

BCUOMA Unrecoverable Antifreeze Study



Prepared by:

DesRosiers Automotive Consultants Inc.

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Executive Summary

1.1 The Project

This project was undertaken with the goal of evaluating the market size, and potential unrecoverable amount of used antifreeze in British Columbia. This market is complex, fragmented and poorly documented and, as such, has limited data available regarding its size and scope. Given this lack of quantitative data, DAC utilised a variety of primary research and statistical modelling techniques to estimate the key market parameters. As such all data should be treated strictly as estimates.

1.2 Antifreeze

With interchangeable terms—coolant, antifreeze, etc.—automotive antifreeze is a specific formulation used in engines of various types and sizes that aids in their cooling. Generally, two main types exist. The first type is propylene glycol based, or PG, which is relatively non-toxic and is broadly considered safe for human consumption or contact and is generally not used in automotive applications. The other common type of antifreeze is ethylene glycol (or EG) which can have various levels of harm to organisms, up to being fatal when ingested. Additive packages are included as well, depending on the specific product and use-case. The potential harm of EG makes that type of antifreeze a particular concern for the environment and a particular focus of collection and recycling efforts. By volume, EG-based fluids are the most commonly used. The general focus of this project was EG based antifreeze products that are sold with Environmental Handling Charges.

1.3 Background

The light vehicle fleet in British Columbia has been growing steadily from the beginning of the previous decade until 2019, with a total of 3.87 million vehicles registered on the roads. This figure has increased from 2.11 million in the year 2000. All else being equal, an increase in the size of the light vehicle fleet in BC increases the demand for antifreeze, with the light vehicle fleet being the single largest destination for antifreeze by volume. However, due to increased availability of long-life fluids, this relationship has somewhat broken down. While light vehicle sales have seen some decreases in British Columbia since the market peak in 2017, sales remained quite high compared to earlier in the decade with 204,277 new light vehicles sold in 2019. Of course, the impacts of the coronavirus shrank sales in 2020 to 167,561 units. One potential disruptor to antifreeze use in British Columbia could be ZEV vehicles, comprised of PHEVs and BEVs. Depending on the particular technologies adapted by the growing ZEV market in the future, antifreeze use within and outside of the light vehicle fleet will likely shrink. However, despite impressive sales growth, these vehicles occupy a small portion of the in-use fleet and will continue to hold a relatively small share in the short-term.

The number of registered off-road, construction, and farm vehicles increased sharply in the past few years, rising to nearly 65 thousand units. Registered vehicles weighing 15,000 kilograms or more have grown steadily in the past ten years, rising to over 46 thousand. Buses—while less consistent in their growth—numbered over 10 thousand on the roads of British Columbia in 2019. These larger vehicles represent a disproportionate use of antifreeze when compared to the light vehicle fleet due to their larger engines and maintenance interval shifts, despite there being a smaller number of them in use.

1.4 Target Loss Areas

Building on the existing DAC coolant market size model, interviews were conducted with key industry stakeholders to refine the total market size estimates and establish several **target loss areas** where antifreeze is lost and can be considered unrecoverable. These target loss areas were identified as:

- The Light Vehicle Fleet
- The Medium Vehicle Fleet
- The Heavy Duty Fleet
- Buses
- Motorcycles, ATVs, and UTVs
- Aviation
- Marine
- Off-road, Construction, and Farm Vehicles
- Industrial Coolant Re-Use
- Stationary Equipment + Others
- Other Industrial Uses
- Light Vehicle Scrappage
- Heavy Vehicle Scrappage

These target loss areas were analysed with the aid of research, interviews, and data collection. Two were removed from tabulation—aviation and other industrial—due to using antifreeze products that do not qualify as automotive fluids with Environmental Handling Charges. The implication of antifreeze loss in those spaces nonetheless remains a useful point of note when considering antifreeze loss and environmental impacts on the broader market.

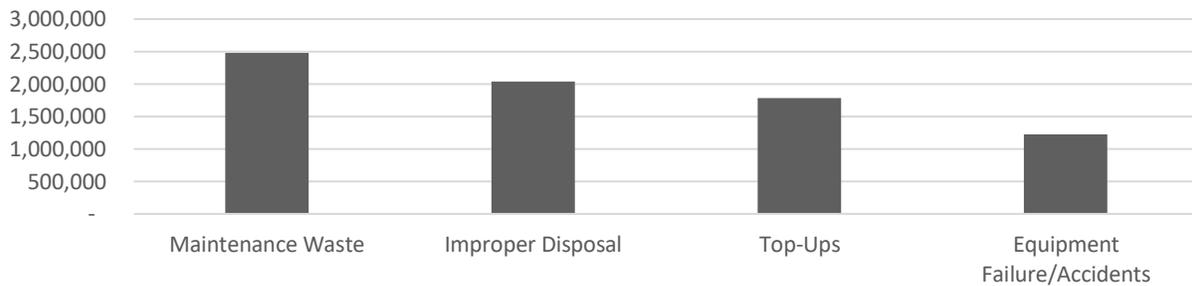
These categories of loss areas were further grouped by their specific sources of loss. These were:

- Maintenance Waste
- Improper Disposal
- Top-Ups
- Equipment Failure and Accidents

1.5 Unrecoverable Antifreeze Estimate

In terms of 50/50 diluted antifreeze, the total volume of unrecoverable antifreeze was identified as **7,534,969 Litres** while the total market size was estimated to be **12,131,751 Litres** for British Columbia in 2019. This results in an unrecoverable rate estimate of **62.1%** for the province with an estimated **4,596,782 Litres** of 50/50 diluted antifreeze or **37.9%** left as potentially recoverable.

Unrecoverable Antifreeze by Source



Source: DesRosiers Automotive Consultants

Unrecoverable Antifreeze Estimate by Source of Loss

Volume of 50/50 Diluted Antifreeze - Litres - 2019

Loss Source	Estimated Volume
Maintenance Waste	2,482,863
Improper Disposal	2,041,831
Top-Ups	1,785,497
Equipment Failure and Accidents	1,224,778
Total Unrecoverable Estimate	7,534,969
Sales Estimate	12,131,751
Unrecoverable Rate	62.1%
Recoverable Rate	37.9%
Recoverable Volume	4,596,782

Source: DesRosiers Automotive Consultants

Methodology

In order to create an estimate of the unrecoverable rate of antifreeze in the British Columbia market, DesRosiers Automotive Consultants Inc. utilized a three-step methodology.

- DesRosiers defined its existing coolant market size estimates, predominantly outlining the demand from the light vehicle side of the fleet in British Columbia.
 - Following this, DAC reviewed previously studies and information provided regarding the rate of unrecoverable antifreeze.
- Informational interviews were then conducted with industry stakeholders including antifreeze producers, collector and recyclers, as well as stakeholders from industries outside of automotive where antifreeze is used. Outside information was acquired as necessary.
 - This allowed DAC to create a list of target loss areas where significant volumes of antifreeze were left unrecovered. An analysis of these target loss areas was conducted in order to understand how antifreeze is used in these areas and what efforts are taken to ensure collection and proper handling.
 - A preliminary estimate was further created for each of these target loss areas regarding antifreeze volumes and collection rates.
- These target loss areas were considered and combined with DAC's existing coolant market size estimates in order to build a more thorough understanding of antifreeze use beyond the automotive space.
 - With consideration of information gathered, an unrecoverable antifreeze estimate for the BC market was then created.

It should be noted that the market in question is complex, fragmented and poorly documented and, as such, has limited data available regarding its size and scope. Given this lack of quantitative data, DAC utilised a variety of primary research and statistical modelling techniques to estimate the key market parameters. All data contained in this report are estimates, and given the lack of verifiable information should be treated as such. Accordingly, DAC makes no representation or warranty as to the accuracy or completeness of the estimates contained in this report and DAC shall have no liability whatsoever for any loss or damage arising in connection with the use of the report or any actions or strategy based in whole or in part on such research.

