A Review of the Ontario Green Commercial Vehicle Program Pilot (2008-2010)

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McMASTER INSTITUTE FOR
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This report offers a review of the Ontario Green Commercial Vehicle Program (GCVP) pilot that ran from 2008-2010 and assesses whether firms can save money by investing in these environmentally friendly green technologies (anti-idling devices and alternative fuel vehicles). Results suggest that this is indeed the case (see table below).

GCVP Financial Summary Table of Primary Technologies

Device	APU	Cab Heater	Cab Cooler	Propane Vehicle	Hybrid Vehicle
Cost (or Incremental Cost) per Unit	$8,200	$1,400	$2,500	$6,000	$24,400
Units Funded	591	459	58	252	258
GCVP Funding	$1.615 M	$214,200	$48,333	$504,000	$2.098M
Annual Per Unit Fuel Savings	$2471	$2203	$1337	$913	$2135
Fleet Lifecycle Fuel Savings	$10.891M	$6.342M	$465,146	$3.451M	$6.059M
Lifecycle Length (Years)	6	6	6	15	11
Annual Per Truck GHG Emissions Reduction (tonnes)	6.83	5.12	2.97	1.06	4.03
Fleet-wide Lifecycle GHG Emissions Reduction (tonnes)	24,221	14,105	1,034	3,995	11,440
GHG Reduction Cost per tonne to GCVP	$67	$15	$47	$126	$183
GHG Reduction Cost per Tonne Total	-$162	-$385	-$309	-$485	$21
ROI on Participant's Funds[1]	171%[2]	1316%[3]	381%	242%	44%
Months Before Break Even Achieved (without grant)	40	8	23	79	137
Months Before Break Even Achieved (with grant)	27	6	15	53	92

[1] This is calculated as Simple ROI with no discounting mechanisms involved. No discounting is involved in the calculation of breakeven/payback periods also. [2]$50 monthly maintenance. [3]$100 annual maintenance.

For three of the five primary technologies evaluated, the payback period for investments with GCVP support was less than three years.

The report also ascertains whether there was a business case for both: (a) firms purchasing green vehicles/technologies, and (b) government providing grants to assist in their purchase. Results suggest that, even without government grants, investments in these primary vehicle technologies make sense from a financial perspective. When environmental benefits are added to the equation the decision to invest becomes more compelling.

One of the important roles of the pilot was to collect and analyze key performance data to evaluate the efficacy and performance of the technologies eligible for the grants. In terms of anti-idling devices, the financial case for investments in cab heaters is quite justified given the cool weather in Ontario. Other devices have merit depending on specific circumstances. Auxiliary power units (APUs) were also beneficial although maintenance costs varied considerably between respective models, sometimes reducing the benefit of the APU. With regard to alternative fuels, investments in propane technologies can leverage the low prices of propane fuel to generate significant returns on investment over the lifecycle of a vehicle.

In the summary immediately below and the detailed chapters on specific technologies that follow, the GCVP experience with these technologies is outlined. While results did vary by technology, particularly some of the more speculative alternative fuel technologies, the overall outcome suggests that clean commercial vehicle technologies make good business sense.

It should be noted that the GCVP was in effect for only a short period in time. Since it was launched, enhancements and upgrades to alternative fuel vehicles and anti-idling technologies have occurred, and the financial and environmental case for them have considerably improved over and above what was experienced by the early adopters monitored by the pilot.

Introduction and Objectives

In 2007, the Ontario government sought to provide a program that would assist its Go Green Action Plan for climate change to help reduce harmful GHG emissions produced by the transportation sector which was significant. Transportation contributed one-third of all GHG emissions in the province.

The government had already developed a growth plan for sustainable urban communities, established tougher emission standards, provided for significant expansion of the public rapid transit network, assisted in the purchase of new hybrid

diesel-electric buses and electric vehicles, and expanded its high occupancy vehicle lane network.

After consultation with stakeholders and subject matter experts, the Ontario government launched the Green Commercial Vehicle Program pilot in November, 2008.

The GCVP's primary objectives were to:

- Fuel savings and enhanced competitiveness for Ontario's trucking companies.
- Supporting economic development.
- Lowering GHG emissions from transportation sources.
- Making transportation more economically and environmentally sustainable.
- Evaluating the performance of green technologies and developing business tools to aid the private sector in making purchase decisions.
- Raising awareness of available technologies to reduce emissions and improve fuel efficiency to thereby encourage broader market change.

Insofar as the pilot acted as a catalyst to affect the demand for and supply of green technologies for commercial vehicles, it was important that the most appropriate technologies were identified for the private sector.

Methods to Achieve Objectives

The GCVP provided grants for medium-duty and heavy-duty commercial vehicles such as hybrid and battery electric, propane, natural gas or hydrogen-injection. These are vehicle types that lower fuel use and greenhouse gas emissions in urban areas. Another focus was on anti-idling technologies, such as auxiliary power units (APU), cab heaters and cab coolers for heavy-duty vehicles (with sleeper cabs) which also lower fuel use.

The GHG benefit could be realized in either urban or rural locations. GCVP grants were designed to offset company investments in green vehicles and green technologies and to reduce the payback period, which varied considerably by technology. Up to one-third of the capital cost of eligible alternative fuel vehicles and environmentally-friendly technologies that reduce GHG emissions and fuel consumption could be reimbursed up to a specified cap per individual technology.

To support future policy decisions, the province collected data as part of the GCVP to measure the effectiveness of alternative fuel vehicles and anti-idling devices at improving fuel efficiencies and reducing GHG emissions.

Grant Recipients

The GCVP issued $4.7 million in grants to 171 Ontario-based companies; 65 of the companies were owner-operators. Approximately $2.7 million was flowed to companies acquiring alternative fuel vehicles while $2.0 million was received by companies purchasing anti-idling technologies. The grants were provided to a broad cross-section of firms with most being medium-sized. Some companies operated hundreds of power units and two to four times as many trailers and had operations that spanned much of North America. Other firms operated less than ten power units and specialized in the transportation of specific commodities over shorter distances.

The GCVP provided grants to 14 of Canada's top 100 carriers. Three of those companies were in the top 20 carrier category. Seven firms received more than $100,000 each. Five firms received between $50,000 and $100,000 while 13 received between $25,000 and $50,000. The majority of grant recipients were awarded less than $10,000.

The GCVP awarded 1,635 commercial vehicle grants, which included anti-idling technology grants for 459 cab heaters, 591 auxiliary power units (APUs) and 58 cab coolers. It also provided alternative fuel vehicle grants for 258 hybrid-electric vehicles, 252 propane vehicles, 7 hydrogen injection vehicles, 6 natural gas vehicles and 4 plug-in/battery-electric vehicles.

The geographic distribution of grant recipients was as follows: 45% of grants were issued in Central Ontario, 34% in Southwestern Ontario, 14% in Eastern Ontario and 8% in Northern Ontario. Virtually all of the alternative fuel grants (i.e. propane, natural gas) were provided to Central Ontario-based companies that operated in an area with higher population densities and shorter distance freight trips.

Pilot Program Accomplishments

The GCVP increased the competitiveness and efficiency of Ontario firms by reducing their fuel and maintenance costs, lowering idling time and by enabling greater use of cleaner fuel types leading to lower GHG emissions. Other accomplishments of the GCVP included:

- Raised awareness of available technologies to reduce emissions and improve fuel efficiency resulting in the purchase of 527 alternative fuel vehicles and 1,108 anti-idling devices by grant recipients.
- Significant reduction in vehicle idling rates.
- Annual fuel savings of 3 million litres translating to a cost savings of $4 million annually.

- Anticipated direct reduction of 19 million litres of diesel fuel for grant vehicles over their lifecycle.
- An expectation of over 56,000 tonnes of GHG emissions reductions over lifecycles of vehicles receiving grants funding. Although not directly tracked by this research, other types of harmful emissions such as nitrogen oxides, carbon monoxide, particulate matter and volatile organic compounds will also be reduced.
- Increased device and vehicle uptake by reducing the payback period for firms. Indeed, the GCVP induced purchases of more than 200 additional alternative fuel vehicles and anti-idling devices – these purchases took place without the support of GCVP incentives and were likely based on a favourable experience during the pilot.
- The generation of additional economic activity in Ontario; For example, $1 million in material costs for hybrid-electric vehicles was Ontario content.
- The leveraging of $24 million of private sector investment in green vehicles and technologies.
- Improved evaluation of vehicle/technology performance aiding future purchase decisions.
- An improved understanding of why vehicles idle, how much idling is discretionary, the costs of idling to firms, and the issues and benefits of new alternative fuel and anti-idling technologies.

Beyond the primary technologies supported, three types of alternative fuel vehicles were funded, which included six natural gas, seven hydrogen injection, and four battery-electric vehicles. A total of $167,000 of GCVP funding was provided for the purchase of these 17 alternative fuel vehicles to offset their price premium.

Note, that collectively, use of anti-idling devices was positive. A number of fleets found their rates of idling without anti-idling devices to be on the order of 25% to 30%; these were reduced to 10% idling or less with the introduction of anti-idling devices.

With proper maintenance, the payback period for investments in cab heaters was less than a year. It was less than two years for cab coolers. It was little more than two years for an auxiliary power unit, depending on the model purchased. It was found truck drivers played a significant role in whether fuel savings and environmental objectives were achieved; technologies had to be used correctly.

The payback period for propane vehicles was less than three years, while for hybrid-electric vehicles it was approaching eight years. For the latter, the initial hybrid-electric vehicles purchased had a longer time to breakeven compared with those which were outfitted with newer lithium-ion batteries.

For seventeen other alternative fuel vehicles in the pilot the ROI was unclear.

For natural gas vehicles, the GCVP data showed an average payback period of 7 years. Industry experts have noted that an initial investment can now be recouped in between two to seven years (Pike Research, quoted in 'TMW Investments in Natural Gas Show Major Growth' http://appian.tmwsystems.com/industry-news/investments-natural-gas-trucks-show-major-growth). The less favourable outcome seen for natural gas vehicles in the GCVP could be a function of a limited sample size or an evolving technology.

The payback for battery-electric vehicles is a function of duty cycle and route length. Payback had been envisioned to be between 3.5 to 5 years but the limited results from the GCVP did not support these estimates primarily because of undersized batteries and climatic conditions. (See 'Charged Electric Vehicle Magazine Plug-In Fleets Featuring VIA Motors' http://www.viamotors.com/news/fleetvehicles/ for more information).

The return of investment for hydrogen injection devices in trucks is reputed to be less than three years but this outcome was also not exhibited by commercial vehicles supported by the GCVP. (News: Real Life Stories, www.h2andyou.org/caseStudies_injection.asp).

Overall, and with respect to all the technologies supported, the degree to which the pilot has improved uptake is not known. There is no census of how prevalent alternative fuel vehicles are, or how many Class 8 vehicles with sleeper cabs have anti-idling devices. Challenging logistics have, to this point, precluded a follow up survey to improve the state of knowledge on these issues.

1.0 Introduction and Background

1.1. Structure of the Report

This report provides an overview of the results that were experienced by firms participating in the pilot of the Ontario Green Commercial Vehicle Program (GCVP). To the extent possible, these experiences are evaluated in financial terms based on data collected about the actual operation of vehicles in the pilot. The results presented here should give a reasonable representation of the financial viability of investments in these technologies. Return on investment is estimated both with and without financial support from the government.

In the chapters that follow, there are observations that are more qualitative in nature and which have come about as the result of a survey conducted by the Ontario Ministry of Transportation and administered to GCVP participating firms. Henceforth, the source of these survey results will be referred to as the "Ministry survey" in the text below.

The structure of this report is as follows. As well as describing the report, Chapter 1 provides a background description of the GCVP. Chapters 2 to 6 examine green technologies one at a time. Chapters 2, 3 and 4 deal with the three main anti-idling technologies (auxiliary power units, cab heaters and cab coolers) while Chapters 5 and

6 examine propane and hybrid vehicles which are two of the most prominent alternative fuel technologies.

Chapter 7 addresses three alternative fuel technologies that are less widespread and at this stage somewhat more speculative in nature. These are natural gas, hydrogen injection and battery electric. Evaluation of these latter technologies is hampered by aspects such as few participants in the GCVP for these technologies and thus minimal data. Finally, Chapter 8 offers some concluding comments and summarizes results across technologies.

1.2. Pilot Program Initiation

In Ontario, transportation is responsible for 60 mega-tonnes or 35% of annual GHG emissions (Environment Canada, 2015). A total of 13.4 mega-tonnes, or 22% of the GHG emissions are caused by medium- and heavy-duty trucks (Environment Canada, 2015)[2]. In response, the Ontario government developed a program in 2007 geared to the freight transportation sector. The Action Plan calls for 99 Mt of reductions by 2020 relative to business-as-usual, 6% of which is anticipated to come from "Freight & Diesel." This translates to 6 Mt.

After consultation with stakeholders and subject matter experts, the pilot for Green Commercial Vehicle Program (the "GCVP") was announced on August 1, 2007. It had multiple objectives, which included:

- Fuel savings and enhanced competitiveness for Ontario's trucking companies.
- Supporting economic development.
- Lowering GHG emissions from transportation sources.
- Making transportation more economically and environmentally sustainable.
- Evaluating the performance of green technologies and developing business tools to aid the private sector in making purchase decisions.
- Raising awareness of available technologies to reduce emissions and improve fuel efficiency to thereby encourage broader market change.

At inception, several green technology options were available to the freight sector; however, these options were only available at a cost premium, which in part limited

[2] Passenger cars and light trucks accounted for 29 Mt or almost one-half of GHG related transportation emissions in 2008. Also of interest is that Industrial processes generated 52 Mt of GHG emissions (27%) while buildings and electricity/heat generation produced a further 33 Mt and 27 Mt respectively (17% and 14% respectively) (Environment Canada, 2015).

industry uptake due to uncertainty about the return on investment. Also, the freight sector was not sufficiently comfortable with alternative fuel options and was reluctant to invest in them because the payback period was thought to be longer than the accepted industry standard.

The GCVP provided grants to offset the cost of purchasing approved alternative fuel vehicles and anti-idling technologies. This would reduce the cost of these technologies so that firms would be willing to invest in them. Performance data would then be collected with the intent to educate the market on the value of such investments.

1.3. Ontario's Commercial Vehicle Fleet

The Ontario commercial vehicle fleet consists of approximately 200,000 vehicles, which in the 2007 Canadian Vehicle Survey, were identified as 42% medium-duty and 58% heavy-duty (Natural Resources Canada, 2009).

Medium-duty commercial vehicles (classes 3 to 6) operate in urban areas and are between 4,500 kg and 14,970 kg in gross weight. They include city delivery and walk-in trucks, conventional vans (i.e., straight trucks), refuse vehicles, home fuel tankers, rack trucks, and beverage trucks. Their duty cycle consists of less-than-truckload (LTL) linked trips (i.e., pick up and deliveries) or fragmented direct delivery trips of short distances (i.e., "return to base"). Medium-duty vehicles are most commonly operated by private carriers (firms that carry their goods – e.g., retailers). This vehicle class, with its urban focus, allows for the use of alternative fuel vehicles with shorter ranges.

Heavy-duty commercial vehicles (classes 7 and 8) are greater than 14,970 kg in gross weight and include tractor-trailer combinations, tankers, dump trucks, refrigerated vans, and cement mixers, which are used for both inter-city and intra-city (within a city) transport, on both a truckload and a less-than-truckload basis. For-hire carriers operate most heavy-duty goods movement vehicles. The GCVP support for anti-idling devices focused on heavy-duty commercial vehicles engaged in long-haul transport that have a sleeper berth where the driver can rest when they are not driving, and vehicles that have to idle more by virtue of the commodity they are transporting (e.g., tankers that take some time to load/unload).

