

DRAFT
FINAL REPORT

ALBERTA
renewable**DIESEL**
DEMONSTRATION

JANUARY 2009



MANAGED BY



Climate Change Central
Albertans taking action

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This report is a summary of the observations of the Alberta Renewable Diesel Demonstration (ARDD). It provides a general account of the project scope, methods and observations employed in this multi-stakeholder real-world demonstration of low-level renewable diesel fuels in challenging winter conditions. This report provides feedback to stakeholders regarding the use of renewable diesel fuels in Canada's on-road diesel fuel market and confirms 'operability' of low level renewable diesel blends under the specific conditions tested ensuring full and continuous compliance with CAN/CGSB 3.520. The results obtained during the demonstration will be provided as documentation in response to the Government of Canada's Notice of Intent (NOI) to regulate a Renewable Fuel Standard (RFS).

The ARDD was Canada's first demonstration to work with major petroleum producers and distributors to provide pilot-level experience of renewable diesel blending at full commercial scale, using in-line blending at a primary diesel terminal, or 'rack'. The ARDD was also Canada's first demonstration to adjust the finished fuels' cloud points using ultra low sulphur kerosene (ULSK) in order to fully meet the cold operability specifications in the CAN/CGSB 3.520 fuel standard. From December, 2007 to March, 2008, blending to meet the cloud point schedule required ULSK addition of 21-43% of the blend for B2 FAME and 8-15% of the blend for 2% HDRD.

In December of 2007, the ARDD completed construction and commissioning of a temporary commercial blending facility at Shell Canada's Sherwood Marketing Terminal in Edmonton, Alberta. The facility was designed to allow rack loading of 2% and 5% renewable content of two different types of renewable

diesel fuel: fatty acid methyl ester (or FAME, commonly known as biodiesel) and hydrogenation derived renewable diesel (or HDRD, a second-generation renewable diesel product). During the winter months (December 16, 2007 through April 15, 2008), canola methyl ester (CME) was used exclusively while in spring and summer months (April 16 through September 30, 2008) a blend of 75% canola methyl ester to 25% tallow methyl ester (TME) was used as the biodiesel blending stock. Fuels were blended using in-line blenders at a commercial terminal designed to ensure homogeneity and consistency. The ARDD Steering Committee opted to limit the biodiesel blend concentration to 2% during the winter months to ensure cold operability. This concentration was raised to 5% in spring and summer along with the transition to mixed-feedstock FAME (75% canola methyl ester / 25% tallow methyl ester).

Over the span of the demonstration, the ARDD dispensed over 1.6 million litres of blended fuel. During the winter period the ARDD dispensed 245,000 litres of B2 (2% FAME) and 400,000 litres of 2% HDRD. In spring/summer the ARDD dispensed 540,000 litres of B5 (mixed feedstock FAME) and 425,000 litres of 5% HDRD. No stalls or loss of business were experienced across the fleet while running on blended fuel.

Blended fuels were dispensed from participating commercial card locks across Alberta. A fleet of 59 vehicles was recruited to run on the two test fuels (29 on FAME blends and 30 on HDRD blends). In addition, a control group of 16 vehicles was monitored using normal ultra low sulphur diesel (ULSD) for comparison, creating a total fleet of 75 ARDD vehicles. The fleets spanned Class 8 transport trucks with and without exhaust after-treatment technologies (pre- and post 2007 model year units), school buses, a variety of delivery trucks and a group of heavy-duty oilfield services vehicles. All participating vehicles were 2002 model year or later.

The ARDD generated a number of observations for Canada's fuel industry, including notes about transporting, handling, quality control, storage and operability that may be noteworthy in preparation for implementing a national Renewable Fuel Standard. The ARDD showed that it is possible to create, dispense and use low level blends of renewable diesel fuels (both FAME and HDRD) in Canada's cold climates using existing distribution and commercial infrastructure. Regarding the principal objective of assessing operability, no loss of service events were noted in the ARDD (one vehicle from the school bus fleet changed a fuel filter to aid in starting). Storage and blending infrastructure was created by designing and constructing a temporary blending facility integrated into Shell's Sherwood Marketing Terminal in Edmonton, Alberta, adding purpose-built storage capacity, blenders and an unloading area using currently available technology within the fuel handling industry.

