG Reduction (tCO_2e)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Lifecycle Operational Savings ($)	Payback Period (years)	Return on Investment, ROI (%)
CNG Snowplow (replacing diesel)	5.0	50.4	+$52,100	-$5,500	$55,000	9.5	6%
Diesel Snowplow (with hybrid axle)	2.9	28.8	+$40,000	-$1,200	$12,000	33.3	-70%

The hybrid axle system does not achieve a payback over the snowplow lifecycle but does serve as a viable interim option to help reduce emissions for trucks not operating in close proximity to a CNG fueling station. However, the magnitude of GHG emissions may not be significant enough to warrant investment in this system.

6.2.5.2 SINGLE AXLE TRUCKS

The lifecycle analysis for the opportunity to pilot a BEV Class 8 truck starting in 2025 is presented in Figure 38 with inputs listed in Appendix B. Reference values are taken from the single axle diesel trucks currently in the fleet.

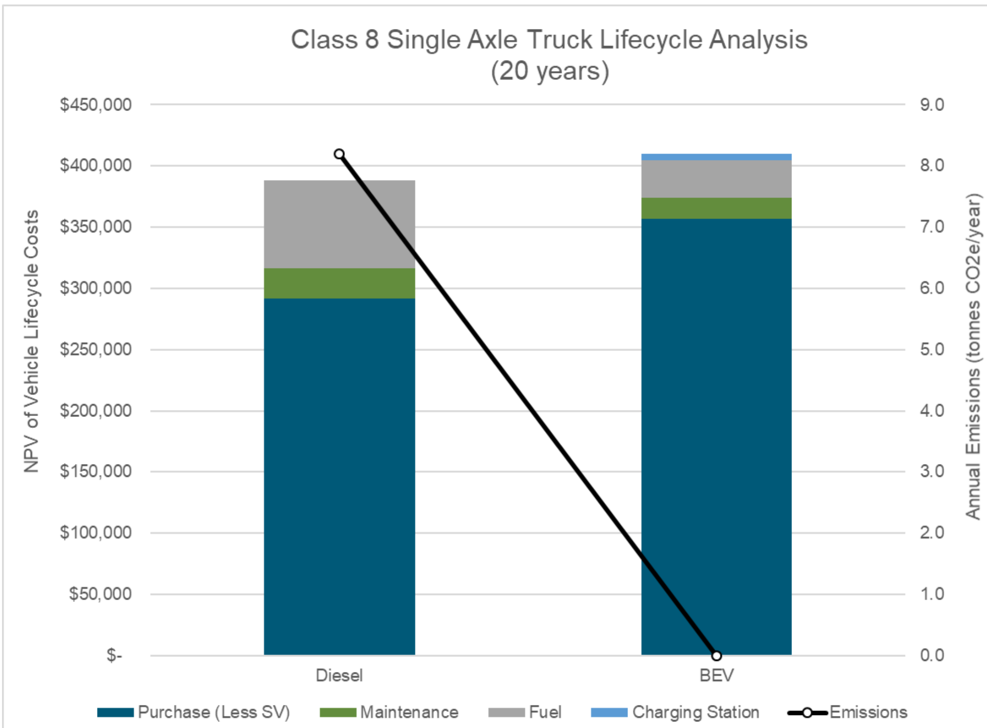

Figure 38 Class 8 Truck (Reference Single Axle Truck) Lifecycle Analysis

Replacement of this single axle diesel truck with a pilot BEV can reduce annual emissions by approximately 8 tonnes of CO_2e. However, the cost savings on diesel fuel over the lifecycle of the truck will not be able to recover the additional capital cost for the BEV truck and charger as shown in Table 48. This is largely due to the lower utilization of the truck in comparison to other heavy-duty trucks in the fleet such as the snowplows.

However, one benefit of lower utilization is that the truck could have a longer lifecycle. The Sterling single axle diesel trucks currently used in this application were purchased in 2005 and are scheduled for replacement by 2025 thereby, demonstrating potential for a 20 year lifecycle.

Although the economics are currently unfavorable for a BEV truck in this application it could be viewed as a strategic opportunity for Oxford County to gain experience with a heavy-duty BEV truck at a lower level of risk in order to build experience for future deployments.

Table 48 Economics & GHG Reduction Summary of BEV Truck Pilot

Vehicle Type	Est. Annual GHG Reduction (tCO_2e/year)	Lifecycle GHG Reduction (tCO_2e)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Lifecycle Operational Savings ($)	Payback Period (years)	Return on Investment, ROI (%)
BEV Truck (replacing diesel)	8.2	164	+$70,000	-$2,400	$48,000	29.2	-31%

The replacement timeline of two CNG snowplows at the Woodstock yard and a BEV truck pilot is outlined in Table 49 below. These initiatives would bring a total reduction of 18 tonnes of CO_2e/year.

Table 49 Heavy-Duty Truck Replacement Strategy

Asset ID	Make/Model	Replace Year	Current Fuel	Proposed Technology	Potential Emissions Reduction (tonnes CO_2e/year)
373	Freightliner 114SD	2021	Diesel	CNG	5.0
387	Volvo VHD	2021	Diesel	CNG	5.0
684	Sterling L8513	2025	Diesel	BEV	8.2
				Total:	**18.2**

6.2.6 ANTI-IDLE TECHNOLOGY

There is an opportunity to explore wider implementation of anti-idling systems for the Public Works fleet. In 2019, Oxford County conducted a study of vehicle utilization and idling time.

The rollout of anti-idling technology should be prioritized for vehicles with high non-productive idle time as in some applications vehicle idling is still a requirement to power auxiliary systems (i.e. dump truck hydraulics). However, there is currently a data gap with Oxford County's GPS provider. The previous provider was able to distinguish between non-productive and productive idle (i.e. power take-off (PTO) engaged) but that is no longer the case.

Figure 39 GRIP Idle Management Unit

Oxford County has the GRIP anti-idle system installed on two diesel tandem trucks (Assets 362 and 367). The GRIP unit works via a CAN-BUS interface with the vehicle. When the vehicle is parked or in neutral, without the PTO engaged it will shut off the engine. The GRIP system provides a 5 amp ignition signal to restart the engine and can also provide cab climate controls to run off the vehicle battery when the engine is shut off.

The quoted cost for the GRIP system is approximately $6,700 (including installation and taxes). The majority of heavy-duty trucks, which would likely have a high percentage of idling time, are replaced according to a 10-year lifecycle. Therefore, there would need to be a case for the anti-idling system reducing idle time and diesel fuel consumption by approximately 6,800 L (680 L/year) to achieve payback over the vehicle lifecycle.

Table 50 presents Oxford County's fleet of heavy-duty trucks with an idle percentage of 20% or more. A priority ranking is assigned for considering installation of an anti-idle system based on a combination of the truck's idle time, annual fuel consumption and GHG emissions. Thereby, prioritizing trucks with high idling time and high annual fuel consumption which would likely achieve the payback period. The results of this analysis are also shown in Figure 40.

Table 50 Public Works Vehicles with High Idle Time

Asset ID	Make/Model	User Group	Workday Idle (%)	Fuel Type	2019 Fuel (L or kg)	Emissions (tCO_2e/year)	Priority Rank
391	Volvo VHD	Roads (Woodstock)	43%	Diesel	12,937	35.4	1
744	Freightliner M2	Waste Management	37%	Diesel	12,754	34.9	2
368	International 7600 SFA 6x4	Roads (Highland)	29%	Diesel	14,862	40.7	3
374	Volvo VHD	Roads (Highland)	31%	Diesel	12,267	33.6	4
366	International 7600 SFA	Roads (Springford)	30%	Diesel	12,572	34.4	5
387	Volvo VHD	Roads (Highland)	35%	Diesel	10,389	28.4	6
364	International 7600 SFA	Roads (Highland)	32%	Diesel	10,838	29.7	7
360	International WorkStar 7600	Roads (Highland)	30%	Diesel	11,375	31.1	8
365	International 7600 SFA	Roads (Drumbo)	26%	Diesel	13,155	36.0	9
375	Freightliner 114 SD	Roads (Woodstock)	30%	CNG	10,366	30.7	10
386	Volvo VHD	Roads (Springford)	32%	Diesel	10,228	28.0	11
373	Freightliner 114 SD	Roads (Springford)	35%	Diesel	8,789	24.1	12
371	Freightliner 114 SD	Roads (Woodstock)	29%	CNG	9,572	28.4	13
361	Volvo VHD	Roads (Woodstock)	24%	Diesel	11,785	32.3	14
370	International 7600 SFA 6x4	Roads (Drumbo)	25%	Diesel	11,075	30.3	15
382	Volvo VHD	Roads (Drumbo)	21%	Diesel	8,647	23.7	16

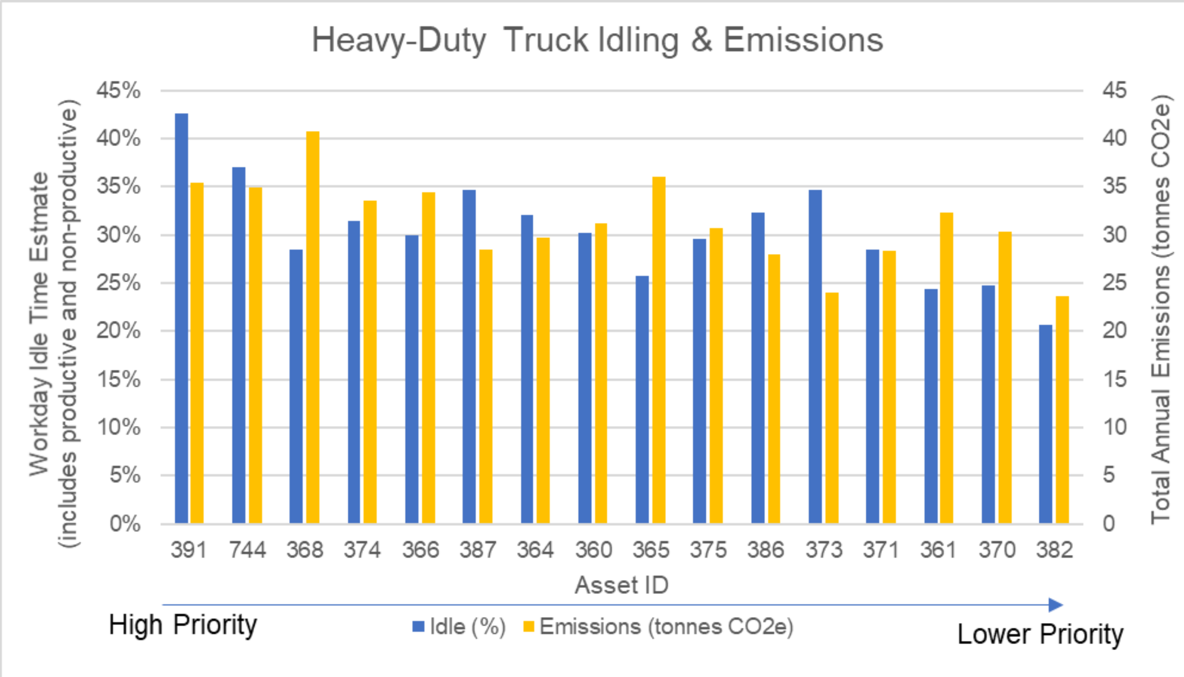

Figure 40 Priority for Anti-Idling Consideration

Overall, there are 16 trucks in this list which should be considered for installation of anti-idle technology. If Oxford County can update their fleet GPS technology such that PTO can be recorded, then the effectiveness of anti-idling technology can be studied further.

By performing a sensitivity analysis on the estimated non-productive idle time (%) and investing in 16 additional anti-idling units for this fleet the payback period and potential emissions reduction can be evaluated. Note that the non-productive idling is presented as a percentage of the total idling time.

Table 51 Sensitivity Analysis of Anti-Idling Economics & Emissions Reduction Potential

Non-Productive Idling (%)	Est. Annual Fuel Savings ($)	Emissions Reduction (tCO_2e/year)	Payback Period (years)	ROI (%) over 10-years
5%	$2,700	7.7	39.6	-75%
10%	$5,400	15.3	19.8	-50%
15%	$8,100	23.0	13.2	-24%
20%	$10,800	30.7	9.9	1%
25%	$13,500	38.3	7.9	26%

If non-productive idling time accounts for 20% of total idling, then there is a strong case for anti-idling technology for this fleet. The capital investment of $107,200 would reach a payback period within the 10-year vehicle life and could reduce fleet emissions by approximately 31 tonnes of CO_2e/year.

6.2.7 WASTE MANAGEMENT EQUIPMENT (DOZER)

Oxford County currently has a 2006 model Caterpillar D7R11 dozer (Asset ID 742) scheduled for replacement in 2024 for which the D6XE dozer or equivalent could be a viable replacement option. The D6XE dozer can offer improvements on fuel consumption and emissions due to its electric drive transmission and slightly smaller size. The inputs used in the lifecycle comparison of a traditional diesel dozer against this option with the electric drive are noted in Appendix B. Data is sourced from Oxford County's fleet and OEM specifications.

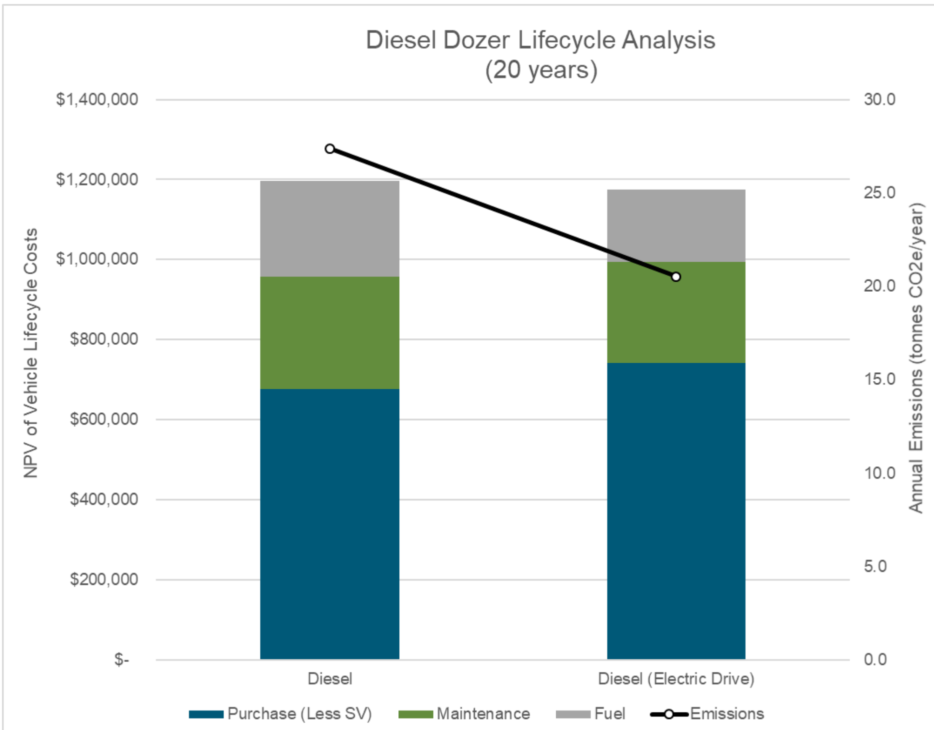

Figure 41 Dozer Lifecycle Analysis

The lifecycle analysis shown in Figure 41 demonstrates that the diesel dozer with an electric drive is actually less costly over the long-term. The annual savings in maintenance and fuel can payback the investment in approximately 17 years with a ROI of 17% over a 20-year lifecycle. In addition, this type of dozer can reduce emissions up to 7 tonnes CO_2e per year.

Table 52 Financial & GHG Reduction Summary of Dozer with Electric Drive

Vehicle Type	Est. Annual GHG Reduction ($tCO_2e/year$)	Lifecycle GHG Reduction (tCO_2e)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Lifecycle Operational Savings ($)	Payback Period (years)	Return on Investment, ROI (%)
Dozer	6.8	136.9	+$65,000	-$4,400	$88,000	14.8	35%

6.2.8 HYBRID AMBULANCE PROGRAM

There is an opportunity for Oxford County to continue its replacement program of retiring diesel ambulances and replacing these vehicles with gasoline ambulances outfitted with the XL hybrid drivetrain and rooftop solar panels. Appendix B lists the input parameters used to derive a lifecycle cost comparison of these different propulsion types as well as the emissions reduction potential, the output is shown in Figure 42.

Oxford County has communicated very positive feedback about the gas-hybrid ambulances to date. The City of Toronto is also proceeding to incorporate the same hybrid technology into their fleet. A use case study from XL Fleet has shown that the XL hybrid drivetrain has improved fuel economy by 28% in ambulances[34]. Oxford County is encouraged to continue the evaluation of the XL hybrid drivetrain performance in their specific fleet operations as well as exploring other beneficial technology options as they become available, such as plug-in hybrid systems.

Referenced from Figure 42 which shows the NPV, the gas-hybrid alternative incurs an incremental capital cost of approximately $33,000 per vehicle and can offer a savings of $1,500 on fuel costs annually. Note that there is no assumption on maintenance cost savings due to the strict ministry requirements to maintain PS vehicles to a very high standard of reliability.

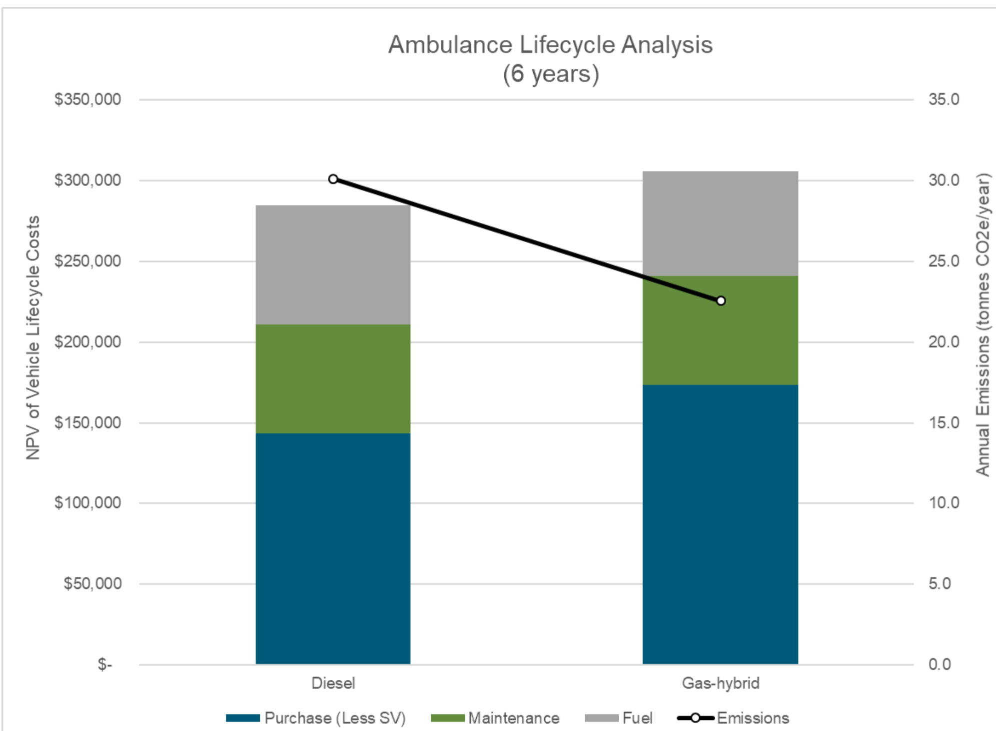

Figure 42 Ambulance Lifecycle Analysis

[34] XL Fleet Meeting, February 22nd, 2021, Jake Obert – City of Toronto hybrid ambulance deployments

The replacement of one diesel ambulance with a gas-hybrid can reduce annual emissions by almost 8 tonnes of CO_2e. There are five diesel ambulances scheduled for replacement over the next 5-years[35] which would complete the transition of the entire fleet to gas-hybrids and contribute a cumulative total reduction of 38 tonnes of CO_2e/year. However, the annual fuel savings is not enough to achieve payback over the lifecycle of the vehicle. Table 53 provides a summary of the results. Note that a higher salvage value is expected for the gas-hybrid ambulances in comparison to diesel which impacts the payback period and ROI calculations.

Table 53 Financial & GHG Reduction Summary of Hybrid Ambulances

Vehicle Type	Est. Annual GHG Reduction (tCO_2e/year)	Lifecycle GHG Reduction (tCO_2e)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Lifecycle Operational Savings ($)	Payback Period (years)	Return on Investment, ROI (%)
Hybrid Ambulance (replacing diesel)	7.6	45.3	+$32,900	-$1,500	$9,000	19.9	-64%

There could be a future opportunity to further improve the economics of the hybrid ambulance conversions by salvaging and repurposing a hybrid drive system from a retiring vehicle for installation in a new vehicle. However, at this time XL Fleet has stated they do not have any use cases for this type of hybrid system reuse. Furthermore, due to ambulance fleet needing to maintain a very high service standard of reliability there is a high level of risk associated with this opportunity and it is not advised at this time.

However, the payback and ROI analysis does account for a $3,000 higher salvage value of the hybrid versus gasoline ambulance, refer to Appendix B for estimated salvage values.

6.2.9 HYBRID ERV PROGRAM

Oxford County is also in the process of replacing its current fleet of ERVs with more fuel efficient hybrid options. Currently, two out of the four ERVs are gas-hybrids with the Toyota Rav4 being purchased as an OEM hybrid option and the XL Fleet hybrid drivetrain being installed on the Ford F-250. The Chevrolet 3500 ERV truck (Asset 1317) is already being replaced with a gas-hybrid on order from 2020.

Table 54 outlines upcoming vehicle replacements along with the opportunity to replace these vehicles with hybrid options or fully battery electric. A lifecycle cost and emissions comparison of hybrid and BEV options for technology changes for these ERVs is also presented.

Table 54 ERV Replacement Plan

Asset ID	Make/Model	Fuel Type (Current)	Proposed Replacement	Replacement Year
1317	Chevrolet 3500 HD	Diesel	Gas (hybrid)[36]	2020
1318	Chevrolet Tahoe LS 4WD	Gas	Gas (hybrid)	2022
1316	Ford F-250	Gas (hybrid)	Gas (hybrid)	2023
1320	Toyota Rav4	Gas (hybrid)	BEV	2024

[35] Scheduled retirement plan for assets 1003, 1006 and 1007 (in 2021), 1192 and 1193 (in 2022)
[36] This vehicle has already been purchased by Oxford County in 2020 and is awaiting its delivery.

There is an opportunity to replace Asset 1318 as a gas-hybrid vehicle at its upcoming replacement in 2022. As there is currently no OEM available hybrid option available for these heavy-duty pickups the assumption is that the XL Fleet hybrid drivetrain will be installed, similar to Assets 1316 and 1317.

From the market review of BEV trucks coming available it is unlikely that a BEV option will be available in 2023 for the replacement of the gas-hybrid ERV truck (Asset 1316). Therefore, it is recommended to retain the current gas-hybrid technology for this vehicle and re-evaluate BEV options on its next replacement cycle.

However, there can be an opportunity to consider a BEV in 2024 for the ERV (Asset 1320) which is currently a Toyota Rav4 hybrid SUV. Appendix B lists the setup parameters for this analysis while Figure 43 presents the lifecycle analysis.

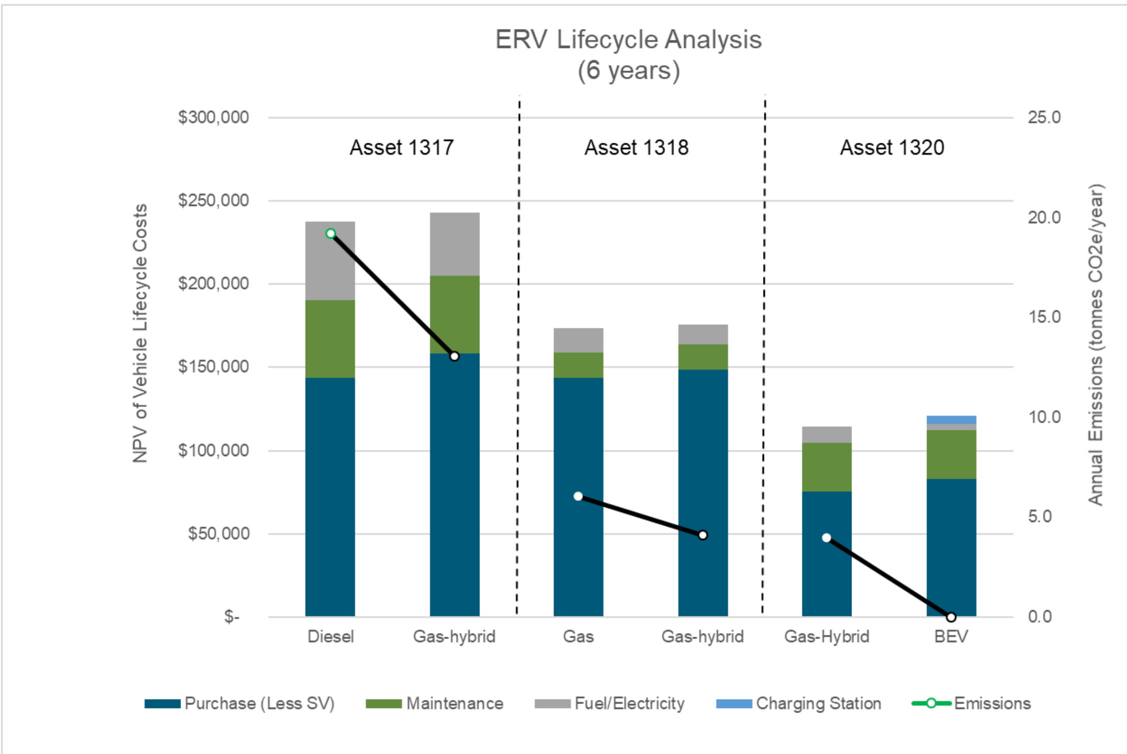

Figure 43 ERV Lifecycle Analysis

The conversion of Asset 1317 and Asset 1318 to a gas-hybrids along with considering a BEV option for Asset 1320 can contribute a combined reduction of up to 12 tonnes of CO_2e per year. However, the hybrid and BEV options are costly and despite annual savings on fuel cost payback over the vehicle lifecycle of 6 years will not be achieved. Table 55 summarizes the results.

Table 55 Financial & GHG Reduction Summary of Hybrid ERVs

Vehicle Type	Est. Annual GHG Reduction (tCO_2e/year)	Lifecycle GHG Reduction (tCO_2e)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Lifecycle Operational Savings ($)	Payback Period (years)	Return on Investment, ROI (%)
1317 Hybrid ERV (replacing diesel)	6.2	36.9	+$15,000	-$1,600	$9,600	9.4	-36%
1318 Hybrid ERV (replacing gasoline)	1.9	11.6	+$5,000	-$500	$3,000	10.0	-40%
1320 BEV ERV (replacing gas-hybrid)	3.9	23.4	+$12,500	-$1,000	$6,000	12.5	-52%

6.2.10 BIO-DIESEL

There is an opportunity to consider bio-diesel or renewable diesel as an alternative fuel mainly for off-road vehicles and equipment however, renewable diesel is currently not widely available in Ontario. Bio-diesel usage can target replacement of dyed diesel fuel currently used by Oxford County's Public Works at on-site fueling stations.