Transportation by trucks has a significant influence on the competitiveness of shippers, particularly in today's "scheduled economy". Faster, frequent and reliable deliveries reduce inventory and product costs and maintain customer loyalty. The old logistics model was based on the resupply of inventory, where manufacturers scheduled a production run and then pushed the resulting products into customer markets. Today products are pulled from the manufacturing process through the use of advanced communications and point of sale information, which provides a "make what you will sell

next" system, rather than sell what has been made. This just-in-time inventory management paradigm has been embraced by many sectors of the economy.

Such precision-based inventory management approaches reduce inventories at all stages of the production and staging (distribution) cycle. Under these circumstances, enterprises tend to have minimal stockpiles; however, any shortages in the inventory management system may lead to lost sales opportunities or a temporary plant shutdown. The result is a heavy reliance on transportation. Inventory and stocking locations have subsequently been centralized into regional and national production and distribution centres, from where products are produced and transported in smaller quantities but higher frequencies in response to customer demands. This process favours fast, reliable transportation and has led to greater use of commercial vehicles both for intra-city and inter-city trips.

Commercial vehicle movements and excessive vehicle idling can generate significant negative externalities, such as pollution, noise and increased congestion. In economic terms, an efficient system can contribute to growth, while an inefficient system can retard it or encourage economic activity to locate elsewhere. Efficient goods movement leads to productivity gains that form part of the final cost of goods. Long-term prosperity and social well-being involve balancing economic and environmental goals while fostering healthy communities. Green technologies that provide both environmental and economic benefits are likely to be adopted more rapidly.

The use of commercial vehicles has been increasing in concert with Ontario's population and employment growth and the adoption of supply chain management principles. At a minimum, trucking is expected to maintain its market share of commercial vehicle travel in the province. It can be expected that with a major change to the transportation sector, the sector will continue to increase along with Ontario's population. Given this likely growth, it is imperative that greater economic and environmental efficiencies be achieved.

1.4. GCVP Objectives

Several strategies were available to help the GCVP achieve its economic and environmental objectives. In the US, some states provided grants of varying amounts for the purchase of anti-idling devices while others provided loans. Several states provided grants to cover the incremental costs of purchasing alternative fuel vehicles. A prior Canadian federal government program had provided grants for anti-idling devices. In Ontario, it was decided to mirror other government-industry partnerships and focus on shelf-ready green technologies to reduce petroleum consumption and support cleaner fuels.

1.4.1. Fuel Savings and Enhanced Competitiveness of Firms

The competitiveness of a trucking firm is significantly dependent on fuel costs, which account for about one-quarter of the line-haul intercity costs for the trucking industry. This share is slightly less than the cost of the driver. The cost of fuel is proportionately much lower for straight trucks in urban operations (9% versus 57% for the cost of the driver) since much more time is spent loading and unloading the vehicle (Transport Canada, 2005). In the United States, for the first quarter of 2010, the cost of fuel accounted for 31% of motor carrier marginal costs (about 47 cents per mile), compared to 28% in 2009 (ATRI, 2011).

About 3.9 billion litres of diesel fuel were consumed in Ontario in 2007 (Natural Resources Canada, 2009). That year heavy-duty trucks travelled 9.5 billion vehicle-kilometres in Ontario, consuming 35 litres of diesel fuel per 100 kilometres. Medium-duty trucks travelled 2 billion vehicle-kilometres, consuming 23 litres of diesel fuel per 100 kilometres (Natural Resources Canada, 2009). Accordingly, the estimated annual fuel consumption for medium and heavy trucks in Ontario is about 3.8 billion litres annually.

Given the considerable amount of fuel consumed, adoption of green vehicles or green technologies would seem to be a sound business proposition for the trucking industry. Moreover, heavy duty vehicles are estimated to idle between 1,500 and 2,400 hours annually (Lim, 2003), with a second study identifying 1,830 hours as their base case (Stodolsky et al. 2000). Reduction of truck idling is also important to be in alignment with new anti-idling legislation, and anti-idling bylaws in numerous jurisdictions (albeit, mostly to address automotive idling). In addition, green technologies assist in avoiding cold starts during the winter, reducing maintenance costs and oil changes as well as extending the life of truck engines. Many of the benefits are realized by limiting the amount of engine-on time when idling.

In more urbanized environments, the modified electronics controls and drive-trains of some green vehicles significantly reduce fuel consumption through electric launch assists and regenerative braking. Improvements in conventional starter life are also noted.

Driver retention is also an important consideration for the trucking industry, particularly for long-haul, heavy-duty truck drivers. It ranked as the third most critical issue in the trucking industry in 2011 according to an American Transportation Research Institute Survey (ATRI, 2011b). Principal issues to drivers are compensation (i.e., pay/incentives, getting enough miles to earn revenue), time spent on the road (and conversely time spent with family), communication/respect, and equipment/driver comfort. It is estimated

to be on the order of $5,000 to $10,000 (US Dollars) to replace and retrain a driver (ATRI, 2011b).

There is growing recognition that improving driver comfort can help reduce driver turnover. Some green technologies provide energy for non-driving functions and enable drivers to get more and better rest per day to help comply with driver hours of service regulations. Well rested drivers are also safer less stressed drivers (Refrigerated Transporter, 2007). In addition, anti-idling devices such as auxiliary power units (APU) enable the parking lights to be left on during the evening to improve the visibility of the vehicle even as heating and cooling are being provided. These are all elements that lead to improved job comfort.

1.4.2. Supporting Economic Development

The GCVP supported the provincial initiative to generate positive economic opportunity. Though not specifically quantified for this analysis, economic benefits were generated by:

- Raising awareness about available technologies to increase the demand for high efficiency, low GHG emitting vehicles.
- Encouraging the continued enhancement of green technologies, supporting their early adoption.
- Spurring investment in new technologies and manufacturing and related industries for environmentally-friendly vehicles in Ontario, thus promoting economic development opportunities.

Producers of green technologies often call on governments to create an environment that encourages market transformation. It is seen as important that policy and legislation support the industry by providing incentives to help technologies reach commercialization (Gan et al., 2007). The GCVP and the Electric Vehicle Incentive Program are examples of such.

Economic theory suggests greater product demand could translate into superior economies of scale for manufacturers of green vehicles and technologies, which could lead to more manufacturers of such products, greater production and variety in those products and possibly lower prices. With significant uptake for green vehicles and technologies, production lines could be established in Ontario.

1.4.3. Reducing GHG Emissions

Apart from the GHG reduction focus in the GCVP, the province has supported a wide range of measures to help avoid significant quantities of GHG emissions over the

foreseeable future. Support includes a growth plan for sustainable urban communities, tougher emission standards, significant expansion of the public rapid transit network, the purchase of new hybrid electric diesel buses and electric vehicles, and the expansion of the High Occupancy Vehicle (HOV) lane network.

The reduction of GHG emissions is associated with two general technology classes in the GCVP. The first is anti-idling devices for heavy-duty commercial vehicles (class 8), which reduce the need to idle the engine during downtimes. The second is alternative fuel medium-duty vehicles (class 3 to 6 commercial vehicles), which generate lower emissions than a traditional internal combustion engine running on either gasoline or diesel. Medium- and heavy-duty commercial vehicles are responsible for about 22% of GHG emissions attributed to transportation (Environment Canada, 2015). In encouraging firms to adopt green technologies for the purpose of reducing GHG emissions, it is important to consider how these reductions are measured in the varying contexts considered in this report.

In general, the estimation of vehicular emissions is an involved topic. Typically, emission factors are expressed as rates such as grams per km travelled or grams per cold start depending on context. Emission factors can be influenced by a range of issues such as time of year, vehicle speed, road grade and traffic congestion among others. Emission factor estimates are often derived under controlled conditions in the laboratory where high-accuracy monitoring of the vehicle's emissions can be conducted while controlling the environmental factors. For an overview of issues surrounding the derivation of emission factors see Franco et al. (2013).

In this research we conducted an analysis of the emissions produced by a number of different vehicle types across a range of operating conditions. Our methods included tracking the amount of idle time saved per vehicle because anti-idling devices were being used instead, and determining the amount of engine time offset due to the employment of hybrid vehicles. During periods of idle, vehicles burn fuel at a relatively constant rate that is dependent on the vehicle class. By definition, this is a simpler context then assessing emissions from a vehicle in motion.

The typical derivation of tailpipe GHG emissions saved by an anti-idling device for a truck over a period of time is:

GHG(kg) = cumulative device usage (hours) * GHG equivalent of fuel (kg/litre) *

(fuel consumed when idling (litres/hour) – fuel consumed by device (litres/hour))

The GHG result in kg is then converted to tonnes by dividing by 1000. For the GHG fuel equivalent: 2.78 kg per litre is assumed in the case of diesel and 2.36 kg per litre in the

case of gasoline. The fact that cab heaters, for example, burn fuel when operating adds other factors that must be taken into account in estimating savings.

Similar logic is used for alternative fuel vehicles with the particulars covered in later chapters.

1.4.4. Making Transportation More Economically and Environmentally Sustainable

For anti-idling technologies, every idle hour prevented reduces fuel consumption and thus GHG production. Some idling is required during driving; however, much idling is discretionary and occurs when a vehicle is parked. A driver may idle their commercial vehicle to provide appropriate climate control within the cab, warm the engine or vehicle in the cold, power appliances such as microwaves without draining the vehicle's battery, and build air pressure for brake releases.

Unfortunately, some idling is done in the mistaken belief that it is necessary (e.g., that modern diesel engines, need to idle for several minutes or more on cold mornings), or it is just habitual (i.e., driver behaviour). The GCVP's intent was to reduce the amount of unnecessary idling.

Alternative technologies such as hybrids also reduce fuel consumption and GHG emissions by generating their own energy via on-board equipment. This is important given the increasing demand for lower production and distribution inventory levels and the adoption of just-in-time inventory/supply chain management principles that lead to more frequent trips over the course of a day.

The GCVP targeted alternative fuel technologies for new medium-duty trucks since innovations to reduce GHGs and increase fuel efficiency have emerged for vehicles in that sector. In general, technology options generally decrease as vehicle weights increase. While the greatest potential reductions on a per vehicle basis could result from medium-duty trucks being converted to hybrid, it requires a buyer who is willing to take on the risk and expense of a relatively new technology.

The GCVP targeted anti-idling technologies for heavy-duty commercial vehicles since their drivers generally travel longer distances and were more likely to idle for longer periods of time. Federal regulations require truckers (generally Class 8 heavy-duty long distance haulers) to rest for eight continuous hours every twenty-four hours. During that time, engines are often left running to control the temperature in the cab and/or to power on-board devices. Every hour that a Class 8 truck idles, it consumes 3.7 litres of fuel (EPA, 2002). A significant economic and environmental penalty results from such idling.

Given the lower cost of anti-idling technologies, more of these technologies can be acquired per fleet which can translate into significant fuel savings, large GHG reductions and less engine wear. This is further enhanced by the fact that Class 8 heavy-duty trucks use diesel fuel, which has higher carbon content than gasoline (2.78 kg/L vs. 2.36 kg/L for gasoline). The GCVP was also designed to enable older trucks, not targeted through incoming federal regulations on fuel and emissions, to reduce their GHG emissions and fuel consumption.

1.5. Improving Our Understanding of the Benefits of Green Vehicles and Green Technologies

An essential feature of the pilot was the collection of data. Such data included performance, efficacy, GHG reduction capability, maintenance requirements, and reliability. This valuable information helps guide the province in making future policy decisions and can be used by both industry and government in making capital investment decisions with respect to green technologies.

As a condition to participate in the GCVP, applicants/grant recipients agreed to allow the Ministry, or a third party service provider retained by the Ministry, to install, operate and maintain a telematics device in each vehicle. Telematics would then be used to collect performance data for a period of up to one year. The data collected by the telematics devices included fuel consumed, kilometres driven, jurisdictional or regional location, service location (urban, rural, suburban), idle time and GHG emitted. Alternatively, a participant could submit manual reports that recorded the amount of travel per month and the degree of use of the green technology. Manual reports were primarily associated with Class 8 vehicles.

Telematics devices are electronic on-board recorders attached to the engine control module of vehicles which help fleets optimize operations with real-time data. The odometer reading was verified by a certified Periodic Commercial Motor Vehicle Inspection (PMVI) inspector or Ministry approved equivalent as part of the annual PMVI. Provision was made to monitor up to 1,000 vehicles with telematics devices while the remainder would provide manual reports; a total of 748 vehicles (46% of grant recipients) were actually outfitted with such devices.

Emphasis was placed on the deployment of telematics devices on alternative fuel vehicles as there was less available field data on such vehicles relative to vehicles outfitted with anti-idling technologies. Anti-idling technologies are generally add-on features that are installed on conventionally fuelled heavy-duty commercial vehicles. Although they are more widely available and can reduce fuel consumption, they still require an upfront investment which, in the absence of the GCVP, has been a purchase deterrent to the freight sector. The GVCP sought to offset the incremental cost of green

vehicles and reduce the payback period to allow uptake and analysis of the ROI (Return on Investment).

Recipients who received GCVP funding for more than ten vehicles were required to install the telematics device on conventionally fuelled vehicles or those vehicles that did not have anti-idling devices. Thus, it was possible to measure the GHG and fuel efficiency improvements achieved by vehicles with green technologies against conventional vehicles.

About sixty companies that received GCVP grants were also contacted by Ministry staff to provide qualitative impressions on their maintenance experiences with green vehicles and green technologies.

1.6. Eligible Vehicles

The Ministry consulted extensively with stakeholders during the initiation of the pilot, and its scope reflects those consultations. A balance was sought in promoting the most promising technologies, achieving fuel savings and reducing GHG emissions across the commercial vehicle fleet.

Stakeholders recognized the value of stimulating the market for innovative technologies while helping businesses to lower their operating costs and realize efficiencies in their businesses. They also appreciated that more efficient fuel savings and GHG dollars spent could be achieved by providing more trucks with more affordable green technologies rather than by focusing on one particular class of vehicle or duty cycle.

Provision was made in the GCVP for the Ministry to consider expanding the list of eligible technologies and vehicles to capture new and emerging technologies provided that policy goals would be achieved. Proponents of the new technology and vehicles were required to verify their performance claims through a recognized agency and meet other applicable safety standards.

After significant consultation, discussion with subject matter experts, an extensive review of best practices elsewhere and internal evaluations, the two primary technology streams that were included in the GCVP were medium-duty and heavy-duty alternative fuel vehicles and anti-idling technologies for heavy-duty vehicles. Also included were alternative fuel vehicles. Eligible vehicle types used fuels that are not primarily or exclusively petroleum-based such as gasoline and diesel, but are substantially, in the opinion of the Ministry; non-petroleum based. Accordingly, the GCVP included natural gas, propane, electricity and other fuels, such as hydrogen injection.

Other options considered but not adopted for one reason or another were improved aerodynamics, rolling resistance and engine performance.

Anti-idling devices were installed in a vehicle for the purpose of eliminating the use of the main drive engine when the vehicle is idling. They include cab heaters and cab coolers which provide heat and/or air conditioning to the truck interior with the main vehicle engine shut off. Auxiliary power units (APUs) provide electrical, mechanical, or thermal energy to the primary engine, truck cab, and/or sleeper berth as an alternative to idling the primary engine. Typically, APUs support multiple functions (e.g., providing power to a cab heater, cab cooler, engine block heater, other auxiliary devices such as lights, computer), which can run concurrently for eight consecutive hours while the main engine is shut off.

A number of eligibility conditions were developed for the GCVP related to the application process, the applicant, location of use, the vehicle and the technology in question in order to meet the pilot's objectives.

Applicants were required to be an Ontario-based private sector business or individual. Applicants were required to possess a Ministry "excellent, satisfactory or satisfactory" un-audited Commercial Vehicle Operator's Registration (CVOR) rating at the time of application. Federal, provincial, municipal or territorial government or not-for-profit entities were not eligible for grants.