2 Background

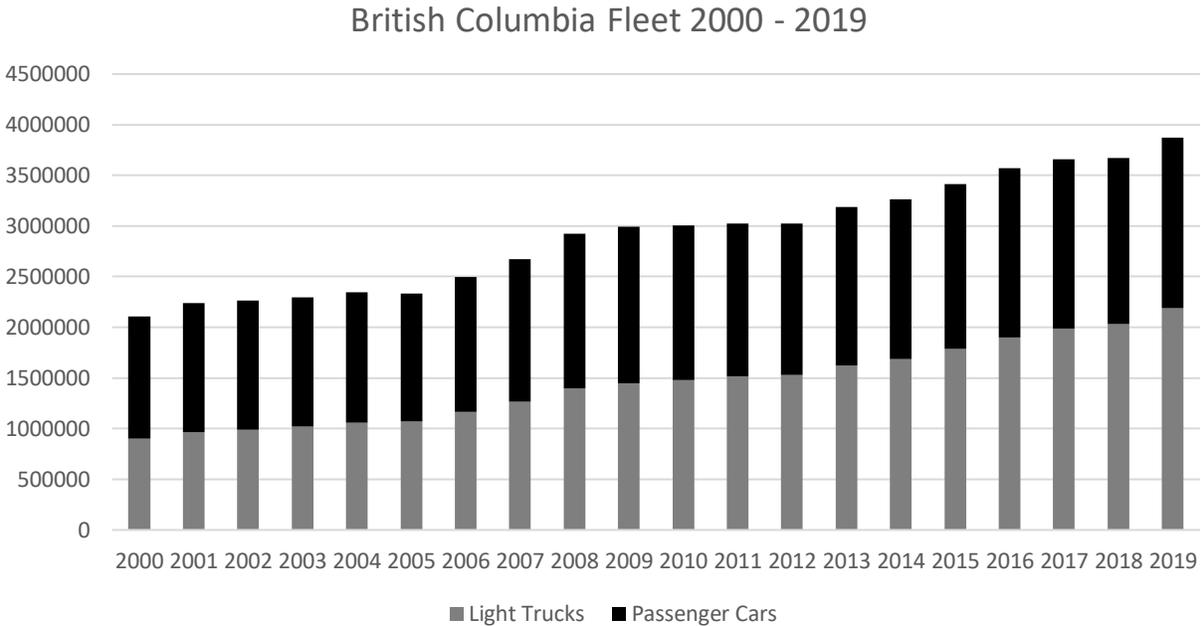
2.1 Antifreeze Overview

In broad terms, antifreeze is a fluid containing an additive that lowers its freezing point, and often raises the boiling point as well. Most of the time, this is diluted in water—which functions as a coolant on its own—creating an effective measure in a variety of use cases. The terms coolant and antifreeze are used interchangeably, however, with antifreeze carrying a clearer connection to use in engines. Furthermore, there exists a large spectrum of commercial and industrial uses beyond the most commonly thought of use in engines. Although engine use is one of the most common uses by volume, similar formulations are used to de-ice airplanes, used in certain marine and RV applications, as an industrial heat-transfer fluid, and much more. Any study of antifreeze use and recovery must take into account its various uses outside of the commonly known automotive applications.

Although specific formulations vary, as do concentrations and additive packages in particular mixtures, there exists two broad types of antifreeze. The first type is propylene glycol based, or PG, which is relatively non-toxic and is broadly considered safe for human consumption or contact. It can be used as aircraft de-icing fluid depending on climate and precipitation, or as a coolant where direct contact with living organisms is a clear risk. Although, it still retains use as engine coolant in some circumstances. It is also commonly used in food flavouring as well as the e-liquids used in electronic cigarettes. The other common type of antifreeze is ethylene glycol, or EG. EG oxidizes into different organic acids (formic, oxalic, glycolic, glyoxylic and acetic acid) that can have various levels of harm to organisms, up to being fatal when ingested. It is therefore unappealing to leave EG-based antifreeze uncollected and spreading through the environment. EG is the most common type of antifreeze used in engines, and has a broad range of other uses that will be discussed in the report. Due to the volume and toxicity, EG will be the primary focus of this research into unrecoverable antifreeze.

In terms of uses and specific industries, this study will focus on applicable products that are bundled with Environmental Handling Charges; generally, these are engine-oriented products marketed as ‘antifreeze’. While related industries and related EG/PG use will be discussed—such as the airline industry and de-icing fluid—they will not factor directly into any size or rate calculations.

2.2 Light Vehicle Fleet

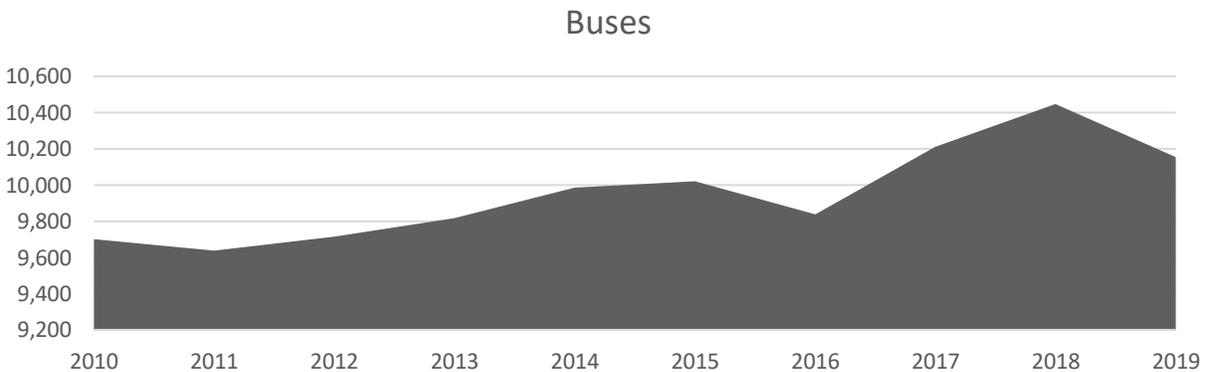
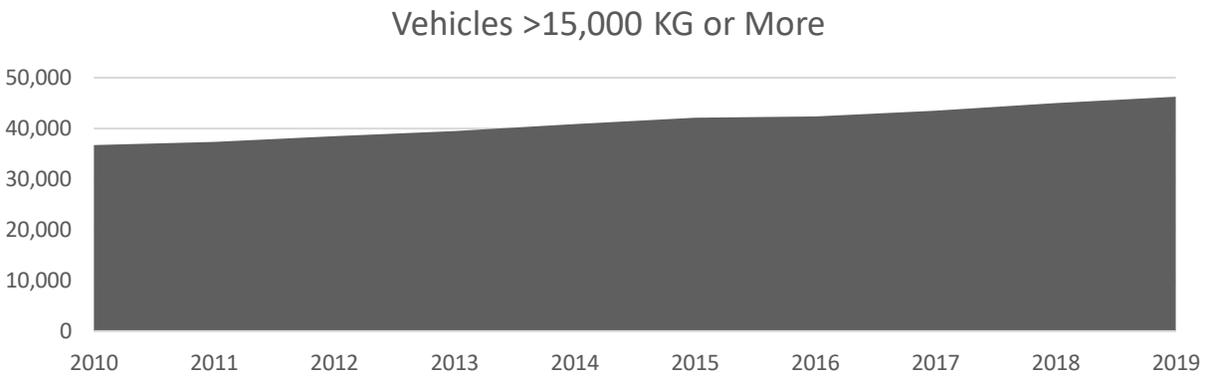
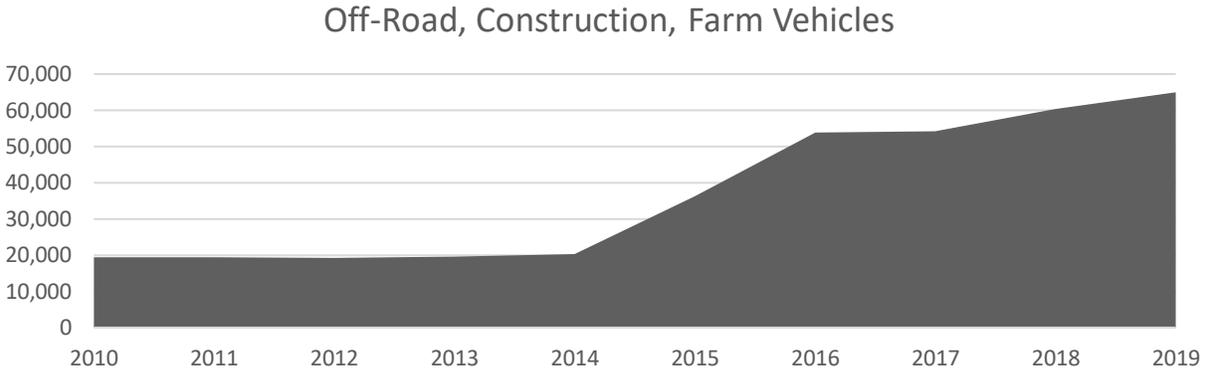


Source: DesRosiers Automotive Consultants Inc. and Registration Data © IHS Automotive driven by Polk, 2019 data released Fall 2019. The use of any part of these tables or charts reproduced, transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, or stored in a retrieval system, without prior written consent of IHS Automotive is an infringement of copyright law.

When considering the market for antifreeze, the first step should be an analysis of the light vehicle fleet which occupies the single largest segment of antifreeze use by volume. Much like Canada overall, British Columbia has seen its light vehicle fleet increase steadily in the past two decades, rising from 2.11 million in the year 2000 to 3.87 million in 2019. The past decade has largely shown considerable growth in the overall size of the provincial fleet. Light truck popularity has been increasing steadily as well with consumer sentiment shifting clearly in favour of light trucks following the 2008/2009 recession. This trend has continued unabated since light trucks overcame passenger cars as the dominant portion of the fleet in British Columbia. The specifics of the composition of the fleet are vital in tracking antifreeze use as volumes used change with vehicle age, vehicle size, engine size and design, and more.

While growth has been the consistent trend in the past decade, the impacts of the coronavirus pandemic will likely result in slower growth in the fleet in the short term due to the depressed light vehicle sales in 2020 and 2021. However, a return to higher growth rates is expected in 2023 and beyond.