Table 56 lists the inputs used to build a cost comparison and GHG emissions estimate of using B5 and B20 blends as an alternative. Note that the B20 use case considers a B5 blend for 3-months of the year, in order to mitigate the concern of cold weather use with higher bio-diesel concentrations.

The impact of using bio-diesel is analyzed over a 5-year period to account for carbon tax effect on the diesel fuel price. The output is shown in Figure 44. The annual consumption of dyed diesel has been relatively consistent for Oxford County's fleet (refer to

Table 13). As there is a limited market of alternatives for diesel powered tractors and construction equipment, it is assumed that dyed diesel fuel consumption will be similar to the 2019 value, used as a proxy over the next 5 years.

Table 56 Bio-diesel Cost Assessment & Emissions Modeling Inputs

Input/Assumption	Value	Source
Diesel (Dyed) Annual Consumption	168,000 L	2019 Oxford County Fuel Records
Cost Premium B5 Bio-diesel*	+2%	US Department of Energy – ratio of cost premium B20 and blend % applied for B5
Cost Premium B20 Bio-diesel*	+8%	US Department of Energy
B5 Emissions Reduction	5.7%	Natural Resources Canada Emissions Factor for B5 in Ontario
B20 Emissions Reduction	20.2%	Natural Resources Canada Emissions Factor for B20 in Ontario
Seasonal Use Case: B20 use with B5 use in winter (3 months)	16.6%	Weighted average of B5 and B20 usage

*Increment of carbon tax impact relative to base fuel price is not applied to 5% of the fuel cost for B5 and correspondingly 20% of the fuel cost for B20 blend. For example, the 2.7 cent/L increase would only be applied as 2.2 cents/L for B20 fuel.

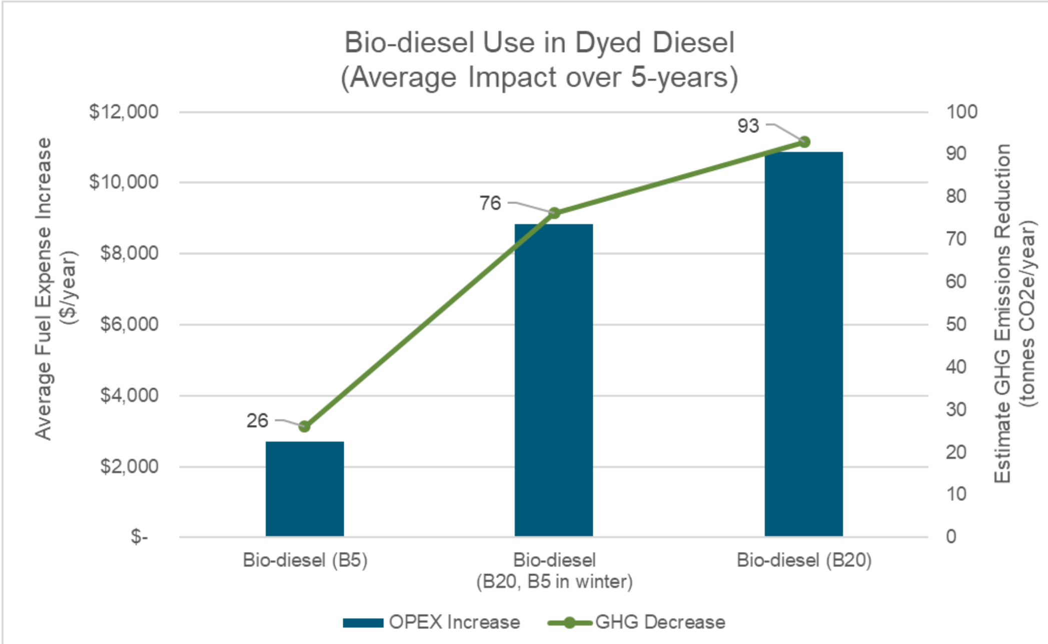

Figure 44 Impact of Bio-diesel Use

The use of a B5 (5%) blend can contribute an emissions reduction of 26 tonnes CO_2e/year while the use case of B20 (20%) and B5 (5%) for winter operations can reduce 76 tonnes CO_2e/year. The incremental cost on annual fuel expense is estimated around $2,700 for B5 and $8,800 for the B20 use case. There would be no impact on capital costs as bio-diesel can be used interchangeably with Oxford County's existing on-site fueling infrastructure.

The use of bio-fuels can be a hedging approach to the carbon tax as lower emission fuels will be less impacted by the escalating carbon tax from 2021 to 2030 (reference Section 5.2).

6.2.11 CNG INFRASTRUCTURE ASSESSMENT

Change Energy Services (CES) has contributed to this Green Fleet Plan as a specialist in CNG fueling and infrastructure to assess the capabilities and opportunities for further CNG adoption in Oxford County's fleet as well as the potential for an on-site fueling station located on Oxford County's property.

6.2.11.1 *FLEET POTENTIAL FOR CNG*

Fuel consumption data was provided by Oxford County for their fleet, for CES to review and assess. CES identified medium and heavy-duty vehicles that could be considered for conversion or remain operating on CNG fuel.

These vehicles were first sorted by location, to determine which vehicles could potentially fuel at the existing Rural Green Energy station in Woodstock, and which vehicles would likely require fueling at a new site. Vehicles were then further sorted by class/type (i.e. vans, heavy-duty trucks) and by fuel (i.e. gasoline, diesel, propane, or CNG), to determine an average fuel consumption by vehicle type. This process has been summarized in Table 57 below.

Table 57 Potential for CNG Fuel Conversion

Vehicle Type	Fuel	Count	Annual CNG Consumption (kg)	Annual Propane Consumption (L)	Annual Gasoline Consumption (L)	Annual Diesel Consumption (L)
Rural Green Energy Station						
Pickup	Gasoline	9			4,105	
Van	Gasoline	1			8,499	
Van	Gasoline/CNG	2	1,039		2,220	
Work Truck	CNG	2	9,969			
Work Truck	Diesel	15				10,725
Vac Truck	Diesel	1				7,215
Proposed Refueling Station (Scenario 1)						
Pickup	Gasoline	9			4,679	
Van	Gasoline	3			3,326	
Work Truck	Diesel	12				9,403
Vac Truck	Diesel	1				6,408
Forklift	Propane	1		1,868		
Forklift	Gasoline	1			2,490	
Proposed Refueling Station (Scenario 2)						
MD Pickup	Gasoline	1			5,281	
Work Truck	Diesel	7				9,387

6.2.11.2 *CNG FUELING OPTIONS*

Existing CNG Fuel Station

The Rural Green Energy fuel station currently includes 130 hp worth of compression equipment and a total of approximately 51,800 scf of ground storage at 4,000 psig. This storage is set up as a buffer system but could easily be rearranged as a 3-stage cascade system, if necessary. Rural Green Energy also expects to install an additional 100 hp compressor unit in the near future. Based on the average fuel consumption associated with the vehicles that would refuel at this location and CES modelling, it is expected that Rural Green Energy would have sufficient capacity to serve Oxford County’s fleet.

Proposed CNG Fueling Site at 59 George Johnson Boulevard

Oxford County was considering a CNG fuel station at the Ingersoll Water Operations Centre, located at 59 George Johnson Boulevard. (reference Section 2.3.2.6). However, there are primarily light-duty vehicles stationed in proximity to this site and the configuration was proposed as a slow fill CNG fuel station which could be inconvenient for fleet operations.

There is potential for CNG conversion of light-duty vehicles such as pickup trucks and cargo vans. However, the feedback expressed from Oxford County’s stakeholders on the dual fuel CNG/gasoline vehicles currently in the fleet has not been very favorable. There have been concerns with the fuel system, vehicle performance, and these vehicles are still running primarily on gasoline. Furthermore, users have commented that the CNG fuel tank takes up valuable cargo space thereby limiting storage capacity and utility.

Although CNG is still an option for light-duty vehicles the availability of hybrid and battery electric vehicles coming to market present a better alternative for green fleet adoption. Consequently, CNG adoption should focus on more of the heavy-duty vehicles (i.e. diesel trucks).

Alternate New CNG Fueling Site

When sizing a new CNG refuelling station, two (2) scenarios were considered:

1. **Scenario 1:** considers a station capable of serving the remaining 27 vehicles identified in Table 57. It is recommended that the proposed fuel station in this scenario be located at Oxford County's Springford Patrol Yard, as this location currently houses more heavy-duty vehicles than any of the other yards under consideration (i.e., yards whose vehicles would not refuel at Rural Green Energy).
2. **Scenario 2:** considers a station capable of serving only the 8 medium/heavy-duty vehicles currently operating out of Oxford County's Springford Patrol Yard. The proposed fuel station in this scenario would be located on-site at the Springford Patrol Yard as well.

In addition to these scenarios, there is an opportunity to start phasing in CNG adoption with the lifecycle replacement of heavy-duty diesel trucks stationed at the Springford Patrol Yard. Table 58 lists the trucks scheduled for upcoming replacement.

Table 58 Springford Trucks Replacement Plan

Asset ID	Make/Model	Vehicle Class	Fuel Type (Current)	Proposed Replacement	Replacement Years
391	Volvo VHD	Class 8	Diesel	CNG	2022
386	Volvo VHD	Class 8	Diesel	CNG	2022
352	Chevrolet Silverado 3500HD	Class 3	Gasoline	CNG	2022
325	Ford F-550	Class 6	Diesel	CNG	2025
334	Freightliner M2	Class 8	Diesel	CNG	2025
366	International 7600	Class 8	Diesel	CNG	2026
394	International HV513	Class 8	Diesel	CNG	2028
367	Freightliner 114SD	Class 8	Diesel	CNG	2029

Oxford County is replacing the diesel tandem truck (Asset 373) with a CNG tandem as part of their 2021 approved budget. Asset 373 is currently assigned to the Springford Yard. It's replacement CNG tandem will be assigned to the Woodstock Yard and a diesel tandem (Asset 391) will then be reallocated to the Springford Yard.

Table 59 describes the proposed CNG fuel station options. The total station costs provided in this table include the cost of all equipment, installation, commissioning, training, project management, engineering services, general contractor fees, approvals, and a contingency fund. The operating costs associated with this infrastructure have also been provided below, and include the cost of maintenance and personnel, electricity, training, CNG delivery, and CNG commodity costs. It is worth noting that these costs vary on an annual basis (i.e. with inflation and based on compressor overhaul schedules) a 20-year average unit cost and a 20-year average annual cost have been provided.

Table 59 Proposed Springford CNG Fueling Station Parameters

General Facility Parameter	Scenario 1	Scenario 2	Units
Daily Site Consumption	399	163	kg/day
Operating Days per Year	365	365	days/year
Inlet Pressure	60	60	psig
Discharge Pressure	4,500	4,500	psig
Redundancy Adjustment	110%	110%	%
Base No. of Compressors	1	1	unit(s)
No. of Redundant Compressors	0	0	unit(s)
Compressor Required	21	16	HP
Flow Rate Required	52	39	scf/minute
Flow Rate Required (Alt. Units)	88	66	m^3/hour
Flow Rate Required (Alt. Units)	61	46	kg/hour
Ground Storage Required	17	13	m^3
Ground Storage Required (Alt. Units)	3,971	1,985	kg
Total Site Power	243	235	kW
Monthly Consumption	168	162	kWh
No. of Slow Fill Vehicles	0	0	vehicle(s)
No. of Slow Fill Posts	0	0	post(s)
No. of Fast Fill Vehicles	27	8	vehicle(s)
No. of Fast Fill Dispensers	2	1	dispenser(s)
Total Station Cost	$674,727	$433,725	$
20-Year Average Operating Cost	**$0.4331**	**$0.4959**	**$/$m^3$**
20-Year Average Operating Cost (Alt. Units)	**$0.6280**	**$0.7190**	**$/kg**
20-Year Average Operating Cost (Alt. Units)	**$91,447**	**$42,883**	**$/year**

The average operating cost includes the CNG commodity cost as well as maintenance, training, management and other costs rolled into the total cost of the CNG fuel as $/$m^3$ or $/kg. It should be noted that this CNG fuel cost is lower than the $0.92 per kg currently paid by Oxford County for fueling at the Rural Green Energy station.

6.2.11.3 *MOBILE CNG FUELING STATION OPTION*

Mobile fueling stations, in various forms, have been around for the last 35 years. Although a mobile CNG fuelling solution is typically more expensive (directionally) than a fixed fueling solution, such solutions may be used for reasons ranging from provision of temporary fueling, flexibility regarding the relocation of assets, or providing fueling in locations where gas grid infrastructure does not exist. As mobile fuel stations are often provided using the assets of a third party this solution may be used to convert capital costs to operating costs. This may be attractive in cases where there is a low appetite for capital expenditure, but a higher operating cost is acceptable.

Figure 45 Mobile CNG Fueling Compressor Station

Further to this, the licence for a CNG fueling station in Ontario requires a fixed address. As a result, a compliant mobile fueling solution would require that at least some portion of the stations be semi-permanently installed at a fixed location. However, even in these cases, facilities are temporary and removeable and the natural gas can be transported by a tube trailer to a location that is convenient to the fleet operator.

There are several different mobile refuelling service providers operating in southern Ontario and the costs of these services vary on a contract-by-contract basis. In the event that Oxford County is interested in mobile refuelling, these options can be explored. Figure 45 shows a trailer mounted compressor for a mobile CNG fuel station.

6.2.11.4 *CNG FUEL STATION BUSINESS CASE*

A business case has been prepared including the payback period, ROI and potential GHG reduction for the case of CNG adoption of heavy-duty trucks at the Springford site and installation of a CNG fueling station under Scenario 2.

Table 60 lists the inputs used in this analysis. The capital investment of the fueling station and CNG upfitting cost of trucks would need to be recovered by the annual fuel cost savings of CNG. Based on the replacement timeline of the Springford trucks and phasing in CNG adoption with lifecycle replacements this analysis is presented over 20-years.

Table 60 Springford CNG Fuel Station Business Case Inputs

Input/Assumption	Value	Source
CNG Fuel Station - CAPEX	$434,000	CES Modeling Estimate
Fuel Station Lifecycle	20 years	CES Modeling
CNG Upfitting (Class 3 Truck)	1x	Reference Chevrolet 3500HD
CNG Upfitting (Class 6 and above)	7x	HD Diesel Trucks at Springford
CNG Upfitting (Class 3 Truck)	$11,500	The CNG fuel tanks and systems added to vehicles range from $9,000 to $13,000 depending on tank size.
CNG Upfitting (Class 6 and above)	$52,100	TAC Award Submission (Tandem CNG trucks)
MD Pickup Truck Lifecycle	5 years	Oxford County Asset Management
Sign Truck Lifecycle	9 years	Oxford County Asset Management

Input/Assumption	Value	Source
Tandem Truck Lifecycle	10 years	Oxford County Asset Management
Paint Truck Lifecycle	20 years	Oxford County Asset Management
Diesel Base Fuel Price	0.98 $/L	Oxford County Fuel Records
Gasoline Base Fuel Price	1.002 $/L	Oxford County Fuel Records
CNG Base Fuel Price	0.72 $/kg	CES Modeling Estimate

The financials of investing in a CNG station are not attractive. The total fuel cost savings over a 20-year period is just below the capital cost of the fueling station and would not be enough to achieve payback on the fuel station (refer to Table 61). In addition, the capital cost for upfitting the fleet with CNG engine/powertrains would not be recovered.

Furthermore, the magnitude of GHG reduction is low, compared to what could be achieved with hybrid or battery electric vehicles. Replacement of a single heavy-duty diesel truck with a BEV could reduce emissions by 15 to 30 tonnes of CO_2e. The investment in a CNG station would confine the fleet to this technology over a long period thereby reducing the opportunity for BEVs.

Table 61 Economics & GHG Reduction Summary of Springford CNG Fleet Adoption

Est. Annual GHG Reduction by 2025 (tCO_2e/year)	Est. Annual GHG Reduction by 2040 (tCO_2e/year)	Capital Budget Impact ($)	20-year Fuel Savings ($)	Net 20-year Savings ($)	Payback Period (years)	Return on Investment, ROI (%)
11.0	22.0	+$1.2 million	$396,000	-$822,500	N/A	-67%

Note: the capital investment includes $434,000 for the CNG fuel station and $784,000 for all CNG upfitting costs of trucks being replaced over this 20-year timeline. This upfitting cost is incurred each time a truck is replaced (as the cost differential between a diesel and CNG truck).

6.2.11.5 *KEY TAKEAWAYS*

An investment in a CNG fueling station could offer a viable alternative for supporting CNG adoption for heavy-duty trucks for which there are currently limited alternatives available in the market. However, the payback period for a fixed installation CNG station is lengthy (excess of 20 years) and could thereby constrain Oxford County to this fuel over a long term and may jeopardize meeting future emission reduction targets.

Oxford County has the long term objective to become 100% renewable and eliminate dependence on fossil fuels. Therefore, hybrids and the gradual introduction of zero emission vehicles such as battery electric offer a better alignment with the County's strategic objectives. There is a fast maturing market in the light-duty class of hybrid and battery electric vehicles which can be captured in this iteration of the 5-year Green Fleet Plan. Heavy-duty BEV trucks could also be considered for a small pilot fleet (i.e. one or two vehicles) in the later part of the 5-year plan as their technology and market availability matures.

6.3 SUMMARY OF RECOMMENDATIONS

Table 62 presents the summary of recommendations on technology changes for fleet vehicles, equipment and fueling. The estimated annual reduction of GHG emissions is provided along with key metrics for financial implications of each recommendation. Note that some deviations in calculations may be present due to rounding. A positive cost indicates an additional expenditure while a negative cost implies a cost savings. Recommendations are listed from most to least impactful based on the overall opportunity to lower GHG emissions, according to vehicle type/class.

Table 62 Green Fleet Opportunities – Evaluation Matrix

No	Description of Opportunity	Total Fleet GHG Reduction (tonnes CO_2e/year)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Lifecycle Operating Cost Impact ($)	Net Lifecycle Cost ($)	Payback Period (years)	Return on Investment, ROI (%)
1	Hybrid Pickup Trucks (35x)	91	+$178,200	-$35,200	-$176,000	+$2,200	5.1	-1%
2	B20 Bio-diesel (20%) for Major Equipment[37]	76	N/A	+$8,800	N/A	N/A	N/A	N/A
3	BEV Pickup Trucks (7x)	67	+$140,000	-$26,700	-$133,500	+$6,500	5.2	-5%
4	BEV Cargo Vans (8x)	44	+$126,100	-$13,800	-$82,800	+$43,300	9.1	-34%
5	Hybrid Ambulances (5x)	38	+$164,500	-$7,500	-$45,000	+$104,500	19.9	-64%
6	Anti-Idle Technology (16x)[38]	31	+$107,200	-$10,800	-$108,000	-$800	9.9	1%
7	PHEV SUVs (3x)	14	+$24,600	-$4,200	-$25,200	-$600	5.9	2%
8	CNG Snowplows (2x)	10	+$104,200	-$11,000	-$110,000	-$5,800	9.5	6%
9	BEV Single Axle Truck (1x)	8	+$70,000	-$2,400	-$48,000	+$22,000	29.2	-31%
10	Diesel Dozer (with electric drive) (1x)	7	+$65,000	-$4,400	-$88,000	-$23,000	14.8	35%
11	Hybrid ERV (Asset 1317)	6	+$15,000	-$1,600	-$9,600	+$5,400	9.4	-36%
12	BEV ERV (Asset 1320)	4	+$12,500	-$1,000	-$6,000	+$6,500	12.5	-52%
13	Hybrid ERV (Asset 1318)	2	+$5,000	-$500	-$3,000	+$2,000	10.0	-40%
	Total	**398**	**+$1,012,300**	**-$110,300**	**-$835,100**	**+$177,200**	**9.2**	**-18%**

[37] Operating cost impact stated as total impact for all off-road vehicles and equipment dyed diesel fuel usage. Assumes B5 blend used in winter.
[38] Assumes a minimum 20% of total idling is non-productive for the 16 trucks listed in Section 6.2.6. Capital and operating budget impacts, lifecycle savings, payback and ROI are presented for the entire fleet of 16 trucks being outfitted with anti-idling systems.

GHG Reduction Potential: The set of recommendations presented in Table 62 provides Oxford County a pathway to stay on track and potentially exceed their emission reduction target moving forward to 2025. This set of recommendations propose a potential reduction at **398 tonnes of CO2e**.

The next target set for 2025 is a reduction of 14.1% (316 tonnes of CO_2e). Comparing 2019/2020 fleet data to historical 2015 fleet data, it is noted that annual emissions have already been reduced by approximately **40 tonnes of CO_2e**. An additional **276 tonnes of CO_2e** will need to be reduced by 2025.

Financial Sustainability: A positive or close to breakeven ROI and payback period is achieved for several of the recommendations, including the hybrid pickup trucks, plug-in hybrid SUVs, CNG snowplows and anti-idling systems, thereby demonstrating a degree of financial sustainability.

However, there are some recommendations where a positive ROI is not achieved. The more costly initiatives to implement include the BEV cargo vans, the BEV single axle truck, ambulances and ERVs requiring an aftermarket hybrid system conversion.

- **BEV Fleet:** The BEV fleet provides the clearest path towards emissions reduction. However, the purchase price for BEVs is still quite high in comparison to conventional gasoline or diesel vehicles. This cost differential is the highest for the BEV single axle truck. In addition, there are additional costs at this time to setup EV charging infrastructure. The lifecycle and ROI analysis for each BEV assumes a $5,000 cost for a charging station.
- It is expected that this additional financial cost of the BEVs can be absorbed in order to start phasing in EVs and enabling users to gain familiarity with this technology before further rollout is implemented. Furthermore, there could be an opportunity to monitor and possibly extend the lifecycle of BEVs in order to improve their ROI.
- **PS Vehicles:** For the Paramedic Services fleet, although the hybrid ambulances and ERVs do not show a ROI and achieve payback over the vehicle lifecycle these technology initiatives are still an integral part of the fleet plan. There are limited options available in the market for PS vehicles and fewer still in the area of green technology. From phasing in new hybrids these vehicles can collectively contribute a reduction of 50 tonnes of CO_2e/year.

Subsequent sections set the timeline of implementing these recommendations over the next 5-years and present the main conclusions from development of this Green Fleet Plan.

6.4 5-YEAR GREEN FLEET PLAN

The implementation of these recommendations is shown in the figures below, noting the new technologies, vehicle propulsion types, reduction in GHG emissions and impacts on capital and operating costs. Figure 46 estimates the GHG reduction with phasing in the recommendations.

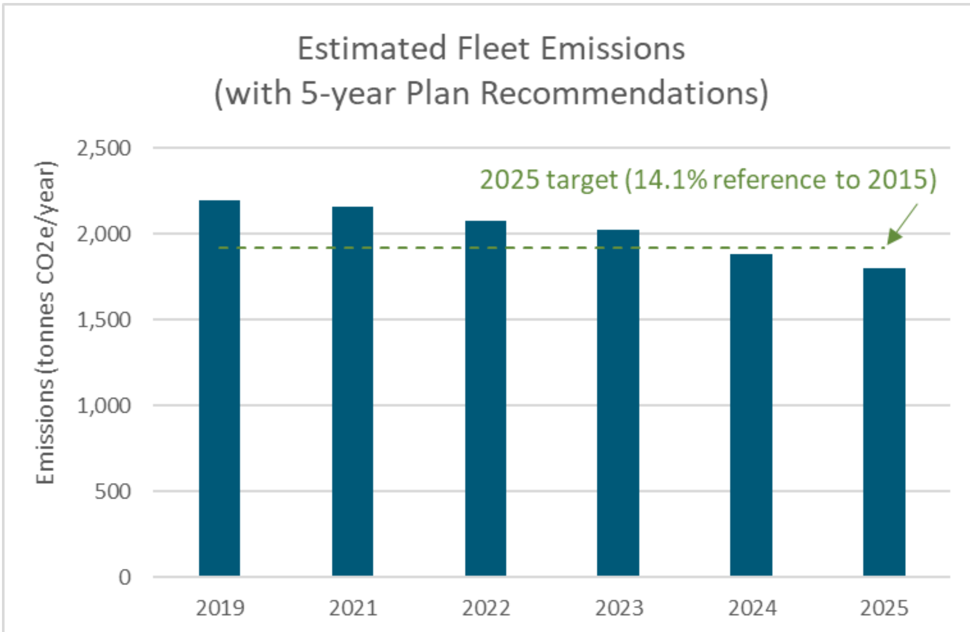

Figure 46 Estimated 5-year Fleet Emissions

In Figure 46, it is assumed that the bio-diesel fuel recommendation is implemented from 2024 onwards and the anti-idling technology is phased in with the outfitting of a minimum four (4) trucks per year from 2022 to 2025. "Like-for-like" replacements are not shown, only deviations to new "green vehicle" or more fuel efficient technologies. The annual GHG reduction is subtracted off the estimated 2020 fleet emissions estimated at 2,200 tonnes of CO_2e (using 2019 Public Works data as a proxy for 2020).

Table 63 summarizes the new technology transitions phased into the fleet replacement plan over the next 5-years. The detailed breakdown by vehicle type, user groups and sites are included in Appendix C.

Table 63 Green Fleet Plan (5-year) New Technology Adoption

Year	Vehicle Type	Technology Change	Quantity
2020	ERV (Truck)[39]	Gas (hybrid)	1
2021	Ambulance	Gas (hybrid)	3
2021	ERV (Truck)	Gas (hybrid)	1
2021	Cargo Van	BEV	1
2021	Tandem (Snowplow)	CNG	2
2022	Ambulance	Gas (hybrid)	2
2022	Pickup (compact and ½ ton)	Gas (hybrid)	9
2022	Pickup (1 ton)	Gas (hybrid)	5
2023	Pickup (compact and ½ ton)	Gas (hybrid)	9
2023	Pickup (1 ton)	Gas (hybrid)	1
2023	SUV	PHEV	2
2023	Cargo Van	BEV	4
2024	ERV (SUV)	BEV	1
2024	Pickup (compact and ½ ton)	Gas (hybrid)	8
2024	Pickup (compact and ½ ton)	BEV	1
2024	Pickup (¾ ton)	Gas (hybrid)	3
2024	SUV	PHEV	1
2024	Cargo Van	BEV	2
2024	Dozer	Diesel (hybrid drive)	1
2025	Pickup (compact and ½ ton)	BEV	2
2025	Pickup (¾ ton)	BEV	4
2025	Cargo Van	BEV	1
2025	Single Axle Truck	BEV	1

[39] This vehicle has already been purchased by Oxford County in 2020 and is awaiting its delivery.

7 GREEN FLEET PLAN CONCLUSIONS

Overall, Oxford County is in a strong position to achieve and potentially exceed their GHG reduction target for fleet by 2025. Several of the green fleet initiatives already implemented have demonstrated promising results and provide a case for continued rollout. The key elements of the 5-year Green Fleet Plan includes the following summarized in Table 64 and illustrated via the implementation pictogram in Figure 47.