1.6.1. Location Requirements

The GCVP was not targeted at fully-off road vehicles such as farm equipment or drayage. For eligible vehicles, it was required that each participant vehicle:

- Be operated by an Ontario based enterprise for the term of an agreement coincident with the data collection period.
- Be operated on roads and highways for a minimum of seventy-five percent of the vehicle kilometres travelled during the term of the agreement.
- Not be used on off-road or within an applicant's premises for more than twenty-five percent of the vehicle kilometres travelled during the term of the agreement.
- Travel at least twenty percent of their annual VKT on Ontario highways to ensure greater GHG benefits accrue to Ontario (in the case of vehicles fitted with an anti-idling device).
- Have an Ontario license plate.

1.7. Pilot Program Uptake

The GCVP received 2,600 grant applications from about 280 businesses; 80% of all applications were approved. Interest was greater but a number of companies did not apply since they believed they could not meet some of the aforementioned eligibility conditions. Approximately 210 companies were awarded $5.5 million in total. The value

of those approved grants was $3.0 million for 560 alternative fuel vehicles and $2.5 million for 1,520 anti-idling devices.

Participation levels were encouraging given that the GCVP was launched at a time of economic uncertainty, and many companies had postponed purchasing new vehicles and green technologies. Some companies approved for grants ultimately did not participate in the pilot. This may have been because they could or would not comply with all of the eligibility conditions (i.e., signing of a legal agreement, providing field data, having a 'safe' driving record). Others scaled back their initial estimates of how many vehicles or devices they intended on applying for; for some vehicles, there were production and delivery issues which could not be resolved.

A total of 1,635 grants, with a value of $4.7 million, were ultimately flowed to 169 companies. 1,108 of the grants were for anti-idling devices while 527 were for alternative fuel vehicles; 65 companies were owner-operators. Approximately $2.7 million or 59% accrued to companies acquiring alternative fuel vehicles while $2.0 million (42%) was received by companies purchasing anti-idling technologies.

The GCVP issued anti-idling technology grants for 459 cab heaters, 591 auxiliary power units and 58 cab coolers. It also passed out alternative fuel vehicle grants for 258 hybrid-electric vehicles, 252 propane vehicles, 7 hydrogen injection vehicles, 6 natural gas vehicles and 4 battery-electric vehicles.

GCVP grants were provided to a broad cross-section of trucking firms, but most were medium-sized companies. Some firms had hundreds of power units with two to four times as many trailers. Such firms had several terminals providing truckload and less than truckload services to all parts of Canada and the United States using both company drivers and owner-operators. Others had less than 10 power units and specialized in the transportation of specific commodities only over shorter distances.

The GCVP provided grants to 14 of Canada's top 100 carriers. 3 companies were in the top 20 carrier category. Seven firms received more than $100,000 each. Five firms received between $50,000 and $100,000. A total of 34 received between $10,000 and $30,000 in grants while 116 companies received less than $10,000 in grants. In the latter case, these were companies that were unsure about a large commitment to investing in green technologies.

The geographic distribution of grant recipient firms was a function of the head office/principal location of the firm's principal depot(s) and the nature of its business (i.e., national versus regional carrier, nature of commodities transported, etc.); for anti-idling devices it was 45% in Central Ontario, 34% in Southwestern Ontario, 14% in Eastern Ontario and 8% in Northern Ontario. Virtually all of the alternative fuel grants accrued to Central Ontario based companies.

How well this allocation corresponds to the geographic distribution of trucking firms, or overall trucking activity in the province in general, is not known, given the scarcity of data on this subject. These proportions are similar to those for Ontario's population for the East and the North. Southwest has a higher proportion than its population size would suggest, but this is not surprising, given the amount of Ontario's trade with, and Southwest's proximity to the United States.

2.0 Auxiliary Power Units

Auxiliary power units provide heating, air conditioning, and power to a commercial truck's cab and sleeper, helping to maintain a comfortable environment for the driver with minimal fuel consumption. Use of an APU greatly reduces engine idle time and cold starts and these reductions mean less engine wear. APUs are also able to charge engine batteries if they fail.

APUs provide both emission and noise reduction benefits in comparison to idling an engine. Electronics such as computers, coffee-makers, televisions and microwaves may be run in the cabin. An APU consumes about 1 litre per hour of fuel, which is 2.7 litres of fuel less per hour than an idling engine. (Transport Canada 2012)

APUs with inverters can use battery power to run a commercial vehicle's electrical devices and can automatically recharge the batteries when they run low while still powering the vehicle. APU power varies, with higher BTU capacity units cooling or heating more efficiently than smaller models.

APUs are well suited to Ontario trucking businesses. Ontario-based long distance drivers must contend with the cold of Canadian winters and the heat of American

summers for overnight rest periods. These drivers must also spend a considerable amount of downtime while their vehicle is loading/unloading (e.g., tankers). Other anti-idling devices such as cab heaters and cab coolers, by design, are only used during parts of the year.

2.1. Vehicle Fleet Outfitted

The GCVP provided funds to supplement the purchase of APUs for 591 vehicles. The total value of these grants was $1.6 million. Ninety companies received grants for an APU; 52 purchased just one device while 17 companies acquired more than 10; the highest number of APU grants for a single company was 62.

For the analysis of the APU environmental and economic values, 195 vehicles from 12 companies were outfitted with telematics devices. The number of telematics devices installed per company ranged from a low of 1 to a high of 31. Manual reports, providing monthly estimates of Vehicle Kilometers Travelled (VKT) and APU use, were provided for the remaining vehicles.

Table 1: APU Telematics Data Monthly Survey

Month	Average VKT	Average Device Usage (hours)	Average Fuel Savings (litres)
January	13,758	102	276
February	12,937	89	239
March	15,584	78	211
April	15,446	59	160
May	20,257	59	159
June	21,282	68	185
July	24,884	69	187
August	26,728	73	198
September	26,400	68	183
October	26,352	79	214
November	24,711	80	216
December	20,949	85	229
Average	20,774	76	205
Yearly Total	249,288	910	2,457

2.2. VKT and Device Usage

The telematics monitored vehicles and manually reported vehicles differed in their average annual VKT. The dataset from telematics devices was much more extensive with 3,069 months of data compared to 312 months from the manual reports.

Company-specific information showed a wide divergence in distance travelled. This can be attributed to the type of commodities transported, the specific markets served, whether a company driver or independent owner operator did the transporting (generally the owner operator travelled greater distances) and the duty cycle (i.e., how many stops had to be made on a trip). For example, some companies transported a single commodity between specific points in Southern Ontario and Quebec while others made extensive truck-load and less-than-truckload runs into the US South and Mid-West.

Consider a series of round trips with Toronto as origin. A round trip to and from Montreal is some 1,100 kilometres; to Thunder Bay it is about 1,400 km while to Chicago it is slightly further: 1,700 kilometres. A round trip to Halifax on the east coast is 3,600 kilometres. A Laredo, Texas round trip is considerably further: approximately 6,000 kilometres while the distance for Los Angeles is 8,100 kilometres and for Vancouvereven longer: 8,700 km. It is understandable there could be such large variations in distance travelled.

The monthly breakdown of average VKT collected from telematics is presented in Table 1 above. The most heavily travelled months were August, September and October.

The annual distances travelled by trucks that were recipients of GCVP grants are greater than reported in other sources. The average VKT by heavy trucks in Ontario was some 84,200 kilometres in 2007, while heavy trucks from Quebec and Manitoba averaged 108,000 kilometres (Natural Resources Canada, 2009).

A US survey indicated that almost 60% of trucks with sleeper cabs travelled between 160,000 and 208,000 kilometres per year (American Transportation Research Institute, 2006). Companies with vehicles participating in the GCVP varied in their annual average VKT from a low of 122,000 km up to a maximum of 347,000 km. These values were identified with telematics.

Figure 1: Annual VKT for Vehicles with APUs (by Selected Companies)

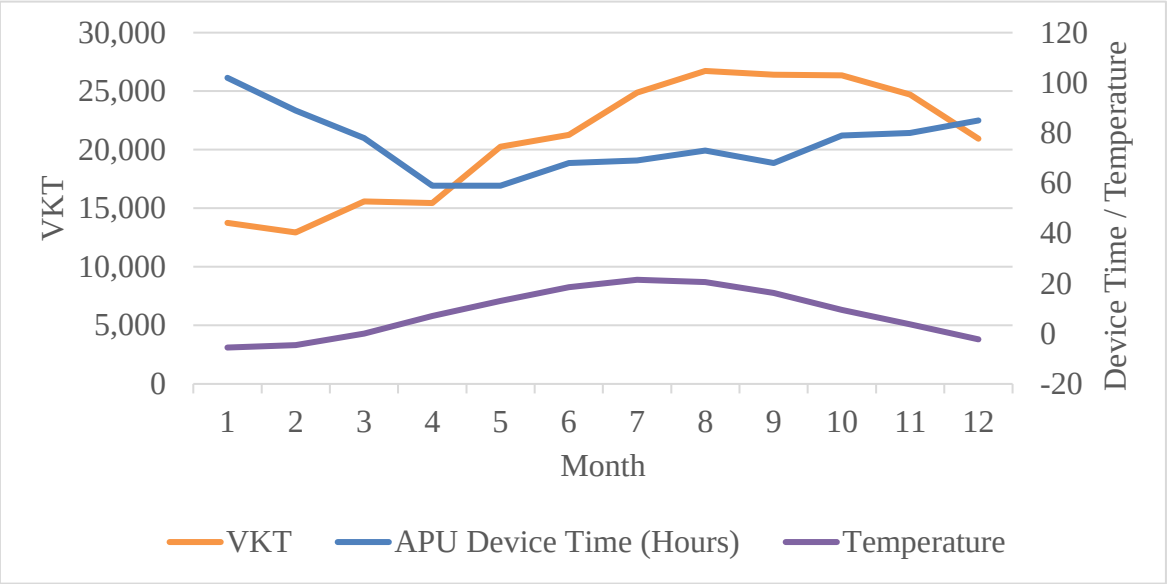
Annual average APU usage per vehicle, as recorded with telematics devices, was 910 hours. The typical APU was used on the order of 80 hours per month; September was the lowest use month with 55 hours, and January was the highest use month with over 100 hours. The variation by company of annual average VKT is presented in Figure 1.

The data indicated that there was a strong relationship between APU use and the prevailing climate (use was highest in winter) but there was not a strong linear relationship between APU use and distance traveled. This scenario is best demonstrated in January, which has a low average VKT of 14,000 but the highest APU operating hours.

The average device operation time, the VKT, and temperature at Toronto's Pearson Airport are plotted in Figure 2 for illustrative purposes. The temperature profile for northern Ontario and the western provinces will be decidedly colder but considerably warmer for some parts of the United States.

The degree to which an APU was used varied substantially between fleets and within fleets. Short-haul drivers do not use them as much as long-haul drivers who have to adhere to hours of rest regulations.

Figure 2: Monthly Temperature, APU Operation and VKT



The severity of the climate and the amount of time spent loading/unloading a vehicle (e.g., tankers and LTL loads take longer) will dictate the degree of technology deployment. Other factors include driver habits, the amount of noise from an anti-idling device a driver will tolerate, company policies and whether other anti-idling devices (such as shut-off mechanisms) are triggered.

APU use varied within companies due to driver habits and duty cycle. One company showed a variance of 100% from its average utilization, with vehicle usage of +38% and -62% over the course of a year for its monitored vehicles. Monthly differences were equally distinct and profound; each truck had a unique monthly pattern of device use that deviated considerably from the average.

Higher APU deployment occurred in the manually reported data (over 50% greater use). More manual reports were submitted by owner-operators who travel greater distances requiring more evenings and hence, more opportunities for APU use per trip. It is also surmised that owner-operators may be more concerned with the operating cost of their vehicles since they directly bear those costs while company drivers do not.

The GCVP required funded vehicles to travel at least 20% of their time in Ontario. Telematics data identified APU equipped vehicles as travelling an average of 49% of their VKT in Ontario. Adhering to the 20% requirement meant that trucking companies whose vehicles travelled large distances outside Ontario (e.g. to California) could/did not participate in the GCVP. Accordingly, APU usage based on solely on the GCVP is likely understated.

Manual reports were provided by companies for vehicles that were not tracking their vehicles with telematics. The data from these reports demonstrated lower annual average VKT. These data along with the fuel savings from the use of the APU are presented Table 2.

Table 2: APU Manual Data Monthly Survey

Month	Average Distance Travelled (km)	Average Device Usage (hours)	Average Fuel Savings (litres)
January	11,996	138	373
February	18,201	114	309
March*	18,893	116	312
April	19,585	117	316
May	11,074	109	295
June	15,445	134	362
July	19,678	148	398
August	13,097	131	353
September	11,650	138	373
October	21,291	130	351
November	18,629	129	348
December	16,684	115	310
Average	16,352	127	342
Yearly Total	196,222	1,518	4,100

*Estimated from February and April use due to manual reporting approach.

Idle time was not significantly correlated to APU usage. The relationship is complex in that as either device time or idle time increases from zero; the other variable does not increase, which suggests both options were not being utilized during the same period. However, many of the vehicles demonstrate low idle and device times, which may be due to operators staying in hotels instead of their cab, or routes/trips that can be completed within a single day.

2.3. Fuel and GHG Emission Savings

Apart from obvious environmental benefits, APUs improve the bottom line of trucking companies that use them. The more a truck travels and stops to make use of the device, the more is saved. All firms with an APU experienced a significant reduction in the amount of vehicle idling from upwards of 35% to 50% to as low as 5% to 10% idle.

The telematics data[3] identified that per vehicle fuel consumption is reduced by 2,457 litres per annum with the use of an APU. That is significant, amounting to $3,071 of savings in fuel alone (assuming $1.25 per litre). Other benefits are reduced maintenance and longer engine life.

Table 3 below shows per vehicle and overall fleet savings that result from the use of APUs across the 591 vehicles outfitted via the GCVP. GHG results reflect the assumption that a litre of diesel fuel consumed in an internal combustion engine produces 2.78 kg of GHG (Environment Canada, 2011). Results are shown on an annual and lifecycle basis with a six year lifecycle assumed.

The financial cost for reducing each tonne of GHG (based on the telematics data) was $67 for the pilot and $288 considering the total costs of both the pilot and the participant. If annual savings are taken into account, this latter figure becomes -$162. This negative cost for the total reflects very substantial fuel savings that overwhelm the capital costs in relatively short order.