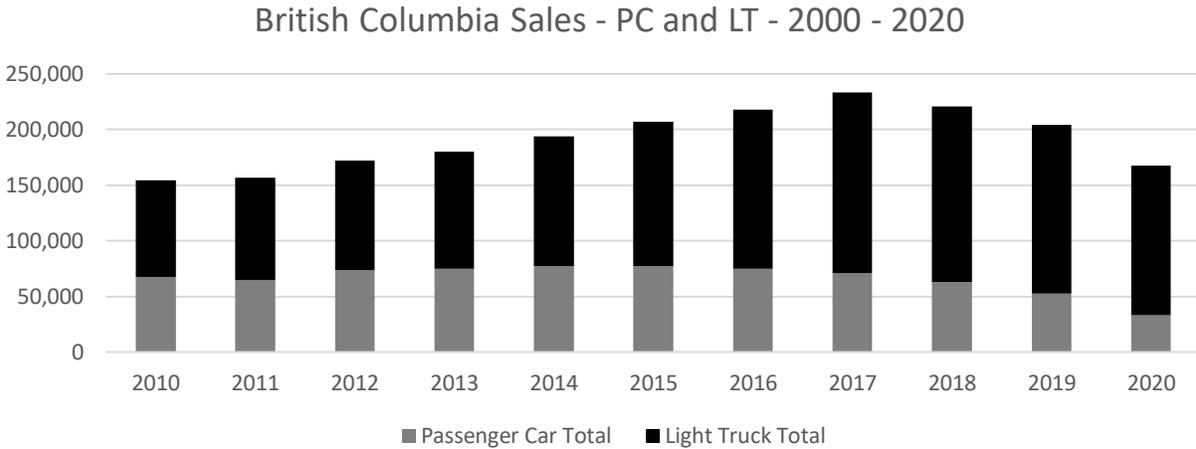
2.3 Medium and Heavy Vehicles



Source: DesRosiers Automotive Consultants Inc., Statistics Canada

Beyond the automotive light vehicle fleet, there are a number of other vehicles in operation in British Columbia that generally operate on similar cooling systems. Antifreeze is utilized in most of these vehicles, and generally in far greater volumes per unit due to larger engine sizes and heavier usage intensity resulting in a disproportionately large impact on antifreeze use when compared to light vehicles. The number of off-road, construction, and farm vehicles in BC has increased sharply into 2019, reaching nearly 65 thousand units. Growing more slowly, vehicles weighing over 15,000 kilograms grew to reach over 46 thousand units. Buses, while fluctuating, have generally increased in volume over the past decade, with over 10 thousand on the road in 2019.

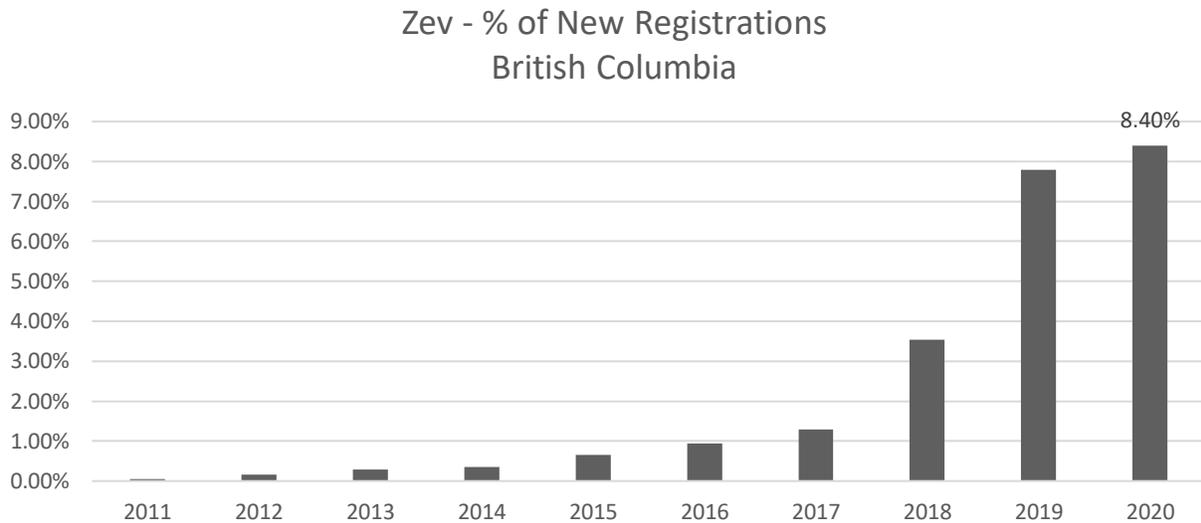
2.4 Light Vehicle Sales



Source: DesRosiers Automotive Consultants Inc., CVMA and GAC

New light vehicle sales have spent much of the past decade steadily growing in British Columbia, as they did in Canada more broadly. This led to a sales peak in 2017 of 233,615 units sold, comprised of 70,734 passenger car sales and 162,881 light truck sales. The years following all showed sales decreases with new light vehicle sales dropping to 220,595 in 2018 and 204,277 in 2019. Due the COVID-19 pandemic, new light vehicle sales across Canada dropped by nearly 20 percent. In British Columbia, total sales dropped by 18.0% in 2020. This sales drop will likely have lasting effects on the composition of the light vehicle fleet in BC for years to come, as the 'damage' moves through the age range. Alongside this, passenger car sales continued to perform poorly relative to light truck sales, even among the sales downturn in 2020 when passenger car sales dropped 37.7% and light truck sales dropped just 11.1%. This sales disparity too should impact the fleet composition for years to come.

2.5 EV Sales/Registrations



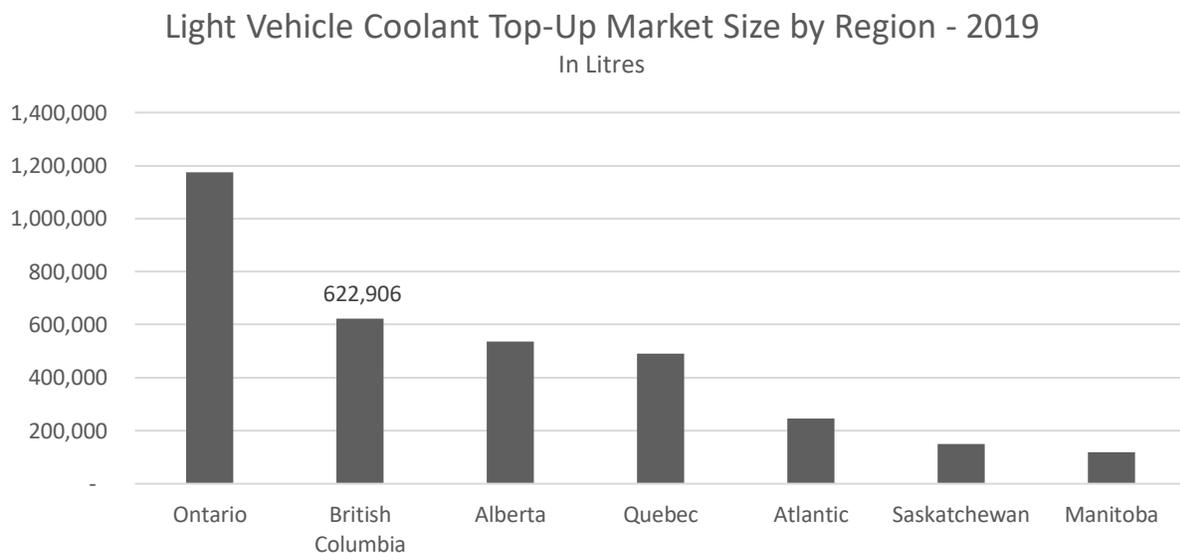
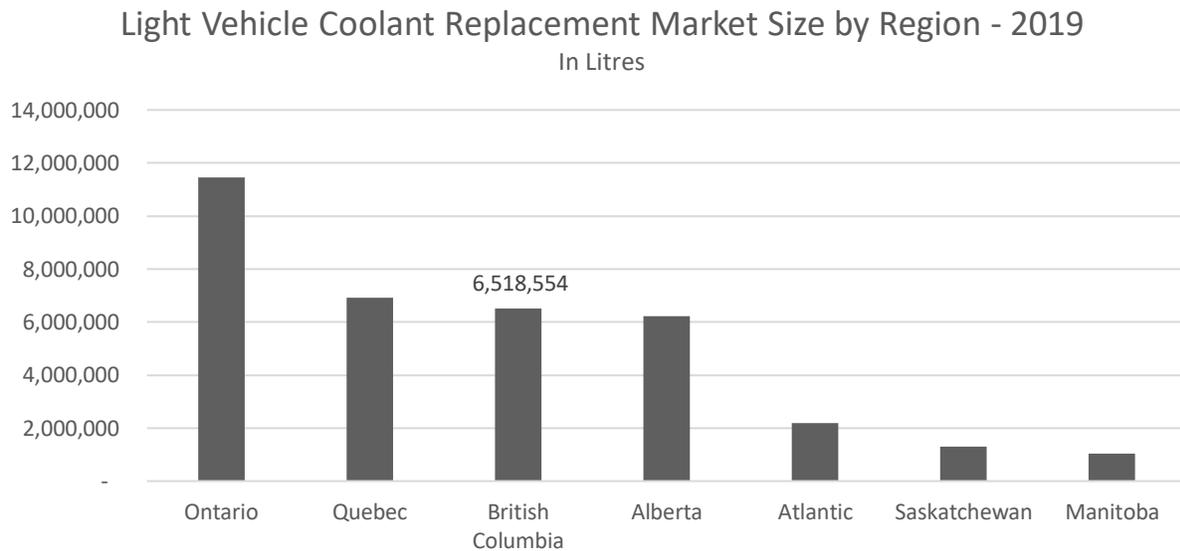
Source: DesRosiers Automotive Consultants Inc. and Statistics Canada