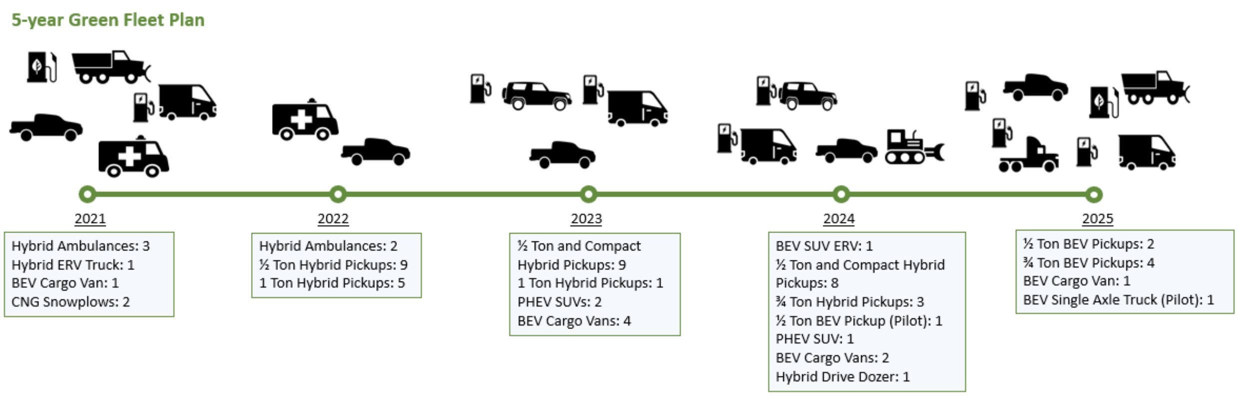

Figure 47 Green Fleet Transition Replacements by Year

Referencing 2019/2020 fleet data, annual emissions have been reduced by approximately **40 tonnes of CO_2e**. An additional **276 tonnes of CO_2e** will need to be reduced by 2025. The set of recommendations posed in this plan (listed in Table 62) can contribute up to **398 tonnes of CO_2e** in further reduction.

Table 64 Strategic Summary of 5-year Green Fleet Plan

Green Fleet Plan Component	Notes on Strategic Direction
Paramedic Service Vehicles	• Continue the replacement of ambulances and ERVs with hybrid vehicles. • Consider a BEV option for the SUV ERV (Asset 1320) in 2024. • Although payback and positive ROI is not achieved over the vehicle lifecycle there are limited green technologies available to PS vehicles and this fleet serves strategic importance for fleet GHG reduction. • The continued transition to hybrid vehicles and a BEV SUV can contribute a reduction of approximately **50 tonnes of CO_2e/year**.
Light-Duty CNG Vehicles	• Phase out light-duty CNG vehicles with lifecycle replacements transitioning to hybrids, PHEVs and ultimately BEVs. • CNG upfitting of light-duty vehicles (i.e. pickup trucks, cargo vans and SUVs) has not demonstrated significant GHG reduction due to the inconvenience of fueling at the CNG station in Woodstock and operator behaviour preference for gas utilization As a result, vehicles run primarily on gasoline. • With the market development of EVs, there are more cost effective light-duty vehicle alternatives which can also provide greater GHG reduction.

Green Fleet Plan Component	Notes on Strategic Direction
Light-Duty Hybrid and BEVs	• With the market development of EVs, there are more cost effective light-duty vehicle alternatives which can also provide greater GHG reduction and savings on fuel cost. • Hybrid and plug-in hybrid (PHEVs) can start the EV transition, for users to gain familiarity with EV technology (i.e. regenerative braking and plug-in charging). • Continued advancement in the light-duty EV market sector offers multiple make/models to be considered (i.e. pickup trucks, cargo vans and SUVs). • The pickup truck fleet should be the primary focus, followed by cargo vans and SUVs, due to the number of replacements schedule over the next 5-years. • Recommendations for light-duty hybrid and BEVs could achieve reduction of up to **216 tonnes of CO_2e/year**.
Heavy-Duty CNG Vehicles	• CNG is a viable interim technology to achieve GHG reduction for heavy-duty fleet. However, the CNG fueling infrastructure in proximity to Oxford County's fleet operations does pose some limitations on further adoption. • Oxford County is replacing two diesel tandem trucks (snowplows) in 2021 with CNG tandems and allocating these trucks to the Woodstock Patrol Yard. These two conversions can cut emissions by **10 tonnes of CO_2e** and achieve payback due to the lower cost of CNG versus diesel fuel.
Heavy-Duty BEVs	• The market has been developing BEVs for Class 6 to 8 heavy-duty trucks with some pilot fleets underway in waste disposal and logistic fleets in North America. • Near the later part of this 5-year plan there can be an opportunity to pilot a heavy-duty BEV truck. This pilot should target a less operations critical truck (i.e. non snowplow). A viable option could be a single axle truck used by Water Treatment. • A pilot BEV truck could cut fleet emissions by approximately **8 tonnes of CO_2e/year**. Although this truck would not achieve a payback over the vehicle lifecycle it can serve a strategic importance for Oxford County to begin gaining familiarity with heavy-duty BEVs before further rollouts.
CNG Infrastructure	• The cost of an on-site CNG fueling station does not provide a justifiable business case. The fuel cost savings and cost of upfitting CNG trucks will not achieve a payback over the 20-year lifecycle of a CNG fuel station. • Investment in a CNG station can fixate Oxford County on this technology over a long-term and potentially impact reaching future GHG reduction targets when BEVs and other zero emission technologies are more available.
EV Infrastructure	• The Green Fleet Plan recommends twenty (20) plug-in EVs (includes PHEVs and BEVs) by 2025. • EV charging stations are recommended to be installed at the home sites for this fleet of EVs. The cost of EV charging stations is factored into the lifecycle cost at $5,000 (for a Level 2 charger). • There are 25 publicly available EV charging stations installed by Oxford County in Woodstock, Tillsonburg, Thamesford, Ingersoll and Salford which can also be leveraged by Oxford County's fleet operations.

Green Fleet Plan Component	Notes on Strategic Direction
Anti-Idling Technology	• There are 16 additional trucks with high idling times which can be strong candidates for installation of the GRIP anti-idle system. • Breakeven would occur if 20% of total idling time is non-productive idling, based on fuel cost savings. • Anti-idling technology on 16 trucks can reduce up to **31 tonnes of CO_2e/year**.
Major Equipment	• There are developments on-going in battery electric and more fuel efficient construction equipment. However, the maturity of battery electric construction equipment is not viable for this 5-year plan but should be revisited in future plans. • Caterpillar has developed the first diesel (electric drive) dozer as a more fuel efficient option which could be considered for replacement of the dozer used by Waste Management. This alternative could yield reduction up to **7 tonnes of CO_2e/year**. • As an alternate fuel, bio-diesel up to a B20 (20%) blend can be introduced for on-site fueling, with considering a lower B5 (5%) blend in winter months to mitigate cold weather concerns on fuel gelling. • Bio-diesel can reduce up to **76 tonnes of CO_2e/year** and hedge against the carbon tax escalation on fuel prices.

APPENDIX A - Vehicle Market Scan & OEM Specifications

Growing stronger together

For information contact:
519-539-9800 | 1-800-755-0394

Battery Electric Cars					
Manufacturer	Chevrolet	Hyundai	Nissan	Volkswagen	Tesla
Model	Bolt EV	Ioniq Electric	Leaf	e-Golf	Model 3
Model Year	2020	2020	2020	2020	2021
Availability	Available today	Available today	Available today	Available today	Available today
Greening Potential					
Fuel Consumption (L/100km equivalent) (combined)	2	1.8	2.1	2.1	1.8
Est. Energy Consumption (kWh/km)	0.14	0.14	0.17	0.18	0.18
All-Electric Range (km)	417	274	363	198	423
Battery					
Battery Material	Litihium ion	Litihium Polymer	Litihium ion	Litihium ion	Litihium ion
Battery Size (kWh)	60	38.3	40 or 62	35.8	75
Vehicle Dimensions					
Length (mm)	4,166	4,470	4,480	4,270	4,694
Width (mm)	1,765	1,820	1,790	1,798	1,933
Height (mm)	1,575	1,445	1,560	1,453	1,443
Wheelbase (mm)	2,600	2,700	2,700	2,629	2,875
Curb Side Weight (kg)	1,616	1,529	1,560	1,567	1,645
Gross Vehicle Weight (kg)	N/A	1,900	N/A	N/A	N/A
Passenger Capacity					
Seating	5	5	5	5	5
Cost					
MSRP (Starting from)	$44,998	$41,499	$44,298	$37,895	$52,990

Battery Electric Cars					
Manufacturer	**Ford**	**Hyundai**	**Kia**	**Kia**	**Volkswagon**
Model	**Mustang Mach-E (SUV)**	**KONA Electric**	**Niro EV**	**Soul EV**	**ID.4**
Model Year	**2021**	**2021**	**2020**	**2021**	**2021**
Availability	**Available today**	**Available today**	**Available today**	**Available today**	**Available Summer 2021**
Greening Potential					
Fuel Consumption (L/100km equivalent) (combined)	2.2	1.8	2.2	2	TBA
Est. Energy Consumption (kWh/km)	0.19	0.15	0.17	0.16	0.19
All-Electric Range (km)	475	415	383	248	340
Battery					
Battery Material	Litihium ion	Litihium Polymer	Litihium Polymer	Litihium Polymer	N/A
Battery Size (kWh)	68 or 88	64	64	39.2	82
Vehicle Dimensions					
Length (mm)	4,724	4,180	4,195	4,195	4,584
Width (mm)	1,880	1,800	1,800	1,800	
Height (mm)	1,600	1,570	1,605	1,605	1,631
Wheelbase (mm)	2,972	2,600	2,600	2,600	2,771
Curb Side Weight (kg)	1,993	1,685	1,612	1,612	2,124
Gross Vehicle Weight (kg)	N/A	1,900	N/A	N/A	2,660
Passenger Capacity					
Seating	5	5	5	5	5
Cost					
MSRP (Starting from)	$50,495	$44,999	$44,995	$42,995	$73,000 (est.)

Plug-in Hybrids								
Manufacturer	Chrysler	Ford	Honda	Hyundai	Kia	Kia	Mitsubishi	Toyota
Model	Pacifica Hybrid	Fusion Plug-In Hybrid	Clarity PHEV	Ioniq plug-in-hybrid	Niro PHEV	Optima PHEV	Outlander PHEV	Prius Prime
Model Year	2020	2020	2021	2020	2020	2020	2020	2021
Availability	Available today	Available today	Available today	Available today	Available Today	Available today	Available today	Available today
Greening Potential								
Fuel Consumption (Le/100km)	2.8	2.3	2.1	2.2	2.2	2.3	3.2	1.8
Est. Energy Consumption (kWh/km)	0.31	0.21	0.22	0.19	0.21	0.22	0.34	0.22
All-Electric Range (km)	51	42	76	47	42	45	35	40
Battery								
Battery Material	Litihium ion	Litihium ion	Litihium ion	Litihium ion	Litihium ion	Litihium ion	Litihium ion	Litihium ion
Battery Size (kWh)	16	9	17	8.9	8.9	9.8	12	8.8
Vehicle Dimensions								
Length (mm)	5,176	4,871	4,895	4,470	4,855	5,176	4,695	4,645
Width (mm)	2,022	1,852	1,902	1,820	1,860	2,022	1,800	1,760
Height (mm)	1,777	1,474	1,478	1,445	1,460	1,777	1,710	1,470
Wheelbase (mm)	3,089	2,850	2,750	2,700	2,805	3,089	2,670	2,700
Curb Side Weight (kg)	2,262	1,808	1,843	1,550	1,775	2,262	1,895	1,530
Passenger Capacity								
Seating	7	5	5	5	5	7	5	4
Cost								
MSRP (Starting from)	$48,995	$33,930	$46,306	$33,749	$35,995	$43,995	$43,998	$33,550

Hybrid Cars								
Manufacturer	Toyota	Toyota	Toyota	Kia	Honda	Honda	Hyundai	Hyundai
Model	Camry Hybrid	Corolla Hybrid	Prius	Optima Hybrid	Accord Hybrid	Insight Hybrid	Sonata Hybrid	Ioniq hybrid
Model Year	2021	2021	2021	2020	2021	2021	2021	2020
Availablility	Available today	Available today	Available today	Available Today	Available today	Available Today	Available today	Available today
Greening Potential								
Fuel Consumption (L/100km) (combined)	4.9	4.5	4.5	5.5	5	4.9	5	4.1
Vehicle Dimensions								
Length (mm)	4,895	4,630	4,575	4,855	4,882	4,663	4,900	4,470
Width (mm)	1,840	1,780	1,760	1,860	1,906	1,878	1,860	1,820
Height (mm)	1,445	1,435	1,471	1,460	1,450	1,411	1,445	1,445
Wheelbase (mm)	2,825	2,700	2,700	2,805	2,830	2,700	2,840	2,700
Curb Side Weight (kg)	1,620	1,380	1,380	1,586	1,524	1,382	1,600	1,370
Gross Vehicle Weight (kg)	2,097	2,839	1,775	N/A	N/A	N/A	2,100	1,870
Passenger Capacity								
Seating	5	5	5	5	5	5	5	5
Cost								
MSRP (Starting from)	$31,550	$25,090	$28,850	$30,995	$37,590	$30,276	$40,199	$25,399

Hybrid Cars							
Manufacturer	Ford	Ford	Ford	Kia	Toyota	Toyota	Toyota
Model	Fusion Hybrid	Escape Titanium Hybrid	Explorer Limited	Niro Hybrid	Highlander Hybrid	RAV4 Hybrid	Venza
Model Year	2020	2020	2021	2020	2021	2021	2021
Availablility	Available today	Available Today	Available Today	Available today	Available today	Available today	Available today
Greening Potential							
Fuel Consumption (L/100km) (combined)	5.5	5.9	9.6	4.7	6.7	6	6.1
Vehicle Dimensions							
Length (mm)	4,871	4,355	5,050	4,855	4,950	4,600	4,630
Width (mm)	1,852	1,805	2,004	1,860	1,930	1,855	1,780
Height (mm)	1,474	1,535	1,783	1,460	1,730	1,701	1,435
Wheelbase (mm)	2,850	2,700	3,025	2,805	2,850	2,690	2,700
Curb Side Weight (kg)	1,664	1,467	2,144	1,583	2,015	1,680	1,380
Gross Vehicle Weight (kg)	N/A	N/A	N/A	N/A	2,839	2,250	2,839
Passenger Capacity							
Seating	5	5	6	5	8	5	5
Cost							
MSRP (Starting from)	$29,375	$34,649	$49,799	$26,845	$45,490	$32,950	$38,490

Hydrogen Fuel Cell Eletric Cars		
Manufacturer	Toyota	Hyundai
Model	Mirai	Nexo
Model Year	2020	2020
Availability	Available in QC and BC	Available today
Greening Potential		
Fuel Consumption (L/100km equivalent) (combined)	3.57	3.86
Range (km)	500	570
Fuel System		
Tank Make/Model	-	-
Tank Size (litres)	122	157
Vehicle Dimensions		
Length (mm)	4,890	4,670
Width (mm)	1,816	1,859
Height (mm)	1,534	1,631
Wheelbase (mm)	2,779	2,789
Curb Side Weight (kg)	1,848	1,867
Gross Vehicle Weight (kg)	N/A	2,340
Passenger Capacity		
Seating	5	5
Cost		
MSRP (Starting from)	$73,870	$73,000

Note: Vehicle configurations for subsystem components (i.e. front/rear axles, transmission and suspension) can be subject to change and request through procurement specifications

Natural Gas Trucks					
Manufacturer	**Freightliner**	**Autocar**	**Autocar**	**Autocar**	**Autocar**
Model	114SD 	ACMD 4X2 	ACMD 4X2 	ACMD 6X4 	ACX 4X2 
Availability	Available Today	Available Today	Available Today	Available Today	Available Today
Vehicle Dimensions					
Length (mm)	7,544	5,662	5,662	7,084	6,477
Width (mm)	2,590	2,388	2,388	2,388	2,565
Height (mm)	2,874	3,408	3,408	3,416	N/A
Wheelbase (mm)	4,064 + 1,321	4,166	4,166	5,639 + 1,397	3,581
Curb Side Weight (kg)		N/A	N/A	N/A	N/A
Gross Vehicle Weight (kg)	41,730	14,968	15,875	23,586	N/A
Vehicle Class	Class 8	Class 8	Class 8	Class 8	Class 8
Fuel System					
Tank Make/Model	Carbon fiber-reinforced aluminum type 3 compressed natural gas (CNG) fuel tanks with approximate range of 644 km, depending on application	Stainless Steel for CNG or LNG	Stainless Steel for CNG or LNG	Stainless Steel for CNG or LNG	Stainless Steel for CNG or LNG
NG Tank Size	60 gallon tank	50, 75 and 100 gallon tanks available	N/A	N/A	N/A
Powertrain					
Engine Make/Model	Cummins L9N Cummins ISX12N	Cummins L9N	Cummins L9N	Cummins L9N	Cummins L9N Cummins ISX12N
Engine (hp)	320 hp (Cummins L9N) 400 hp (Cummins ISX12N)	250 to 320 hp	250 to 320 hp	250 to 320 hp	250 to 320 hp (Cummins L9N) 400 hp (Cummins ISX12N)
EPA Generation	2018	2018	2018	2018	2018
Transmission	Eaton-Fuller Manual Transmission Eaton Autoshift 10 / 18 speed, Ultrashift 10 speed Allison Automatic with optional output retarder	Allison 3500	Allison 3500	Allison 3000	Allison 4500
Front Axle	Detroit DA-F-14.7-3	Dana 1202 Steer Axle	Dana 12k Steer Axle	Dana 1202W Steer Axle	Meritor 20k Steer Axle
Front Axle Capacity	rated at 5,443 kg	5443 kg	N/A	5443 kg	N/A
Rear Axle(s)	Tridem rear axles MT-40-14X	Meritor RS24-160 (Single Reduction 6.14:1 Ratio)	Meritor RS24-160 (Single Reduction 6.14:1 Ratio)	Meritor MT40-14X	Dana S30-190
Rear Axle(s) Capacity	rated at 18,143 kg	9525 kg	N/A	18143 kg.	N/A
Suspension	Front: Taper or Flat Leaf Spring Rear: Freightliner AirLiner, TufTrac, Hendrickson and Chalmers	Front: Flatleaf (5,500 lb) Rear: Hendrickson HTS21k	Front: Flatleaf (5,500 lb) Rear: Hendrickson HTS21k	Front: Flatleaf (5,500 lb) Rear: Hendrickson HMX400	Front: Rear: Hendrickson PAX EX-232
Brakes System	Front: Meritor 16.5x5 Q+ Rear: Meritor 16.5x8.62 Q+	Front: Meritor 15x4 Q Plus (Drum Brakes) Rear: Meritor 15x4 Q Plus (Drum Brakes)	Front: Meritor 16.5x5 QP (Drum Brakes) Rear: Meritor 16.5x5 QP (Drum Brakes)	Front: Meritor 16.5x6 QP (Drum Brakes) Rear: Meritor 16.5x6 QP (Drum Brakes)	Front: Meritor 16.5x7 QP (Drum Brakes) Rear: Meritor 16.5x7 QP (Drum Brakes)
Tires	Front: 12R22.5 Rear: 11R22.5	11R22.5G	11R22.5G	11R22.5G	N/A

Natural Gas Trucks					
Manufacturer	Autocar	Autocar	Mack	Mack	Peterbilt
Model	ACX 6X4 	ACX 8X4 	TerraPro 	LR Model 	520 Model 
Availability	Available Today	Available Today	Available Today	Available Today	Available Today
Vehicle Dimensions					
Length (mm)	8,610	12,212	N/A	N/A	N/A
Width (mm)	2,565	2,565	N/A	N/A	N/A
Height (mm)	N/A	N/A	N/A	N/A	N/A
Wheelbase (mm)	5,258	7,924	N/A	N/A	N/A
Curb Side Weight (kg)	N/A	N/A	N/A	N/A	N/A
Gross Vehicle Weight (kg)	N/A	N/A	15,875 to 36,740	15,875 to 32,658	N/A
Vehicle Class	Class 8	Class 8	Class 8	Class 8	Class 8
Fuel System					
Tank Make/Model	Stainless Steel for CNG or LNG	Stainless Steel for CNG or LNG	N/A	N/A	N/A
NG Tank Size	N/A	N/A	7.3 U.S. GALLONS	N/A	23" Aluminum 50 - 120 Gallon 26" Aluminum 50 - 150 Gallon
Powertrain					
Engine Make/Model	Cummins L9N Cummins ISX12N	Cummins L9N Cummins ISX12N	Cummins L9N	Cummins L9N	Cummins Westport ISLG Cummins Westport ISX12G
Engine (hp)	250 to 320 hp (Cummins L9N) 400 hp (Cummins ISX12N)	250 to 320 hp (Cummins L9N) 400 hp (Cummins ISX12N)	320 hp	320 hp	N/A
EPA Generation	2018	2018	2018	2018	N/A
Transmission	Allison 4500	Allison 4500	Allison 4500 Allison 3000	Allison 4500 Allison 3000	Fuller Manual 10 or 13 Speed Allison Automatic 4, 5 or 6 Speed
Front Axle	Meritor 20k Steer Axle	N/A	Mack UniMax	Mack XL 20	Dana Spicer (12,000 lbs., 14,600 lbs. or 20,000 lbs.) Meritor (12,000 lbs. Single) Meritor (36,000 lbs.Tandem)
Front Axle Capacity	N/A	N/A	18,000 or 20,000 lbs	N/A	N/A
Rear Axle(s)	Meritor RT46	N/A	Mack 200 Series	N/A	N/A
Rear Axle(s) Capacity	N/A	N/A	46,000 lbs	N/A	N/A
Suspension	Front: Rear: Hendrickson HMX 46k	Front: Rear: Chalmers 70k	Mack Camelback Mack mRIDE	Mack Camelback Mack mRIDE	N/A
Brakes System	N/A	N/A	N/A	N/A	Air Disc or Air Cam Drum
Tires	N/A	N/A	N/A	N/A	N/A

Battery Electric Trucks & Vans						
Manufacturer	Havelaar	Rivian	Bollinger	Tesla	Ford	GMC
Model	Bison	R1T	B2	Cybertruck	F-150 Electric	Hummer EV SUT
Model Year	N/A	2021	N/A	N/A	2022	N/A
Availability	TBD	Available 2021	Not Currently Available	Available today	2022	2022
Greening Potential						
Est. Energy Consumption (kWh/km)	0.13	0.28	0.37	N/A	N/A	0.54
All-Electric Range (km)	Up to 300 km	Up to 643 km	Up to 322 km	Up to 800 km	Up to 350 km	Up to 650 km
Battery						
Battery Material	Litihium ion	Litihium ion	Litihium ion	Litihium ion	Litihium ion	Litihium ion
Battery Size (kWh)	40	105 / 135 / 180	120	-	-	350
Vehicle Dimensions						
Length (mm)	N/A	5,486	5,271	5,885	N/A	N/A
Width (mm)	N/A	2,014	1,961	2,027	N/A	N/A
Height (mm)	N/A	1,819	1,847	1,905	N/A	N/A
Wheelbase (mm)	N/A	3,449	3,531	3,807	N/A	N/A
Curb Side Weight (kg)	N/A	2,670	2,268	N/A	N/A	N/A
Gross Vehicle Weight (kg)	N/A	3,427	4,536	N/A	N/A	N/A
Passenger Capacity						
Seating	5	5	4	6	5	6
Cost						
MSRP (Starting from)	$58,000 CAD (est.)	$69,000 USD (est.)	$125,000 USD (est.)	$50,000 USD (est.)	$56,000 USD (est.)	$70,000 USD (est.)

Battery Electric Trucks & Vans					
Manufacturer	**Arrival**	**Workhorse**	**BYD**	**Navistar Inc.**	**Ford**
Model	**The Arrival Van**	**C1000**	**Class 6 Step Van**	**eStar**	**E-Transit**
Model Year	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Availability	**2022**	**Available today**	**Available today**	**Available today**	**2022**
Greening Potential					
Est. Energy Consumption (kWh/km)	**0.81**	**0.44**	**1.11**	**0.50**	**0.33**
All-Electric Range (km)	**Up to 160 km**	**Up to 160 km**	**Up to 200 km**	**Up to 160 km**	**Up to 203 km**
Battery					
Battery Material	**Litihium ion**	**Litihium ion**	**Litihium ion**	**Litihium ion**	**Litihium ion**
Battery Size (kWh)	**130**	**70**	**221**	**80**	**67**
Vehicle Dimensions					
Length (mm)	**N/A**	**8,230**	**8,270**	**6,477**	**Reference OEM Spec Options**
Width (mm)	**N/A**	**2,184**	**2,461**	**2,000**	**Reference OEM Spec Options**
Height (mm)	**N/A**	**3,099**	**3,086**	**2,692**	**Reference OEM Spec Options**
Wheelbase (mm)	**N/A**	**4,826**	**4,521**	**3,599**	**Reference OEM Spec Options**
Curb Side Weight (kg)	**N/A**	**N/A**	**5,791**	**3,185**	**Reference OEM Spec Options**
Gross Vehicle Weight (kg)	**N/A**	**N/A**	**10,433**	**5,498**	**Reference OEM Spec Options**
Passenger Capacity					
Seating	**2**	**Not Listed**	**Not Listed**	**2**	**2**
Cost					
MSRP (Starting from)	**N/A**	**Not Listed**	**N/A**	**N/A**	**$58,000 CAD (est.)**

Note: Vehicle configurations and models are currently under development and can be subject to change, as a result there is limited specifications data available for some models.