Table 3: Fuel and GHG Savings from Auxiliary Power Unit Use

Duration		Per Vehicle	Fleet
Annual	Fuel Saved (litres)	2,457	1.452M
	Fuel Saved ($)	3,071	1.815M
	GHG Avoided (tonnes)	6.83	4037
Lifecycle	Fuel Saved (litres)	14,742	8.713M
	Fuel Saved ($)	18,427	10.891M
	GHG Avoided (tonnes)	40.98	24,221

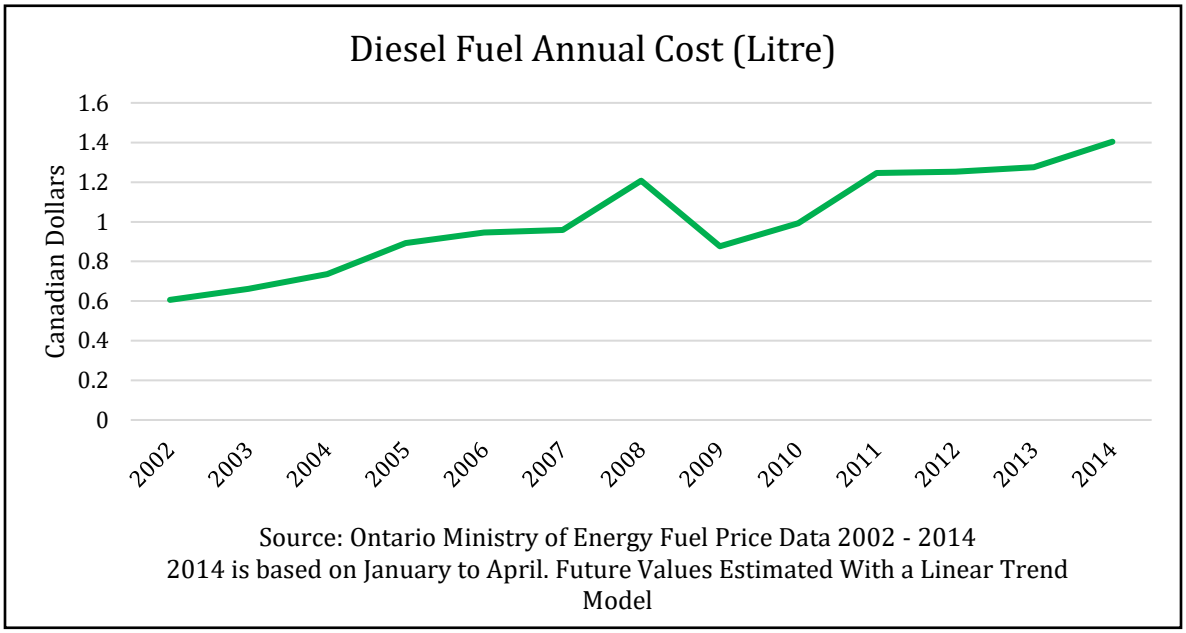
2.4. Return on Investment

The cost of APUs varied considerably; the GCVP contributed one-third of the capital cost for an APU, up to a maximum of $3,100. The purchase price of APUs ranged from $6,000 to $16,700. The average cost for an APU during the GCVP was $8,200 (excluding installation), of which the average vehicle subsidy was $2,750 with average matching funds from the participant of $5,500.

[3] The telematics data set was adjusted to remove those records which appeared exaggerated (e.g., zero VKT values or VKT greater than 44,800 km, and APU operations times greater than 310 hours per month). This represented 20% of the data.

It is important to note not all APUs are equal; some perform better than others; durability is an issue. As well, APUs require timely maintenance to be effective and such costs can vary considerably depending on the particular brand, the degree of use of the device, the climatic conditions experienced, who performed the service (in-house or contracted) and whether there were issues with getting parts/scheduling service.

Figure 3: Ontario Diesel Fuel Prices 2002-2014



Accordingly, an APU's ROI is largely dependent on fuel and maintenance costs. The Ontario average for fuel cost between 2002 and 2014 is presented in Figure 3 above. In 2009, at the start of the GCVP, the price of diesel fuel was under a dollar per litre. During the pilot, the price continued to rise to a 2014 peak. To determine the ROI, a diesel fuel price of $1.25 per litre has been assumed.

Some findings regarding firms that invested in APUs are as follows:

- A number of firms experienced a positive return after only a 1 ½ to 2-year period.
- Firms with average monthly APU maintenance costs of $50 a month, began to recognize a net gain on their APU investment after the third year.
- The lifecycle financial return for an APU after 6 years was $9,361.
- Firms with $100 monthly maintenance costs also had a positive financial gain after three years and their lifecycle return after 6 years was $5,761.

- The few firms with average maintenance costs of $300 a month were unable to get a return on their investment and would lose $8,639 over time..
- Without GCVP funding, the lifecycle ROIs would have been reduced to net gains of $6,628 and $3,028 assuming monthly maintenance costs of $50 and $100 respectively.

The lifecycle (6 year) ROI for APUs was 171%.

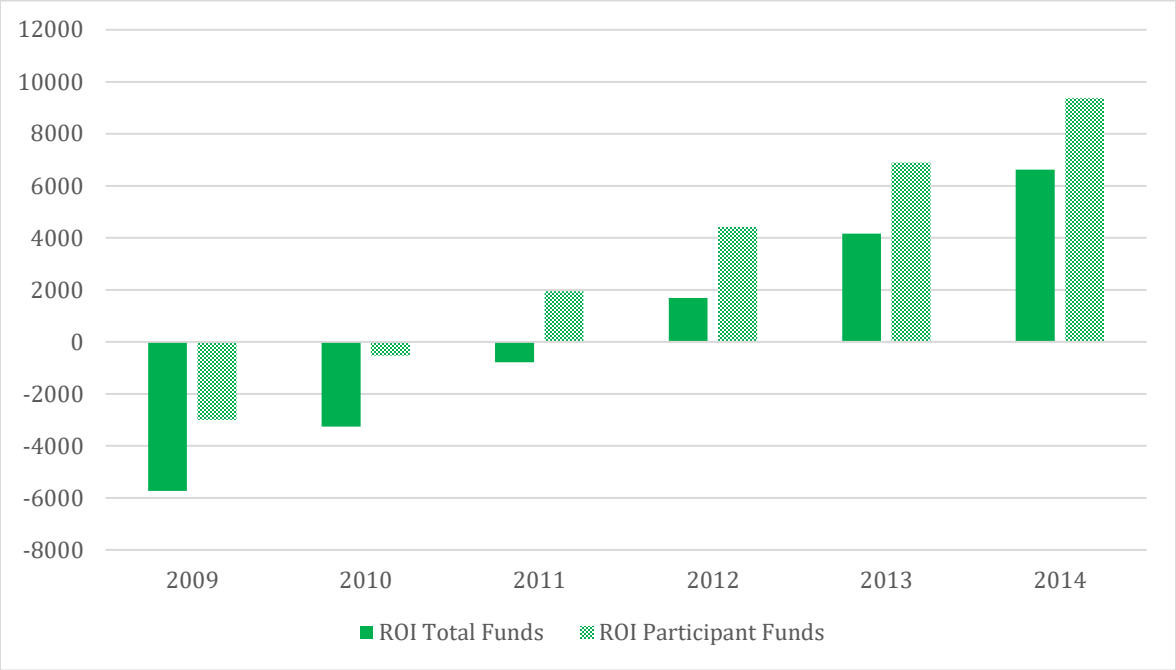
It is important to note that use of an APU will generally extend the life of an engine through less "wear and tear". This improves APU ROI to an even greater extent than can be identified here. Also, having an APU means inverters are not needed to run appliances off a truck's battery, which could otherwise cause the battery to fail. Finally, APUs were an attractive feature for drivers, providing greater comfort and flexibility for them and contributing to their bottom line; having an APU lessened the need for more expensive restaurant food.

APUs were not necessarily appropriate for all trucking companies given the higher capital costs. APUs generally cost twice that of cab coolers, seven times that of cab heaters and slightly more than the cost of both together. As well, APUs use twice as much fuel as cab heaters on an hourly basis and have much higher operating costs. One firm indicated the difference in fuel alone amounted to over a thousand dollars annually per truck.

Firms which did not send their trucks as far south or west into the United States did not gain as much benefit from APUs because they did not require the air conditioning feature as much. Figure 4 illustrates cumulative ROI for investments in APUs based on $50 per month maintenance costs. As noted, these are higher ROI scenarios.

The reason for the range in maintenance costs was partly associated with the poor performance of specific APU models. Researching available options and finding out the collective experiences of other trucking companies is thus very important before purchasing an APU. Warranties generally cover product deficiencies in its early years of life.

Figure 4: APU Cumulative Return on Investment



Firms experienced issues associated with belts, motherboards, generator/alternator/water pump failures and the rusting of APU covers given their location on the truck. APU downtime was a notable challenge for some firms. Service and the lack of available parts were the primary concerns.

The ROI of APUs is partially dependent on the driver (e.g., better for long distance haulers provided they use them correctly) and climatic conditions (i.e., is it necessary to have them work for only a few hours to maintain cab temperatures or every hour for the entire night). As with any piece of motorized equipment, preventative maintenance was important (e.g., changing oil, filters and belts). Firms which were proactive in this regard had a more positive experience.

Of those companies that purchased APUs through the GCVP, about one-half of companies surveyed had very positive experiences, one-quarter had somewhat positive experiences while for one-quarter, the experience was considered negative.

Some of the latter however, were not convinced that the alternatives (i.e., cab and engine heaters, cab coolers, truck stop electrification, overnight motel stays, leaving the windows open, continued idling) were necessarily better given particular climate challenges, battery sizes and costs, security issues and where their vehicle was being loaded/unloaded or laid over. Owner-operators were overwhelmingly appreciative of APUs, despite the costs.

On the whole, APUs were a reasonable investment for Ontario firms, mirroring or exceeding American experiences. For example, a US survey identified that two-thirds of those respondents that used APUs were satisfied or very satisfied (American Transportation Research Institute, 2006).

3.0 Cab Heaters

A cab heater draws air from outside of the cab into a combustion chamber where a small amount of fuel ignites and warms the surrounding air. The warmth provides comfort heat and can be used to pre-heat an engine to provide starting assistance in cold weather. During milder months, a cab heater can be used to reduce the dampness in the truck during the morning, providing a more comfortable environment for the driver.

Cab heaters run on the vehicle's own diesel fuel and obtain power from the vehicle's battery. Cab heaters provide an average potential fuel savings of 3.45 litres per hour when being used to warm the cab as opposed to running the engine to provide heat. Unlike the 3.7 litres per hour an internal combustion engine uses at idle, cab heaters only use 0.25 litres of fuel per hour. (Transport Canada 2012)

Cab heaters are believed to be of most benefit to Ontario businesses with smaller operating budgets or lower returns per kilometer traveled whose long distance drivers deal mostly with colder climatic conditions. Those that serve the southern U.S. but find the cost of an APU prohibitive would opt for a cab heater and cab cooler combination.

The challenge with estimating the fuel savings of cab heaters is that the telematics data do not identify if the vehicle is idling at the time. Operators may idle the vehicle to provide additional power sources for equipment such as laptops, which would result in higher fuel use than “basic” idling. Our analysis assumes the cab heater is functioning with the engine not idling in parallel.

3.1. Vehicle Fleet Outfitted

The GCVP provided funds to outfit 459 vehicles with cab heaters. At an average unit cost of $1400, the grant value for a cab heater was much lower than for an APU. The pilot funds for cab heaters totaled $215,000. Telematics could not monitor the number of hours of cab heater use; instead manual reporting was used in our analysis. Manual reports were submitted monthly and provided the number of hours of device use and the VKT; a total of 144 months of manual data were provided. Telematics devices were installed on 198 of the 459 vehicles to monitor distance travelled and location of that travel. A predetermined relationship between cab heater use and APU use was assumed to arrive at an alternative estimate of hours used for that device for such employed vehicles.

Table 4: Monthly Cab Heater Summary

Month	Average VKT– Manual Reporting	Average VKT – Telematics Reporting	Average Device Usage (Hours)	Fuel Savings (Litres)
January	9,927	13,680	87	300
February	13,401	12,476	83	286
March	13,144	15,769	80	276
April	14,103	25,982	52	179
May	16,095	21,332	14	48
June	15,531	21,654	7	24
July	14,301	25,751	9	31
August	16,383	27,950	8	28
September	12,098	25,505	10	35
October	14,732	25,928	42	145
November	12,011	26,299	66	228
December	17,551	23,240	75	259
Average	14,106	22,131	44	152
Yearly Total	169,276	265,556	534	1842

3.2. VKT and Device Usage

Cab heaters were used an average of 534 hours per year, on vehicles that averaged 170,000 VKT annually. An interesting note is that vehicles with cab heaters travelled about 30,000 km less per year on average than those with APUs. Cab heaters were rarely deployed during the summer months, i.e., 10 hours or less a month in June, July, August and September. Use during the warm months was during early morning hours in more northern or elevated climates where temperatures are cooler.

At these times, use of a cab heater is more to improve engine starts rather than to provide heat to the cab or moisture reduction.

The greatest use was between November and February when it was deployed for more than 65 hours for each month; the highest reported use was in January (87 hours). Device use and average VKT are presented in Table 4 above.

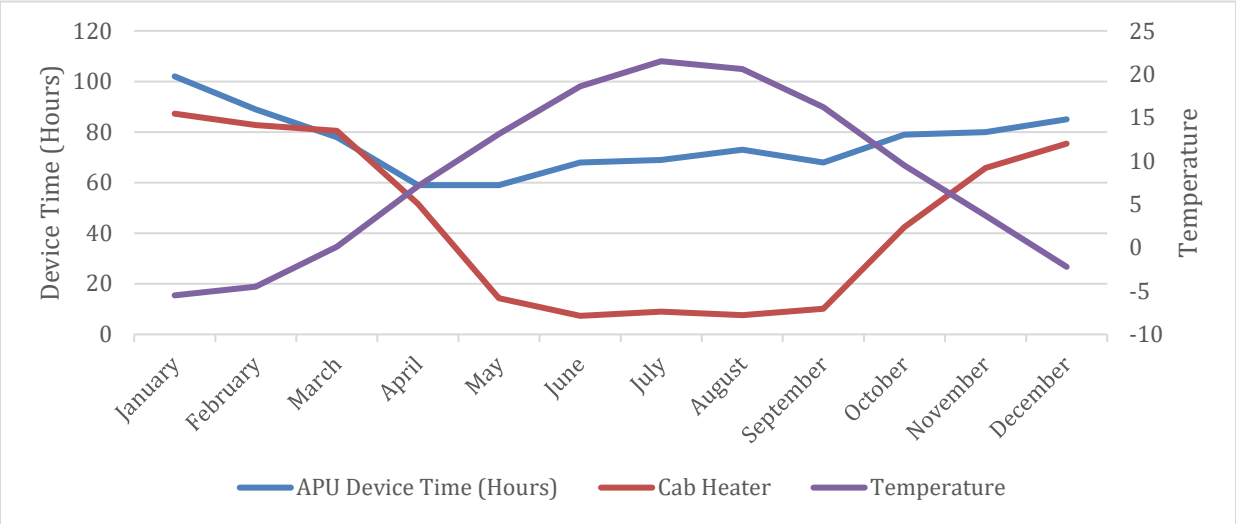
By contrast, for vehicles with telematics devices, cab heaters were used an average of 720 hours per year, on vehicles that travelled an average of 266,000 VKT annually (much greater than the VKT experienced for vehicles with APUs which had manual reported experiences). For this group, cab heaters were rarely used during the summer months – about 20 hours in June and less than 2 hours in July. The highest use was between November and February when deployment was for more than 100 hours each month; the highest reported was in December (115 hours).

The average engine-on time for vehicles with cab heaters was 400 hours per month, very similar to vehicles equipped with APUs at 378 hours. The average idle time for vehicles with cab heaters was 118 hours per month for the 12-month period, about twice that for vehicles with APUs (67 hours). Idle time accounted for 30% of total vehicle operating time. It ranged from a low of 49 hours in March and to a high of 197 hours in July.

The average VKT for vehicles with cab heaters was about 14,000 kilometres per month or 610 kilometres per working day (assuming 275 working days per year). It was lowest in January to February and highest in December, which is likely in response to the winter holidays.

Company specific information also showed a wide divergence in distance traveled for vehicles with cab heaters. Of those companies whose vehicles had only cab heaters, one company had their vehicles travel less than 12,000 km per month on average, while another had their vehicles travel more than 30,000 km per month on average (222,000 km per year).