Zero emission vehicles, in this case consisting of battery electric and plug-in hybrid vehicles, have the potential to partially disrupt the demand for antifreeze in the light vehicle fleet. With lower need for coolant in terms of volumes and/or increased drain intervals among PHEVs and far more limited need in EVs depending on their cooling methods, growth in this area would change the balance of the antifreeze market in significant ways. In 2020, ZEVs accounted for 3.52% of new Canadian light vehicle registrations. British Columbia, however, was far more welcoming to green vehicles, with ZEVs occupying 8.40% of new light vehicle registrations in 2020. It should be emphasized that it will take many years for these vehicles to have a serious impact on the composition of the light vehicle fleet as a whole. Increased vehicle longevity means that the ICE vehicles being sold today (and accounting for 90+% of sales in BC) will still be on the road in 15 years. However, ZEV sales growth remains an important dynamic of change that needs to be considered when forecasting the future size and structure of the coolant market.

3 Antifreeze Market Size and Unrecoverable Rate

3.1 Antifreeze Market Size – Light Vehicle Fleet

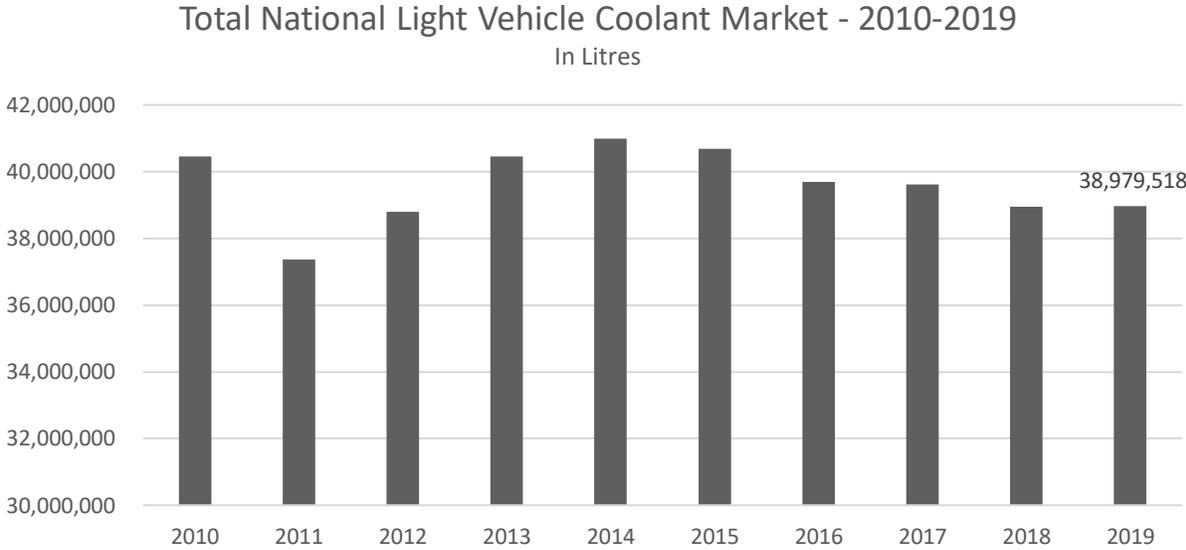
DesRosiers Automotive Consultants Inc. has an established estimate of the coolant market sizes in Canada. These figures represent replacement and top-up demand for the light vehicle fleet both nationally and by province, represented by liters of diluted coolant.



Source: DesRosiers Automotive Consultants Inc.

In terms of coolant demand, British Columbia's coolant market represented a total of 7.14 million litres in 2019, destined primarily for the light vehicle fleet. In terms of coolant replacement, British Columbia represented the third largest market in Canada, behind Ontario and Quebec. However, in terms of coolant top-up demand, British Columbia occupied second place, behind only Ontario. This discrepancy in market size for replacement vs. top-up is the result of fleet composition alongside specific consumer

preferences which vary with geography. The BC fleet has one of the highest average ages of all the provincial fleets, which contributes significantly to the high top-up coolant use as older vehicles tend to have more leaks, and are more likely to be under-maintained with relatively fewer complete coolant replacement jobs.



Source: DesRosiers Automotive Consultants Inc.

The overall national market, including British Columbia and the rest of Canada, has seen shifting demand levels since 2010. A sharp increase was observed following a drop in 2011 and in recent years, the market has fallen slightly from a peak in 2014 and has continued to shrink into 2019. As longer-life fluid increasingly becomes the norm in vehicles, demand for antifreeze is expected to slowly shrink despite increases in the size of the fleet offsetting much of the loss. The impacts of the coronavirus are further expected to dampen the demand for antifreeze in the short-term.

Of course, these estimates capture only the light vehicle side of the coolant market. Although this is the single largest portion of the overall market, significant volumes are sold in other parts of the automotive space as well as numerous other industries. The light vehicle fleet, other areas of the automotive space, and these other industries have been identified as target loss areas and are discussed in section 4 below.

3.2 Review of Unrecoverable Antifreeze – Previous Study

Dessau – Ni 2012 Unrecoverable Antifreeze Study

The Dessau report covered Canada broadly, focusing on antifreeze use and recovery rate nation-wide but offered data broken out into specific regions. For British Columbia, the study estimated a rate of *recoverable* antifreeze at 47.6% for drains/replacement and 45.0% for coolant lost due to consumption and breakages. The study utilized data from as early as 2006 in the calculation process and the landscape of the industry changed significantly since then. Some clear use cases for antifreeze were also omitted.

- DIY versus DIFM rates have shifted significantly. According to the DesRosiers Light Vehicle Study, 26.1% of individuals choose to perform complete coolant replacement themselves in British Columbia. These rates have an impact on the unrecoverable rate due to the relative reliability of professional repair shops and their materials handling processes versus an average consumer choosing to perform work themselves. For coolant top-up, 47.3% chose to perform it themselves in BC.
- Volumes of antifreeze used in vehicles vary with engine size, among other factors. The fleet in British Columbia consisted of a larger amount of passenger cars in 2010 (the year of the data used) versus more recently. The ratio of light trucks in the fleet has increased, which has likely shifted the average volumes of coolant used.
- A variety of other factors have shifted in the light vehicle fleet since 2010 than require consideration. The same is true for the medium and heavy-duty fleets as well as other on and off-road vehicles.
- Motorcycles, mopeds, and similar vehicles were not given consideration in the Dessau study. Many of these vehicles (with the exception of air-cooled models) utilize antifreeze and make up a non-insignificant portion of vehicles in British Columbia. In fact, these vehicles alongside ATVs, UTVs and the like represent a growing demand as well as their own difficulties in terms of used antifreeze collection.
- The calculation for industries outside of automotive consisted of looking at the number of heavy equipment sold per year. Several industrial uses outside of this exist.
- While the marine industry may not require the volumes that ground-based engines do, boats and boat engines still utilize a non-negligible amount of antifreeze for cooling and winterization use.