Battery Electric Trucks					
Manufacturer	Volvo	Volvo	BYD	BYD	Mack
Model	Volvo FE Electric 	Volvo FL Electric 	Class 8 Day Cab 	Class 6 Truck 	Mack LR BEV 
Availability	Available in North America in 2020	Available in North America in 2020	Available today	Available today	First pilot testing will be in 2020 in NY City
Vehicle Dimensions					
Length (mm)	1,600 to 2,200	1,600 to 2,980	6,910	N/A	N/A
Width (mm)	2,300	2,100	2,500	N/A	N/A
Height (mm)	2,305	2,305	3,085	N/A	N/A
Wheelbase (mm)	N/A	N/A	4,224	N/A	N/A
Curb Side Weight (kg)	N/A	N/A	11,500	N/A	N/A
Gross Vehicle Weight (kg)	12,247 kg (27,000 lbs)	14,515 kg (32,000 lbs)	47,627 kg (105,000 lbs)	11,793 kg (26,000 lbs)	15,800 to 32,600 lbs
Vehicle Class	Class 8	Class 8	Class 8	Class 6	Class 8
Battery					
Battery Material	Litihium ion	Litihium ion	Litihium ion	N/A	Lithium Nickel Manganese Cobalt
Battery Size (kWh)	100 to 300 kWh	100 to 300 kWh	435 kWh	221 kWh	Four NMC Lithium-ion batteries (kWh not listed)
Charging Power	Max charging 150 kW DC Low Power Charging: 22 kW AC	Max charging 150 kW DC Low Power Charging: 22 kW AC	upto 300 kW ; CCS1	CCS1	150kW SAE J1772 plug-in
Charging Time	DC Fast Charging: 1.5 hrs AC Charging: up to 10 hrs	DC Fast Charging: 1 to 2 hours AC Charging: up to 10 hours	3 hrs AC / 1.5 hrs DC	N/A	N/A
Powertrain					
Drive Motor Make/Model	N/A	N/A	N/A	N/A	Mack Integrated Electric Powertrain
Drive Motor Power (kW)	260 kW two AC Motors (130 kW each) 370 kW (peak)	130 kW (single motor) 185 kW (peak)	483 hp	335 hp	Two AC Motors (400 kW peak output)
Transmission	2-speed Volvo Transmission	N/A	N/A	N/A	2-speed Mack Powershift
Front Axle	N/A	N/A	N/A	N/A	Mack FXL20
Front Axle Capacity	8,000 kg	7,100 kg	N/A	N/A	9,100 kg
Rear Axle(s)	N/A	N/A	N/A	N/A	Mack S522R (x2)
Rear Axle(s) Capacity	23,000 kg	11,500 kg	N/A	N/A	23,500 kg (each)
Suspension	N/A	Front: Leaf Suspension (parabolic or parabolic reinforced) & Air, Rear: Leaf (normal, reinforced, short & stiff) OR Air	Front: Leaf Spring Rear: Air Suspension	N/A	Mack mRIDEtm (23,500 kg)
Brakes System	Front / Rear: Disc Brakes	Front / Rear: Disc Brakes	Front: Air disc brakes Rear: Air drum brakes	N/A	Two stage regenerative
Performance					
Range (km)	200 km	300 km	200 km	136 km	90 km
Est. Energy Consumption (kWh/km)	2.23 to 3.35 kWh/km	N/A	N/A	N/A	N/A

Battery Electric Trucks				
Manufacturer	**Lion**	**Lion**	**Peterbilt**	**Freightliner**
Model	Lion8 	Lion6 	220EV 	eM2 106 
Availability	Available Today	Available Today	Available Today	Available 2021
Vehicle Dimensions				
Length (mm)	1,530 (cab only)	N/A	Reference OEM Spec Sheet	9,931
Width (mm)	2,578	N/A	Reference OEM Spec Sheet	2,540
Height (mm)	2,717	N/A	Reference OEM Spec Sheet	2,604
Wheelbase (mm)	5,588	4,953 to 5,385	Reference OEM Spec Sheet	N/A
Curb Side Weight (kg)	11,160	N/A	Reference OEM Spec Sheet	N/A
Gross Vehicle Weight (kg)	27,216 kg (60,000 lbs)	11,793 kg (26,000 lbs)	26,000 to 33,000 lbs	26,000 to 33,000 lbs
Vehicle Class	Class 8	Class 6	Class 6 and 7	Class 6 and 7
Battery				
Battery Material	Lithium Nickel Manganese Cobalt	Lithium Nickel Manganese Cobalt	N/A	Lithium ion
Battery Size (kWh)	336 kWh	252 kWh	141 or 282 kWh	315 kWh
Charging Power	Level II (AC) SAE J1772 Level III (DC) - CCS - Combo	Level II (AC) SAE J1772 Level III (DC) - CCS - Combo	Fast Charge: 125 to 350 kW DC Low Power Charging: 11 kW AC	N/A
Charging Time	Dependent on charging type: Level II (7 to 16 hours) Level III (2.5 to 5 hours)	Dependent on charging type: Level II (5 to 16 hours) Level III (2.5 to 6.5 hours)	1 to 2 hours (fast charging)	80% in 60 min
Powertrain				
Drive Motor Make/Model	SUMO HD HV3500-9 Phases	SUMO MD 6 phases	Reference OEM Spec Sheet	N/A
Drive Motor Power (kW)	AC Motor 350 kW	AC Motor 250 kW	AC Motor 220 kW250 kW (peak)	360 kW (peak)
Transmission	Direct Drive (No Transmission)	Direct Drive (No Transmission)	2-speed Meritor Drive Axle	N/A
Front Axle	Hendrickson	Hendrickson	Reference OEM Spec Sheet	N/A
Front Axle Capacity	6,622 kg	5,443 kg	Reference OEM Spec Sheet	N/A
Rear Axle(s)	Dana Tandem Axle	Dana Single Axle	Reference OEM Spec Sheet	N/A
Rear Axle(s) Capacity	9,027 kg (each)	8,618 kg	Reference OEM Spec Sheet	N/A
Suspension	Hendrickson Air Suspension	Hendrickson Air Suspension	Reference OEM Spec Sheet	N/A
Brakes System	Front / Rear: Air Disc Brakes (Bendix)	Front / Rear: Air Disc Brakes (WABCO)	Reference OEM Spec Sheet	N/A
Performance				
Range (km)	274 km	290 km	Up to 320 km (282 kWh)	370 km
Est. Energy Consumption (kWh/km)	1.24 kWh/km	N/A	N/A	N/A

2021 FORD F-150

TECHNICAL SPECIFICATIONS

BODY

Construction/materials	Fully boxed, high-strength steel frame. High-strength, military-grade, aluminum alloy body
Body style	Body on frame, Regular Cab, SuperCab, SuperCrew®
Trim levels	XL, XLT, LARIAT, King Ranch®, Platinum, Limited
Final assembly location	Dearborn Truck Plant, Kansas City Assembly

DRIVETRAIN

Layout standard	Front engine, rear wheel drive
Layout optional	Front engine, electronically-controlled 4x4 with open differential rear axle Front engine, electronically-controlled 4x4 with electronic locking rear differential Front engine full hybrid, rear wheel drive Front engine full hybrid, electronically-controlled 4x4 with electronic locking rear differential
Transfer Case (4x4 models)	Electronic Shift on the Fly (XL, XLT, Lariat with Snow Plow) with Flat Tow Mode 2-Speed Torque on Demand (Lariat+) with Flat Tow Mode

ENGINES

	3.3-liter Ti-VCT V6 FFV	2.7-liter EcoBoost® V6	5.0-liter Ti-VCT V8
Configuration	Naturally-aspirated 60-degree V6, overhead cams	Twin-turbocharged and intercooled 60-degree V6, overhead cams	Naturally-aspirated 90-degree V8, overhead cams
Block/Head material	Aluminum block, aluminum heads	Compacted graphite iron block, aluminum heads	Aluminum block, aluminum heads
Displacement	3.3 liters (3,340 cubic centimeters, 203.8 cubic inches)	2.7 liters (2,700 cubic centimeters, 165.0 cubic inches)	5.0 liters (5,038 cubic centimeters, 307.0 cubic inches)
Bore x stroke	3.56 inches x 3.41 inches	3.267 inches x 3.267 inches	3.66 inches x 3.65 inches
Compression ratio	12:1	10:1	12:1
Valvetrain	Direct acting mechanical bucket	Roller finger follower	Roller finger follower
Ignition system	Coil on plug	Coil on plug	Coil on plug
Recommended fuel	Regular unleaded or E85 (minimum 87 unleaded octane)	Regular unleaded (minimum 87 unleaded octane)	Regular unleaded or E85 (minimum 87 unleaded octane)
Fuel delivery	Port fuel injection and direct injection	Port fuel injection and direct injection	Port fuel delivery and direct injection
Engine control system	Electronic	Electronic	Electronic
Oil service fill volume/grade	6 quarts with Filter (5W-20 SAE GF6)	6 quarts with Filter (5W-30 SAE GF6)	7.75 quarts (5W-30 SAE GF6)
Coolant capacity	12 liters	14.3 liters	12.5 liters
Horsepower	290 @ 6,500 rpm	325 @ 5,000 rpm	400 @ 6,000 rpm
Torque	265 lb.-ft. @ 4,000 rpm	400 lb.-ft. @ 3,000 rpm	410 lb.-ft. @ 4,250 rpm

ENGINES CONTINUED

	3.0-liter Power Stroke® V6	3.5-liter EcoBoost® V6	3.5-liter PowerBoost™ Full Hybrid V6
Configuration	Turbocharged and intercooled 60-degree V6 diesel	Twin-turbocharged and intercooled 60-degree V6, overhead cams	Twin-turbocharged and intercooled 60-degree V6, overhead cams
Block/Head material	Compacted graphite iron block, aluminum heads	Aluminum block, aluminum heads	Aluminum block, aluminum heads
Displacement	3.0 liters (3,000 cubic centimeters, 183.0 cubic inches)	3.5 liters (3,497 cubic centimeters, 213.4 cubic inches)	3.5 liters (3,497 cubic centimeters, 213.4 cubic inches)
Bore x stroke	3.31 inches x 3.54 inches	3.64 inches x 3.41 inches	3.64 inches x 3.41 inches
Compression ratio	16:1	10.5:1	10.5:1
Valvetrain	Roller finger follower	Roller finger follower	Roller finger follower
Ignition system	Compression	Coil on plug	Coil on plug
Recommended fuel	Ultra low sulfer diesel or up to B20 compatible	Regular unleaded (minimum 87 unleaded octane)	Regular unleaded (minimum 87 unleaded octane)
Fuel delivery	Common rail	Port fuel injection with direct injection	Port fuel injection with direct injection
Engine control system	Multicore powertrain control module	Electronic	Electronic
Oil service fill volume/grade	6.5 quarts (5W-30 SAE FA4)	6 quarts with Filter (5W-30 SAE GF6)	6 quarts with Filter (5W-30 SAE GF6)
Coolant capacity	13 liters	13.5 liters	14.5 liters high temp loop, 6.8 liters low temp loop
Horsepower	250 @ 3,250 rpm	400 @ 6,000 rpm	430 @ 6,000 rpm
Torque	440 lb.-ft. @ 1,750 rpm	500 lb.-ft. @ 3,100 rpm	570 lb.-ft. @ 3,000 rpm

TRANSMISSIONS

		10-Speed SelectShift® Automatic	10-Speed Modular Hybrid Transmission
Configuration		Electronically controlled hydraulic 10-speed automatic	Electronically controlled hydraulic 10-speed automatic
Gear Ratios	First	4.696	4.696
	Second	2.985	2.985
	Third	2.146	2.146
	Fourth	1.769	1.769
	Fifth	1.520	1.520
	Sixth	1.275	1.275
	Seventh	1.000	1.000
	Eighth	0.854	0.854
	Ninth	0.689	0.689
	Tenth	0.636	0.636
	Reverse	4.866	4.866

SUSPENSION

Front configuration	Independent double-wishbone with coil-over shock and stamped lower control arm
Front shock absorber type	Heavy-duty gas-pressurized
Rear configuration	Leaf spring/solid axle
Rear shock absorber type	Heavy-duty gas-pressurized

STEERING

Electronic Power-Assisted

	Wheelbase (inches)	Diameter (feet)
Turning circle (curb-to-curb)	122.8	41.2
	141.5	46.4
	145.4	47.8
	157.2	51.1
	164.1	52.5

BRAKES

	Standard	Heavy-Duty	Max Trailer Tow/Heavy Payload
Booster type	Electronically controlled brake boost	Electronically controlled brake boost	Electronically controlled brake boost
Front type	Power anti-lock vented disc	Power anti-lock vented disc	Power anti-lock vented disc
Front rotor/drum diameter/thickness/material	Nitro Tough Iron, 350 mm x 34 mm	Nitro Tough Iron, 350 mm x 34 mm	Nitro Tough Iron, 350 mm x 34 mm
Front caliper configuration	2 x 51 mm sliding caliper	2 x 51 mm sliding caliper	2 x 51 mm sliding caliper
Front pad material	FER9213	FER9213	FER9213
Front swept area	51547 mm^2	51547 mm^2	51547 mm^2
Rear type	Power anti-lock vented disc	Power anti-lock vented disc	Power anti-lock vented disc
Rear rotor/drum diameter	Nitro Tough Iron, 336 x 20 mm	Nitro Tough Iron, 336 x 20 mm	Nitro Tough Iron, 350 x 24 mm
Rear caliper configuration	1 x 54 mm sliding eIPB	1 x 54 mm sliding eIPB	1 x 54 mm sliding eIPB
Rear pad material	GA9105	GA9105	GA9105
Rear swept area	40998 mm^2	40998 mm^2	42997 mm^2
Parking/Emergency Brake	18.5 kN electronic parking brake	25.5 kN electronic parking brake	25.5 kN electronic parking brake

FUEL CAPACITY

Engine	Fuel tank capacity, gallons (dependent on cab and box configuration)
3.3-liter Ti-VCT	23 gallons, 26 gallons, 36 gallons*
2.7-liter EcoBoost	23 gallons, 26 gallons, 36 gallons*
3.5-liter EcoBoost	23 gallons, 26 gallons, 36 gallons*
5.0-liter V8	23 gallons, 26 gallons, 36 gallons*
3.0-liter Power Stroke	26 gallons
3.5-liter PowerBoost™	30.6 gallons

FUEL ECONOMY

		EPA-Estimated Fuel Economy		
	Drive	City	Highway	Combined
3.3-liter Ti-VCT V6	4x2	20	24	21
	4x4	19	22	20
2.7-liter EcoBoost® V6	4x2	20	26	22
	4x4	19	24	21
5.0-liter V8	4x2	17	24	20
	4x4	16	22	19
3.5-liter EcoBoost® V6	4x2	18	24	20
	4x4	18	23	20
3.0-liter Power Stroke® V6	4x4	TBD	TBD	TBD
3.5-liter PowerBoost™ Full Hybrid V6	4x2	TBD	TBD	TBD
	4x4	TBD	TBD	TBD

STANDARD SAFETY

ABS/Stability control	Four-Wheel Anti-Lock Brakes, AdvanceTrac® with Roll Stability Control™ (RSC®)
Airbags	Front, Driver and passenger Front, Driver and passenger seat-mounted side Front, Driver and Passenger knee Safety Canopy® side curtains
Chassis safety	Tire Pressure Monitoring System (TPMS), SOS Post-Crash Alert System™

*Not available with 122" WB.

FORD CO-PILOT360™ TECHNOLOGIES

Standard	Auto Hold, Auto On/Off Headlamps, AutoBeam Headlamps, Forward Collision Warning and Dynamic Brake Support, Hill Start Assist, Pre-Collision Assist with Automatic Emergency Braking (with Pedestrian Detection), Rear View Camera with Dynamic Hitch Support
Available	Active Drive Assist Prep Kit, Active Park Assist 2.0, Blind Spot Information System with Cross-Traffic Alert and Trailer Coverage, Distance Alert/Distance Indication, Evasive Steering Assist, Forward and Reverse Sensing Systems, Intelligent Adaptive Cruise Control (with Stop-and-Go, Lane Centering and Speed Sign Recognition), Intersection Assist, Lane Keeping System, Post-Collision Braking, Pro Trailer Backup Assist, Trailer Reverse Guidance, Reverse Brake Assist

LIGHTING

Headlamps	Standard Halogen Quad Beam Headlamp. Optional LED Quad Beam Headlamp with Daytime Running Lamp, or optional Adaptive LED Projector with Autommatic Leveling and Dynamic Bending and Daytime Running Lamp
Taillamps	Standard Halogen Taillamps, LED Taillamps optional
Aux	Daytime Running Lamps, Cargo Lamp, Integrated Marker Lights (optional), Tailgate LED (optional), LED Side-Mirror Spotlights (optional), LED cargo box lights (optional), Halogen or LED fog lamps (optional)

EXTERIOR DIMENSIONS (INCHES UNLESS OTHERWISE NOTED)

	5.5-ft. Styleside		6.5-ft. Styleside		8.0-ft. Styleside	
REGULAR CAB	4x2	4x4	4x2	4x4	4x2	4x4
Wheelbase	NA	NA	122.8	122.8	141.5	141.5
Overall length	NA	NA	209.1	209.1	227.7	227.7
Cab height	NA	NA	75.6	77	75.2	77
Width - Excluding mirrors	NA	NA	79.9	79.9	79.9	79.9
Width - Including standard mirrors	NA	NA	95.7	95.7	95.7	95.7
Width - Standard Mirrors folded	NA	NA	83.6	83.6	83.6	83.6
Width - Including trailer tow mirrors	NA	NA	105.9	105.9	105.9	105.9
Width - Trailer tow mirrors folded	NA	NA	85.3	85.3	85.3	85.3
Track width - Front	NA	NA	67.9	67.9	67.9	67.9
Track width - Rear	NA	NA	68.3	68.3	68.3	68.3
Overhang - Front	NA	NA	37.6	37.6	37.6	37.6
Overhang - Rear	NA	NA	48.6	48.6	48.6	48.6
Angle of approach	NA	NA	21.7°	23.9°	21°	24.6°
Angle of departure	NA	NA	23.9°	26.2	23.9°	26.1°
Ramp breakover angle	NA	NA	20.8°	23.5°	18.3°	21°
Ground clearance	NA	NA	8.7	9.4	8.3	9.4
Open tailgate to ground	NA	NA	33.9	35.7	33.9	35.6
Front bumper to back of cab	NA	NA	121.4	121.4	121.4	121.4

EXTERIOR DIMENSIONS (INCHES UNLESS OTHERWISE NOTED)

	5.5-ft. Styleside		6.5-ft. Styleside		8.0-ft. Styleside	
SUPERCAB	4x2	4x4	4x2	4x4	4x2	4x4
Wheelbase	NA	NA	145.4	145.4	164.1	164.1
Overall length	NA	NA	231.7	231.7	250.3	250.3
Cab height	NA	NA	75.5	77.2	75.6	77.1
Width - Excluding mirrors	NA	NA	79.9	79.9	79.9	79.9
Width - Including standard mirrors	NA	NA	95.7	95.7	95.7	95.7
Width - Standard Mirrors folded	NA	NA	83.6	83.6	83.6	83.6
Width - Including trailer tow mirrors	NA	NA	105.9	105.9	105.9	105.9
Width - Trailer tow mirrors folded	NA	NA	85.3	85.3	85.3	85.3
Track width - Front	NA	NA	67.9	67.9	67.9	67.9
Track width - Rear	NA	NA	68.3	68.3	68.3	68.3
Overhang - Front	NA	NA	37.6	37.6	37.6	37.6
Overhang - Rear	NA	NA	48.6	48.6	48.6	48.6
Angle of approach	NA	NA	21.5°	24.6°	21.2°	24.9°
Angle of departure	NA	NA	23.2°	25.4°	23.9°	25.6°
Ramp breakover angle	NA	NA	17.6°	20.2°	16°	18.2°
Ground clearance	NA	NA	8.4	9.4	8.2	8.7
Open tailgate to ground	NA	NA	33.1	35.0	33.8	35.2
Front bumper to back of cab	NA	NA	144.0	144.0	144.0	144.0

	5.5-ft. Styleside		6.5-ft. Styleside		8.0-ft. Styleside	
SUPERCREW®	4x2	4x4	4x2	4x4	4x2	4x4
Wheelbase	145.4	145.4	157.2	157.2	NA	NA
Overall length	231.7	231.7	243.5	243.5	NA	NA
Cab height	75.6	77.2	75.8	77.6	NA	NA
Width - Excluding mirrors	79.9	79.9	79.9	79.9	NA	NA
Width - Including standard mirrors	95.7	95.7	95.7	95.7	NA	NA
Width - Standard Mirrors folded	83.6	83.6	83.6	83.6	NA	NA
Width - Including trailer tow mirrors	105.9	105.9	105.9	105.9	NA	NA
Width - Trailer tow mirrors folded	85.3	85.3	85.3	85.3	NA	NA
Track width - Front	67.9	67.9	67.9	67.9	NA	NA
Track width - Rear	68.3	68.3	68.3	68.3	NA	NA
Overhang - Front	37.6	37.6	37.6	37.6	NA	NA
Overhang - Rear	48.6	48.6	48.6	48.6	NA	NA
Angle of approach	21.8°	24.3°	21.0°	24.0°	NA	NA
Angle of departure	22.9°	25.3°	23.9°	26.3°	NA	NA
Ramp breakover angle	17.6°	20.0°	16.6°	19.0°	NA	NA
Ground clearance	8.5	9.4	8.2	8.8	NA	NA
Open tailgate to ground	32.9	34.9	33.8	35.8	NA	NA
Front bumper to back of cab	155.8	155.8	155.8	155.8	NA	NA

INTERIOR DIMENSIONS (INCHES UNLESS OTHERWISE NOTED)

	Regular Cab	SuperCab	SuperCrew
Seating	3	5, 6	5, 6
Front headroom	40.8	40.8	40.8
Front leg room SAE ("max" is currently listed)	43.9	43.9	43.9
Front shoulder room	66.7	66.7	66.7
Front hip room	62.5	62.5	62.5
Rear head room	N/A	40.3	40.4
Rear leg room SAE ("max" is currently listed)	N/A	33.5	43.6
Rear shoulder room	N/A	66.1	66.0
Rear hip room	N/A	62.6	62.6

CARGO CAPACITIES (INCHES UNLESS OTHERWISE NOTED)

	5.5-ft. Styleside	6.5-ft. Styleside	8.0-ft. Styleside
Inside Length (at floor)	67.1	78.9	97.6
Width between wheelhouses	51.1	51.1	51.1
Inside Height	21.4	21.4	21.4
Cargo box volume	52.8 cu. ft.	62.3 cu. ft.	77.4 cu. ft.

WHEELS

Standard	17-inch silver-painted steel wheels
Optional	17-inch silver-painted aluminum alloy wheels 18-inch machined-aluminum alloy wheels with magnetic pockets 18-inch machined-aluminum alloy wheels with ebony black pockets 18-inch silver-painted aluminum alloy wheels 18-inch aluminum alloy chrome-like PVD wheels 20-inch aluminum alloy chrome-like PVD wheels 20-inch aluminum alloy premium painted tarnished dark wheels 20-inch machined-aluminum alloy wheels with magnetic pockets 20-inch machined-aluminum alloy wheels with light caribou-painted pockets 20-inch polished-aluminum alloy wheels 22-inch polished-aluminum alloy wheels

TIRES

Standard	245/70R17 black side wall (BSW) all-season tires
Optional	245/70R17 outlined white letters (OWL) all-terrain tires LT265/70R17C BSW all-terrain tires 265/60R18 BSW all-season tires 275/65R18 OWL all-terrain tires LT265/70R18C OWL all-terrain tires 275/60R20 BSW all-season tires 275/60R20 OWL all-terrain tires 275/60R20 BSW all-terrain tires 275/50R22 BSW all-season tires

BASE CURB WEIGHTS (LBS.)

REGULAR CAB	4x2	4x2	4x2	4x2	4x2	4x2
Pickup box style	5.5-ft. Styleside		6.5-ft. Styleside		8.0-ft. Styleside	
Base Curb Weight – 3.3L Ti-VCT V6	—	—	4,021	4,275	4,122	4,363
Base Curb Weight – 2.7L EcoBoost® V6	—	—	4,171	4,441	4,263	4,546
Base Curb Weight – 5.0L Ti-VCT V8	—	—	4,300	4,564	4,396	4,650
Base Curb Weight – 3.5L EcoBoost® V6	—	—	—	—	4,428	4,690
SUPERCAB	4x2	4x2	4x2	4x2	4x2	4x2
Pickup box style	5.5-ft. Styleside		6.5-ft. Styleside		8.0-ft. Styleside	
Base Curb Weight – 3.3L Ti-VCT V6	—	—	4,345	4,598	—	—
Base Curb Weight – 2.7L EcoBoost® V6	—	—	4,469	4,755	4,574	—
Base Curb Weight – 5.0L Ti-VCT V8	—	—	4,554	4,810	4,675	4,941
Base Curb Weight – 3.5L EcoBoost® V6	—	—	4,607	4,860	4,764	5,025
Base Curb Weight – 3.0L Power Stroke® V6	—	—	—	5,208	—	—
SUPERCREW®	4x2	4x2	4x2	4x2	4x2	4x2
Pickup box style	5.5-ft. Styleside		6.5-ft. Styleside		8.0-ft. Styleside	
Base Curb Weight - 3.3L Ti-VCT V6	4,465	4,705	—	—	—	—
Base Curb Weight - 2.7L EcoBoost® V6	4,584	4,838	4,616	—	—	—
Base Curb Weight - 5.0L Ti-VCT V8	4,661	4,912	4,712	5,014	—	—
Base Curb Weight - 3.5L EcoBoost® V6	4,696	4,948	4,752	4,995	—	—
Base Curb Weight - 3.0L Power Stroke ® V6	—	5,243	—	5,292	—	—
Base Curb Weight - 3.5L PowerBoost™ Full Hybrid V6	5,260	5,517	5,228	5,540	—	—

MAXIMUM PAYLOAD (LBS.)

REGULAR CAB	GVWR (lbs.)	122.8" WB 4x2	122.8" WB 4x4	141.5" WB 4x2	141.5" WB 4x4
3.3L Ti-VCT V6	6,010	1,985	–	–	–
	6,050	–	1,775	–	–
	6,100	–	–	1,975	–
	6,325	–	–	–	1,960
2.7L EcoBoost V6	6,050	1,875	–	–	–
	6,150	–	1,705	–	-
	6,170	–	–	1,905	–
	6,435	–	–	–	1,885
	6,800	–	–	–	2,125*
	6,900	–	–	2,480*	–
5.0L V8	6,200	1,900	–	–	–
	6,400	–	1,835	–	–
	6,750	–	–	2,350	–
	6,950	–	–	–	2,300
	7,850	–	–	3,325**	3,050**
3.5L EcoBoost V6	7,050	–	–	–	2,360
	7,050	–	–	2,620	–
	7,850	–	–	3,250**	3,035**

MAXIMUM PAYLOAD (LBS.)

SUPERCAB	GVWR (lbs.)	145.4" WB 4x2	145.4" WB 4x4	164.1" WB 4x2	164.1" WB 4x4
3.3L Ti-VCT V6	6,250	1,905	–	–	–
	6,480	–	1,880	–	–
2.7L EcoBoost V6	6,325	1,855	–	–	–
	6,500	–	1,745	1,925	–
	6,750	2,175*	–	–	–
	6,900	–	–	2,225	–
	7,000	–	2,165*	–	–
5.0L V8	6,900	2,345	–	–	–
	7,000	–	–	2,325	–
	7,050	–	2,240	–	–
	7,150	–	–	–	2,205
	7,850	–	–	3,010**	2,765**
3.0L Power Stroke V6	7,050	–	1,840	–	–
3.5L EcoBoost V6	6,900	2,290	–	–	–
	7,050	–	2,190	2,285	–
	7,150	–	–	–	2,125
	7,850	–	–	2,980**	2,740**

SUPERCREW®	GVWR (lbs.)	145.4" WB 4x2	145.4" WB 4x4	157.2" WB 4x2	157.2" WB 4x4
3.3L Ti-VCT V6	6,250	1,785	–	–	–
	6,470	–	1,765	–	–
2.7L EcoBoost V6	6,400	1,815	–	–	–
	6,450	–	–	1,830	–
	6,600	–	1,760	–	–
	6,650	1,960*	–	–	–
	6,800	–	–	2,085*	–
	6,900	–	1,965*	–	–
5.0L V8	6,800	2,135	–	–	–
	6,950	–	–	2,235	–
	7,050	2,335	2,135	–	–
	7,150	–	–	–	2,135
	7,850	–	–	2,900**	2,650**
3.0L Power Stroke V6	7,050	–	1,805	–	–
	7,100	–	–	–	1,805
3.5L EcoBoost V6	6,750	2,050	–	–	–
	7,000	–	–	2,245	–
	7,050	2,300***	2,100	–	–
	7,150	–	–	–	2,155
	7,850	–	–	2,880**	2,640**
3.5L PowerBoost Hybrid	7,350	2,090	1,830	2,120	1,810

*2.7L V6 EcoBoost Payload Package **Heavy-Duty Payload Package ***Max Trailer Tow Package

MAXIMUM CONVENTIONAL TOWING CAPABILITIES (LBS.)