Figure 5: Monthly Cab Heater Use, APU Use and Temperature



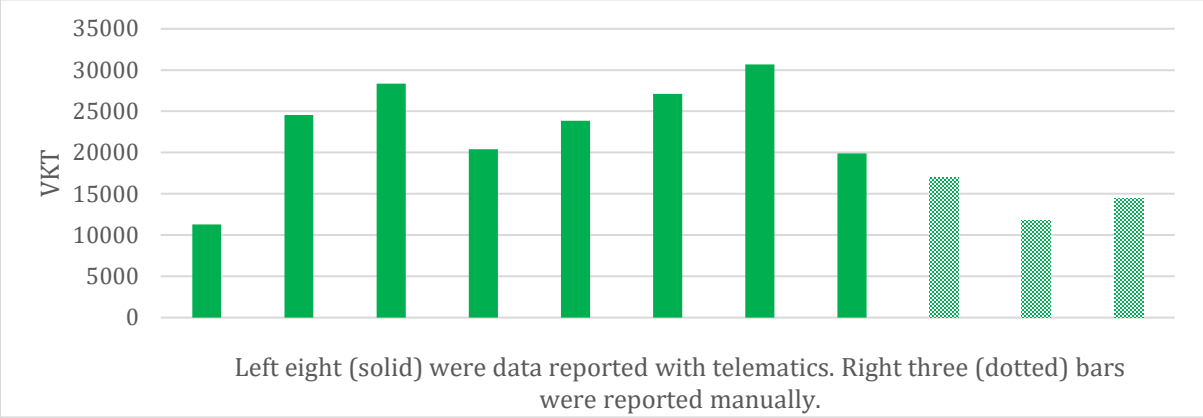
Cab heater use is well-aligned with the APU device time during months with cold temperatures. Correlation between temperature and cab heater use was very strong with r = -0.98, which indicates that cab heater use increases as temperatures goes down. Cab heaters demonstrate a smaller productive period compared to APUs because of the temperature dependence. Figure 5 above presents the APU and cab heater monthly hours of use along with the temperature.

The annual average VKT was 170,000 km, with an annual cab heater usage of 534 hours. Cab heaters were used on average 378 hours less than APUs due to the limited operation period; however, cab heaters are used primarily during the winter, which is also when APU usage is highest.

Even though telematics data were unavailable to track cab heater usage, the telematics devices were present and could be used for ascertain total VKT, VKT driven in Ontario, and total idle time. When VKT for the two sets of values was compared, the manually reporting companies were on the low end of the VKT distribution. The VKT by company is presented in Figure 6.

Tracking of vehicles with cab heaters installed showed that an average of 47% of VKT was travelled within Ontario. This result aligns with the APU finding that related vehicles traveled 48% of their VKT within Ontario.

Figure 6: Monthly Average VKT by Company for Cab Heater Vehicles



3.3. Fuel and GHG Emission Savings

Fuel savings are based on a reduction in fuel consumption of 3.45 litres per hour compared to an idling engine. The cab heater lifecycle is estimated to be six years. For the fuel and GHG savings outlined below in Table 5, bear in mind that the fleet of GCVP vehicles for this device was 459 vehicles with an average annual usage of 534 hours (recorded manually). As with APUs, other benefits beyond those below result from reduced maintenance and longer engine life.

The financial cost to the GCVP of reducing a single tonne of GHG is $15, the total cost including the participant's funds is $65. If savings are taken into account, the cost becomes -$385. Overall, this outcome is more favourable than for APUs.

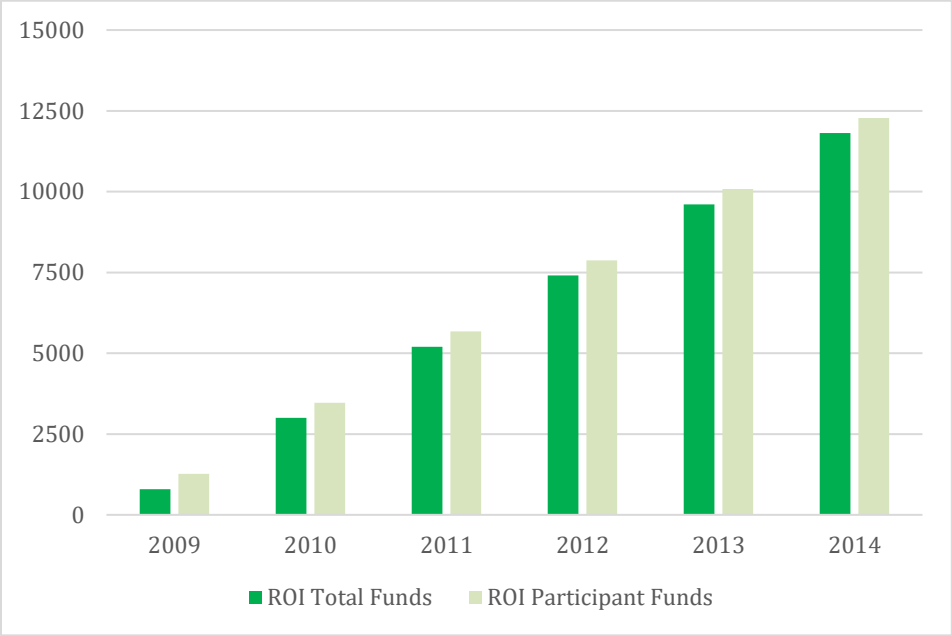
Table 5: Fuel and GHG Savings from Cab Heater Use

Duration		Per Vehicle	Fleet
Annual	Fuel Saved (litres)	1,842	0.846M
	Fuel Saved ($)	2,303	1.057M
	GHG Avoided (tonnes)	5.12	2351
Lifecycle	Fuel Saved (litres)	11,053	5.074M
	Fuel Saved ($)	13,817	6.342M
	GHG Avoided (tonnes)	30.73	14,105

3.4. Return on Investment

The GCVP contributed one-third of a cab heater's purchase price, up to a maximum value of $1,000. The pilot funded 459 vehicles at a total cost of $215,000. The purchase price of cab heaters ranged from a low of $590 to a high of $3,400. The average cost of a cab heater was $1,400, of which the vehicle grant was $468, with another $936 contributed by the participant. As with APUs, a cab heater's ROI is largely dependent on fuel cost and maintenance costs. Fuel costs were assumed $1.25 per litre and the maintenance costs (based on interviews) were estimated to be $100 annually.

Figure 7: Cab Heater Cumulative Return on Investment



The return on investment calculations are based on the same fuel estimates for the same 6-year period as the APU ROI estimates. The year by year ROI findings are presented in Figure 7, broken down by GCVP funds only and total funds.

The lifecycle (6 year) ROI for Cab Heaters was 1316%.

- **Firms were able to recoup cab heater costs within the first year, with a net financial gain of $1,100, when assuming an annual maintenance cost premium of $100.**
- **Over the six-year lifecycle, the firms saved $12,284 per equipped vehicle**
- **Without GCVP financial incentives, the lifecycle financial benefits were about $11,817 savings per vehicle.**

The ministry survey of trucking firms found an overwhelmingly positive impression of cab heaters. Nevertheless, in order to deal with extremely low temperatures on trips to Western Canada (e.g., less than minus 35 degrees centigrade), some firms found it necessary to also deploy engine heaters.

One obstacle to achieving high ROI was that some drivers at times failed to use the technology to its full potential in that they idled their engine at the same time. Companies attempted to change this behavior through idle reduction strategies or through use of various financial incentives.

4.0 Cab Coolers

Cab coolers deliver cool air to the truck's cabin without the need to idle the engine. The device that was tested in the GCVP was a battery powered no-fuel option. Leveraging the cooling properties of evaporation, the unit draws warm air from inside the cab. The air is circulated through a pre-cooling chamber and is cooled when the air molecules try to evaporate water. Given that cab coolers require no fuel, the hourly fuel savings were 3.7 litres when compared to an idling internal combustion engine.

4.1. Vehicle Fleet Outfitted

A total of 58 vehicles with cab coolers were funded by the pilot. Like cab heaters, the maximum grant value was $1,000. The cost of cab coolers ranged from $1000 to $8200. The average purchase price was $4200 and the total GCVP funds for cab coolers amounted to $48,000. Telematics could not be used to track the use of cab coolers. A combination of manual cab cooler, cab heater and APU usage data were used to determine the product's return.

4.2. Device Usage

To improve upon the manual data set, the APU and cab heater device time data were leveraged to estimate cab cooler use, which could be confirmed with the manual reports. A strong correlation exists between cab heaters and temperature, with their use being reduced to very little during the summer months; however, drivers with APUs were continuing use during the warmer months for air conditioning purposes and to power other devices.

The number of hours of cab cooler use was estimated by subtracting the number of hours of cab heater use from the number of hours of APU use. Cab cooler use was limited to the months of May to September. Estimates were validated using the manually reported data. These values are presented in Table 6; a suitable agreement between cab cooler usage estimates and the manually reported values is identified. Annual per vehicle cab cooler use is estimated to be 289 hours.

Table 6: APU, Cab Heater and Cab Cooler Hours of Use

Month	APU	Cab Heater	Cab Cooler Estimate	Cab Cooler Manual Reports
May	59	14	45	35
June	68	7	61	52
July	69	9	60	62
August	73	8	65	56
September	68	10	58	37

Battery-powered cab coolers are often nowadays a passive module powered by a truck's existing battery. Accordingly, the electricity that powers the cab cooler has essentially been harvested from the movement of the truck itself and thus does not detract from potential emissions reductions or monetary savings. For models of cab coolers where this is not the case, the costs of the electricity are assumed negligible.

4.3. GHG Emission Savings

In alignment with the prior GHG estimates, it is assumed that the engine was turned off during the operation hours of the cab cooler, for each hour of operation, the fuel savings is 3.7 litres. Note that the fuel savings per hour of operation are higher with a cab cooler than a cab heater (3.45 litres per hour) because a cab heater burns some fuel during operation. In common with cab heaters, a six-year lifecycle was assumed for cab coolers and an annual usage of 289 hours per vehicle is assumed based on results from 58 vehicles. Fuel and GHG savings are shown in Table 7.

The financial cost to the GCVP of reducing a single tonne of GHG is $47, the total cost including the participant's funds is $140 and taking savings into account, the total cost is -$309. These rates are less favourable than those of cab heaters mainly because less cooling was required in the predominant regions of use. Nevertheless, a cab cooler is a less expensive option than an APU.

Table 7: Fuel and GHG Savings from Cab Cooler Use

Duration		Per Vehicle	Fleet
Annual	Fuel Saved (litres)	1,069	62,019
	Fuel Saved ($)	1,337	77,524
	GHG Avoided (tonnes)	2.97	172
Lifecycle	Fuel Saved (litres)	6,416	372,116
	Fuel Saved ($)	8,020	465,146
	GHG Avoided (tonnes)	17.84	1034

4.4. Return on Investment

Consistent with the cab heaters, the GCVP contributed one-third of the purchase cost of the cab coolers, up to a maximum value of $1,000. The pilot funded 58 vehicles at a total cost of $48,000. The average vehicle grant was $830, with another $1,660 contributed by the participant, which resulted in an average cost of $2,500. The year by year ROI findings for cab coolers are presented in Figure 8 below.

- **Firms recouped their capital investment cost of purchasing the cab coolers by the end of the second year.**
- **The lifecycle net financial savings for each unit was $6,353. Without GCVP support, the net financial savings would be $5,520.**

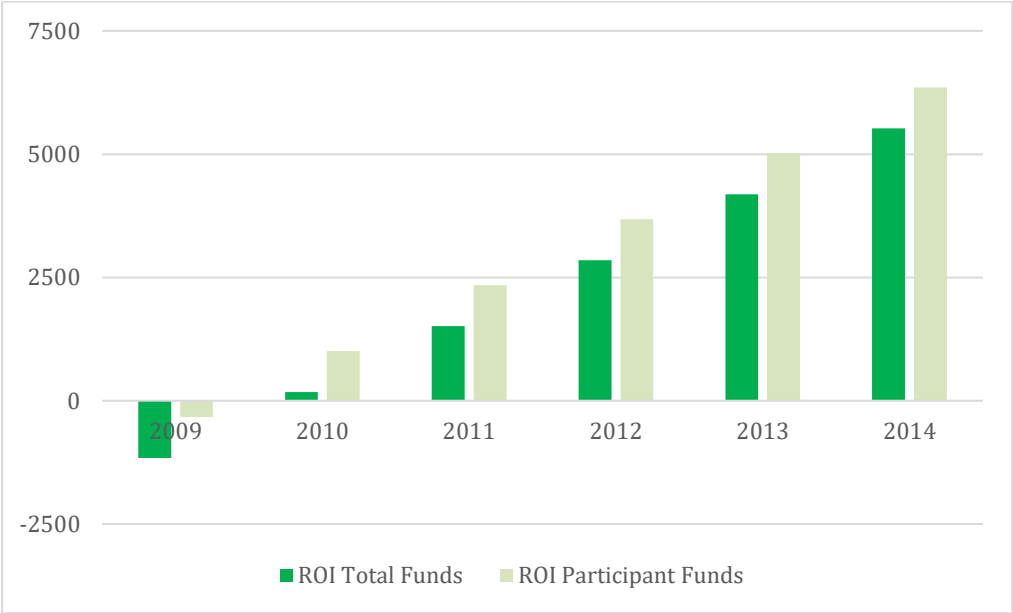
The lifecycle (6 year) ROI for Cab Coolers was 381%.

The ministry's survey of trucking firms determined that there were, at the time, issues associated with how long cab coolers could be run to deliver cold air effectively. The observed duration was generally only 5 to 6 hours and some models were less effective than others. Newer models with more batteries offer more consistent cooling comfort for a more extended period of time (i.e., the entire evening). These newer models also add additional weight because they involve more batteries.

In hot environments (e.g., Texas), it is difficult for cab coolers (and APUs for that matter) to provide sustained cool temperatures. In the ministry's survey of grant recipients, it was found that a common practice would be for drivers to run the air conditioning for a time until it was sufficiently cool and then engage the cab cooler (or APU) to maintain that temperature.

Since the conclusion of the GCVP, there have been great advances in cab cooler technologies (i.e., larger and more effective batteries). While more expensive, these deliver cooler temperatures for a much longer period of time.

Figure 8: Cab Cooler Cumulative Return on Investment



5.0 Propane Vehicles

Dedicated propane vehicles run either only on propane or use propane sequential injection technology (aftermarket systems designed to start the vehicle in cold weather using gasoline). Eligible propane powered vehicles ran exclusively on propane or had a sequential injection technology where the system automatically switched from gasoline to propane once the engine had reached the temperature required for liquid petroleum gas vaporization. Regulations stated that the switch from gasoline to propane fuel was to occur automatically and no longer than 10 minutes after vehicle start.

Propane fueling facilities are provided at commercial vehicle depots for convenience purposes. Given that such facilities are generally not widely available in many urban areas, there is an element of range anxiety with respect to this technology given the absence of a backup fuel source. The vehicles that were funded in the pilot were medium-duty intra-city delivery trucks which had a vehicle range of about 320 km.

Propane vehicles entail a capital cost premium, and the GCVP funds provided an offset of this premium. The analysis compares the ROI, fuel consumption, and GHG emission reductions based on a comparable vehicle operating with gasoline. The assessment assumes 100% propane operation with a 15 year vehicle life-cycle.