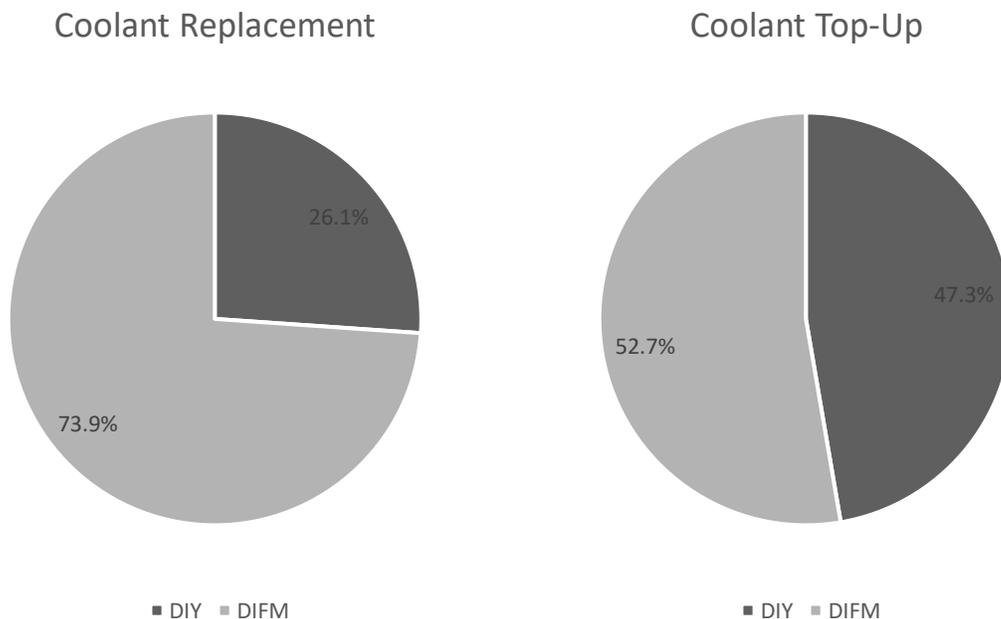
4 Target Loss Areas

4.1 Light Vehicle Fleet

The light vehicle fleet, consisting of passenger cars and light trucks such as SUVs, vans, and pickups make up the largest portion of antifreeze use in British Columbia. In 2019, the light vehicle side of the fleet was comprised of roughly 3.87 million vehicles on the road, occupying 93.6% of the total on-road vehicle fleet. The other 6.4% was comprised of medium and heavy duty trucks, buses, as well as motorcycles and mopeds. As a result of sheer numbers, the BC light vehicle fleet is comprised of a wide variety of vehicles with different engine displacements, engine and cooling designs, efficiency targets, overall age, and applicable cooling methods. This wealth of variables directly impacts differences in antifreeze use as well as loss.

Coolants are sold and marketed for light vehicles with a very broad lifecycle range. Some older and cheaper fluids require a full coolant flush at as early as 30 thousand kilometers while others are filled with fluid that is expected to last the lifetime of the vehicle, allowing for occasional top-ups.

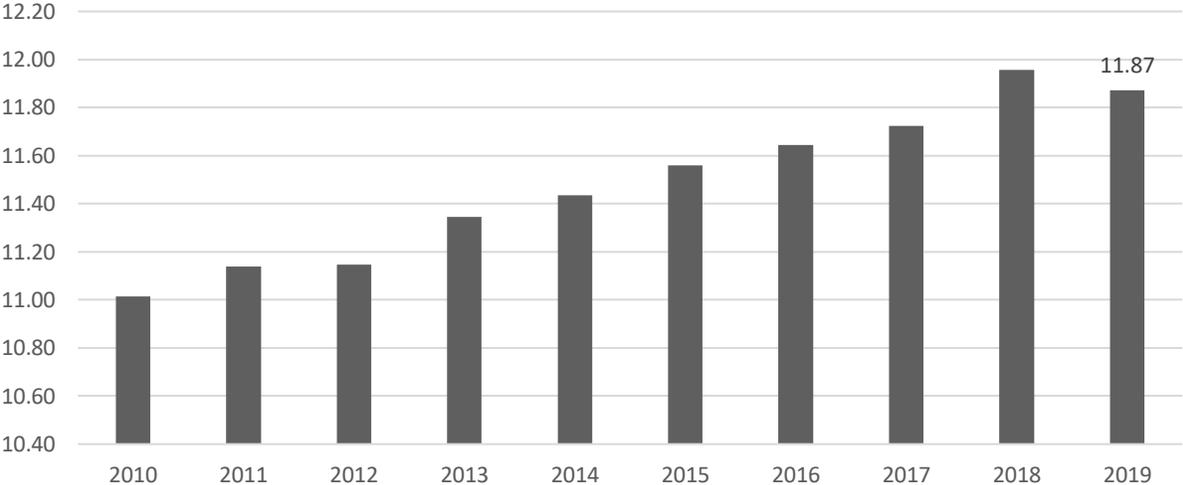
One important point of distinction between the light vehicle fleet versus the medium and heavy duty fleet is the rate of DIY work. In other words, the light vehicle fleet sees a greater percentage of vehicle owners opting to perform routine work on their vehicles themselves rather than have a professional perform it for them. This distinction is crucial as unrecoverable antifreeze through improper disposal is more likely in the case of DIY work. With a wealth of regulatory oversight in the province, professional outlets are unlikely to dump used coolant onto the ground, into a wastebbin, into the plumbing, or a variety of locations that an individual owner may consider to be far more convenient than proper disposal. It is expected that the rate of DIY work performed has a direct impact on at least a portion of the total unrecoverable antifreeze in BC. Although, even in professional environments, full coolant replacement often only captures a portion of the antifreeze, with significant amounts flushed with water from the cooling system. This remaining antifreeze is either lost to the environment or is too diluted to be worth collecting and processing.



Source: DesRosiers Automotive Consultants Inc. LVS Study

Vehicle age is another important factor in British Columbia, which has one of the nation’s oldest fleets at an average of 11.87 years old compared to the national average of 9.82 for 2019. It goes without saying that older vehicles are more likely to develop coolant leaks, which are basically 100% unrecoverable, certainly while undetected. Older vehicles are also more likely to have DIY work performed on them, further increasing the potential for coolant loss. As such, vehicle age also has a direct impact on at least a portion of the BC total unrecoverable rate for antifreeze.

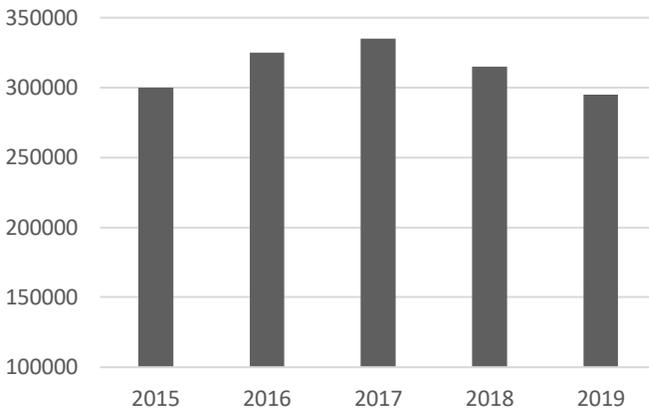
Average Age of BC Fleet - 2000-2019



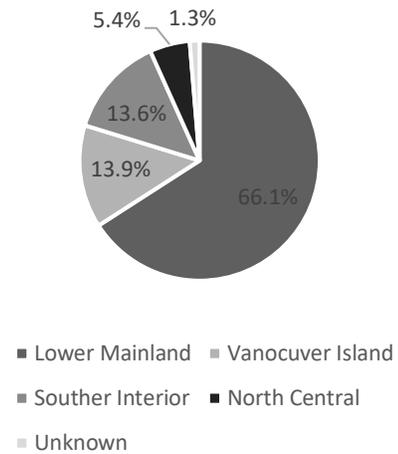
Source: DesRosiers Automotive Consultants Inc. and Registration Data © IHS Automotive driven by Polk, 2019 data released Fall 2019. The use of any part of these tables or charts reproduced, transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, or stored in a retrieval system, without prior written consent of IHS Automotive is an infringement of copyright law.

Collisions are also a very common source for antifreeze loss. Of total collisions on the road in 2019, the light vehicle fleet made up 95.2%—roughly proportional to their presence in the larger fleet. In the case of a significant frontal or side collisions, damage to radiators or the cooling system is fairly common and, in these cases, the majority of antifreeze is lost. This is largely an unavoidable source of antifreeze loss that will persist for—at the very least—decades to come. On average over the past 5 years, 315 thousand collisions were reported across British Columbia. The true number is likely greater as well, due to unreported accidents, especially those in more remote regions. The lower mainland area of British Columbia—in a typical year—accounts for approximately two thirds of all reported collisions in BC with other regions occupying a far smaller percentage by comparison.

Collisions Reported to ICBC - 2015-2019



Collisions by Region - 2019



Source: DesRosiers Automotive Consultants Inc. and ICBC

This will only start to shrink as a source of antifreeze loss once internal combustion engine vehicles are replaced by electric vehicles in significant numbers. Although EV collisions will also be a source of some coolant loss as most EV's have coolant-based battery thermal management, with a chance of coolant spills in significant collision events. Further into the future, autonomous driving technology is theorized to be able to mitigate collision rates, but this would be a very long-term change.

Collectors have clear incentive to pursue used coolant available from vehicle repair shops of various kinds. Through direct interview with collectors, the bulk of the used coolant coming from this source is shipped across provincial lines after processing, with the intent of recycling into new antifreeze or other industrial use.

Overall, the light vehicle fleet sees unrecoverable antifreeze result from top-ups, waste during maintenance, improper disposal, as well as equipment failure or accidents.

4.2 Medium Vehicle Fleet, Heavy Vehicle Fleet, and Buses

Medium and heavy-duty vehicles—including buses—account for a total of 4.6% of the on-road fleet in British Columbia. Despite this small presence in the fleet, these vehicles have a disproportionate effect on antifreeze use. Part of this is due to their high rate of use. Although these vehicles are fewer in number, they are driven far more and generally have a longer service life so any given number of medium and heavy-duty trucks will travel significantly more kilometers annually than the same number of light vehicles. Another factor adding to this is the volume of coolant used, with larger engine sizes necessitating larger cooling systems, and therefore more antifreeze.