REGULAR CAB	Axle Ratio	GCWR (lbs.)	122.8" WB 4x2	122.8" WB 4x4	141.5" WB 4x2	141.5" WB 4x4
3.3L Ti-VCT V6	3.55	9,400	5,000	–	–	–
	3.55	9,500	–	–	5,000	–
	3.55	9,700	–	5,100	–	–
	3.73	12,600	8,200	–	–	–
	3.73	12,700	–	–	8,200	–
	3.73	12,800	–	8,200	–	–
	3.73	12,900	–	–	–	8,200
2.7L EcoBoost V6	3.15/3.55	12,200	7,600	–	–	–
	3.15/3.55	12,300	–	–	7,600	–
	3.55	12,500	–	7,700	–	–
	3.55	12,600	–	–	–	7,700
	3.73	13,200	8,600	–	–	–
	3.73	13,300	–	–	–	8,400
	3.73	13,300	–	8,500	–	–
	3.73	13,300	–	–	8,600	–
	3.73	14,800	–	–	10,000*	–
	3.73	15,100	–	–	–	10,000*
5.0L V8	3.15/3.31	13,000	8,300	–	–	–
	3.31	13,200	–	8,200	–	–
	3.73	13,800	9,100	–	–	–
	3.73	14,600	–	9,600	–	–
	3.31	14,800	–	–	–	9,700
	3.15/3.31	14,800	–	–	9,900	–
	3.73	15,300	–	–	10,400	–
	3.73	15,600	–	–	–	10,500
	3.73	17,900	–	–	–	12,800***
	3.73	17,900	–	–	13,000***	–
	3.73	18,000	–	–	13,000***	–
	3.73	18,300	–	–	–	13,000***
3.5L EcoBoost V6	3.31/3.55	16,100	–	–	11,200	–
	3.31/3.55	16,400	–	–	–	11,200
	3.55	17,900	–	–	–	12,700***
	3.55	17,900	–	–	13,000***	–
	3.73	18,400	–	–	13,000***	13,100***

*2.7L V6 EcoBoost Payload Package **Heavy-Duty Payload Package ***Max Trailer Tow Package

MAXIMUM CONVENTIONAL TOWING CAPABILITIES (LBS.)

SUPERCAB	Axle Ratio	GCWR (lbs.)	145.4" WB 4x2	145.4" WB 4x4	164.1" WB 4x2	164.1" WB 4x4
3.3L Ti-VCT V6	3.55	9,700	5,000	–	–	–
	3.73	12,900	8,200	–	–	–
	3.73	13,100	–	8,100	–	–
2.7L EcoBoost V6	3.15/3.55	12,600	–	–	7,600	–
	3.15/3.55	12,600	7,700	–	–	–
	3.55	12,800	–	7,600	–	–
	3.73	13,300	–	8,100	–	–
	3.73	13,300	–	–	8,300	–
	3.73	13,300	8,400	–	–	–
	3.73	15,000	10,000*	–	–	–
	3.73	15,100	–	–	10,000*	–
	3.73	15,300	–	10,100*	–	–
5.0L V8	3.31	14,800	–	–	–	9,400
	3.31	14,800	–	9,500	–	–
	3.15/3.31	14,800	–	–	9,600	–
	3.15/3.31	14,800	9,800	–	–	–
	3.73	15,500	10,500	–	–	–
	3.73	15,600	–	–	10,400	–
	3.73	15,800	–	–	–	10,400
	3.73	15,800	–	10,500	–	–
	3.73	17,600	–	12,300***	–	–
	3.73	17,800	12,800***	–	–	–
	3.73	18,200	–	–	13,000***	–
	3.73	18,300	–	–	13,000***	–
	3.73	18,400	–	–	–	13,000***
	3.73	18,500	–	–	–	13,000***
3.0L Power Stroke V6	3.31/3.55	16,300	–	10,500	–	–
	3.55	17,900	–	12,100***	–	–
3.5L EcoBoost V6	3.31/3.55	16,200	11,000	–	–	–
	3.31/3.55	16,500	–	11,100	–	–
	3.31/3.55	16,500	–	–	11,200	–
	3.31/3.55	16,800	–	–	–	11,200
	3.55	17,500	12,300***	–	–	–
	3.55	17,700	–	12,300***	–	–
	3.55	19,400	–	–	–	13,800***
	3.55	19,400	–	–	14,000***	–
	3.73	19,400	–	–	14,000***	13,800***

*2.7L V6 EcoBoost Payload Package **Heavy-Duty Payload Package ***Max Trailer Tow Package

MAXIMUM CONVENTIONAL TOWING CAPABILITIES (LBS.)

SUPERCREW®	Axle Ratio	GCWR (lbs.)	145.4" WB 4x2	145.4" WB 4x4	157.2" WB 4x2	157.2" WB 4x4
3.3L Ti-VCT V6	3.55	9,900	5,100	–	–	–
	3.73	13,000	8,200	–	–	–
	3.73	13,300	–	8,200	–	–
2.7L EcoBoost V6	3.15/3.55	12,700	7,700	–	–	–
	3.15/3.55	12,800	–	–	7,800	–
	3.55	12,900	–	7,700	–	–
	3.73	13,300	–	8,100	–	–
	3.73	13,300	8,300	–	–	–
	3.73	13,300	–	–	8,300	–
	3.73	15,100	10,000*	–	10,000*	–
	3.73	15,400	–	10,100*	–	–
5.0L V8	3.31	14,800	–	–	–	9,300
	3.31	14,800	–	9,400	–	–
	3.15/3.31	14,800	–	–	9,600	–
	3.15/3.31	14,800	9,700	–	–	–
	3.73	15,600	–	–	10,400	–
	3.73	15,600	10,500	–	–	–
	3.73	15,800	–	–	–	10,300
	3.73	15,800	–	10,400	–	–
	3.73	18,100	12,900***	–	–	–
	3.73	18,200	–	–	13,000***	–
	3.73	18,400	–	–	–	12,900***
	3.73	18,400	–	13,000***	–	–
	3.73	18,400	–	–	13,000***	–
	3.73	18,600	–	–	–	13,000***
3.0L Power Stroke V6	3.31/3.55	16,300	–	10,400	–	–
	3.31/3.55	16,300	–	–	–	10,400
	3.55	18,000	–	12,100***	–	–
	3.55	18,000	–	–	–	12,100***
3.5L EcoBoost V6	3.31/3.55	16,500	11,200	–	–	–
	3.31/3.55	16,600	–	–	11,300	–
	3.31/3.55	16,800	–	–	–	11,200
	3.31/3.55	16,800	–	11,300	–	–
	3.55	19,300	–	–	14,000***	–
	3.55	19,400	–	–	–	13,800***
	3.55	19,400	–	13,900***	–	–
	3.55	19,400	14,000***	–	–	–
	3.73	19,400	–	–	14,000***	
	3.73	19,500	–	–		13,800***

*2.7L V6 EcoBoost Payload Package **Heavy-Duty Payload Package ***Max Trailer Tow Package

MAXIMUM CONVENTIONAL TOWING CAPABILITIES (LBS.)

SUPERCREW®	Axle Ratio	GCWR (lbs.)	145.4" WB 4x2	145.4" WB 4x4	157.2" WB 4x2	157.5" WB 4x4
3.5L PowerBoost Hybrid	3.55	16,700	11,000	–	–	–
	3.55	16,800	–	–	11,100	–
	3.73	17,000	–	11,000	–	–
	3.73	17,000	–	–	–	11,000
	3.55	18,400	12,700***	–	–	–
	3.55	18,400	–	–	12,700***	–
	3.73	18,400	–	12,400***	–	–
	3.73	18,400	–	–	–	12,400***

TECHNOLOGY

Standard	Over-the-air-updates, FordPass Connect™ (with remote lock/unlock, vehicle status check, schedule remote start times, Trailer Theft Alert, Trailer Light Check and other truck features), 4-inch productivity screen in instrument cluster, 8-inch center stack touchscreen, selectable drive modes, SYNC® 4, wireless phone connection
Available	2.0kW Pro Power Onboard, 2.4kW Pro Power Onboard, 7.2kW Pro Power Onboard, 12-inch center touchscreen,Connected Built-In Navigation, 8-inch productivity screen in instrument cluster, 12-inch productivity screen, 360-Degree Camera with Split-View Display, Intelligent Access with push-button start, 8-speaker B&O Sound System by Bang & Olufsen with HD Radio™, 18-speaker B&O Sound System Unleashed by Bang & Olufsen with HD Radio™, Sirius XM 360L, 4G LTE with WiFi® hotspot, extended power running boards with kick switch, Remote Start System, MyKey®, SecuriCode™ keyless entry keypad, rain sensing wipers, Fleet Telematics (fleet only)

WARRANTY

Bumper-to-bumper	3 years/36,000 miles
Powertrain	5 years/60,000 miles
Aluminum body panels	5 years/unlimited miles
Corrosion - sheetmetal (Perforation only excluding aluminum)	5 years/unlimited miles
Paint Adhesion	5 years/unlimited miles
Roadside assistance	5 years/60,000 miles
Diesel Engine	5 years/100,000 miles

*2.7L V6 EcoBoost Payload Package **Heavy-Duty Payload Package ***Max Trailer Tow Package

ALL-NEW 2019 RAM 1500

SPECIFICATIONS

New 2019 Ram 1500

SPECIFICATIONS

Specifications are based on the latest product information available at the time of publication.
All dimensions are in inches (millimeters) unless otherwise noted.
All dimensions measured at curb weight with standard tires and wheels.

GENERAL INFORMATION

Vehicle Type	Quad Cab and Crew Cab, 2WD, 4WD
Assembly Plant	Sterling Heights Assembly Plant, Sterling Heights, Michigan
EPA Vehicle Class	Standard Pickup

BODY/CHASSIS

Layout	2WD — Longitudinal, front engine
	4WD — Longitudinal, front engine, transfer case
Construction	2WD — Ladder-type frame, steel cab, double-wall steel pickup box
	4WD — Ladder-type frame, steel cab, double-wall steel pickup box

ENGINE: 3.6-LITER PENTASTAR V-6 WITH eTORQUE

Type and Description	60-degree V-type, liquid-cooled
Hybrid Battery	48-volt, 12-cell lithium-ion, nickel manganese cobalt (NMC) graphite chemistry, .43 kWh
Belt-starter Generator	9kW power, 90 lb.-ft. launch torque
Displacement	220 cu. in. (3,604 cu. cm)
Bore x Stroke	3.78 x 3.27 (96.0 x 83.0)
Valve System	Chain-driven DOHC, 24 valves and hydraulic end-pivot roller rockers
Fuel Injection	Sequential, multiport, electronic, returnless
Construction	Aluminum deep-skirt block, aluminum alloy heads
Compression Ratio	11.3:1
Power	305 hp (224 kW) at 6,400 rpm

Torque	269 lb.-ft. (364 N•m) at 4,800 rpm
Max. Engine Speed	6,400 rpm (electronically limited)
Fuel Requirement	Unleaded regular, 87 octane
Oil Capacity	6.0 quarts (5.7 liters)
Coolant Capacity	14.0 quarts (13.25 liters)
Emission Controls	Dual three-way catalytic converters, heated oxygen sensors
EPA Fuel Economy mpg (city/hwy)	TBA

ENGINE: 5.7-LITER HEMI® V-8

Type and Description	90-degree V-8, liquid-cooled
Displacement	345 cu. in. (5,654 cu. cm)
Bore x Stroke	3.92 x 3.58 (99.5 x 90.9)
Valve System	Variable-cam timing, pushrod-operated overhead valves, 16 valves, hydraulic lifters with roller followers
Fuel Injection	Sequential, multiport, electronic, returnless
Construction	Deep-skirt cast-iron block with cross-bolted main bearing caps, aluminum alloy heads with hemispherical combustion chambers
Compression Ratio	10.5:1
Power	395 hp (291 kW) @ 5,600 rpm
Torque	410 lb.-ft. (556 N•m) @ 3,950 rpm
Max. Engine Speed	5,800 rpm
Fuel Requirement	Unleaded mid-grade, 89 octane — recommended
	Unleaded regular, 87 octane — acceptable
Oil Capacity	7.0 quarts (6.6 liters)
Coolant Capacity	14.0 quarts (13.33 liters)
Emission Controls	Three-way catalytic converters, heated oxygen sensors and internal engine features
EPA Fuel Economy mpg (city/hwy)	15/22

ENGINE: 5.7-LITER HEMI V-8 eTORQUE

Type and Description	90-degree V-8, liquid-cooled
Hybrid Battery	48-volt, 12-cell lithium-ion, nickel manganese cobalt (NMC) graphite chemistry, .43 kWh
Belt-starter Generator	12kW power, 130 lb.-ft. launch torque
Displacement	345 cu. in. (5,654 cu. cm)
Bore x Stroke	3.92 x 3.58 (99.5 x 90.9)
Valve System	Variable-cam timing, pushrod-operated overhead valves, 16 valves, hydraulic lifters with roller followers
Fuel Injection	Sequential, multiport, electronic, returnless
Construction	Deep-skirt cast-iron block with cross-bolted main bearing caps, aluminum-alloy heads with hemispherical combustion chambers
Compression Ratio	10.5:1
Power	395 hp (291 kW) @ 5,600 rpm
Torque	410 lb.-ft. (556 N•m) @ 3,950 rpm
Max. Engine Speed	5,800 rpm
Fuel Requirement	Unleaded mid-grade, 89 octane (R+M)/2 — recommended
	Unleaded regular, 87 octane (R+M)/2 — acceptable
Oil Capacity	7.0 quarts (6.6 liters)
Coolant Capacity	14.0 quarts (13.33 liters)
Emission Controls	Three-way catalytic converters, heated oxygen sensors and internal engine features
EPA Fuel Economy mpg (city/hwy)	TBA

TRANSMISSION: TORQUEFLITE 845RE EIGHT-SPEED AUTOMATIC

Availability	Standard with 3.6-liter Pentastar V-6
Description	Adaptive electronic control, automatic or Electronic Range Select (ERS) manual control. Five-clutch-pack design with only two open clutches in any gear. Torque converter lock with turbine torsional damper for low lock-up speeds in 1st through 8th gear
Gear Ratios	
1st	4.71
2nd	3.14
3rd	2.10

4th	1.67
5th	1.29
6th	1.00
7th	0.84
8th	0.67
Reverse	3.30
Axle Ratios	3.21, 3.55, 3.92 (Rebel only)

TRANSMISSION: TORQUEFLITE 8HP75 EIGHT-SPEED AUTOMATIC

Availability	Standard with 5.7-liter HEMI V-8 and 5.7-liter V-8 with eTorque assist
Description	Adaptive electronic control, automatic or ERS manual control. Five-clutch-pack design with only two open clutches in any gear. Torque converter lock with turbine torsional damper for low lock-up speeds in 1st through 8th gear
Gear Ratios	
1st	4.71
2nd	3.14
3rd	2.10
4th	1.67
5th	1.29
6th	1.00
7th	0.84
8th	0.67
Reverse	3.30
Axle Ratios	3.21, 3.55 (excluding 5.7-liter HEMI V-8), 3.92

TRANSFER CASE: BW 48-12 PART-TIME

Availability	3.6-liter Pentastar V-6 4x4 with eTorque assist, 5.7-liter HEMI V-8 4x4 and 5.7-liter HEMI V-8 with eTorque assist
Shift Mechanism	Electric
Available Speeds	Two-speed
Operating Modes	2WD High; 4WD High, Locked; Neutral; 4WD Low, Locked

Low-range Ratio	2.64
Center Differential Type	None

TRANSFER CASE: BW 48-11 ON-DEMAND

Availability	5.7-liter HEMI V-8 4x4 and 5.7-liter HEMI V-8 with eTorque assist
Shift Mechanism	Electric
Available Speeds	Two-speed
Operating Modes	2WD High; 4WD Auto; 4WD High, Locked; Neutral; 4WD Low, Locked
Low-range Ratio	2.64
Center Differential Type	None

AXLES

Front	215mm
Rear	235mm (standard) with available open, limited slip or electronic locking differential
	256mm (optional max tow with Dana Super 60 center section)
Available Ratios	3.21, 3.55, 3.92

ELECTRICAL SYSTEM

Architecture	Powernet
Alternator	160-amp, 180-amp, 220-amp (Special Services Package)
Battery	Group 94R, low-maintenance H7 730 CCA (3.6-liter Pentastar V-6, 5.7-liter HEMI V-8 and 5.7-liter HEMI V-8 eTorque assist)

SUSPENSION

Front	Upper and lower A-arms, coil springs, twin-tube shock absorbers and stabilizer bar. Optional air suspension replaces twin-tube shock absorbers and progressive rate coil springs
Rear	Five-link with track bar, progressive rate coil springs, stabilizer bar, twin-tube shock absorbers, solid axle. Optional air suspension replaces progressive rate coil springs

BRAKES	
Front	
Size and Type	14.9 x 1.2 (378 mm x 30 mm) vented disc with 2.2 in. (57 mm) two-piston pin-slider caliper and anti-lock braking system (ABS)
Swept Area	493.6 sq.in. (3,184 sq.cm)
Rear	
Size and Type	14.8 x 0.87 (375 mm x 22 mm) disc with 2.2 in. (57 mm) single-piston pin-slider caliper and ABS
Swept Area	367.6 sq.in. (2,371.9 sq.cm)
Power-assist	Dual-rate, tandem diaphragm vacuum

AIR BAGS	
Quad Cab	6
Crew Cab	6

EXTERIOR DIMENSIONS

QUAD CAB PICKUP, 6FT., 4IN. BOX		
MODEL – TIRE SIZE	**2WD - 275/55R20**	**4WD - 275/55R20**
Wheelbase (nominal)	140.5 (3,569)	140.5 (3,569)
Track, Front	68.5 (1,741)	68.5 (1,741)
Track, Rear	68.1 (1,729)	68.1 (1,729)
Overall Length	228.9 (5,814)	228.9 (5,814)
Overall Width	82.1 (2,084)	82.1 (2,084)
Overall Height	77.6 (1,971)	77.7 (1,973)

GROUND CLEARANCE	2WD - 275/55R20	4WD - 275/55R20
Front Axle	7.8 (199)	8.2 (208)
Rear Axle	8.7 (221)	8.7 (221)
Open Tailgate to Ground	34.6 (979)	34.4 (875)
Pickup Body Height	21.4 (545)	21.4 (545)
Approach Angle, degrees	18.1	18.9
Departure Angle, degrees	25.2	25.0
Ramp Breakover Angle Without Skid Plate, degrees	19.5	19.9
Ramp Breakover Angle With Skid Plate, degrees	—	17.8
Ground Clearance Without Skid Plate	8.4 (213)	8.7 (221)
Ground Clearance With Skid Plate	—	8.2 (208)
Fuel Tank Capacity	23-gal. (87-liter) (standard) 26-gal. (98-liter) (standard) 33-gal. (125-liter) (optional)	23-gal. (87-liter) (standard) 26-gal. (98-liter) (standard) 33-gal. (125-liter) (optional)

QUAD CAB PICKUP, 6FT., 4IN. BOX – AIR SUSPENSION, 4X2 AND 4X4

TIRE SIZE: 275/55R20

SUSPENSION MODE	ENTRY / EXIT	NORMAL RIDE HEIGHT	OFF ROAD 1	OFF ROAD 2
Wheelbase (nominal)	140.5 (3,569)	140.5 (3569)	140.5 (3,569)	140.5 (3,569)
Track, Front	68.5 (1,741)	68.5 (1,741)	68.5 (1,741)	68.5 (1,741)
Track, Rear	68.1 (1,729)	68.1 (1,729)	68.1 (1,729)	68.1 (1,729)
Overall Length	228.9 (5,814)	228.9 (5,814)	228.9 (5,814)	228.9 (5,814)
Overall Width	82.1 (2,084)	82.1 (2,084)	82.1 (2,084)	82.1 (2,084)
Overall Height	75.9 (1,927)	77.7 (1,973)	78.7 (1,998)	79.7 (2,025)

GROUND CLEARANCE	ENTRY / EXIT	NORMAL RIDE HEIGHT	OFF ROAD 1	OFF ROAD 2
Front Axle	8.2 (208)	8.2 (208)	8.2 (208)	8.2 (208)
Rear Axle	8.7 (221)	8.7 (221)	8.7 (221)	8.7 (221)
Open Tailgate to Ground	32.9 (836)	34.4 (875)	35.1 (893)	36.4 (925)
Pickup Body Height	21.4 (545)	21.4 (545)	21.4 (545)	21.4 (545)
Approach Angle, degrees	14.4	18.9	21.5	23.1
Departure Angle, degrees	22.5	25.0	25.9	27.3
Ramp Breakover Angle Without Skid Plate, degrees	16.5	19.9	21.8	23.5
Ramp Breakover Angle With Skid Plate, degrees	14.4	17.8	19.7	21.3

QUAD CAB PICKUP, 6FT., 4IN. BOX – AIR SUSPENSION, 4X2 AND 4X4

GROUND CLEARANCE	ENTRY / EXIT	NORMAL RIDE HEIGHT	OFF ROAD 1	OFF ROAD 2
Ground Clearance Without Skid Plate	6.7 (169)	8.7 (221)	9.9 (251)	10.7 (273)
Ground Clearance With Skid Plate	6.1 (156)	8.2 (208)	9.4 (238)	10.2 (260)
Fuel Tank Capacity	23-gal. (87-liter) (standard) 26-gal. (98-liter) (standard) 33-gal. (125-liter) (optional)			

CREW CAB PICKUP

MODEL – TIRE SIZE	2WD – 275/55R20		4WD – 275/55R20	
BOX LENGTH	**5FT., 7IN.**	**6FT., 4IN.**	**5FT., 7IN.**	**6FT., 4IN.**
Wheelbase (nominal)	144.6 (3,672)	153.5 (3,898)	144.6 (3,672)	153.5 (3,898)
Track, Front	68.5 (1,741)	68.5 (1,741)	68.5 (1,741)	68.5 (1,741)
Track, Rear	68.1 (1,729)	68.1 (1,729)	68.1 (1,729)	68.1 (1,729)
Overall Length	232.9 (5,916)	241.8 (6,142)	232.9 (5,916)	241.8 (6,142)
Overall Width	82.1 (2,084)	82.1 (2,084)	82.1 (2,084)	82.1 (2,084)
Overall Height	77.5 (1,968)	77.4 (1,966)	77.6 (1,971	77.5 (1,968)

GROUND CLEARANCE	5FT., 7IN.	6FT., 4IN.	5FT., 7IN.	6FT., 4IN.
Front Axle	7.8 (199)	7.8 (199)	8.2 (209)	8.1 (207)
Rear Axle	8.6 (220)	8.7 (220)	8.7 (220)	8.6 (220)
Open Tailgate to Ground	34.5 (877)	34.4 (875)	34.3 (872)	34.3 (871)
Pickup Body Height	21.4 (543)	21.4 (545)	21.4 (543)	21.4 (545)
Approach Angle, degrees	18.0	18.1	19.0	18.9
Departure Angle, degrees	25.1	25.0	24.9	24.9

CREW CAB PICKUP

MODEL – TIRE SIZE	2WD – 275/55R20		4WD – 275/55R20	
GROUND CLEARANCE	**5FT., 7IN.**	**6FT., 4IN.**	**5FT., 7IN.**	**6FT., 4IN.**
Ramp Breakover Angle Without Skid Plate, degrees	19.0	18.4	19.5	18.7
Ramp Breakover Angle With Skid Plate, degrees	—	—	17.5	16.7
Ground Clearance Without Skid Plate	8.3 (211)	8.3 (212)	8.7 (222)	8.6 (220)
Ground Clearance With Skid Plate	—	—	8.2 (209)	8.1 (207)
Fuel Tank Capacity	23-gal. (87-liter) (standard) 26-gal. (98-liter) (standard) 33-gal. (125-liter) (optional)			

CREW CAB, 5FT., 7IN. BOX – AIR SUSPENSION, 4X2 AND 4X4

TIRE SIZE: 275/55R20

SUSPENSION MODE	ENTRY / EXIT	NORMAL RIDE HEIGHT	OFF ROAD 1	OFF ROAD 2
Wheelbase (nominal)	144.6 (3,672)	144.6 (3,672)	144.6 (3,672)	144.6 (3,672)
Track, Front	68.5 (1,741)	68.5 (1,741)	68.5 (1,741)	68.5 (1,741)
Track, Rear	68.1 (1,729)	68.1 (1,729)	68.1 (1,729)	68.1 (1,729)
Overall Length	232.9 (5,916)	232.9 (5,916)	232.9 (5,916)	232.9 (5,916)
Overall Width	82.1 (2,084)	82.1 (2,084)	82.1 (2,084)	82.1 (2,084)
Overall Height	75.8 (1,926)	77.6 (1,971)	78.6 (1,996)	79.6 (2,023)

CREW CAB, 5FT., 7IN. BOX – AIR SUSPENSION, 4X2 AND 4X4

TIRE SIZE: 275/55R20

GROUND CLEARANCE	ENTRY / EXIT	NORMAL RIDE HEIGHT	OFF ROAD 1	OFF ROAD 2
Front Axle	8.2 (209)	8.2 (209)	8.2 (209)	8.2 (209)
Rear Axle	8.7 (220)	8.7 (220)	8.7 (220)	8.7 (220)
Open Tailgate to Ground	32.8 (833)	34.3 (872)	35.0 (890)	36.3 (923)
Pickup Body Height	21.4 (543)	21.4 (543)	21.4 (543)	21.4 (543)
Approach Angle, degrees	14.6	19.0	21.7	23.3
Departure Angle, degrees	22.4	24.9	25.8	27.2
Ramp Breakover Angle Without Skid Plate, degrees	16.2	19.5	21.4	23.0
Ramp Breakover Angle With Skid Plate, degrees	14.2	17.5	19.3	21.0
Ground Clearance Without Skid Plate	6.7 (170)	8.7 (222)	9.9 (252)	10.8 (273)
Ground Clearance With Skid Plate	6.2 (157)	8.2 (209)	9.4 (239)	10.3 (261)
Fuel Tank Capacity	23-gal. (87-liter) (standard) 26-gal. (98-liter) (standard) 33-gal. (125-liter) (optional)			

CREW CAB, 6FT., 4IN. BOX – AIR SUSPENSION, 4X2 AND 4X4				
TIRE SIZE: 275/55R20				
SUSPENSION MODE	ENTRY / EXIT	NORMAL RIDE HEIGHT	OFF ROAD 1	OFF ROAD 2
Wheelbase (nominal)	153.5 (3,898)	153.5 (3,898)	153.5 (3,898)	153.5 (3,898)
Track, Front	68.5 (1,741)	68.5 (1,741)	68.5 (1,741)	68.5 (1,741)