5.1. Vehicle Fleet Outfitted

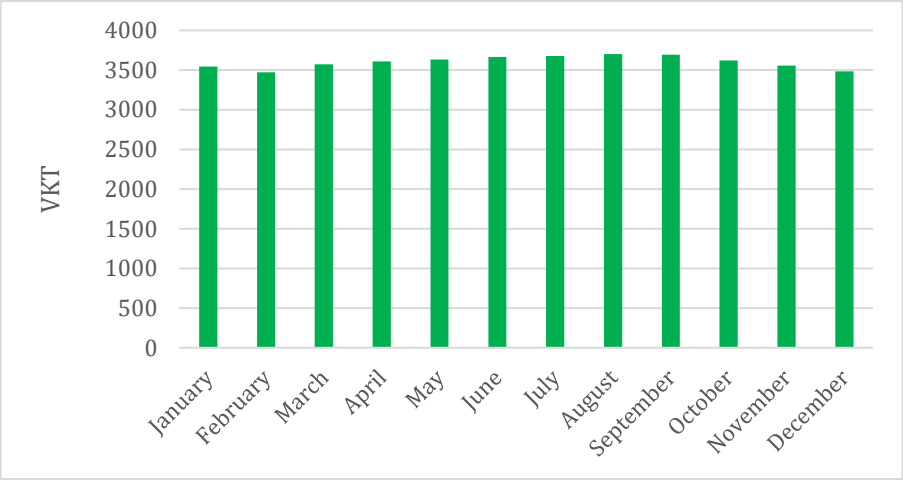
All propane vehicles were deployed for largely intra-city delivery, operating out of several distribution centres in different communities. There were 252 medium duty vehicles which received grants and these vehicles were deployed in a number of Ontario municipalities. The per-vehicle grant value for this device was $2,000, the maximum permitted for this technology; the total GCVP funds for propane vehicles amounted to $504,000. Telematics were used to track the VKT, and unlike anti-idling technologies, propane vehicles demonstrated reduced emission rates per kilometer travelled compared to gasoline powered vehicles.

5.2. Vehicle Kilometres Travelled

There was general uniformity between the various distribution centres in terms of their average monthly VKT both in aggregate and between each month. Annually these vehicles travel an average of 43,230 km, considerably less than inter-city vehicles. The annual average propane fuel consumption was 5,190 litres per vehicle.

Monthly results are shown in Figure 9.

Figure 9: Propane Vehicles Monthly VKT



5.3. Fuel and GHG Emission Savings

The use of propane as a fuel changes both the emissions and energy output per unit of fuel. The estimate of GHG emission savings is based on a comparable gasoline-fueled vehicle. Gasoline engines emit 2.3 kg of GHG per litre consumed, and propane engines emit only 1.5 kg of GHG (Environment Canada, 2011).

However, the energy generated by burning a litre of both fuels is not equal. In particular, propane requires 1.35 litres to equal the energy content of one litre of gasoline.

Accordingly, using the average of 5190 litres of propane per vehicle from above translates into 3844 litres of gasoline annually for a gasoline-powered vehicle to do the same travel. Applying the appropriate emission factors yields a total of approximately 8.8 tonnes of GHG annually for a gasoline-powered vehicle versus 7.8 tonnes of GHG for a propane-powered vehicle. A total of 1.06 tonne per year of GHG is thus saved through use of the propane vehicle.

The fuel and GHG savings are detailed in Table 8. Note that fuel savings in litres cannot be estimated since the number of litres used is not comparable between propane and gasoline.

Table 8: Fuel and GHG Savings from Propane Vehicle Use

Duration		Per Vehicle	Fleet
Annual	Fuel Saved (litres)	n/a	n/a
	Fuel Saved ($)	913	230,076
	GHG Avoided (tonnes)	1.06	266
Lifecycle	Fuel Saved (litres)	n/a	n/a
	Fuel Saved ($)	13,695	3.451M
	GHG Avoided (tonnes)	15.85	3995

GHG savings are obtained at a GCVP cost of $126 per tonne, and $256 per tonne when matched by participant funds, for a total cost of $385. Taking into account fuel savings, the total cost per tonne declines to -$485 per tonne. This latter number is the best result of all the technologies.

5.4. Return on Investment

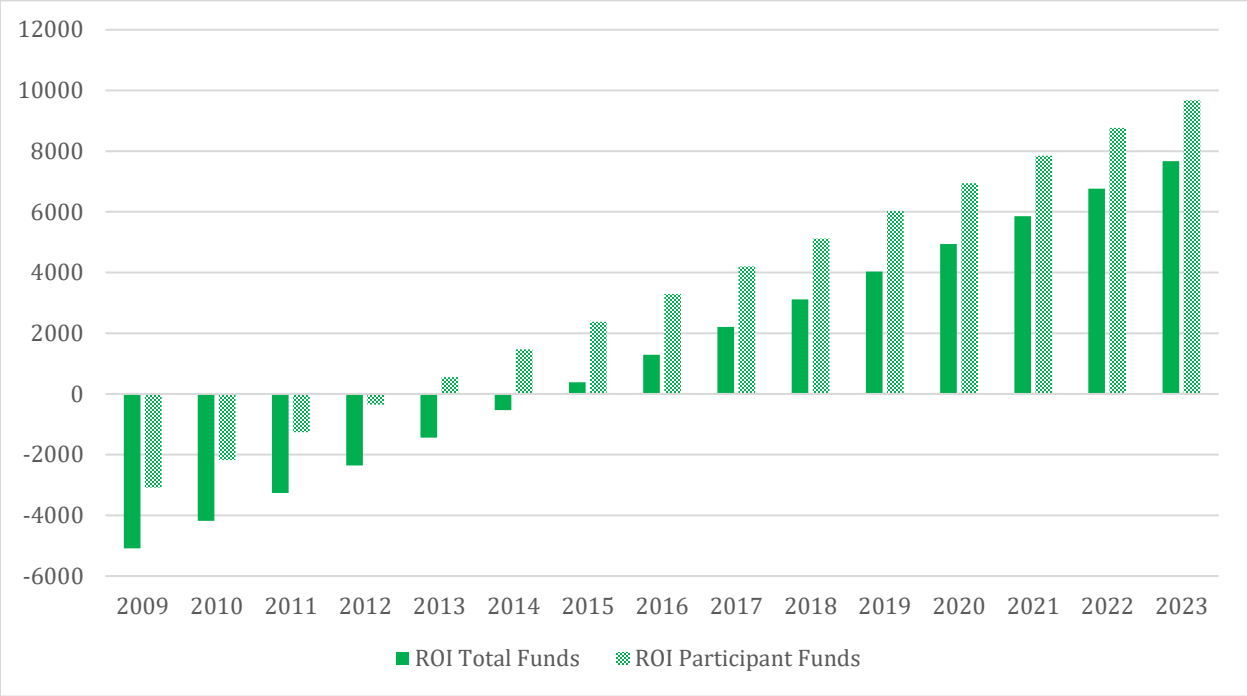
The ROI on propane vehicles is dependent on the price differential between propane and gasoline fuels and also how much the vehicle is used. Historically, the price for propane has been substantially less than gasoline in Ontario. For example, the 2013 average price for propane in Ontario was 73.0 cents per litre, 57% that of regular gasoline at $1.27 (Ontario Ministry of Energy, 2014). For the purposes of the ROI calculations, a price of $0.75 per litre is assumed[4]. This is used as a representative

[4] This price for propane has not been adjusted for the different energy content of gasoline and propane. In the GHG and ROI calculations, differential energy content has been taken into account by adjusting for volume in litres in Section 5.3.

price given that prices have varied substantially higher and lower than this figure in recent years. For gasoline the assumed price per litre is $1.25.

For each propane vehicle, the estimated price premium over a conventional vehicle was estimated at $6,000. The ROI for the 15-year life-cycle was calculated beginning in 2009. The year by year ROI is presented in Figure 10.

Figure 10: Propane Vehicles Cumulative Return on Investment



The results indicate that:

- **Firms recouped the incremental cost of purchasing the propane vehicles within five years with the support of a grant and within seven years without grant support.**
- **The lifecycle net financial savings for each unit a firm purchased was $9695 with GCVP support.**

The lifecycle (15 year) ROI for Propane was 242%.

The ministry survey of companies found that the maintenance costs associated with propane vehicles was comparable to conventional vehicles[5]. While the number of

[5] Accordingly, any maintenance costs associated with propane vehicles are not reflected in the ROI calculations as they will not generate any difference relative to the benchmark gasoline technology. This is in contrast to anti-idling technologies where maintenance costs will have a more direct bearing on the decision.

refueling stations was fewer than first envisioned, there was sufficient belief in the technology to acquire additional propane vehicles, despite the absence of further grants. The lack of stations spanning southern Ontario did result in some geographically specific range issues and consideration of alternative measures from the perspective of firms (e.g., locating propane tanks at selected terminals, use of dual fuel vehicles).

At present, fuels for alternative fuel vehicles are not so heavily taxed as gasoline or diesel because of their low use and their positive environmental benefits. With increased use, there could be temptation by government to increase fuel taxes. One concern for the alternative fuel sector is if too much of the fuel price differential is eliminated, it could reduce uptake in alternative fuel vehicles, retarding the continued development of the associated technologies.

Ontario taxes vary across fuels. Taxes are 14.7 cents per litre of unleaded gasoline, 17.7 cents per litre of leaded gasoline, and 4.3 cents per litre of propane. National taxes are in addition to the provincial taxes and include 10 cents per litre on gasoline and 4.0 cents per litre on diesel. The Harmonized Sales Tax applies to both natural gas and propane.

6.0 Hybrid-Electric Vehicles

Hybrid-electric commercial vehicles combine conventional internal combustion engines with an electric propulsion system. The hybrid technology engages when the vehicle is stopped and assists propulsion at low speeds. The hybrid electric drive train electronically supports power steering and braking providing superior engine start/stops, reduces idle and offers lower maintenance costs. Significant improvements in starter life and reduced brake wear are expected. Better fuel economy is achieved through regenerative braking and electric launch assists as opposed to accelerations powered by gasoline or diesel fuel. The results are lower operating costs and carbon emissions.

However, such investments are not without risk. As a new technology evolves, parts and service can become problematic. As well, the resale of older vehicles can be a concern because the market for such has not necessarily developed.

6.1. Vehicle Fleet Outfitted

A total of 258 hybrid-electric vehicles were purchased with funds from the GCVP, and these were deployed in a number of municipalities in Ontario. These vehicles were provided the highest level of per vehicle grants, up to 33% of the incremental capital cost of the green technology to a maximum of $15,000.

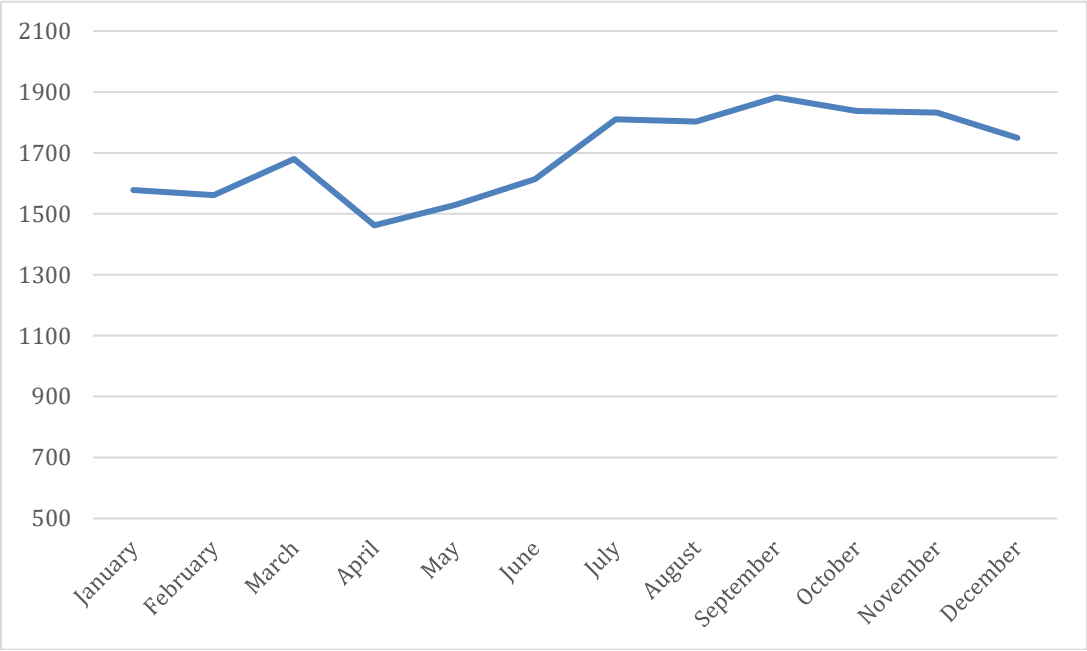
The funding for hybrid-electric vehicles totaled $2,098,000. The average GCVP funding provided for each vehicle purchased was $8,100, for a total average hybrid electric vehicle incremental capital cost of $24,400.

Considerable data was provided through the telematics devices, with 4,320 monthly records. Each record had an average idle time value. This quantity is used to calculate fuel savings since the engine would not run during this idle time.

6.2. VKT

Hybrid-electric vehicles, given their deployment in a number of communities and in both urban and suburban applications, varied in their monthly VKT, with an average monthly VKT of 1686. VKT of 1188 and 1998 defined the 25th and 75th percentiles respectively (Figure 11). The highest VKT across all vehicles occurs in September and the lowest VKT in April. The annual average VKT was 20,339, about half the distance driven by the propane vehicles described in Chapter 5. This circumstance was a function of the duty cycle chosen and the number and nature of the clients being served and was not related to the performance characteristics of the technology. This lighter usage clearly has an impact on the ROI calculations to follow.

Figure 11: Hybrid Electric Vehicles Monthly VKT Averages



6.3. GHG Emission Savings

The technology implemented in hybrid electric vehicles, directly reduces emissions by not requiring the internal combustion engine to run during idle (including short stops). The vehicle accelerates from stopped using the electric engine and switches to the internal combustion engine as necessary. For every hour of engine idling, a hybrid is estimated to save 2.0 litres in gasoline for a GHG savings of 4.72 kg, using an emission factor of 2.36 kg of GHG per litre. This result is from Gaines et al. (2007) for conventional multi-stop vans travelling less than 40,000 miles annually and forms the basis for these GHG calculations.

The average monthly idle time was 68 hours a month or 854 hours per year[6]. The hybrid-electric engine eliminates idling emissions of a conventional internal combustion engine, reducing the per vehicle fuel consumption by 1,708 litres or $2,135 per year (at $1.25 per litre). This translates into GHG emissions savings of 4.03 tonnes.

Duration		Per Vehicle	Fleet
Annual	Fuel Saved (litres)	1,708	440,664
	Fuel Saved ($)	2135	550,830
	GHG Avoided (tonnes)	4.03	1040
Lifecycle	Fuel Saved (litres)	18,788	4.847M
	Fuel Saved ($)	23,485	6.059M
	GHG Avoided (tonnes)	44.34	11,440

The financial cost to the GCVP of reducing a single tonne of GHG is $183, the total cost including the participant's funds is $550 and taking savings into account, the total cost is $21. This latter figure for hybrids is the only one of the main five technologies where a favourable result less than zero is not achieved. Largely, this reflects the high capital costs associated with purchasing a hybrid light truck and the lighter use of the vehicles supported under the GCVP.

[6] Limitations in the data available for this analysis means that savings were assessed based on observed periods of sustained idling. In reality, hybrids also save substantial fuel and reduce emissions in "stop-and-go" periods of driving. Accordingly, these estimates define a conservative lower boundary of savings and thus provide a more conservative estimate of ROI.