The coolant lifecycle in medium and heavy-duty trucks can vary as much as in the light vehicle fleet. Some older legacy fluids are designed to last no more than 30 thousand kilometers. However, there are fluids available that are designed to last well into the millions of kilometers of use, allowing for occasional top-ups.

In line with their presence in the fleet, medium and heavy-duty vehicles accounted for 4.1% of reported accidents on the road in 2019. According to mechanics, general sentiment points towards a greater chance of coolant loss in the event of collisions for medium and heavy-duty trucks due in part to the placement and relative vulnerability of the radiators and cooling systems in these vehicles. Of course, the loss of coolant is greater per collision compared to a light vehicle.

One important area of note for these vehicles is the difficulty of collection procedures in remote areas. With some trucks operating largely away from the full reaches of antifreeze recyclers, collection and proper disposal of coolant becomes increasingly difficult with distance. This is true for smaller mechanic shops operating in these areas that may stray way from regulation due to convenience, or the financial costs of used coolant shipping that proper disposal would impose. This is likely a fringe case relative to the bulk of the medium/heavy fleet but it bears mention as collection efforts have significant blind sides further North into the province.

In terms of DIY work, it is expected that DIY work is performed less frequently on these vehicles versus light vehicles, and is less of an issue when unrecoverable antifreeze is concerned. Although there are plenty of older trucks on the roads in British Columbia, general standards for preventative maintenance are expected to be higher, reducing the impact of leaks and small accumulating damage over time, although this is still a point of concern. The same points about coolant lost during full coolant replacement apply in the medium and heavy duty space the same as for the light vehicle market.

Much like the light vehicle fleet, antifreeze is left unrecoverable in the medium and heavy duty fleet through top-ups, waste during maintenance, as well as equipment failure or accidents. However, improper disposal can be considered a lesser issue for these larger vehicles.

4.3 Motorcycle, ATV, and UTV

Motorcycles, ATVs, UTVs and mopeds are a very small portion of the fleet in British Columbia, accounting for roughly 1.77% of the total. However, these vehicles cannot be painted with quite the same brush as other vehicles. One important area of distinction between motorcycles and other parts of the fleet is the rate of DIY work. Vehicle owners perform routine maintenance on their two wheeled vehicles at greater rate than other vehicle types due to a variety of factors including ease of maintenance due to size, cost, limited access to workshops, and cultural factors (motorcycle owners are encouraged by their cohorts to 'turn their own wrenches'). As discussed, a higher rate of DIY work would go hand-in-hand with a higher rate of unrecoverable antifreeze due to individual owners being more likely to ignore regulation and best practises regarding used antifreeze.

Some important distinctions of note are the volumes. With smaller displacement engines, motorcycles use less coolant per flush and per top-up, reducing the overall impact of the increased DIY work. While some vehicles in this category are air cooled, these are largely targeted at children or entry-level off-road purposes. The majority of modern motorcycles are liquid cooled, in a similar manner to a typical light vehicle.

Alongside this, the popularity of ATV's, UTV's, and Side-by-Sides is rapidly growing. These are all vehicles utilizing liquid cooling, with larger cooling system capacities than typical motorcycles. Beyond this, these vehicles are far more likely to be involved in collisions or off-road accidents leading to coolant loss in the field due to the nature and location of their use. As many of them are off-road only vehicles, they are

difficult to move on the road—requiring a trailer and significant time—and are therefore far more likely to have DIY work performed on them when maintenance is required.

All the same sources of antifreeze loss that apply to the light vehicle fleet apply here, although with different proportions. This includes top-ups, waste during maintenance, improper disposal, as well as equipment failure or accidents.

4.4 Aviation

The main source of unrecoverable antifreeze in the aviation industry is aircraft de-icing fluid. While multiple types of de-icing fluids are used, the selection of which needs to be used is based often on climate. In significantly colder northern climates, BC airports—smaller in size relative to southern airports—use higher amounts of propylene glycol based de-icing fluids. In more temperate conditions, a greater quantity of ethylene glycol fluid is used. Precipitation also greatly affects the choice of de-icing formulation. This fluid is sprayed directly onto airplanes right on the tarmac at the airport. Some amount of it flies away with the airplane, and a large amount of it ends up falling to the ground where it is applied. This can be applied and handled directly by the airport or by the airline companies or third-party companies.

There are collection methods that are well known to airports. The common method would be collection pools where the de-icing fluid is moved/flows to. This collected antifreeze is collected and processed and resold, sometimes by the airport themselves. However, these open-air pools present a significant problem. Water from precipitation often gets in, alongside various kinds of contaminants. These need to be removed in processing in order for the antifreeze to be usable. If the concentration becomes too low, it becomes distinctly expensive to process it and not worthwhile to collect it with that intent. As a result, many airports do not have thorough collections in place and the bulk of the de-icing fluids used in these circumstances end up elsewhere. Oftentimes, while the de-icing fluid is still collected, it ends up in holding tanks where—after some testing to comply with local regulations—the antifreeze is drained into a sanitary sewer. The specifics change with jurisdictions. Higher volumes would be a determining factor as well, with higher volume airports more likely to find collection with the intent of re-use or selling to be more profitable.

The aviation industry by necessity also utilizes a fleet of vehicles for a variety of tasks including snow plows, loaders, and even dump trucks and firetrucks. These fall into the medium and heavy-duty fleet analysis and are usually maintained to fairly strict standards either by the airport themselves or an outside company. Combined with the limited chance of accidental damage and collisions, antifreeze loss from these vehicles air airports is minimal at a provincial scale.

This industry is a large source of unrecoverable antifreeze—or a similar-enough fluid—in British Columbia, but is not a focus for BCUOMA and will therefore not be factored into final calculations. However, it should be included as a point of discussion when considering the full breadth of EG and PG use across BC.

4.5 Marine

British Columbia is a coastal province, with largely year-round accessible waters available for watercraft used for both business and leisure. The marine fleet in British Columbia is comprised of approximately

20 thousand individual boats of varying sizes. Mostly, these are fishing boats, recreational boats, and ferries. The vast majority of these boats are filled with inboard marine engines and these engine types have closed cooling loops built in of varying sizes. Small leaks in these cooling systems are often pumped out with the bilge water and as such, frequently go unrepaired for long stretches of time. While most of this marine fleet is likely professionally maintained, more remote regions on the waterway likely make proper recycling of coolant difficult. As part of the regular maintenance of these engines—more often outboard—antifreeze is also used to winterize them. In both applications, individuals will likely opt to use the more commonly available EG-based automotive coolants.

In total, the marine industry sees unrecoverable antifreeze coming from top-ups, waste during maintenance, and improper disposal. While equipment failure and accidents may occur, these are most likely quite rare and account for negligible quantities of antifreeze.

4.6 Off-Road, Construction, Farm Vehicles and Industrial Coolant Re-Use

A large quantity of antifreeze is also used in the industrial space. Much of this is used in the fleets of vehicles—both on and off-road—that are required for a variety of industrial tasks. Examples range from excavation equipment, earth movers, bulldozers, loaders, trenchers, and the like. These machines differ only superficially when compared to heavy-duty trucks given similarly large engines and large volume requirements for coolant. Past this, stationary engines are frequently used for industrial purposes which can use large quantities of coolant but often have a very long lifecycles with limited need for top-ups. With the volumes in question, thorough regulatory and best-practises framework is applied for such machinery and the disposal and collection of antifreeze is generally performed by regulation-abiding outside companies. With large enough industrial players, in-house maintenance teams are maintained that work on the machinery on-location, allowing for a controlled horizontal spread of business tasks, minimizing antifreeze loss as a percentage of volume. While coolant loss through accidents is less common, equipment/part failure is a notable concern. EG products see use in the mining industry as well. However, concrete information about volumes of EG use in this space are limited as is information about the source of the EG (i.e. new product, collected and re-used product, recycled product, etc.).

These vehicles and engines are responsible for unrecoverable antifreeze through top-ups, waste, improper disposal, and volume lost to equipment failure or accidents.

4.7 Stationary Equipment + Others

Although briefly mentioned in previous sections, a considerable quantity of stationary machinery utilizes coolant. Examples of this are mobile or stationary generators, pumps, and compressors used in industrial purposes. A great majority of this machinery is utilized in remote areas and most of this is in the form of mobile rental equipment. This category encompasses a large array of engine sizes, but most are medium to large industrial diesel engines with coolant capacity that is comparable to medium and heavy-duty trucks. As most of these machines are rented, professional maintenance is generally performed and proper recycling and collection methods are utilized. However, further remote areas offer significantly less opportunity to properly dispose of used coolant and a degree of loss is present in such cases.

These machines contribute to unrecoverable antifreeze through top-ups, waste during maintenance, improper disposal, as well as equipment failure.