CREW CAB, 6FT., 4IN. BOX – AIR SUSPENSION, 4X2 AND 4X4				
TIRE SIZE: 275/55R20				
SUSPENSION MODE	ENTRY / EXIT	NORMAL RIDE HEIGHT	OFF ROAD 1	OFF ROAD 2
Track, Rear	68.1 (1,729)	68.1 (1,729)	68.1 (1,729)	68.1 (1,729)
Overall Length	241.8 (6,142)	241.8 (6,142)	241.8 (6,142)	241.8 (6,142)
Overall Width	82.1 (2,084)	82.1 (2,084)	82.1 (2,084)	82.1 (2,084)
Overall Height	75.7 (1,922)	77.5 (1,968)	78.4 (1,993)	79.5 (2,019)

GROUND CLEARANCE	ENTRY / EXIT	NORMAL RIDE HEIGHT	OFF ROAD 1	OFF ROAD 2
Front Axle	8.1 (207)	8.1 (207)	8.1 (207)	8.1 (207)
Rear Axle	8.6 (220)	8.6 (220)	8.6 (220)	8.6 (220)
Open Tailgate to Ground	32.7 (832)	34.3 (871)	35.0 (889)	36.3 (922)
Pickup Body Height	21.4 (545)	21.4 (545)	21.4 (545)	21.4 (545)
Approach Angle, degrees	14.5	18.9	21.5	23.1
Departure Angle, degrees	22.7	24.9	25.8	27.1
Ramp Breakover Angle Without Skid Plate, degrees	15.5	18.7	20.6	22.1
Ramp Breakover Angle With Skid Plate, degrees	13.5	16.7	18.5	20.1
Ground Clearance Without Skid Plate	6.6 (168)	8.6 (220)	9.8 (250)	10.7 (271)
Ground Clearance With Skid Plate	6.1 (155)	8.1 (207)	9.3 (237)	10.2 (259)
Fuel Tank Capacity	23-gal. (87-liter) (standard) 26-gal. (98-liter) (standard) 33-gal. (125-liter) (optional)			

CARGO BOX

NOMINAL BOX SIZE	5FT., 7IN. (CREW)	6FT., 4IN. (REGULAR, QUAD OR CREW)
SAE volume, cu. ft. (cu m)	53.9 (1.5)	61.5 (1.7)
Length-at-Floor, Tailgate Closed	67.4 (1,711)	76.3 (1,937)
Cargo Width	66.4 (1,687)	66.4 (1,687)
Distance Between Wheelhouses	51.0 (1,295)	51.0 (1,295)
Depth	21.4 (543)	21.5 (545)
Tailgate Opening Width	60.0 (1,525)	60.0 (1,525)

INTERIOR DIMENSIONS

ACCOMMODATIONS

MODEL	QUAD CAB	CREW CAB
Seating Capacity, F/R	6	6

FRONT	QUAD CAB	CREW CAB
Headroom	40.9 (1,038)	40.9 (1,038)
Legroom	40.9 (1,040)	40.9 (1,040)
Shoulder Room	66.0 (1,676)	66.0 (1,676)
Hip Room	63.4 (1,610)	63.4 (1,610)
Seat Travel	8.7 (220)	8.7 (220)

FRONT	QUAD CAB	CREW CAB
Recliner Range (degrees)	Total travel 71 degrees (from full forward) 18 degrees forward (from design) 53 degrees rearward (from design)	

REAR	QUAD CAB	CREW CAB
Headroom	39.2 (995)	39.8 (1,011)
Legroom	35.6 (903)	45.2 (1,147)
Shoulder Room	65.7 (1,668)	65.7 (1,670)
Hip Room	63.4 (1,610)	63.4 (1,611)

INTERIOR VOLUME	QUAD CAB	CREW CAB
Front – cu. ft. (cu m)	63.9 (1.8)	63.9 (1.8)
Rear – cu. ft. (cu m)	53.3 (1.5)	68.5 (1.9)

STEERING SPECIFICATIONS

QUAD CAB PICKUP

MEASUREMENT	2WD SHORT BED	2WD LONG BED	4WD SHORT BED	4WD LONG BED	4WD REBEL
Wheelbase (nominal; in/mm)	140.5 / 3,569	140.5 / 3,569	140.5 / 3,569	140.5 / 3,569	140.5 / 3,569
Overall Ratio	16.3:1	16.3:1	16.3:1	16.3:1	17.8:1
Steering Wheel Turns (lock-to-lock)	3.1	3.1	3.1	3.1	3.4
18-in. Tire Turning Diameter (ft. / M)*	46.2 / 14.1	46.2 / 14.1	46.2 / 14.1	46.2 / 14.1	46.2 / 14.1
20-in. Tire Turning Diameter (ft. / M)*	45.1 / 13.74	45.1 / 13.74	45.1 / 13.74	45.1 / 13.74	NA

CREW CAB PICKUP

MEASUREMENT	2WD SHORT BED	2WD LONG BED	4WD SHORT BED	4WD LONG BED	4WD REBEL
Wheelbase (nominal)	144.6 / 3,672	153.5 / 3,898	144.6 / 3,572	153.5 / 3,898	144.6 / 3,572
Overall Ratio	16.3:1	15.5:1	16.3:1	15.5:1	17.8:1
Steering Wheel Turns (lock-to-lock)	3.1	2.9	3.1	2.9	3.4
18-in. Tire Turning Diameter (ft. / M)*	46.2 / 14.08	48.7 / 14.84	46.2 / 14.08	48.7 / 14.84	46.2 / 14.1
20-in. Tire Turning Diameter (ft. / M)*	46.2 / 14.08	48.7 / 14.84	46.2 / 14.08	48.7 / 14.84	NA

* = Curb-to-curb turning diameter is measured at the outside of the tires at curb height. Turning diameters and steering wheel turns, lock-to-lock may differ with optional tires and wheels.

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2022 FORD E-TRANSIT (U.S.)

TECHNICAL SPECIFICATIONS

BODY

Construction/materials	Steel unibody
Body style	Cargo, chassis cab and cutaway vans
Roof heights	Low, medium and high
Lengths	Regular, long and extended
Final assembly location	Kansas City Assembly Plant, Claycomo, MO

DRIVETRAIN

Layout standard	Floor battery, rear wheel drive, rear e-motor

PERFORMANCE

Peak Power [kW/HP]*	Targeting 198 kW / 266 HP
Peak Torque*	Targeting 317 lb.-ft.

BATTERY/CHARGING**

Usable Energy	67 kWh
Battery Configuration	Li-ion, single pack
Onboard Charger	10.5 kW output / 11.3 kW input
Peak DCFC Power	115 kW
Pro Power Onboard	2.4 kW (available)

15-80% DCFC (115 kW)	34 min
15-80% (50 kW)	65 min
0-100% 240V L2 (48A)	8 hours
0-100% 240V L2 (30A)	~12 hours
Ford Mobile Charger (120V/240V)	Standard
Ford Connected Charge Station (48A)	Available

15-min miles (DCFC)†	45 (low-roof van)
10-min miles (DCFC)†	30 (low-roof van)
L2 charging miles per hour (48A)†	15 (low-roof van)
L2 charging miles per hour (30A)†	10 (low-roof van)

STEERING

Type	Electric Power-Assisted

*Calculated via peak performance of the electric motor(s) at peak battery power. Your results may vary.

**Charge times based on manufacturer computer engineering simulations. The charging rate decreases as battery reaches full capacity. Your results may vary based on peak charging times and battery state of charge.

†Range and charge time based on manufacturer computer engineering simulations and US EPA MCT drive cycle methodology (www.fueleconomy.gov/feg/pdfs/EPA test procedure for EVs-PHEVs-11-14-2017.pdf). The charging rate decreases as battery reaches full capacity. Your results may vary based on peak charging times and battery state of charge. Actual vehicle range varies with conditions such as external elements, driving behaviors, vehicle maintenance, lithium-ion battery age and state of health.

SUSPENSION

Front configuration	Front independent MacPherson strut suspension w/stabilizer bar
Front shock absorber type/diameter	Gas-pressurized
Rear configuration	Independent rear suspension with coil springs, semi-trailing arm STA and stabilizer bar
Rear shock absorber type/diameter	Gas-pressurized

BRAKES

Front Type	Power anti-lock vented disc
Front rotor diameter (outer/inner)	12.1 inches / 6.5 inches
Front caliper config	2 piston caliper, 1.89 inches diameter
Rear type	Power anti-lock solid disc
Rear rotor diameter (outer/inner)	12.1 inches / 7.9 inches
Rear caliper config	Single piston caliper, 2.01 inches diameter
Parking brake (type)	Rear brake integrated caliper, electric park brake

SAFETY/CONTROL SYSTEMS

ABS/Stability Control	Four-Wheel Anti-Lock Brakes, AdvanceTrac®with Roll Stability Control™(RSC®), Side-Wind Stabilization System
Airbags	Front, Driver and passenger Front, Driver and passenger seat-mounted side Safety Canopy® side curtains
Chassis safety	Tire Pressure Monitoring System (TPMS), SOS Post-Crash Alert System™

DRIVER ASSIST

Standard	Lane Keeping System with Lane-Keeping Alert, Road Edge Detection, Driver Alert System (drowsiness detection), Pre-Collision Assist with Automatic Emergency Braking, Post Impact Braking, Hill Start Assist, Auto High Beam Controller
Available	Speed Sign Recognition with Navigation, Intelligent Speed Assist, Intelligent Adaptive Cruise Control, Automatic Speed Limiting Device, Blind Spot Information System w/ Trailer Tow, Cross Traffic Alert, Blind Spot Assist/Lane Change Warning & Aid, Pre-Collision Assist, Reverse Brake Assist, Enhanced Active Park Assist, Front Park Aid, Rear Park Aid, Side Park Aid

WHEELS

	Cargo Van	Cutaway	Chassis Cab
16-inch steel wheel with full wheel cover	Standard	Standard	Standard

HEADLIGHTS

Standard hi/low automatic on/off	Halogen
Available	HID with LED signature surround
Fog lamps (optional)	Halogen

KEY SPECS

Length	Regular	Long	Long	Long	Extended
Roof height	Low	Low	Medium	High	High
Cargo Van					
Targeted max payload (lbs.)	3,800	3,700	3,550	3,450	3,240
Range (miles)*	126	126	116	108	108

*Based on full charge. USA targeted range reflecting current capability based on analytical projection consistent with US EPA MCT drive cycle methodology (www.fueleconomy.gov/feg/pdfs/EPA test procedure for EVs-PHEVs-11-14-2017.pdf). Actual range varies with conditions such as external elements, driving behaviors, vehicle maintenance, and lithium-ion battery age.

CAPACITIES

Length	Regular	Long	Long	Long	Extended
Roof height	Low	Low	Medium	High	High
Cargo Van					
Seating	2	2	2	2	2
Cargo volume behind first row (cu. ft.)	246.7	277.7	357.1	404.3	487.3
Targeted max front axle load (lbs.)	4130	4130	4130	4130	4130
Targeted max rear axle load (lbs.)	6000	6000	6000	6000	6000
Targeted base curb weight (total) (lbs.)	5640	5742	5890	5985	6188

WARRANTY

Unique Electrified Components	8 year/100,000 miles

PRODUCT SPECIFICATIONS FOR D6 XE

ENGINE

Engine Model	Cat C9.3B
Power - Net	215 HP
Emissions	U.S. EPA Tier 4 Final, EU Stage V, Korea Tier 4 Final
Net Power - Rated - ISO 9249/SAE J1349 (DIN)	219 mhp
Build Number	20B
Note (1)	Rated horsepower at 1,700 rpm. Net power advertised is the power available at the engine flywheel when the engine is equipped with a fan, air cleaner, clean emissions module and alternator. Net power is tested per ISO 9249:2007 and SAE J1349:2011.
Note (2)	All non-road Tier 4 Interim and Final, Stage IIIB, IV and V and Korea Tier 4 Final diesel engines are required to use only ultra-low sulfur diesel (ULSD) fuels containing 15 ppm (mg/kg) sulfur or less. Biodiesel blends up to B20 (20 blend by volume) are acceptable when blended with 15 ppm (mg/kg) sulfur or less ULSD. B20 should meet ASTM D7467 specification (biodiesel blend stock should meet Cat biodiesel spec, ASTM D6751 or EN 14214). Cat DEO-ULS or oils that meet the Cat ECF-3, API CJ-4, and ACEA E9 specification are required. Consult your OMM for further machine specific fuel recommendations.
Note (3)	Diesel Exhaust Fluid (DEF) used in Cat Selective Catalytic Reduction (SCR) systems must meet the requirements outlined in the International Organization for Standardization (ISO) standard 22241.
Note (4)	Basic machine specs provided below. For complete specifications and dimensions by configuration, blade and track shoe offerings and more, please visit the product download section to view the full D6/D6 XE Technical Specifications.

WEIGHTS

Operating Weight	51333 lb

TRANSMISSION

Power Train	Electric Drive

ENGINE - STANDARD

Net Power - Rated - ISO 9249/SAE J1349	215 HP

SERVICE REFILL CAPACITIES

Fuel Tank	90 gal (US)
DEF Tank	7.4 gal (US)

D6 XE PUSH ARM

Operating Weight	49388 lb
Ground Pressure	8 psi
Width of Standard Shoe	24 in
Blade	Semi-Universal (SU)
Blade Capacity	7.5 yd^3

D6 XE LGP (30-IN) PUSH ARM

Operating Weight	51020 lb
Ground Pressure	6.6 psi
Width of Standard Shoe	30 in
Blade	Semi-Universal (SU)
Blade Capacity	7.6 yd^3

D6 XE LGP (36-IN) PUSH ARM

Operating Weight	53315 lb
Ground Pressure	5.3 psi
Width of Standard Shoe	36 in
Blade	Straight
Blade Capacity	5 yd^3

D6 XE VPAT

Operating Weight	49708 lb
Ground Pressure	7.2 psi
Width of Standard Shoe	24 in
Blade	VPAT
Blade Capacity	5.4 yd^3

D6 XE LGP (30-IN) VPAT

Operating Weight	51333 lb
Ground Pressure	5.9 psi
Width of Standard Shoe	30 in
Blade	VPAT
Blade Capacity	5.9 yd^3

D6 XE LGP (36-IN) VPAT

Operating Weight	52512 lb
Ground Pressure	5.1 psi
Width of Standard Shoe	36 in
Blade	VPAT
Blade Capacity	6.5 yd^3

AIR CONDITIONING SYSTEM

Air Conditioning	The air conditioning system on this machine contains the fluorinated greenhouse gas refrigerant R134a (Global Warming Potential = 1430). The system contains 1.36 kg of refrigerant which has a CO2 equivalent of 1.946 metric tonnes.

D6 XE STANDARD EQUIPMENT

NOTE

- Standard and optional equipment may vary. Consult your Cat dealer for details.

POWER TRAIN

- Electric Drive
- Cat C9.3B diesel engine
- Double reduction planetary final drives
- Hydraulic reversing fan

OPERATOR ENVIRONMENT

- Fully redesigned cab, sound suppressed, with Integrated Roll Over Protective Structure (ROPS)
- Full-color 10-inch (254 mm) liquid crystal touch screen display
- Integrated rearview camera
- Adjustable operator controls/armrests
- Cab mounted modular Heating/Ventilation/Air Conditioning (HVAC) system
- Added storage areas
- Electrohydraulic implement and steering controls
- Cloth seat
- Lights - 6 LED

CAT TECHNOLOGY

- Slope Indicate
- Product Link, Cellular
- Remote Control Ready
- Remote Flash/Remote Troubleshoot
- Operator ID
- Machine Security - Passcode

UNDERCARRIAGE

- Redesigned track roller frame

SERVICE AND MAINTENANCE

- Rear access ladder
- Shovel holder

- Ground level service center
- 30-minute cab removal
- Fast fuel fill
- Fire extinguisher mounting provision
- Ecology drains
- Underhood work light

HYDRAULICS

- Independent steering and implement pumps
- Load sensing hydraulics

ATTACHMENTS

- Ripper-ready rear hydraulics
- Ripper and winch-ready rear hydraulics

D6 XE OPTIONAL EQUIPMENT

NOTE

- Standard and optional equipment may vary. Consult your Cat dealer for details.

OPERATOR ENVIRONMENT

- Deluxe leather heated/ventilated seat
- Powered precleaner
- Premium lights - 12 LED
- Integrated warning lights
- Communication radio ready

CAT TECHNOLOGY

- ARO with Assist: includes Slope Assist, Traction Control, Stable Blade, Blade Load Monitor, AutoCarry, Third Party Grade Control Ready
- Cat Grade with 3D: includes full-color 10-inch (254 mm) touchscreen grade display
- Product Link Dual Cellular/Satellite
- Grade Connectivity

- Machine Security - Bluetooth
- Cat Command for Dozing

BLADES

- Semi-Universal
- Variable Pitch Angle Tilt (VPAT)
- Straight blade
- Angle blade
- Foldable VPAT - under 3 m (9.9 ft) transport width (Not available in all regions)
- Waste/Landfill

UNDERCARRIAGE

- Heavy Duty (HDXL with DuraLink) or Cat Abrasion
- 10-Roller Fine Grading undercarriage
- Moderate Service or Extreme Service track shoes

SERVICE AND MAINTENANCE

- Refilling fuel pump (EU only)
- High speed oil change
- Rear implement work light

ATTACHMENTS

- High lift ripper with straight or curved shanks
- Winch
- Counterweights
- Side and/or rear screens
- Sweeps
- Drawbar
- Forestry and Waste Special Arrangements

eM2®

Specs

eM2®

Class
6-7

Horsepower
180 - 300 HP

GVWR
26,000 - 33,000 lbs.

Cab/Sleeper Configurations

Day Cab 106" BBC

Propulsion

Single eAxle

Dimensions

- Length: 391"
- Width: 100"
- Height: 102.5" (137.4" with roof fairing)

Range

230 miles

Usable Capacity

Up to 315 kWh

Charging

80% in 60 min.

Videos

eTruck Business Considerations (1:09) (https://freightlineradsAEM.azureedge.net/content/dam/enterprise/videos/4632-etruck_business_considerations-2020-11-19.mp4)

Freightliner Electric Trucks – eCascadia & eM2 (1:38) (https://freightlineradsAEM.azureedge.net/content/dam/enterprise freightliner_electric_trucks__-2020-11-19.mp4)

How an Electric Truck Works (1:18) (https://freightlineradsAEM.azureedge.net/content/dam/enterprise/videos/4634-how_an_electric_truck_works-2020-11-19.mp4)

Lion6

Technical Specifications

WEIGHT & DIMENSIONS

Wheelbase	195-212 in
Gross Vehicle Weight Rating (G.V.W.R)	26,000 lb

ELECTRIC POWERTRAIN

Top Speed	65 mph
Maximum Power	250 kW // 335 HP
Maximum Torque	2,500 NM // 1,800 ft-lb
Range	Up to 180 miles
Battery Capacity	Up to 252 kWh
ePTO	Available
Motor & Inverter	SUMO-MD – 6 phases // Dana/TM4
Transmission	Direct Drive // No Transmission
Charging Type	
Standard	Level III (DC) – CCS-Combo
Optional	Level II (AC) - J1772
Level II - Charging Time	5 - 16 hours
Level III - Charging Time	2.5 – 6.5 hours

CHASSIS

Front Axle	12,000 lb // Hendrickson
Rear Axle	19,000 lb // Dana
Suspension	Air / Spring Suspension // Hendrickson
Braking	Hydraulic / Air Disc Brakes // WABCO

All-electric
Class 6 Truck

LION ELECTRIC

Supercharge your business with new clean power

Lion is building today's ultimate electric urban truck. Designed and purpose-built to optimize your operations.

The Lion6, all-electric class 6 truck, is efficient, sustainable and offers great performance.

The Lion Experience:
- Grant writing and ability to leverage fundings
- Charging infrastructure design and project management
- Complete onboarding trainings

Make your next move a bright one.

Savings
Electric VS. Diesel

80%

ENERGY COSTS REDUCTION

60%

MAINTENANCE COSTS REDUCTION

1 ZERO-EMISSION SOLUTION

2 PROVEN SAFETY RECORDS

3 LOWEST TOTAL COST OF OWNERSHIP

4 REDUCTION OF MAINTENANCE DOWN TIME

5 BEST-IN-CLASS DRIVING EXPERIENCE

6 NO NOISE POLLUTION

Lion8

Technical Specifications

WEIGHT & DIMENSIONS

Cabin Length - BBC	79 in
Cabin Width	96 in
Cabin Height	107 in
Wheelbase	195-280 in
Gross Vehicle Weight Rating (G.V.W.R)	Up to 60,000 lb

ELECTRIC POWERTRAIN

Top Speed	65 mph
Maximum Power	350 kW // 470 HP
Maximum Torque	2,507 ft-lb
Range	Up to 170 miles
Battery Capacity	Up to 336 kWh
ePTO	Available
Motor & Inverter	SUMO HD HV3500 – 9 phases // Dana/TM4
Transmission	Direct Drive // No Transmission
Charging Type	
Standard	Level III (DC) – CCS-Combo
Optional	Level II (AC) - J1772
Level II - Charging Time	7 - 16 hours
Level III - Charging Time	2.5-5 hours

CHASSIS

Front Axle	14,600-20,000 lb // Hendrickson
Rear Axle	Tandem Up to 40,000 lb // Dana
Suspension	Air Suspension // Hendrickson
Braking	Air Disc Brakes // Bendix

All-electric Class 8 Urban Truck

LION ELECTRIC

Purpose-built to give you all the clean power you need.

Lion is building today's ultimate electric urban truck.

Designed and purpose-built to deliver goods, our zero-emission class 8 urban truck is efficient and sustainable, offering a powerful combination of unparalleled performance and exceptional savings.

Each fleet vehicle lightens the global GHG load by up to 100 tons per year.

Complete Customer Experience

- Grant writing and ability to leverage fundings
- Charging infrastructure design and project management
- Complete onboarding trainings

Make your next move a bright one.

Savings
Electric VS. Diesel

80%

ENERGY COSTS REDUCTION

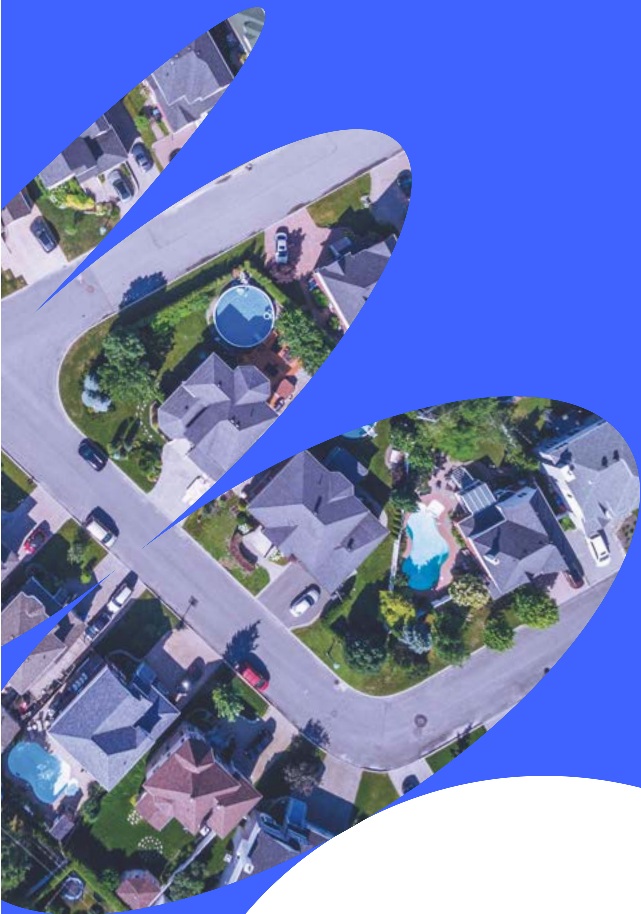
60%

MAINTENANCE COSTS REDUCTION

1. ZERO-EMISSION SOLUTION
2. PROVEN SAFETY RECORDS
3. LOWEST TOTAL COST OF OWNERSHIP
4. REDUCTION OF MAINTENANCE DOWN TIME
5. BEST-IN-CLASS DRIVING EXPERIENCE
6. NO NOISE POLLUTION

Lion8

Technical Specifications



WEIGHT & DIMENSIONS

Cabin Length	79 in
Cabin Width	96 in
Cabin Height	107-110 in
Wheelbase	195-244 in
Gross Vehicle Weight Rating (G.V.W.R)	Up to 66,000 lb

ELECTRIC POWERTRAIN

Top Speed	65 mph
Maximum Power	350 kW // 470 HP
Maximum Torque	3,400 NM // 2,507 ft-lb
Battery Capacity	Up to 336 kWh
ePTO	Available
Motor & Inverter	SUMO HD HV2500 - 9 phases // Dana/TM4
Transmission	Direct Drive // No Transmission
Charging Type	
Standard	Level III (DC) – CCS-Combo
Optional	Level II (AC) - J1772

CHASSIS

Front Axle	14,600-20,000 lb // Hendrickson
Rear Axle	Up to 46,000 lb // Dana
Tag Axle	Available
Suspension	Air / Spring / Rubber // Hendrickson
Braking	Air Disc Brakes // Bendix

All-electric Refuse Truck

LION ELECTRIC

Power and efficiency, purpose-built to serve your collection needs now.

Lion is building today's first zero-emission truck with an all-electric automated arm and collection body.

The Lion8 – Refuse is designed, created and manufactured to be electric. Its components require very little maintenance and further minimize its total cost of ownership.

Our all-electric class 8 refuse truck is running 100% emissions-free and significantly reducing the environmental load on our world.

Complete Customer Experience
- Grant writing and ability to leverage fundings
- Charging infrastructure design and project management
- Complete onboarding trainings

Make your next move a bright one.

Savings Electric VS. Diesel

80%

ENERGY COSTS REDUCTION

60%

MAINTENANCE COSTS REDUCTION

1. ZERO-EMISSION SOLUTION
2. PROVEN SAFETY RECORDS
3. LOWEST TOTAL COST OF OWNERSHIP
4. REDUCTION OF MAINTENANCE DOWN TIME
5. BEST-IN-CLASS DRIVING EXPERIENCE
6. NO NOISE POLLUTION

Lion8

Technical Specifications

WEIGHT & DIMENSIONS

Cabin Length - BBC	79 in
Cabin Width	96 in
Cabin Height	107–110 in
Wheelbase	195-280 in
Gross Vehicle Weight Rating (G.V.W.R)	Up to 60,000 lb

ELECTRIC POWERTRAIN

Top Speed	65 mph
Maximum Power	350 kW / 470 HP
Maximum Torque	2,507 ft-lb
Battery Capacity	Up to 336 kWh
ePTO	Available
Motor & Inverter	SUMO HD HV3500 - 9 phases // Dana/TM4
Transmission	Direct Drive // No Transmission
Charging type	
Standard	Level III (DC) – CCS-Combo
Optional	Level II (AC) - J1772

CHASSIS

Front Axle	14,600-20,000 lb
Rear Axle	Tandem up to 40,000 lb
Suspension	Air/Spring Suspension // Hendrickson
Braking	Air Disc Brakes // Bendix

All-Electric Utility Truck

LION ELECTRIC

Power ahead with the ultimate utility vehicle your world needs now.