6.4. Return on Investment

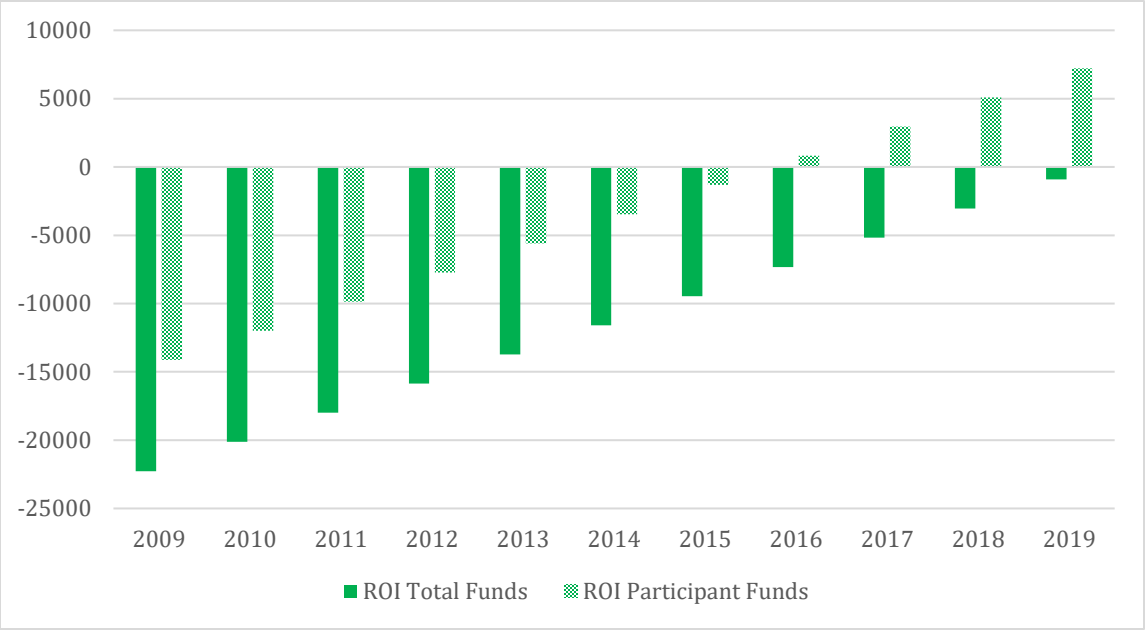
Generally, the hybrid-electric vehicle payback over equivalent internal combustion engine vehicles is estimated to be on the order of 7 to 8 years, with a fuel economy improvement of about 30%. (Gosbee, et al. 2010). Conceivably if the vehicle duty cycle is adjusted to increase frequency of use, the ROI period can be shortened (i.e., if vehicle use is increased from 80 km/day to 100 km/day).

Hybrid vehicles purchased as part of the GCVP had an incremental capital cost of $24,440 relative to a comparable gasoline vehicle. This significant premium may decline in the future as the technology gains a stronger foothold in the market.

- **Firms recouped the incremental capital cost of purchasing a hybrid vehicle within the eighth year with pilot support.**
- **The 11 year lifecycle net financial savings from each unit a firm purchased was $7218. Without GCVP support, there would be a net loss of -$915.**

The lifecycle (11 year) ROI for Hybrid-Vehicles was 44%.

Figure 12: Hybrid Vehicles Cumulative Return on Investment



The year by year ROI for hybrid-electric vehicles is presented in Figure 12. It highlights the long time period associated with retrieving the initial investment via fuel savings.

Despite the unremarkable financial results for hybrid vehicles supported by the GCVP, the overall experience with hybrid vehicles has been positive. From the ministry survey, an observed additional benefit was much lower maintenance costs (on the order of one-third less). These savings were much greater than those of fuel alone and have not entered into the financial calculations.

Where the technology was used was important as was duty cycle (greater savings were realized in dense and congested urban environments) and the size of the truck itself. The smaller trucks used in Ontario had lower maintenance costs than larger such trucks in the US. Over one hundred such vehicles were purchased after the grants were discontinued. An additional benefit for companies involved was the positive public profile associated with the showcasing of more environmentally friendly vehicles.

7.0 Other Alternative Fuel Vehicles

There was little uptake of other alternative fuel vehicles (six natural gas, seven hydrogen injection and four battery-electric) so the collective results for these are presented in this single chapter. Table 9 provides a brief summary of results.

Table 9: Summary Table of Other Alternative Fuel Vehicle Results

Alternative Fuel	Natural Gas	Hydrogen Injection	Battery Electric
Grant Value	$15,000	$2,500	$15,000
Units Funded	6	7	4
Cost per Unit	$45,000	$7,500	$45,000
GCVP Funding	$90,000	$17,500	$60,000
Lifecycle Length (Years)	7	6	7
Annual Per Truck GHG Emissions Reduction (Tonnes)	23.25	Did not appear to improve fuel efficiency measurably	31
Fleet-wide Lifecycle GHG Emissions Reduction (Tonnes)	976		860
GHG Reduction Cost per Tonne to GCVP	$92		$70

7.1. Natural Gas

Natural gas is a hydrocarbon gas that consists primarily of methane. Once the natural gas is extracted, it must be processed in order to remove impurities, hydrocarbon by-products, sulphur and carbon dioxide. Research has demonstrated that compressed natural gas vehicles operated by United Parcel Service (UPS) reduced tailpipe carbon monoxide emissions by 75 percent, nitrogen oxides by 49 percent, hydrocarbons and carbon dioxide by 7% (Chandler *et al.,* 2002). Natural gas vehicles have comparable performance (e.g. acceleration and horsepower) characteristics to conventional vehicles but their driving range is generally less because of the lower energy content of that fuel.

The range of these vehicles can be increased with larger or additional fuel tanks; however, there is an associated trade-off with payload capacity. Due to this range limitation, the technology can be of most benefit for return-to-base fleets with their own refueling infrastructure as well as for fleets that operate in regional corridors. Natural gas can be dispensed in either compressed form (CNG) or liquefied form (LNG). The former is more suited for urban applications, the latter, for long distance travel.

The GCVP supported the purchase of six natural gas vehicles involved in urban duty cycles. Within this group of vehicles purchased were the first factory-built medium-duty trucks in Canada. The grant provided for these six vehicles was on average about $15,000 per vehicle to assist with a significant incremental cost of $45,000 per vehicle. The per vehicle annual VKT for the six vehicles, which were heavily used, was on the order of 120,000, in two very different duty cycles associated with two firms.

Medium duty truck (Classes 4 – 6) fuel consumption ranges from 19 to 47 litres per 100 km based on 2007 data (Davis et al. 2014). In the current analysis, we assume 26 litres per 100 km, which is based on the median value of the fuel consumption range for class 5 trucks. At 120,000 km per year, a diesel vehicle would thus use 31,200 litres. Given that a cubic metre of CNG has the energy equivalent of 1.032 litres of diesel, 30,233 cubic metres of CNG would be required to travel the same distance. Assuming prices of $1.25 per litre for diesel and $0.75 per m^3 (or $1.06 per kg) for CNG leads to an annual savings of $16,326 per vehicle at 120,000 km annual mileage.

The emission factor for CNG is 2.1 kg / m^3 (Environment Canada, 2011) versus 2.78 kg per litre of diesel. At 120,000 km per year the GHG savings per vehicle will thus work out to 23.25 tonnes.

Table 10 below shows financial and emissions outcomes for natural gas vehicles under two scenarios. The first scenario assumes an annual mileage of 20,000 km per year and the second scenario assumes 120,000 km per year.

The latter is the result from the vehicles that participated in the GCVP. The results strongly suggest that the time to realize a return on investment is heavily influenced by how intensely the vehicles are used. At low mileage, such an investment would make little sense.

Table 10: A Comparison of Natural Gas Results

	CNG(20K)	CNG (120K)
Incremental Cost per Unit	$45,000	$45,000
Units Funded	6	6
GCVP Funding	$90,000	$90,000
Annual Per Unit Fuel Savings	$2,721	$16,326
Fleet Lifecycle Fuel Savings	$114,279	$685,674
Lifecycle Length (Years)	7	7
Annual Per Truck GHG Emissions Reduction (tonnes)	3.87	23.25
Fleet-wide Lifecycle GHG Emissions Reduction (tonnes)	163	976
GHG Reduction Cost per tonne to GCVP	$553	$92
GHG Reduction Cost per Tonne Total	$957	-$426
ROI on Participant's Funds	-	281%
Months Before Break Even Achieved (without grant)	198	34
Months Before Break Even Achieved (with grant)	132	23

Given the payback requirements, the market for medium- and heavy-duty natural gas vehicles would be high mileage "return-to-base" and regional corridor fleets. Other reasons to invest in natural gas vehicles are quieter operation and significantly reduced emissions. Following the conclusion of the GCVP, several companies have added new natural gas powered vehicles for refuse collection. Considerable interest in and acquisition of natural gas vehicles occurred subsequent to the pilot for both CNG and LNG vehicles.

The payback period is considerably shortened for several applications including high mileage refuse, transit, and highway tractors. The Canadian Natural Gas Vehicle Alliance report it as being between two and four years for CNG and LNG vehicles,

depending on annual mileage. These reported results thus appear to be in line with the high mileage scenario of Table 10.

The number of natural gas trucks in the province now exceeds 200; the number of light-duty vehicles is five times that (CNGVA, 2014). There is additional promise for natural gas as a fuel for trucks based on affordability (given recent shale gas deposit discoveries near Ontario), the addition of CNG and fueling infrastructure, efforts to harmonize codes and standards, and improvements to engine performance (TMW, 2014).

7.2. Hydrogen Injection

7.2.1. Overview and Quantitative Results

Hydrogen injection involves the addition of hydrogen to the fuel with the intent of increased fuel economy. The hydrogen can be either stored in a secondary fuel tank or produced by the electrolysis of water. GCVP funded vehicles used the electrolysis to generate fuel, which decomposes water into oxygen and hydrogen gas. The system weighs about 100 pounds when filled. This process is demonstrated to improve efficiency when the electrolysis is powered by an external source (Bari and Esmaeil, 2010); however, during real world applications the electrolysis is powered by the alternator.

The seven grant approved hydrogen injection vehicles consisted of a petroleum-based engine with aftermarket hydrogen injection systems. The latter automatically draw amperage from the alternator to generate hydrogen and oxygen that are introduced to the fuel through the air intake.

Hydrogen injection is proposed to increase the combustion efficiency of fuel providing greater horsepower, improved fuel economy and reduced maintenance (through prolonged engine life). This should translate into lower hydrocarbon emissions in particular. The units reportedly provide about 80 hours of operation, equivalent to some 5,600 km of travel. (H2 and You, Case Studies). The seven vehicles enrolled in the GCVP did not realize this fuel economy however. The hydrogen injection vehicles travelled 5 – 7 % less per litre of fuel compared to units without this functionality (see Section 7.2.1 immediately below for an account of the very positive experience of a non-participant firm).

It can be hypothesized that the hydrogen injection failed to improve fuel efficiency because of one or all of the following potential issues:

- The device adds weight to the vehicles (it should be noted that the additional weight is minimal).

- The hydrogen gas is drawn from the intake manifold. In this scenario, the hydrogen gas is mixed with air and diesel fuel and will proceed to the next stage of the four-stroke cycle (the compression stage). In the compression stage the fuel mixture is compressed to its Top Dead Centre (TDC) at over 1,200°F; at this instant the fuel mixture goes into auto-ignition. However, hydrogen gas can ignite at about 932°F which means auto-ignition already occurs well before the piston is in a TDC position. In this situation the ignition is counter-productive and will result in engine backfire, knocking and inefficiency.
- The energy consumed during electrolysis to separate the water into hydrogen and oxygen components derived from the alternator is greater than is produced during combustion.

Overall, the technology delivered marginally less efficiency than conventionally powered diesel vehicles but that may have been a function of vehicle duty cycle; these vehicles were largely deployed in cartage operations. One owner-operator, engaged in intercity travel and using the same technology, experienced more favourable results, notably: more engine power, eight percent less maintenance costs and three percent less fuel costs. However, this single owner-operator may also have paid more attention to driving habits and patterns and may have travelled considerably greater distances than other operators (i.e., profoundly different duty cycle).

7.2.2. Results of Qualitative Assessment

The Ministry carried out a qualitative assessment to support the GCVP; 60 firms were canvassed with representation from all the vehicles/technologies supported by grants. However, only 2 firms used hydrogen-injection technology. As such, interviews were conducted with an installer/servicer of the hydrogen injection technology, and with a small trucking firm that did not participate in the GCVP.

The installer/servicer suggested that the technology may work better with older engines. The engine used by both the aforementioned owner-operator and the commercial vehicle fleet were the same brand, but the owner-operator had an older engine model year. Breakeven was achieved in just one year. The installer/servicer reported that another one of their clients experienced 10% fuel savings from the technology but would not acquire more devices because of cost considerations. They indicated that the process had great potential although various technical issues had still to be resolved (e.g., the distilled water freezing and adaptation of the technology to newer engines).

The trucking firm not participating in the GCVP reported considerable benefit from the use of hydrogen injection on two dozen trucks within their fleet. They estimated between 22% to 36% fuel savings (amounting to almost $10,000 per truck per year) and a reduction in annual maintenance costs of about $1,000 per truck.

An interesting statistic was the low cost ($5.00) and quantity (5 litres) of distilled water needed over a two-week period to generate 30 litres of fuel savings in their trucks.

Their fleet contained a mix of newer and older units involved in shorter trips (< 30 km) and more modest travel (about 65,000 km/year), which suggest there may be duty cycle factors to consider as well as the make/model of the unit. For this latter case, breakeven was also achieved within a year.

7.3. Battery-Electric Vehicles

Battery-electric vehicles (BEVs) primarily serve a niche market because of their limited range (up to 250 kilometers), which is a function of battery size and a lower maximum speed (about 80 km/hour). However, BEVs do provide improved predictability in energy costs compared to diesel, less maintenance costs (because electric motors have far fewer moving parts compared to internal combustion engines), superior acceleration, less noise, zero emissions at point of use, fast charge and overnight charging options (6 to 8 hour recharging) and regenerative braking to add power back to the batteries.

Battery-electric vehicles are generally involved in short haul, predictable, multi-drop pickup and delivery return-to-base operations for mail/parcel, food service and home delivery firms. Firms determine their vehicle requirements by balancing the cost of the battery with the service route length and payload needs.

Vehicles purchased with funds from the GCVP had a 50 kilometre range, chosen to minimize the cost of associated with the lithium-ion battery. The battery-electric vehicle was powered by a 40 kWh battery. The truck was projected to use an estimated $400 worth of electricity in a year versus $10,000 in diesel fuel for the alternative.

Unfortunately, the vehicles were found to be underpowered for the task at hand. There was variability in performance but it was unclear why. The technology worked well in warm weather (> 5 degrees centigrade) but not well enough in cold weather, which impacted driver satisfaction. In a follow-up interview with the company, it was indicated that a large number of its electric vehicles were initially deployed in the US where the Ontario experiences were mirrored.

The factors that most influenced battery-electric operations were weather conditions, terrain and the driver's driving style. The range of the vehicle, as determined by the battery, was considerably influenced by season – the driving range in winter was reduced by one-third.

The vehicles in Ontario were removed from service and returned to the manufacturer in order to replace the battery with a more powerful version along with other modifications.

Despite the aforementioned shortcomings, the benefits of the technology convinced the US parent to deploy some 270+ battery-electric vehicles into their US fleet. These vehicles logged over 3 million kilometres while cutting fleet fuel consumption in half and were found to be twice as reliable as their conventional vehicles. An added benefit was the reduction in cost over time of charging stations for those vehicles as additional vehicles are brought into their fleet

The four battery-electric vehicles In Ontario, which each received a $15,000 grant, were expected to collectively save 224,000 litres over the seven year lifecycle period; at $1.25 per litre, this represents a savings of $280,000. This would also translate into 860 tonnes of tailpipe GHG avoided.

Progress on electric vehicles continues at a rapid pace. Lighter duty use in the consumer sector probably helps to explain the more rapid sales of electric vehicles in that context. Also, the consumer sector has benefited from plug-in hybrid vehicles that can also run on gasoline and thus do not suffer from any range issues. In contrast, the electric vehicles tested in the GCVP were pure electric with no gasoline options. Although not yet widely adopted in public transit, there is considerable technological progress on full size electric buses which ultimately will be used in a heavy-duty context.