4.8 Other Industrial Uses

The next category of consideration includes industrial uses outside of mobile or independent machinery. This category encompasses thermal transfer loops utilized in large buildings, often for large-scale HVAC systems. This would also include gas processing facilities that require heat transfer fluids. These systems are largely efficient and require comparatively small volumes of coolant topped-off monthly and their stationary nature greatly decreases the risk of accidental breakage. However, the main influence of these systems are their initial need for coolant when they are first commissioned. The volumes in question are substantial. However, these types of systems most often go well over 10 years without complete coolant replacement and regular low-volume top-offs. In other words, they influence total coolant volumes, but do not substantially add to the volume of coolant consumed in use.

The fluids used in these cases are largely marketed as heat-transfer fluids and while many are similar in composition to automotive antifreeze, utilizing PG or EG and similar additives, they are not captured in the final calculations of this study due to a lack of relevant incentive schemes. Like the aviation industry, this section remains as a point of discussion when considering the full breadth of EG and PG use across BC.

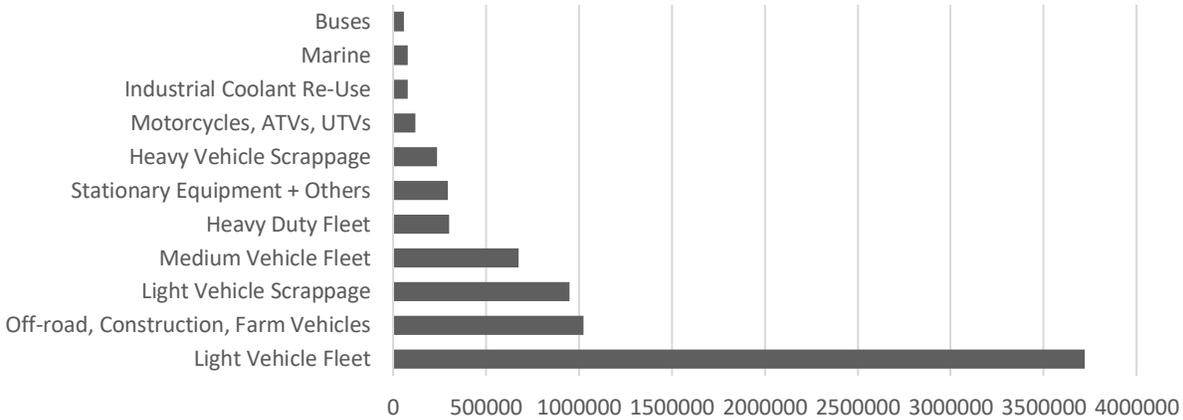
4.9 Light and Heavy Vehicle Scrappage

Vehicle and industrial, agricultural, and off-road equipment scrappage is a significant source of unrecoverable EG based antifreeze. When a vehicle reaches the end of its life and is no longer worth maintaining or repairing, it is scrapped or otherwise abandoned. While some of these vehicles may be sent overseas, most are quite simply crushed, parted-out, sold for scrap metal, and the like. It is difficult to quantify the number of vehicles that are dismantled and/or recycled by qualified personnel in comparison to total scrappage volumes, however in all cases some coolant is not recoverable. Even professional recyclers usually only drain the coolant from a cut hose, and in those cases about 40 to 50% of the coolant is not recovered and ends up lost in the recycling process. In terms of other equipment containing coolants, it is even more likely the case that the item is not dismantled by a certified recycler, and most of the coolant would not be recovered in those cases. Furthermore, with large numbers of vehicle exports from Canada, a significant quantity of coolant leaves the marketplace within the cooling systems of those vehicles. The quantities of coolant that leave the market through the vehicle and equipment export channel are included within this category.

This category contributes to the unrecoverable antifreeze total through improper disposal.

4.10 Volume Estimates and Analysis

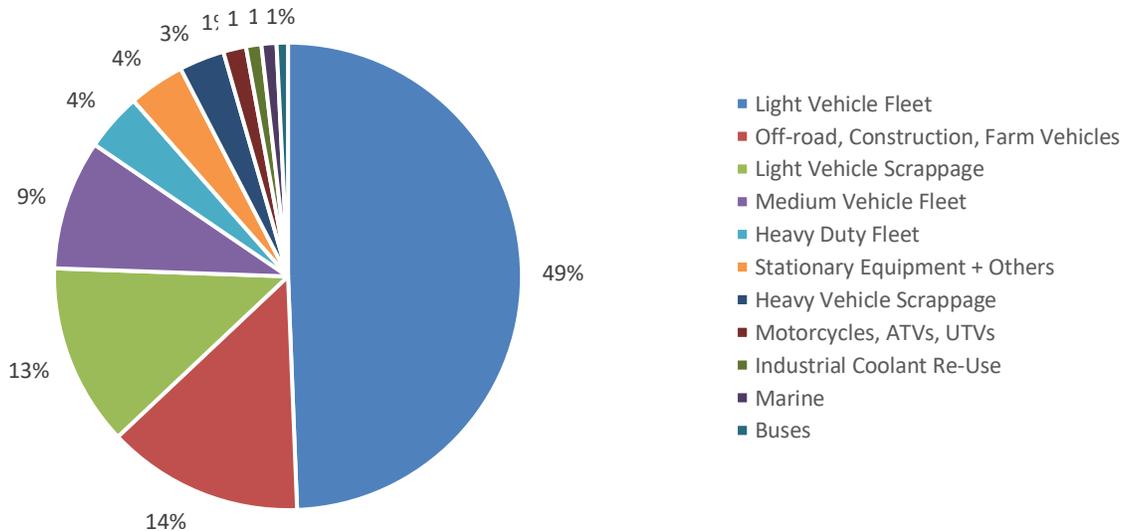
Unrecoverable Antifreeze By Target Loss Area - 2019



Source: DesRosiers Automotive Consultants

When accounting for the target loss areas, we arrive at a total unrecoverable diluted antifreeze estimate of **7,534,969 litres** for the British Columbia market. The single largest part of this total volumes comes from the light vehicle fleet at 3.72 million litres. Off-road, construction, and farm vehicles account for 1.02 million litres, the second largest category. Light vehicle scrappage occupies third place, accounting for nearly 950 thousand litres. The medium and heavy fleets account for nearly 676 thousand and 301 thousand units respectively. While the other categories are small in terms of total volume, they account for roughly 11.5% of the total volume jointly.

Unrecoverable Antifreeze Share by Target Loss Area - 2019



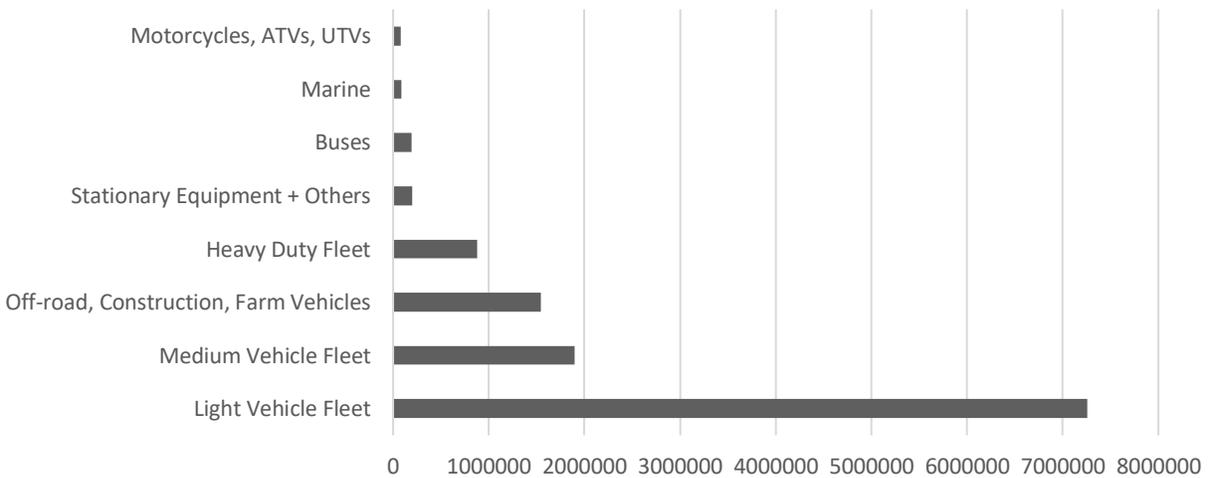
Source: DesRosiers Automotive Consultants

5 Revised Overall Market and Unrecoverable Rate

5.1 Total Antifreeze Market and Unrecoverable Rate

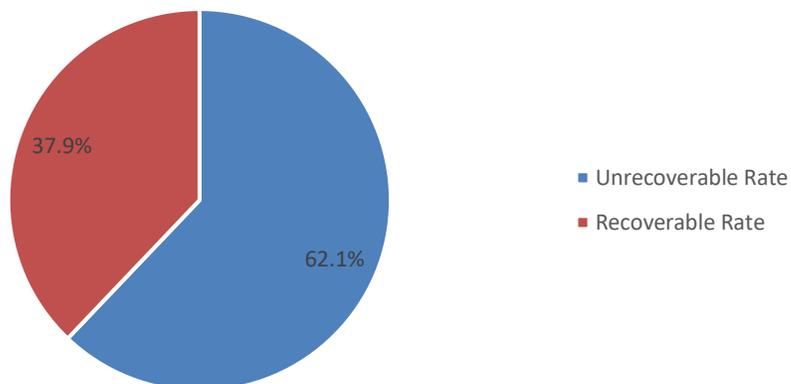
Combining DesRosiers existing coolant market model—for both replacement and top-ups—with the insights gained from industry stakeholders, we arrive at a total antifreeze market size of **12,131,751 Litres** in British Columbia. As discussed above, DAC estimated an unrecoverable volume of **7,534,969 Litres** for the province. As a result, the unrecoverable rate of the relevant antifreeze for British Columbia was **62.1%** for 2019.