Lion is building today's future-minded zero-emission urban trucks.

Purpose-built to lift your business farther and power your operations towards greater sustainability, efficiency and performance.

All 100% free of emissions and significantly reducing the environmental load on our world.

Complete Customer Experience
- Grant writing and ability to leverage fundings
- Charging infrastructure design and project management
- Complete onboarding trainings

Make your next move a bright one.

Savings Electric VS. Diesel

80%

ENERGY COSTS REDUCTION

60%

MAINTENANCE COSTS REDUCTION

1 ZERO-EMISSION SOLUTION

2 PROVEN SAFETY RECORDS

3 LOWEST TOTAL COST OF OWNERSHIP

4 REDUCTION OF MAINTENANCE DOWN TIME

5 BEST-IN-CLASS DRIVING EXPERIENCE

6 NO NOISE POLLUTION

Lion8T

Technical Specifications

WEIGHT & DIMENSIONS

Cabin Length - BBC	79 - 103 in
Cabin Width	96 in
Cabin Height	107 in
Wheelbase	200-244 in
Combined Vehicle Weight Rating (C.V.W.R)	Up to 80,000 lb

ELECTRIC POWERTRAIN

Top Speed	65 mph
Maximum Power	Up to 536 kW
Maximum Torque	5,300 ft-lb
Range	Up to 210 miles
Battery Capacity	Up to 588 kWh
ePTO	Available
Transmission	Direct Drive / No Transmission
Charging type	Level III (DC) – CCS-Combo
Level III - Charging Time	3-7 hours

CHASSIS

Suspension	Front Springs - Air Suspension // Hendrickson
Braking	Air Disc Brakes // WABCO

All-electric
Class 8 Tractor Truck

LION ELECTRIC

Power ahead with transportation innovation your world needs now.

Lion is building today's ultimate electric urban vehicles: purpose-built to optimize your day-to-day operations, plus ease your transition towards zero-emission transportation.

Our all-electric class 8 tractor truck, is efficient, sustainable and offers great performance. The Lion8T is running 100% emission-free and significantly reducing the environmental load on our world.

Complete Customer Experience

- Grant writing and ability to leverage fundings
- Charging infrastructure design and project management
- Complete onboarding trainings

Make your next move a bright one.

Savings Electric VS. Diesel

80%

ENERGY COSTS REDUCTION

60%

MAINTENANCE COSTS REDUCTION

1. ZERO-EMISSION SOLUTION
2. PROVEN SAFETY RECORDS
3. LOWEST TOTAL COST OF OWNERSHIP
4. REDUCTION OF MAINTENANCE DOWN TIME
5. BEST-IN-CLASS DRIVING EXPERIENCE
6. NO NOISE POLLUTION

Peterbilt

220EV

Zero
Emissions
Vehicle

220EV

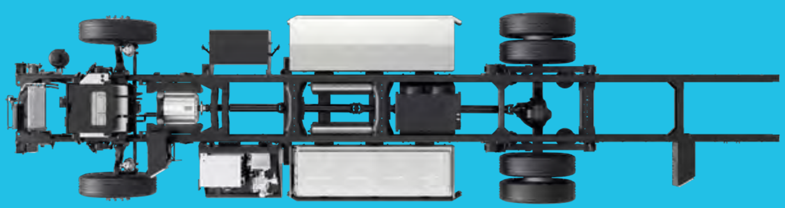
Peterbilt continues to expand its alternative powertrain offerings with the new Model 220EV – its first electric configuration for medium duty applications. The 220EV provides customers a zero emissions vehicle for clean, efficient operation and lower overall maintenance.

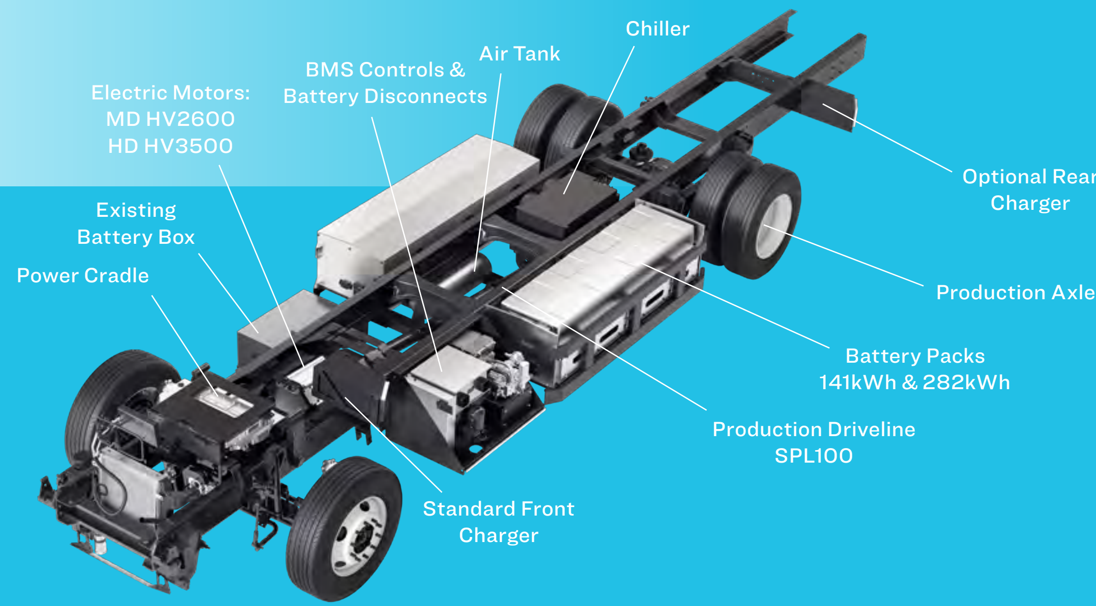
The Model 220EV is equipped with an e-motor, two battery packs and an on-board charger, allowing for a range of up to 200 miles. Using the compatible DC fast-charging system, the state-of-the-art, high-energy density battery packs can recharge in 1-2 hours, making the 220EV ideal for local pickup and delivery, as well as short regional haul operations.

Designed for driver comfort and productivity, the Model 220EV features enhanced visibility, superior maneuverability, a spacious interior and ease of serviceability for maximum uptime.

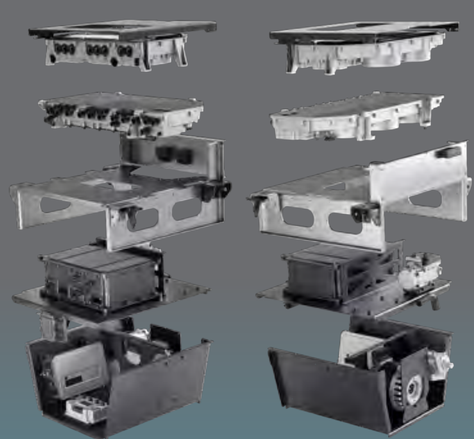
ALL-ELECTRIC POWERTRAIN

The fully integrated, all-electric powertrain of the Model 220EV is designed for optimal weight distribution and performance. Battery packs are mounted outside of the frame rails, with air tanks mounted inside the frame.



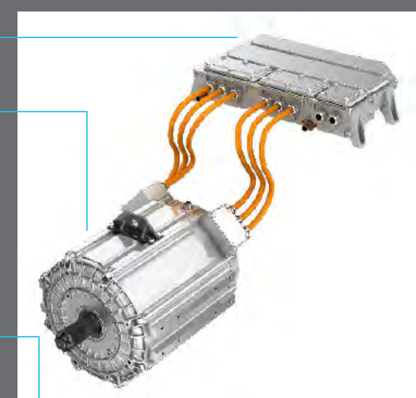


The **power electronics cradle** includes the vehicle's on-board charger, battery disconnect controls, vehicle software, cab heater unit and air compressor. The cradle is located in a single, easily accessible service point, where a traditional diesel engine would be located.



The **inverter** converts the energy from the batteries and provides power to **the electric drive motor.**

The direct-drive motor provides power to the drive shaft, eliminating the need for a transmission.



The Lithium Iron Phosphate (LFP) battery packs are mounted outside the frame rails. The batteries are thermally controlled with the chiller to provide a consistent temperature to optimize battery life.

Regenerative braking captures energy from stop-and-go conditions to recharge the batteries, to help maximize the vehicle's range.

220EV

MODEL 220EV SPECIFICATIONS

E-Motor
- Class 6 – HV2600
  - 154 kW (207 hp) Continuous Power
  - 250 kW (355 hp) Peak Power
- Class 7 – HV3500
  - 259 kW (347 hp) Continuous Power
  - 350 kW (469 hp) Peak Power
- Drive Configuration: 4X2

Batteries
- Lithium Iron Phosphate (LFP), Thermally Controlled
- 618 Volts
- Configurations Available
  - 141 kWh Energy Storage, 100 Mile Range
  - 282 kWh Energy Storage, 200 Mile Range

Charging
- AC
  - 19.2 kW Power Rating
  - 7.5-15 Hour Charge Time
- DC Fast – Charging
  - 150 kW Power Rating
  - 1-2 Hour Charge Time
- Charging Locations
  - BOC – Standard
  - EOF – Optional

Dimensions
- GVWR
  - 26,000 lbs. (Class 6)
  - 33,000 lbs. (Class 7)
- Wheel Bases: 206", 218", 274"
- Body Lengths: 24', 26', 30'
- 12,300 lbs. – 14,800 lbs. Curb Weight

Gross Axle Weight Ratings
- Class 6 Front – 10,000 lbs.
- Class 7 Front – 12,000 lbs.
- Class 6 Rear – 16,000 lbs.
- Class 7 Rear – 21,000 lbs.
- Rear Axle Ratio: 5.57 with 22.5 Wheels/ 4.63 with 19.5 Wheels

Suspensions
- Front Suspension – Parabolic Spring
- Rear Suspension
  - Reyco Mechanical
  - Hendrickson HAS210
  - Hendrickson HAS230 Air Ride

Wheels/Tires/Brakes
- Wheels – 22.5" Steel Painted White
- Wheels – 19.5" Steel Painted White
- Tires – F/R: Bridgestone 11R22.5"
- Tires – F/R: Bridgestone 19.5"
- Brakes – Front Air Disc and Rear Drum Standard

220EV

MODEL 220EV SPECIFICATIONS continued

Frame
- 34" Frame Spacing
- Steel Painted Gray Bumper

Cab
- 63.4" BBC
- 95" Cabin Width
- 104" Cabin Height
- Hydraulic 55-Degree Tilting Steel Cab
- 82.5" Cab Width
- Driver Seat – Air Suspension
- Passenger Seat – 2-Person Bench Standard, Single Person Air Ride Optional
- Center Storage Console & Cupholders
- Heater & Air Conditioning
- Cruise Control
- Power Windows
- Power & Heated Mirrors

Paint
- Cab – Ice White
- Frame – Black

Additional Options
- Speakers & Wiring for Customer Installed Radio
- Rear Shock Absorbers – Reyco
- Rear Axle Stabilizer Bar – Reyco
- Rear Differential Lock
- Rear Mud Flap Hanger & Shields
- Backup Alarm
- Wiring Only for Customer Installed Backup Alarm
- Orange Seat Belts
- Red Seat Belts

Target Applications
- Pickup & Delivery
- Regional Haul
- Lease/Rental
- Food & Beverage

* Technical specifications are dependent on configuration and component selected.

Peterbilt

For more information on the Model 220EV, visit **peterbilt.com**.

PETE-9921 11/2020

VOLVO FL ELECTRIC
A two-axle truck with a gross vehicle weight up to 16 tonnes. We can deliver complete vehicles for urban transport like deliveries and waste collection.

VOLVO FE ELECTRIC
A three-axle truck with a gross vehicle weight up to 27 tonnes. We can deliver complete vehicles for demanding types of urban transport like waste collection, light construction transports and deliveries.

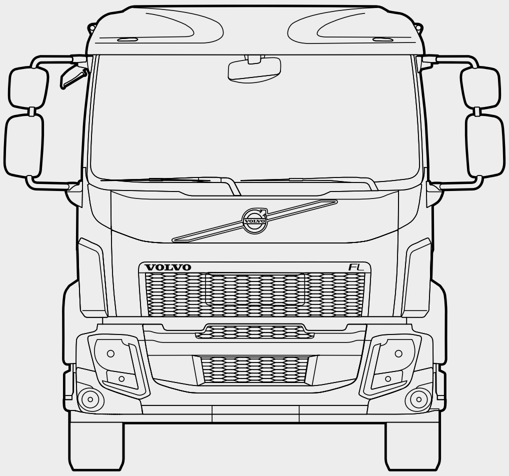
Volvo FL Electric.

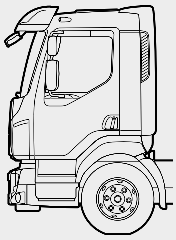
For urban delivery transport and waste collection.

VOLVO FL ELECTRIC

Gross vehicle weight:	16 tonnes
Cab options:	Day cab
Number of axles:	2
Wheel bases:	4400 mm or 5300 mm
Power output (peak/continuous):	200/165 kW
Number of batteries:	4 or 6
Electric motor power output for PTO (peak/continuous):	70 kW/50 kW (small variant), 100 kW/70 kW (large variant)
Electric motor torque for PTO (peak/continuous):	240 Nm/130 Nm (small variant), 530 Nm/270 Nm (large variant)
Charging time (fast/regular):	Less than 1 h/6.5 h (4 batteries), 1.5 h/10.5 h (6 batteries)
Operating range:	Up to 300 km depending on amount of batteries

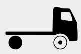
CABS





Day cab

RIGID AXLE CONFIGURATIONS

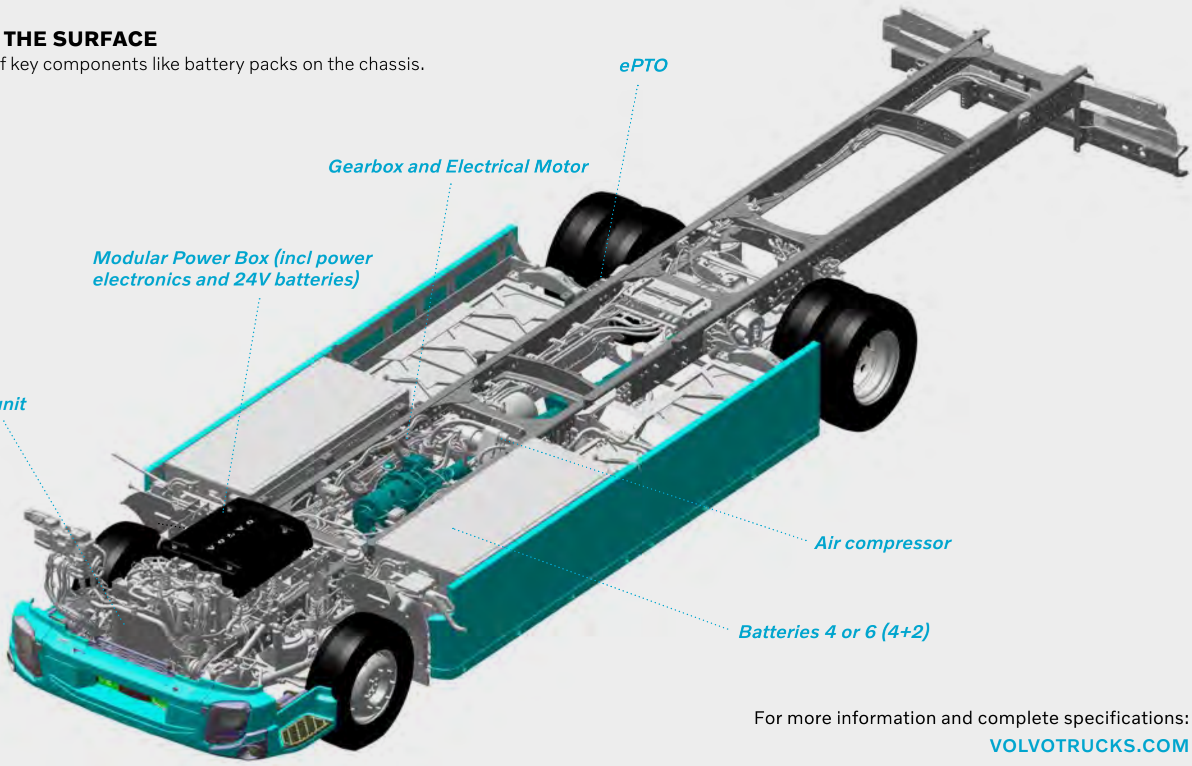


4×2
Medium

● = Drive axle.
⊙ = Non-driven axle
(tag, pusher or front axle).

UNDER THE SURFACE

Packing of key components like battery packs on the chassis.



For more information and complete specifications:
VOLVOTRUCKS.COM

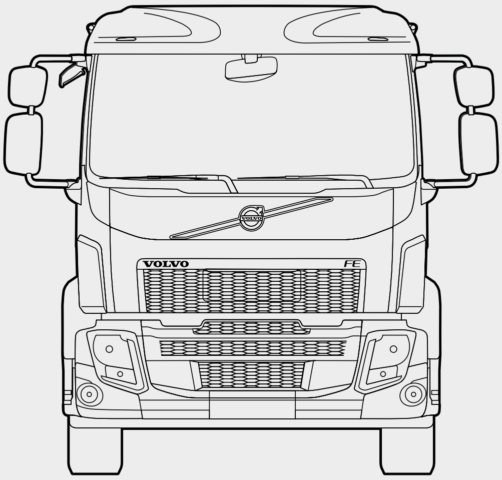
Volvo FE Electric.

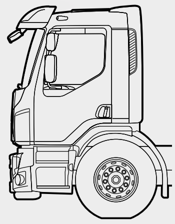
For urban transport of waste collection, consumables and light construction work.

VOLVO FE ELECTRIC

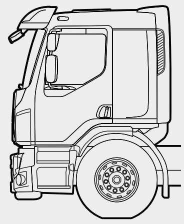
Gross vehicle weight:	Up to 27 tonnes
Cab options:	Day cab, Short sleeper cab, Sleeper cab or Low Entry cab
Number of axles:	3
Wheel base:	3900 mm
Power output (peak/continuous):	400 kW/330 kW
Number of batteries:	4
Electric motor power output for PTO (peak/continuous):	70 kW/50 kW (small variant), 100 kW/70 kW (large variant)
Electric motor torque for PTO (peak/continuous):	240 Nm/130 Nm (small variant), 530 Nm/270 Nm (large variant)
Charging time (fast/regular):	Less than 1 h/6.5 h (4 batteries)
Operating range:	Refuse and light construction up to 120 km, distribution up to 200 km

CABS

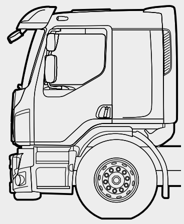




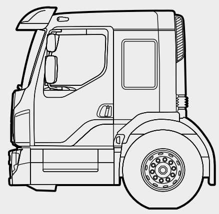
Day cab



Short sleeper cab

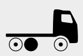


Sleeper cab



Low-entry cab

RIGID AXLE CONFIGURATIONS

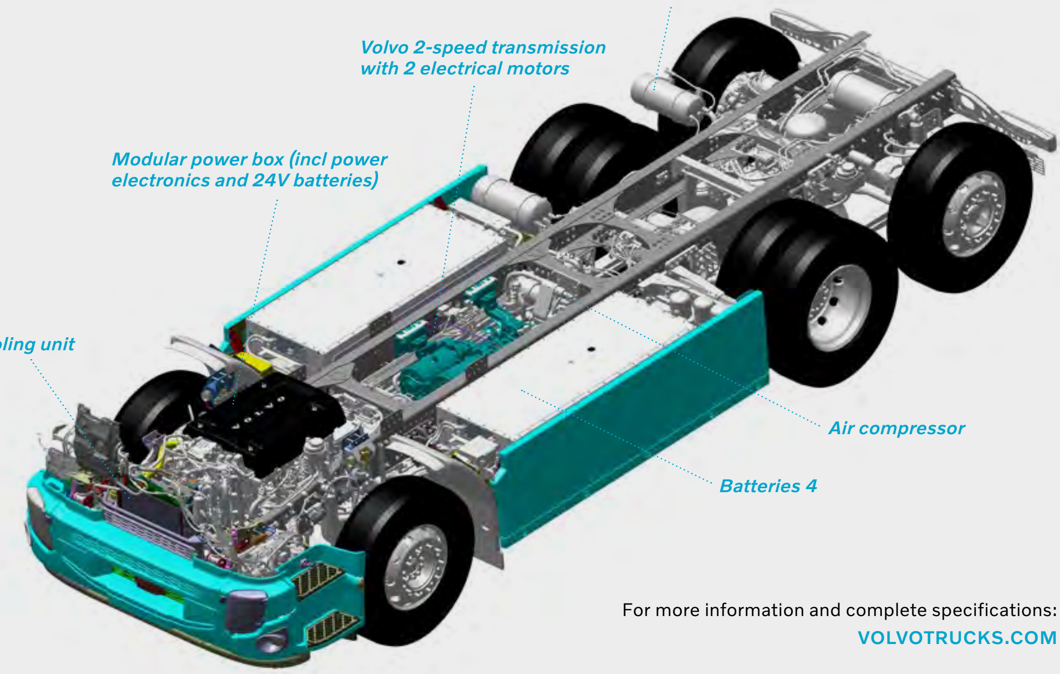


6×2
Medium

● = Drive axle.
⊙ = Non-driven axle
(tag, pusher or front axle).

UNDER THE SURFACE

Packing of key components like battery packs on the chassis.



For more information and complete specifications:
VOLVOTRUCKS.COM

2019-03-25 ENG Version 01

Volvo Truck Corporation
volvotrucks.com

APPENDIX B - Vehicle Lifecycle Assessment Inputs and Assumptions

Oxford County

Growing stronger together

For information contact:
519-539-9800 | 1-800-755-0394

APPENDIX

Pickup Trucks

Input/Assumption	Value	Source
½ Ton and Compact Gasoline Pickup Purchase	$36,000	Average ½ ton pickups (2020 RAM 1500 for Wastewater group) (vehicle purchase only, does not include outfitting costs.)
¾ Ton Gasoline Pickup Purchase	$45,000	Historical Chevrolet Silverado 2500 HD purchases (vehicle purchase only, does not include outfitting costs.)
1 Ton Gasoline Pickup Purchase	$50,000	Historical RAM 3500 and Silverado 3500 HD purchases (vehicle purchase only, does not include outfitting costs.)
CNG Upfitting Cost (applicable only to ½ ton)	$10,000	The CNG fuel tanks and systems added to vehicles range from $9,000 to $13,000 depending on tank size, vehicle type and mounting location of fuel tank.
½ Ton Hybrid Pickup Purchase	$42,840	MSRP Ford F-150 hybrid
¾ and 1 Ton Aftermarket Hybrid System Upgrade	$15,000	XL Fleet review
½ Ton BEV Pickup Cost	$55,000	Estimate Ford F-150 electric
¾ Ton BEV Pickup Cost	$65,000	Assumed $20,000 cost premium for BEV over gasoline based on ½ ton pickup data
1 Ton BEV Pickup Cost	$70,000	Assumed $20,000 cost premium for BEV over gasoline based on ½ ton pickup data
EV Rebate	$5,000	Transport Canada for BEVs
½ Ton Gasoline Fuel Economy	13.4 L/100 km	Average of Oxford County Gasoline Pickups
¾ Ton Gasoline Fuel Economy	14.6 L/100km	Historical fleet data
1 Ton Gasoline Fuel Economy	19.8 L/100km	Historical fleet data
CNG/Gas Fuel Economy	33%	Oxford County 2019 fuel records for CNG pickups 33% total fuel use (gLe) is CNG
½ Ton Hybrid Fuel Economy	9.8 L/100 km	Ford F-150 hybrid
¾ Ton Hybrid Fuel Economy	10.7 L/100km	Assumed hybrid fuel economy improvement over gasoline scaled based on ½ ton pickup data
1 Ton Hybrid Fuel Economy	14.5 L/100km	Assumed hybrid fuel economy improvement over gasoline scaled based on ½ ton pickup data
½ Ton BEV Energy Consumption	26 kWh/100km	Estimate of Tesla and Rivian Trucks
¾ Ton BEV Energy Consumption	28 kWh/100km	Assumed BEV energy consumption scaled based on ½ ton BEV pickup data
1 Ton BEV Energy Consumption	38 kWh/100km	Assumed BEV energy consumption scaled based on ½ ton BEV pickup data
½ Ton Gasoline Pickup Maintenance	$880/year	Oxford County fleet maintenance records (average 2019 pickup maintenance)
½ Ton CNG/Gas Pickup Maintenance	$745/year	Oxford County fleet maintenance records (average 2019 pickup maintenance)[2]
¾ Ton Pickup Maintenance	$1,500/year	Oxford County fleet maintenance records

[2] Note CNG pickup truck vehicle age is less than gasoline pickup trucks. This age difference could contribute to higher costs for CNG pickups later in their lifecycle.

Input/Assumption	Value	Source
1 Ton Pickup Maintenance	$775/year	Oxford County fleet maintenance records
½ Ton Hybrid Pickup Maintenance	$880/year	Estimate same as gasoline
¾ Ton Hybrid Pickup Maintenance	$1,500/year	Estimate same as gasoline
1 Ton Hybrid Pickup Maintenance	$775/year	Estimate same as gasoline
BEV Pickup Maintenance	30%	Estimate 30% reduction, WSP analysis of fleet work order data can attribute 30% to ICE powertrain and exhaust systems
½ Ton Pickup Utilization	31,000 km/year	Historical fleet utilization records
¾ Ton Pickup Utilization	28,000 km/year	Historical fleet utilization records
1 Ton Pickup Utilization	28,000 km/year	Historical fleet utilization records
Pickup Lifecycle	5 years	Oxford County Fleet Asset Management
Salvage Value	$3,000	Oxford County Fleet Asset Management
EV Charging Station CAPEX*	$5,000	Level 2 charger (plus taxes and installation)

Cargo Vans

Input/Assumption	Value	Source
Diesel Cargo Van Purchase	$43,600	Historical Mercedes Sprinter cargo van purchases
Gasoline Cargo Van Purchase	$36,700	Historical 2020 RAM ProMaster purchases
CNG Upfitting Cost	$11,850	Average of Chevrolet Express Vans 104 and 680 CNG upfitting
BEV Cargo Van Purchase	$58,000	Estimate Ford eTransit van
EV Rebate	$5,000	Transport Canada for BEVs
Diesel Fuel Economy[3]	11.2 L/100km	Diesel Mercedes Sprinter 22 mpg
Gasoline Fuel Economy	9.8 L/100 km	RAM ProMaster V6 gasoline 24 mpg
CNG/Gas Fuel Economy	39%	Oxford County 2019 fuel records for CNG cargo vans 39% of total fuel use (gLe) is CNG
BEV Energy Consumption	42 kWh/100km	Average estimate of Ford eTransit, Workhorse and Navistar Vans
Diesel Van Maintenance	$525/year	Oxford County fleet maintenance records (average cargo van maintenance 2017 to 2019)
Gasoline Van Maintenance	$675/year	Oxford County fleet maintenance records (average cargo van maintenance 2017 to 2019)
CNG Van Maintenance	$840/year	Oxford County fleet maintenance records (average cargo van maintenance 2017 to 2019)
BEV Pickup Maintenance	30%	Estimate 30% reduction, WSP analysis of fleet work order data can attribute 30% to ICE powertrain and exhaust systems
Utilization	22,000 km/year	Historical fleet utilization records
Cargo Van Lifecycle	6 years	Oxford County fleet asset management
Salvage Value	$3,000	Oxford County fleet asset management
EV Charging Station CAPEX*	$5,000	Level 2 charger (plus taxes and installation)

*Note EV charging station cost is factored into BEV lifecycle cost as an initial capital expense.