The emissions savings from electric vehicles are substantial. A recent report (Plug'n Drive, 2015) suggests that electric vehicles can reduce GHG emissions anywhere from 67-95% depending on the type of electric vehicle technology. In the case of a pure battery electric vehicle, the source of GHG emissions is from electricity generation and not from tailpipes. In clean generation contexts (e.g. solar) there are truly zero GHG emissions on a "well-to-wheel" basis.

8.0 Conclusions

The GCVP had two principal roles – encouraging the uptake of green vehicles/technologies, and gathering sufficient intelligence on the business and environmental benefits of investing in these vehicles/technologies. The latter was done through the acquisition of field data from both the public and private sectors.

The analysis has found that the primary technologies supported in the GCVP have positive ROI that can lead to substantial financial savings for a firm when scaled up to a fleet. Adoption of these technologies can enhance firm competitiveness via financial savings while protecting the environment. The analysis also determined that there were possible issues associated with some technologies.

The GCVP met its economic stimulation goal by generating $24 million in investment from Ontario trucking firms allocated to the green vehicle technology sector. Over the lifecycle of pilot vehicles, a total of 56,200 tonnes of GHG emission will be avoided. Other lifecycle benefits were realized: 1,800 tonnes of NOx were avoided as were 1,400 tonnes of CO, 260 tonnes of VOC, and 33 tonnes of particulate matter.

Significant investments were made in these vehicles with many companies continuing on to install or purchase these vehicles/technologies without the support of the GCVP.

Indeed, these types of investments make good financial sense, independent of any government contributions. The continued uptake in green technology demonstrates that the GCVP succeeded in raising awareness, stimulating the adoption of these technologies.

Table 11: Summary of Results for Primary Technologies Funded

Device	APU	Cab Heater	Cab Cooler	Propane Vehicle	Hybrid Vehicle
Cost (or Incremental Cost) per Unit	$8,200	$1,400	$2,500	$6,000	$24,400
Units Funded	591	459	58	252	258
GCVP Funding	$1.615M	$214,200	$48,333	$504,000	$2.098M
Annual Per Unit Fuel Savings	$2471	$2203	$1337	$913	$2135
Fleet Lifecycle Fuel Savings	$10.891M	$6.342M	$465,146	$3.451M	$6.059M
Lifecycle Length (Years)	6	6	6	15	11
Annual Per Truck GHG Emissions Reduction (tonnes)	6.83	5.12	2.97	1.06	4.03
Fleet-wide Lifecycle GHG Emissions Reduction (tonnes)	24,221	14,105	1,034	3,995	11,440
GHG Reduction Cost per tonne to GCVP	$67	$15	$47	$126	$183
GHG Reduction Cost per Tonne Total	-$162	-$385	-$309	-$485	$21
ROI on Participant's Funds	171%	1316%	381%	242%	44%
Months Before Break Even Achieved (without grant)	40	8	23	79	137
Months Before Break Even Achieved (with grant)	27	6	15	53	92

The analysis examined the quantifiable benefits in monetary and GHG terms; however, it has not examined any benefits that may derive from improved health outcomes with reduced emissions of criteria air contaminants or from the competitive advantages of

being viewed by consumers as a “green” transportation company. As such, this report may define the lower bound of benefits from investments in green vehicle technology.

A summary of the results associated with the primary five technologies is presented in Table 11. These results suggest that there are reasonable payback periods for the technologies and in some cases, there are rapid paybacks and high return on investment which accrue over the lifecycle (e.g. cab heaters). The results suggest that these investments are financially viable quite apart from their positive environmental contributions.

It is useful to evaluate the pilot in terms of how provincial and private investments helped to reduce GHG emissions since improving the environment is one of the main motivators of the GCVP. The main theme that emerges is that the anti-idling devices were the most cost-effective in this regard. Cab heaters were particularly efficient investments partly due to the cooler climate that prevails in Ontario.

As a comparison, consider results from the similar Green Fleet BC program administered by the Fraser Basin Council from 2007-2009 (Viafara and Larson, 2013). In that program, $2.4 M in investments (provincial contributions + private investments) yielded an estimated overall GHG reduction of 19,200 tonnes. This works out to an investment of $126 per tonne of GHG eliminated. For the five technologies shown above, the corresponding GCVP result is 54,795 tonnes of GHG avoided at a cost of $4.48 M for an average cost of $82 per tonne of GHG avoided. This result is based on the fleet-wide lifecycle estimates for the GCVP.

It is important to note that no discounting mechanisms have been used in this analysis for the calculation of return on investment or in determining breakeven/payback periods. This approach reflects that the analysis in this report is essentially retrospective in nature, based on the experiences of firms that participated in the pilot of the Green Commercial Vehicle Program. The analysis is also intended to be direct and straightforward. For future investments, firms should assess the value proposition of the technology options for themselves, using their own appropriate assumptions about reconciling different costs and benefits that occur at different points in time. The results from this report can certainly act as a starting point.

The total funding provided to support the purchases of APUs, Cab Heaters, Cab Coolers, Propane Vehicles, and Hybrid-Electric Vehicles was $4.7 M. These funds were more than matched by the participants in the pilot. Not only was there a price premium for the associated green technology, there is a considerable premium in the price of trucks themselves. Industry sources report it can be one-third or as much as $50,000 more than their diesel counterparts (Wall Street Journal 2015). The GCVP stimulated

the spending of some $24 M by the private sector. It also induced economy activity in Ontario since $1 M in material costs were Ontario content.

Further specific concluding insights about anti-idling devices and alternative fuel vehicles are presented below.

8.1. Anti-Idling Devices

Three different anti-idling technologies were tested in the pilot: APUs, cab heaters and cab coolers, with average unit capital costs of $8200, $1400, and $2500 respectively. As noted earlier, a number of fleets found their rates of idling without anti-idling devices to be on the order of 25% to 30%; these were reduced to 10% idling or less with the introduction of anti-idling devices.

Of these, APUs have the ability to perform the functions of both a cab heater and cab cooler. The cab cooler tested was a passive system that required no fuel to operate, whereas both the APU and cab heater required diesel fuel. In each case, the amount of fuel required is much less than having the engine idle.

Fuel price is a large determinant in the cost savings obtained from anti-idling devices. In Table 12 below, we present the cost savings by technology that would accumulate for a single vehicle annual at varying levels of fuel cost.

Four options are available for outfitting vehicles with these green technologies: an APU alone, a cab heater or a cab cooler, and the option of installing both a cab heater and cab cooler. Installing a cab heater, cab cooler and an APU would be impractical because they perform the same function.

Cab heaters provide the lowest average cost for reducing GHG, at a total cost of $48 per tonne ($16 of this amount is from the GCVP). Cab coolers and APUs were significantly more expensive for reducing GHG emissions than cab heaters, at $141 and $201 per tonne of GHG avoided.

However, cab coolers have a much shorter useful period for drivers based in Ontario. Results suggest that they eliminated only a total of 2,973 tonnes of GHG annually compared to 4,750 and 6,830 tonnes for cab heaters and APUs respectively. The total benefit for cab coolers is likely understated given pilot conditions that a minimum of 20% of VKT for grant recipients be undertaken in Ontario.

Based on the GCVP experience, if initial capital is a limiting factor in deciding what to install on an Ontario fleet, it is best to install cab heaters on all vehicles initially and then cab coolers may be added at a later date.

Table 12: Anti-idling Annual Fuel Cost Savings for Variable Fuel Prices

Fuel Price	APU	Cab Heater	Cab Cooler
$ 1.00	$ 2,457	$ 1,842	$ 1,069
$ 1.25	$ 3,071	$ 2,303	$ 1,336
$ 1.50	$ 3,686	$ 2,763	$ 1,604
$ 1.75	$ 4,300	$ 3,224	$ 1,871
$ 2.00	$ 4,914	$ 3,684	$ 2,138
$ 2.25	$ 5,528	$ 4,145	$ 2,405
$ 2.50	$ 6,143	$ 4,605	$ 2,673
$ 2.75	$ 6,757	$ 5,066	$ 2,940
$ 3.00	$ 7,371	$ 5,526	$ 3,207
$ 3.25	$ 7,985	$ 5,987	$ 3,474
$ 3.50	$ 8,600	$ 6,447	$ 3,742

If the criteria are not purely financial, it is likely best to install an APU as it will provide additional benefits to the driver when not idling the engine. From a pure ROI perspective, cab heaters are the best option for vehicles primarily operating in Ontario. Some other considerations are that:

- The installation of any of the three technologies should provide the firm with monetary gains of the products lifecycle.
- When choosing technologies firms should consider climate and equipment flexibility.
- Firms conducting business in regions of extreme weather should opt for an APU because they can provide the most functional heating and/or cooling.

8.2. Alternative Fuel Vehicles

Generally speaking, each alternative fuel vehicle type serves a niche market. This is a function of the attributes of the technology itself and the duty cycle of its vehicles. A number of factors will influence whether there is sufficient benefit for a firm to invest in a given technology.

The two principal alternative fuel technologies examined as part of the GCVP were propane and hybrid vehicles. These two technologies have different approaches to fuel savings.

The propane vehicles operated with either a sole propane engine, or a gasoline engine that would run during start-up and then automatically switch to the propane engine. When the latter operates, it has reduced GHG emissions per unit of distance driven when compared to gasoline engines. The hybrid-electric vehicle saves fuel during idling because the internal combustion engine is not operating at that time. Also, the electric engine initiates movement from a stopped position.

The price premium for a hybrid-electric vehicle is much higher than for a propane vehicle because it requires a significantly different platform and additional components such as a battery. Propane technology can be retrofitted to a traditional internal combustion engine vehicle at a low cost. The per unit price premium for propane is estimated at $6,000, and the hybrid-electric incremental cost is estimated at $24,400.

Both technologies provide respectable ROI, with the propane vehicles returning 242% of the initial price premium and hybrid-electric vehicles returning 44% of their incremental cost. Both technologies provide a lifecycle benefit to the operator. The hybrid-electric vehicles provide a greater reduction in GHG emissions compared to the propane vehicles, eliminating about 4 times the GHG emissions annually on a per vehicle basis. Worth noting also is that propane vehicles require separate infrastructure and have range and supply issues.

Three other alternative fuel vehicles supported under the GCVP were examined in Chapter 7. Participation levels with these technologies were generally insufficient to generate adequate samples from which to draw conclusions. Although not widely adopted under the GCVP, natural gas vehicles appeared effective in saving money and reducing emissions. Natural gas vehicles were associated with a high incremental cost but generated large annual savings that became most impressive when vehicles were heavily used.

The experience with hydrogen injection was mixed; battery electric vehicles that were supported experienced some negative performance issues. If commercial vehicles of a certain type cannot perform their duties, they are not really viewed as serious alternatives even if the financials appear attractive on the surface.

8.3. Next Steps

The GCVP was undertaken with a view to addressing the GHGs generated by medium and heavy-duty commercial vehicles in Ontario. Data collected through the GCVP is offering insight into how selected green vehicles/technologies performed. The role of the GCVP was not to choose a preferred technology but to showcase a number of different technologies and to report on their field performance.

This study focuses on only some aspects of the data collected, principally the distance travelled, the amount of fuel saved, the amount of GHG avoided and the return on investment afforded by the green vehicles and technologies. Further insights could be developed from the information collected.

There are a number of possibilities for further research, using these data, or by consulting other sources:

- Comparing the funding against the geographic distribution of trucking firms in the province and their relative significance (i.e., fleet size, location of terminals, number of employees, scale of operations, markets served) to see how representative the grant recipients were;
- For what sectors/regions could these vehicles/technologies have the greatest impact? This analysis could be done by ascertaining where freight-related GHG emissions were the most concentrated in terms of heavily travelled corridors, places with intense loading/unloading and locations where drivers would tend to pull over to sleep.
- Given the low penetration rates of green vehicles and technologies for the entire trucking sector, what price point could encourage greater uptake? What other opportunities might exist (e.g., anti-idling technologies for day-cabs)?
- Identifying how much of the benefit from the lower costs of alternative fuel vehicles in general has been eroded because of improved diesel fuel economies.

Appendix A: Costs and Benefits of a Similar Funding Program

In light of the fuel and GHG savings resulting from the GCVP, an analysis of the potential benefits of a similar program was undertaken. It was assumed that the same provisions would apply: one-third of the cost of the "green feature" of alternative fuel vehicles and one-third of the cost of the green anti-idling technology would be covered by a government grant up to a specified limit. That said, a case could be made for a higher subsidy -- up to 50%, to reduce the return on investment period and improve uptake. In this analysis, a 6-year period was assumed since fleets tend to renew their stock of vehicles every six years.

Anti-Idling Devices

Ontario has 110,000 class 8 vehicles. About 20 to 30% of those vehicles are used for long haul freight movement and have sleeper cabs. These vehicles can benefit from the anti-idling technologies tested in the GCVP. Current trends suggest an annual turnover of 2,000 sleeper cabs and 1,000 day cabs.

We present three scenarios -- one for cab heaters, one for cab coolers, and one for APUs. For each scenario, it is assumed that 50% of the annual replacement of 2,000 sleeper cabs is outfitted by the given anti-idling technology.

Table 9: Summary of Anti-Idling Scenarios

	APU Scenario	Cab Cooler Scenario	Cab Heater Scenario
Government Funds Required (Annually)	$2,750,000	$828,000	$468,000
Government Funds Required (Six Years)	$16,500,000	$4,968,000	$2,808,000
Total Fuel Savings (litres)	15,000,000	6,600,000	10,800,000
Total GHG Savings (tonnes)	245,000	106,920	183,600
Cost to the Government Per Tonne GHG	$67	$47	$15

The results in Table 9 suggest that cab heaters provide the lowest financial cost of the three scenarios. Without factoring in cost, APUs provide the greatest emissions savings per vehicle. These two somewhat different outcome dimensions could be evaluated and a balance struck based on the amount of funding available.

Alternative Fuel Vehicles

In Ontario, most Class 3-6 trucks, such as couriers, operate on a “return-to-base” approach. There are approximately 110,000 of these vehicles. Their lifecycle is longer than for a heavy duty truck, lasting between 11 and 15 years. The payback standard for Class 3 to 6 trucks is 3.5 years.

If 10% (1,100) of these class 3 to 6 trucks were transitioned to propane annually over the next six years, with an assumed lifecycle of 15 years, the first year would see an annual reduction of 1,100 tonnes of GHG emissions; in the sixth year 6,600 tonnes would have been eliminated. Over the lifecycle of these vehicles, 99,297 tonnes of GHG would be eliminated.

If these vehicles were funded at the same level as in the GCVP ($6,000 per unit), the cost would be $2.2 million per year ($13.2 million total), or $128 per tonne of GHG eliminated. The private sector investment would be $4.4 million per year ($26.4 million total) and would recognize a net ROI for the private sector investment of over $51 million. Without government funds, the same goals would be reached with a slightly reduced ROI for the participating firms of $48.8 million ($2.2 million less). No fuel would be saved; instead a cheaper and less carbon intensive fuel is used but significant cost savings result.

Applying the same 10% replacement factor to hybrid-electric vehicles, the first year would see a reduction in 4,433 tonnes of GHG emissions, which is four times the reduction that can be achieved with a switch to propane vehicles. During the sixth year, with all vehicles replaced (a total of 6,600), the GHG savings would be 26,600 tonnes. The scenario would cost $8.95 million per year ($53.7 million in total) and eliminate 292,578 tonnes of GHG at a cost of $183 per tonne over the lifecycle of these vehicles. The technology is currently break even without financial support by the government. If this replacement scenario occurred, it would stimulate the spending of an additional $107 million.

Conclusion

This analysis is presented for illustrative purposes only. It does not recommend a particular approach. The GCVP provided support to a number of green vehicle and green technology options. The above assumptions can be changed; the approach can be stand alone or combined, increased in focus or reduced depending on the objectives of government and the willingness of the private sector to partner with government.

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