Coolant Market Size By Use Area - Litres 2019



Source: DesRosiers Automotive Consultants

Antifreeze Unrecoverable Rate - 2019

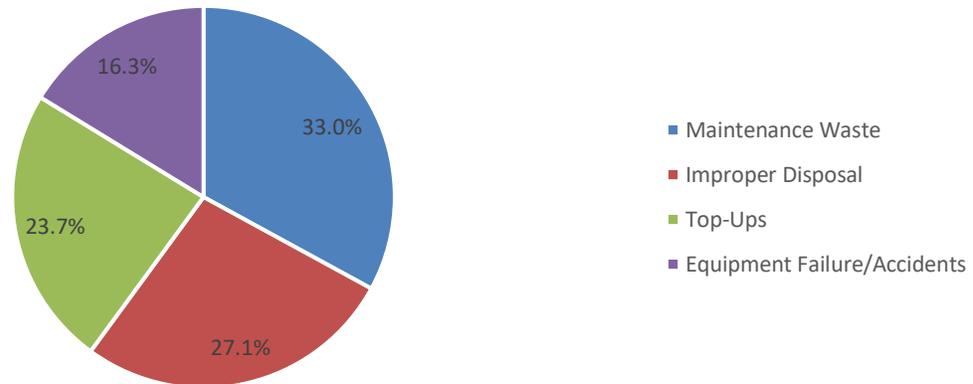


Source: DesRosiers Automotive Consultants

5.2 Unrecoverable Quantity Estimates

While the unrecoverable antifreeze volumes are estimated above by target loss areas, focusing only on specific industries or sectors along does not fully highlight the circumstances. The following section contains unrecoverable antifreeze volume estimates broken out into practical reasons for loss.

Unrecoverable Antifreeze Share by Source



Source: DesRosiers Automotive Consultants

5.2.1 Top-Ups

A top-up, by its nature, replaces an amount of coolant lost over the normal operation of an engine. As a large part of general maintenance and upkeep, it is unavoidable. The amount of antifreeze that is used to top engines up is there to replace the equivalent volume of antifreeze that was essentially lost to the environment. There are a number of reasons for this. Certain older engines, certain types of part failure, or normal wear and tear in older engines will cause some evaporation or leakage leading to coolant loss. Largely, there is no opportunity to recover coolant lost this way. As for volume, antifreeze lost to the environment—necessitating top-ups—amounts to 1.79 million litres annually in British Columbia, 23.7% of the total unrecoverable antifreeze volume.

5.2.2 Maintenance Waste

Even with particularly long-life fluid, antifreeze will need to be flushed and replaced in an engine at some point. A significant portion of the antifreeze in these engines is drained and collected. However, draining alone does not allow for total fluid replacement. A significant portion of the antifreeze remains inside the cooling system of most engines and requires flushing. This flushing process usually involves running water through the cooling system to remove the remainder which usually ends up going down the nearest drain or becoming so diluted as to not be worth collecting. In terms of volume, this maintenance waste is estimated to account for 2.48 million litres annually, 33.0% of total.

5.2.3 Improper Disposal

Improper disposal covers the situations under which the antifreeze collected during maintenance or scrapping is not processed through the appropriate channels. In other words, this is the situation under which antifreeze is simply dumped into the environment, either right onto the ground or into the nearest drain. This type of antifreeze loss is more common when DIY work is performed and in situations where regulations are less of a factor overall. This volume is expected to come largely from the light vehicle fleet, both from maintenance and from the vehicles that are scrapped at end-of-life with a significant portion of their antifreeze remaining inside during the process. The scrapping of medium and heavy-duty vehicles would also impact this figure. Outside of the light vehicle fleet, individuals or small shops performing work on motorcycles, ATVs, farm equipment, off-road equipment, and even marine engines contribute to this number at a higher rate due to the less standardized processes. This improper disposal figure is also higher the more remote a particular region is. In the lower mainland it is likely to be a quite a bit lower as a percentage of antifreeze used versus further up north where access to proper collection requires more effort and time to access and responsible handling of used antifreeze by the DIY sector is less likely. This category would also include industrial re-use of automotive coolant as well as mining use, alongside vehicle scrapping. In terms of volume, improper disposal accounts for 2.04 million litres, or 27.1% of total.

5.2.4 Equipment Failure/Accidents

Equipment failure or accidents are fairly self-explanatory. This category covers anything from a burst hose to a vehicle that is totalled in an accident, all leading to antifreeze loss. Generally, nearly all of the antifreeze lost under these circumstances is entirely unrecoverable. Prevention of loss from this category is basically impossible as is most collection and these situations can occur to basically any engine that utilizes antifreeze from road-vehicles to off-road vehicles and even stationary machinery. This category accounts for an annual volume of 1.22 million litres in British Columbia, or 16.3% of the total volume of unrecoverable antifreeze.

5.3 Opportunities for Recovery

A few highlights of collection opportunities from industry stakeholders:

- Collection in remote areas remains an impediment with few collectors able to justify the cost of collecting from these areas, especially when volumes or concentrations of used antifreeze are particularly low
- Individual and DIY work leads to improper disposal and a portion of this could be due to consumers being unaware of environmental concerns or collection possibilities. Further communication addressing these individuals through public information campaigns or information offered upon purchase of antifreeze (on the label, an attached leaflet, etc.) would reduce the volume of improper disposal if consumers are educated about the steps they can take to dispose of used antifreeze properly
- A general enhancement of the incentive scheme, especially in more remote areas, would enhance the collection rate as well
- Scrappage incentives programs exist in BC, such as the SCRAP-IT program for EV purchases. A scrap incentive program which would apply to all liquid-cooled vehicles would encourage the proper disposal or disassembly of vehicles at a higher rate of recovery of EG through certified automotive recyclers
- A significant portion of fluids similar enough to antifreeze are not collected or considered, although they have the same environmental consequences and can be similarly processed. As mentioned in previous sections, two large examples of this are de-icing fluid used in the airline industry as well as heat transfer fluid that is used in a variety of industrial and large-scale applications.

6 Conclusion

Utilizing DAC's existing coolant market size estimates, in concert with our data gathering efforts and the first-hand experience of select stakeholders an overall coolant market size estimate for 2019 was established at **12,131,751 Litres** of diluted antifreeze in British Columbia.

DAC identified **thirteen** total target loss areas where significant volumes of antifreeze are lost. Of these, **eleven** were noted to be applicable under BCUOMA's mandate. The other two—aviation and 'other industrial uses'—are significant in volumes and are potentially a source of recoverable EG products not marketed as antifreeze, but containing similar enough formulations. Ultimately, these eleven categories were:

- The Light Vehicle Fleet
- The Medium Vehicle Fleet
- The Heavy Duty Fleet
- Buses
- Motorcycles, ATVs, UTVs
- Marine
- Off-road, Construction, and Farm Vehicles
- Industrial Coolant Re-Use
- Stationary Equipment + Others
- Light Vehicle Scrappage
- Heavy Vehicle Scrappage

These categories were studied for both their volume use and recovery processes. This information allowed DAC to estimate an unrecoverable antifreeze total of **7,534,969 Litres** of diluted antifreeze for British Columbia in 2019. This led to an unrecoverable antifreeze estimate of **62.1%** of total for British Columbia in 2019, with **37.9%** left as recoverable

Unrecoverable Antifreeze Estimate by Target Loss Area

Volume of 50/50 Diluted Antifreeze - Litres - 2019

Target Loss Area	Top-Ups	Maint. Waste	Imp. Disposal	Failure/Accidents	Total
Light Vehicle Fleet	934,359	1,264,599	510,403	1,011,402	3,720,764
Medium Vehicle Fleet	244,244	330,569	-	101,107	675,921
Heavy Duty Fleet	112,935	152,851	-	35,614	301,400
Buses	24,796	33,560	-	796	59,153
Motorcycles, ATVs, UTVs	17,628	11,929	87,664	1,276	118,497
Off-road, Construction, Farm Vehicles	352,180	595,818	15,842	59,582	1,023,422
Light Vehicle Scrappage	-	-	948,629	-	948,629
Heavy Vehicle Scrappage	-	-	236,079	-	236,079
Stationary Equipment + Others	58,608	69,407	150,000	15,000	293,015
Industrial Coolant Re-Use	-	-	80,000	-	80,000
Marine	40,747	24,128	13,215	-	78,090
Total	1,785,497	2,482,863	2,041,831	1,224,778	7,534,969

Source: DesRosiers Automotive Consultants