[3] Fuel economy referenced from: https://momentumiot.com/what-is-the-most-fuel-efficient-cargo-van/

Cars

Input/Assumption	Value	Source
PHEV Car Purchase	$38,300	Market Scan
BEV Car Purchase	$42,200	Market Scan
EV Rebate	$5,000	Transport Canada for BEVs and PHEVs
PHEV Energy Consumption	20 kWh/100km	Market Scan
PHEV Gasoline Only Consumption[4]	5.7 L/100km	Market Scan
PHEV Electricity/Gasoline Use[5]	80%	Assumption
BEV Energy Consumption	16 kWh/100km	Average Estimate of Hyundai and Kia SUVs
PHEV Car Maintenance	$290/year	Oxford County fleet maintenance records (PHEV maintenance 2018)
BEV Car Maintenance	$260/year	Oxford County fleet maintenance records (PHEV maintenance 2018)
Car Utilization	11,000 km/year	Historical fleet utilization records
Car Lifecycle	5 years	Oxford County fleet asset management
Salvage Value	$3,000	Oxford County fleet asset management

[4] Ford Fusion = 5.7 L/100km
[5] Chevy VOLT used 61 L (6-months) according to 2020 fuel records, assume 120 L/year at 5.7 L/100km gasoline fuel economy = 2,100 km (gasoline usage). Total PHEV car annual usage estimated at 11,000 km.

SUVs

Input/Assumption	Value	Source
Gasoline SUV Purchase	$22,500	Average of Oxford County historical purchases (Chevrolet Equinox)
CNG Upfitting Cost	$9,275	Average of Chevrolet Equinox SUVs 665 and 803 CNG upfitting
Hybrid SUV Purchase	$31,500	Market Scan, average of Ford, Kia and Toyota SUVs
PHEV SUV Purchase	$40,000	Average of Kia and Mitsubishi SUVs
BEV SUV Purchase	$44,000	Average of Hyundai and Kia SUVs
EV Rebate	$5,000	Transport Canada for BEVs and PHEVs
Gasoline Fuel Economy	10.6 L/100km	Average of Oxford County SUVs
CNG/Gas Fuel Economy	15%	Oxford County 2019 fuel records for CNG SUVs 15% of total fuel use (gLe) is CNG
Hybrid Fuel Economy	5.5 L/100km	Average of Ford, Kia and Toyota
PHEV Energy Consumption	28 kWh/100km	Average of Kia and Mitsubishi SUVs
PHEV Gasoline Only Consumption[6]	7.0 L/100km	Average of Kia and Mitsubishi SUVs
PHEV Electricity/Gasoline Use	80%	Assumption
BEV Energy Consumption	19 kWh/100km	Average estimate of Hyundai and Kia SUVs
CNG SUV Maintenance	$510/year	Oxford County fleet maintenance records (average SUV maintenance 2017 to 2019)
Hybrid SUV Maintenance	$510/year	Estimate dame as gasoline
BEV SUV Maintenance	30%	Estimate 30% reduction, WSP analysis of fleet work order data can attribute 30% to ICE powertrain and exhaust systems
SUV Utilization	25,000 km/year	Historical fleet utilization records
SUV Lifecycle (including CNG)	6 years	Oxford County fleet asset management
EV Charging Station CAPEX*	$5,000	Level 2 charger (plus taxes and installation)

*Note EV charging station cost is factored into BEV lifecycle cost as an initial capital expense.

[6] Based on gasoline versus electricity usage from Oxford County's current PHEV car

APPENDIX

Snowplows

Input/Assumption	Value	Source
Diesel Snowplow Purchase	$330,000	Oxford County replacement budget – Class 8 diesel tandem truck
CNG Upfitting Cost	$52,120	TAC Award Submission
Hybrid Axle System	$40,000	Hiller Truck Tech (includes installation)
Diesel Fuel Consumption	12,360 L/year	Average of snowplows 361 and 391 in 2019
Ratio of CNG/Diesel Fuel Use	0.786 kg/L	TAC Award Submission, comparative testing of snowplows (10,500 L of diesel versus 8,255 kg of CNG)
Est. CNG Fuel Consumption	9,715 kg	Calculated from fuel use ratio and diesel consumption
Hybrid System Fuel Economy Improvement	8.5%	Hyliion stated a general improvement of 7% to 10% and up to 15% on hilly terrain
Snowplow Maintenance	$5,475/year	Average of diesel tandem truck maintenance records from 2015 to 2019
Lifecycle	10 years	Oxford County asset management
Salvage Value (with plow)	$35,000	Oxford County asset management

Single Axle Truck

Input/Assumption	Value	Source
Diesel Truck Purchase	$280,000	Oxford County replacement budget – Single axle diesel truck
BEV (Class 8) Truck Purchase	$350,000	Estimate of Class 6 BEV truck (CN Rail order of Class 8 BEV trucks $400,000)
Diesel Fuel Consumption	34 L/100km	Fuel economy estimate of day cab single axle trucks
BEV Energy Consumption	124 kWh/100km	Estimate of Lion BEV truck
Diesel Truck Maintenance	$1,130/year	Asset 684 maintenance records from 2019
BEV Truck Maintenance	30%	Estimate 30% Reduction, WSP analysis of fleet work order data can attribute 30% to ICE powertrain and exhaust systems
Utilization	8,800 km/year	Historical fleet utilization records
Lifecycle	20 years	Oxford County asset management, Sterling single axle trucks purchased in 2005 scheduled for replacement in 2025
Salvage Value	$10,000	Oxford County asset management
EV Charging Station CAPEX*	$5,000	Level 2 charger (plus taxes and installation)

*Note EV charging station cost is factored into BEV lifecycle cost as an initial capital expense.

APPENDIX

Dozer

Input/Assumption	Value	Source
Dozer Purchase (D7 model)	$700,000	Oxford County replacement budget
Dozer Purchase (D6XE model)	$765,000	2019 market sale price, reference from $529,802 USD (excluding taxes)
Fuel Consumption (D7 model)	10,000 L/year	Oxford County (historical fleet data)
Annualized Maintenance (D7 model)	$12,940/year	Oxford County (historical fleet data) ($64,700 over 5 years, 2015 to 2020 records)
Fuel Savings (D6XE)	25%	Conservative estimate, CAT up to 35%
Maintenance Savings (D6XE)	10%	Conservative estimate, CAT stated up to 12%
Dozer Lifecycle	20 years	Oxford County asset management
Salvage Value	$20,000	Oxford County asset management

Ambulances

Input/Assumption	Value	Source
Ambulance Purchase	$153,000	Paramedic Services fleet replacement budget
XL Fleet Hybrid Drivetrain	$27,850	Oxford County Paramedic Services
Rooftop Solar Installation	$5,040	Oxford County Paramedic Services
Maintenance	$11,000/year	Oxford County (historical fleet data)
Diesel Fuel Consumption	11,000 L/year	Oxford County (historical fleet data)
Gasoline Fuel Consumption (hybrid + solar)	9,700 L/year	20% Fuel economy improvement
Utilization	53,000 km/year	Oxford County (historical fleet data), Average of ambulance mileage in 2019
Ambulance Lifecycle	6 years	Oxford County Paramedic Services
Salvage Value	$9,000	Oxford County Estimate
Hybrid Salvage Value	$12,000	Oxford County Estimate

Emergency Response Vehicles (ERVs) - Trucks

Input/Assumption	Value	Source
ERV Truck Purchase Cost (Diesel)	$153,000	Chevrolet 3500 HD (Unit 1317)
ERV Truck Purchase Cost (Gasoline)	$96,000	Chevrolet Tahoe LS 4WD (Unit 1318)
XL Fleet Hybrid Drivetrain (Asset 1317)	$15,000	XL Fleet XLH hybrid, stated starting price at $10,990 USD [7]
OEM Hybrid Cost Premium (Asset 1318)	$5,000	Ford F-150 cost premium of gasoline versus gas-hybrid option
Maintenance (Diesel)	$7,600	Average from maintenance records (2015 to 2019)
Maintenance (Gasoline)	$2,500	Average from maintenance records (2018 to 2019)
Utilization (Unit 1317)	36,000 km/year	Average utilization from historical fleet data (2016 to 2018)
Utilization (Unit 1318)	17,000 km/year	Average utilization from historical fleet data (2016 to 2018)
Diesel Fuel Economy (Unit 1317)	19.5 L/100km	Average from historical fleet data (2017 to 2018)
Gasoline Fuel Economy (Unit 1318)	13.0 L/100km	Average from historical fleet data (2017 to 2018)
XL Hybrid Fuel Economy Improvement	20%	Conservative estimate on XL Fleet statement of 25%
ERV Lifecycle	6 years	Oxford County Paramedic Services
Salvage Value	$9,000	Estimate based on historical salvage value of ERV trucks. Will depend on mileage and condition.

[7] Aaron Bragman “XL Ford Super Duty F-250 Hybrid: Quick Spin” Available at: https://news.pickuptrucks.com/2018/04/xl-ford-super-duty-f-250-hybrid-quick-spin.html. Note OEM hybrid options are currently unavailable for pickup trucks greater than ½ ton capacity.

APPENDIX

Emergency Response Vehicles (ERVs) - SUV

Input/Assumption	Value	Source
ERV Purchase Cost (Gas-Hybrid)	$85,000	Oxford County Capital Budget (includes PS system outfitting costs)
Cost Premium for BEV SUVs	$12,500	Market Scan Premium for BEV versus Hybrid SUVs
Maintenance	$4,780/year	Unit 1320 maintenance cost in 2019
Utilization (Unit 1320)	24,000 km/year	Average Utilization from 2019 data
Gasoline Fuel Economy (Unit 1320)	6.0 L/100km	Toyota Rav4 Hybrid Fuel Economy
BEV Energy Consumption	19 kWh/100km	Average Estimate of Hyundai and Kia SUVs
ERV Lifecycle	6 years	Oxford County Paramedic Services
Salvage Value	$9,000	Estimate based on historical salvage value of ERVs. Will depend on mileage and condition.

CNG Fueling Station

Input/Assumption	Value	Source
CNG Fuel Station - CAPEX	$433,725	CES modeling estimate
Fuel Station Lifecycle	20 years	CES modeling estimate
CNG Upfitting (Class 3 Truck)	1x	Reference Chevy 3500 HD
CNG Upfitting (Class 6 and above)	7x	Heavy-Duty diesel trucks at Springford
CNG Upfitting (Class 3 Truck)	$11,500	The CNG fuel tanks and systems added to vehicles range from $9,000 to $13,000 depending on tank size
CNG Upfitting (Class 6 and above)	$52,120	TAC Award Submission (Tandem CNG trucks)
MD Pickup Truck Lifecycle	5 years	Oxford County asset management
Sign Truck Lifecycle	9 years	Oxford County asset management
Tandem Truck Lifecycle	10 years	Oxford County asset management
Paint Truck Lifecycle	20 years	Oxford County asset management
Diesel Base Fuel Price	0.98 $/L	Oxford County fuel records
Gasoline Base Fuel Price	1.002 $/L	Oxford County fuel records
CNG Base Fuel Price	0.72 $/kg	CES modeling estimate

APPENDIX C - Detailed Green Fleet Plan 2021 - 2025

Oxford County

Growing stronger together

For information contact:
519-539-9800 | 1-800-755-0394

APPENDIX

Detailed Green Fleet Plan (2021 to 2025)

Asset ID	User Group	Vehicle Type	Estimated Utilization (km/year)	Current Make	Current Model	Current Fuel	Proposed Fuel Transition	Budget Year	Estimated GHG Reduction (tCO2e/year)	Lifecycle GHG Reduction (tCO2e)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Net Lifecycle Cost ($)	Payback Period (years)	ROI (%)
1317	Paramedic Services	ERV	36,000	Chevrolet	Silverado 3500 HD	Diesel	Gas-Hybrid	2020	6.2	36.9	+$15,000	-$1,600	+$5,400	9.4	-36%
373	Transportation Services	Tandem	30,000	Freightliner	114SD	Diesel	CNG	2021	5.0	50.4	+$52,100	-$5,500	**-$2,900**	**9.5**	**6%**
387	Transportation Services	Tandem	30,000	Volvo	VHD	Diesel	CNG	2021	5.0	50.4	+$52,100	-$5,500	**-$2,900**	**9.5**	**6%**
1003	Paramedic Services	Ambulance	53,000	Chevrolet	3500	Diesel	Gas-hybrid	2021	7.6	45.3	+$32,900	-$1,500	+$26,900	19.9	-64%
1006	Paramedic Services	Ambulance	53,000	Chevrolet	3500	Diesel	Gas-hybrid	2021	7.6	45.3	+$32,900	-$1,500	+$26,900	19.9	-64%
1007	Paramedic Services	Ambulance	53,000	Chevrolet	3500	Diesel	Gas-hybrid	2021	7.6	45.3	+$32,900	-$1,500	+$26,900	19.9	-64%
OXF 1	Paramedic Services	Van - Cargo	20,000	Manufacturer	Model	Gasoline	BEV	2021	4.6	27.4	+$21,300	-$1,600	+$11,700	13.3	-55%
326	Transportation Services	Pickup - 1/2 Ton	50,000	Ram	1500	Gasoline	Gas-hybrid	2022	4.2	20.9	+$6,800	-$2,000	**-$3,200**	**3.4**	**47%**
327	Transportation Services	Pickup - 1 Ton	28,000	Chevrolet	Silverado 3500	Gasoline	Gas-hybrid	2022	3.5	17.3	+$15,000	-$1,600	+$7,000	9.4	-47%
328	Transportation Services	Pickup - 1 Ton	28,000	Chevrolet	Silverado 3500	Gasoline	Gas-hybrid	2022	3.5	17.3	+$15,000	-$1,600	+$7,000	9.4	-47%
335	Transportation Services	Pickup - 1/2 Ton	50,000	Ram	1500	Gasoline	Gas-hybrid	2022	4.2	20.9	+$6,800	-$2,000	**-$3,200**	**3.4**	**47%**
338	Transportation Services	Pickup - 1/2 Ton - CNG	50,000	Ram	1500	CNG/Gasoline	Gas-hybrid	2022	3.5	17.5	-$3,200	-$800	**-$7,200**	**< 1 year**	**> 100%**
339	Transportation Services	Pickup - 1/2 Ton - CNG	50,000	Ram	1500	CNG/Gasoline	Gas-hybrid	2022	3.5	17.5	-$3,200	-$800	**-$7,200**	**< 1 year**	**> 100%**
344	Transportation Services	Pickup - 1/2 Ton	50,000	Ram	1500	Gasoline	Gas-hybrid	2022	4.2	20.9	+$6,800	-$2,000	**-$3,200**	**3.4**	**47%**
346	Transportation Services	Pickup - 1/2 Ton	50,000	Ram	1500	Gasoline	Gas-hybrid	2022	4.2	20.9	+$6,800	-$2,000	**-$3,200**	**3.4**	**47%**
350	Transportation Services	Pickup - 1/2 Ton	50,000	Ram	1500	Gasoline	Gas-hybrid	2022	4.2	20.9	+$6,800	-$2,000	**-$3,200**	**3.4**	**47%**
351	Transportation Services	Pickup - 1/2 Ton - CNG	50,000	Ram	1500	CNG/Gasoline	Gas-hybrid	2022	3.5	17.5	-$3,200	-$800	**-$7,200**	**< 1 year**	**> 100%**
352	Transportation Services	Pickup - 1 Ton	28,000	Chevrolet	Silverado 3500HD	Gasoline	Gas-hybrid	2022	3.5	17.3	+$15,000	-$1,600	+$7,000	9.4	-47%
523	Wastewater	Pickup - 1/2 Ton	22,000	Ram	1500	Gasoline	Gas-hybrid	2022	1.8	9.2	+$6,800	-$900	+$2,300	7.6	-34%
637	Water Distribution	Pickup - 1 Ton	28,000	Ram	3500	Gasoline	Gas-hybrid	2022	3.5	17.3	+$15,000	-$1,600	+$7,000	9.4	-47%
638	Water Distribution	Pickup - 1 Ton	28,000	Ram	3500	Gasoline	Gas-hybrid	2022	3.5	17.3	+$15,000	-$1,600	+$7,000	9.4	-47%
1192	Paramedic Services	Ambulance	53,000	Chevrolet	3500	Diesel	Gas-hybrid	2022	7.6	45.3	+$32,900	-$1,500	+$26,900	19.9	-64%
1193	Paramedic Services	Ambulance	53,000	Chevrolet	3500	Diesel	Gas-hybrid	2022	7.6	45.3	+$32,900	-$1,500	+$26,900	19.9	-64%
1318	Paramedic Services	ERV	17,000	Chevrolet	Tahoe	Gasoline	Gas-Hybrid	2022	1.9	11.6	+$5,000	-$500	+$2,000	10.0	-40%
110	Facilities	Van - Cargo	12,000	Mercedes	Sprinter	Diesel	BEV	2023	3.7	22.1	+$14,400	-$1,000	+$8,400	14.4	-58%
116	Facilities	Pickup - 1/2 Ton - CNG	13,000	Ram	1500	CNG/Gasoline	Gas-hybrid	2023	0.9	4.5	-$3,200	-$100	**-$3,700**	**< 1 year**	**> 100%**
353	Transportation Services	Pickup - 1 Ton	28,000	Chevrolet	Silverado 3500HD	Gasoline	Gas-hybrid	2023	3.5	17.3	+$15,000	-$1,600	+$7,000	9.4	-47%
522	Wastewater	Pickup - 1/2 Ton	22,000	Chevrolet	Silverado 1500	Gasoline	Gas-hybrid	2023	1.8	9.2	+$6,800	-$900	+$2,300	7.6	-34%
570	Wastewater	Van - Cargo	20,000	Mercedes	Sprinter	Diesel	BEV	2023	6.1	36.8	+$14,400	-$1,700	+$4,200	8.5	-29%
655	Water Treatment	Pickup - 1/2 Ton	35,000	Ram	1500	Gasoline	Gas-hybrid	2023	2.9	14.7	+$6,800	-$1,400	+$200	**4.9**	**3%**
656	Water Distribution	Pickup - 1/2 Ton	31,000	Ram	1500	Gasoline	Gas-hybrid	2023	2.6	13.0	+$6,800	-$1,200	+$800	5.7	-12%
665	Water Distribution	SUV - CNG	15,000	Chevrolet	Equinox	CNG/Gasoline	PHEV	2023	2.8	16.9	+$8,200	-$800	+$3,400	10.3	-41%
680	Water Treatment	Van - Cargo - CNG	20,000	Chevrolet	Express	CNG/Gasoline	BEV	2023	4.3	25.9	+$9,500	-$1,400	+$1,100	6.8	-12%
682	Water Treatment	Van - Cargo	20,000	Mercedes	Sprinter	Diesel	BEV	2023	6.1	36.8	+$14,400	-$1,700	+$4,200	8.5	-29%
750	Waste Management	Pickup - 1/2 Ton	20,000	Ram	1500	Gasoline	Gas-hybrid	2023	1.7	8.4	+$6,800	-$800	+$2,800	8.5	-41%
752	Waste Management	Pickup - Compact	20,000	Chevrolet	Colorado	Gasoline	Gas-hybrid	2023	1.7	8.4	+$6,800	-$800	+$2,800	8.5	-41%

APPENDIX

Asset ID	User Group	Vehicle Type	Estimated Utilization (km/year)	Current Make	Current Model	Current Fuel	Proposed Fuel Transition	Budget Year	Estimated GHG Reduction (tCO2e/year)	Lifecycle GHG Reduction (tCO2e)	Capital Cost Impact ($)	Operating Cost Impact ($/year)	Net Lifecycle Cost ($)	Payback Period (years)	ROI (%)
805	Fleet	Pickup - 1/2 Ton - CNG	15,000	Ram	1500	CNG/Gasoline	Gas-hybrid	2023	1.0	5.2	-$3,200	-$100	**-$3,700**	**< 1 year**	**> 100%**
915	Construction & Engineering	Pickup - Compact - CNG	25,000	Chevrolet	Colorado	CNG/Gasoline	Gas-hybrid	2023	1.7	8.7	-$3,200	-$300	**-$4,700**	**< 1 year**	**> 100%**
917	Construction & Engineering	SUV - CNG	46,000	Chevrolet	Equinox	CNG/Gasoline	PHEV	2023	8.6	51.8	+$8,200	-$2,500	**-$6,800**	**3.3**	**83%**
919	Construction & Engineering	Pickup - Compact - CNG	25,000	Chevrolet	Colorado	CNG/Gasoline	Gas-hybrid	2023	1.7	8.7	-$3,200	-$300	**-$4,700**	**< 1 year**	**> 100%**
104	Facilities	Van - Cargo - CNG	12,000	Chevrolet	Express	CNG/Gasoline	BEV	2024	2.6	15.5	+$9,500	-$900	+$4,100	10.6	-43%
113	Facilities	Pickup - 1/2 Ton - CNG	13,000	Ram	1500	CNG/Gasoline	Gas-hybrid	2024	0.9	4.5	-$3,200	-$100	**-$3,700**	**< 1 year**	**> 100%**
117	Facilities	Pickup - 1/2 Ton - CNG	13,000	Chevrolet	Silverado 1500	CNG/Gasoline	Gas-hybrid	2024	0.9	4.5	-$3,200	-$100	**-$3,700**	**< 1 year**	**> 100%**
524	Wastewater	Pickup - 1/2 Ton	22,000	Chevrolet	Silverado 1500	Gasoline	BEV	2024	6.9	34.3	+$20,000	-$2,700	+$6,500	7.4	-33%
525	Wastewater	Pickup - 1/2 Ton - CNG	22,000	Chevrolet	Silverado 1500LD	CNG/Gasoline	Gas-hybrid	2024	1.5	7.7	+$3,200	-$300	**-$4,700**	**< 1 year**	**> 100%**
529	Wastewater	Pickup - 1/2 Ton	22,000	Chevrolet	Silverado 1500LD	Gasoline	Gas-hybrid	2024	1.8	9.2	+$6,800	-$900	+$2,300	7.6	-34%
659	Water Distribution	Pickup - 3/4 Ton	28,000	Chevrolet	Silverado 2500	Gasoline	Gas-hybrid	2024	2.6	12.8	+$15,000	-$1,200	+$9,000	12.5	-60%
660	Water Distribution	Pickup - 3/4 Ton	28,000	Chevrolet	Silverado 2500	Gasoline	Gas-hybrid	2024	2.6	12.8	+$15,000	-$1,200	+$9,000	12.5	-60%
661	Water Distribution	Pickup - 3/4 Ton	28,000	Chevrolet	Silverado 2500	Gasoline	Gas-hybrid	2024	2.6	12.8	+$15,000	-$1,200	+$9,000	12.5	-60%
662	Water Treatment	Pickup - 1/2 Ton - CNG	35,000	Chevrolet	Silverado 1500LD	CNG/Gasoline	Gas-hybrid	2024	2.4	12.2	-$3,200	-$500	**-$5,700**	**< 1 year**	**> 100%**
663	Water Treatment	Pickup - 1/2 Ton - CNG	35,000	Chevrolet	Silverado 1500LD	CNG/Gasoline	Gas-hybrid	2024	2.4	12.2	-$3,200	-$500	**-$5,700**	**< 1 year**	**> 100%**
742	Waste Management	Tractor - Dozer	N/A	Cat	D7R	Diesel Dyed	Diesel-Hybrid	2024	6.8	136.9	+$65,000	-$4,400	**-$23,000**	**14.8**	**35%**
803	Fleet	SUV - CNG	15,000	Chevrolet	Equinox	CNG/Gasoline	PHEV	2024	2.8	16.9	+$8,200	-$800	+$3,400	10.3	-41%
804	Fleet	Pickup - Compact - CNG	15,000	Chevrolet	Colorado	CNG/Gasoline	Gas-hybrid	2024	1.0	5.2	-$3,200	-$100	**-$3,700**	**< 1 year**	**> 100%**
905	Library	Van - Cargo - High Roof	51,000	Ford	Transit	Gasoline	BEV	2024	11.6	69.8	+$21,300	-$3,900	**-$2,100**	**5.5**	**10%**
913	Construction & Engineering	Pickup - Compact - CNG	25,000	Chevrolet	Colorado	CNG/Gasoline	Gas-hybrid	2024	1.7	8.7	-$3,200	-$300	**-$4,700**	**< 1 year**	**> 100%**
1320	Paramedic Services	ERV - Hybrid	24,000	Toyota	Rav4	Gas / Hybrid	BEV	2024	3.9	23.4	+$12,500	-$1,000	**-$6,500**	12.5	-52%
114	Facilities	Pickup - 3/4 Ton	28,000	Chevrolet	Silverado 2500 HD	Gasoline	BEV	2025	9.5	47.5	+$20,000	-$3,900	+$500	5.1	-3%
632	Water Treatment	Pickup - 3/4 Ton	28,000	Chevrolet	Silverado 2500 HD	Gasoline	BEV	2025	9.5	47.5	+$20,000	-$3,900	+$500	5.1	-3%
633	Water Treatment	Pickup - 1/2 Ton	35,000	Ram	1500	Gasoline	BEV	2025	10.9	54.5	+$20,000	-$4,200	**-$1,000**	**4.8**	**5%**
646	Water Treatment	Pickup - 1/2 Ton	35,000	Ram	1500	Gasoline	BEV	2025	10.9	54.5	+$20,000	-$4,200	**-$1,000**	**4.8**	**5%**
648	Water Treatment	Pickup - 3/4 Ton	28,000	Chevrolet	Silverado 2500 HD	Gasoline	BEV	2025	9.5	47.5	+$20,000	-$3,900	+$500	5.1	-3%
652	Water Distribution	Pickup - 3/4 Ton	28,000	Chevrolet	Silverado 2500 HD	Gasoline	BEV	2025	9.5	47.5	+$20,000	-$3,900	+$500	5.1	-3%
664	Water Distribution	Van - Cargo	20,000	Chevrolet	Express	Gasoline	BEV	2025	4.6	27.4	+$21,300	-$1,600	+$11,700	13.3	-55%
684	Water Treatment	Single	8,800	Sterling	STE	Diesel	BEV	2025	8.2	163.8	+$70,000	-$2,400	+$22,000	29.2	-31%

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