ACKNOWLEDGEMENTS

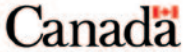
SPONSORS

- Advancing Canadian Agriculture and Agri-food Program, Agriculture and Agri-food Canada
- Alberta Energy – Biodiesel Commercialization and Market Development Program
- Alberta Energy – Biodiesel Infrastructure Development Program
- Canadian Bioenergy Corp.
- Canadian Petroleum Products Institute
- Canadian Renewable Fuels Association
- Canola Council of Canada
- Milligan Bio-Tech
- Neste Oil
- Shell Canada Limited

PARTICIPANTS

- CF Managing Movement Ltd.
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GLOSSARY OF TERMS

COMMON TERMS AND ABBREVIATIONS

ARC	- Alberta Research Council
ARDD	- Alberta Renewable Diesel Demonstration
ASTM	- ASTM International, formerly American Society for Testing and Materials
Biodiesel	- The term used primarily for FAME, or fatty acid methyl ester renewable diesel
Bxx	- Finished blends of biodiesel with ultra-low sulphur diesel, where xx refers to the percentage of biodiesel in the blend
B100	- 100% fatty acid methyl ester
C3	- Climate Change Central
CAN/CGSB	- A CGSB standard recognized by the Standards Council of Canada as an official national standard
CGSB	- Canadian General Standards Board
CME	- Canola methyl ester
FAME	- Fatty acid methyl ester
HDRD	- Hydrogenation derived renewable diesel
NOI	- Notice of Intent to regulate a renewable fuel standard
RDCS	- Renewable Diesel Characterization Study; a suite of lab testing of fuels and blends conducted by Climate Change Central and partners in advance of ARDD
Renewable Diesel	- An umbrella term referring to any sort of diesel fuel from a renewable source
RFS	- Renewable Fuel Standard, or government mandated blending regulation
SFJ	- Shell-Flying J joint venture (card lock stations)
SME	- Soy methyl ester
TME	- Tallow methyl ester
ULSD	- Ultra low sulphur diesel
ULSK	- Ultra low sulphur kerosene

BACKGROUND



CONTEXT

In December 2006 the Government of Canada published its Notice of Intent (NOI) to regulate a Renewable Fuel Standard (RFS) mandating the use of renewable fuels across Canada. The Canadian Renewable Fuel Standard would equate to roughly 650 million litres of renewable diesel nation-wide, representing an additional market for a roughly equivalent volume of plant oil or animal fat feedstock (or approximately 1.4 million tonnes of canola seed. The RFS will require renewable fuel content equivalent to 5% of the gasoline pool by 2010, and an additional renewable fuel content of 2% of the middle distillate pool (diesel fuel, home heating oil, etc) by no later than 2012 ⁽¹⁾ . A broad suite of liquid renewable fuels such as ethanol and renewable diesels are expected to count towards compliance. The NOI stipulates that implementation of the RFS is contingent on the ‘successful demonstration of renewable diesel use under a range of Canadian conditions’.

Responding to this need for a demonstration, a group of diverse stakeholders announced its intention in late 2006 to embark on a renewable diesel demonstration project in Alberta. This demonstration was designed as a two-phased approach: the Renewable Diesel Characterization Study (RDCS) which involved laboratory testing, followed by the Alberta Renewable Diesel Demonstration (ARDD) which demonstrated the on-road fleet use of commercial vehicles running on renewable diesel blends. The fuels met the CAN/CGSB 3.520 & 3.517 fuel standards. The vehicles included 2007 and 2008 model year vehicles with current exhaust after-treatment technologies.

PURPOSE

The ARDD was a demonstration project aimed at providing information and operating experience to stakeholders in the diesel fuel industry. The demonstration took renewable diesel from the lab to the road, providing hands-on experience at 2% and 5% blends (B2 in winter and B5 in shoulder and summer seasons). The ARDD fleet consisted of 59 vehicles running on two types of renewable diesel: methyl ester and hydrogenation derived renewable diesel and an additional group of 16 control vehicles.

⁽¹⁾ For official Gazette text see: <http://canadagazette.gc.ca/part1/2006/20061230/html/notice-e.html#i3>

Through real-world operation and third-party lab testing, the ARDD and its sister study, the Renewable Diesel Characterization Study have provided key information about the cold operability of neat renewable fuels, blends with petroleum diesel, blending and handling in the fuel distribution system, and operational performance. The results of this demonstration have contributed to a body of knowledge upon which stakeholders can evaluate the implementation of a Renewable Fuel Standard in Canada. Downloadable reports for the fuel testing work (RDCS) are available at www.renewablediesel.ca.



INTRODUCTION

OBJECTIVES

The ARDD was designed to provide real-world experience for fuel blenders, distributors and users. The demonstration operated to match the blending, distribution, storage and in-fleet use conditions expected to be widely in use for an RFS. The demonstration marks Canada’s broadest study to date on the performance of renewable diesel in cold weather throughout the fuel supply chain from procurement to end user. Alberta was selected primarily because it represents some of the harsher climates in which renewable diesel would be used, (Edmonton has the same cold operability or cloud point requirements as areas around Saskatoon, SK, Winnipeg, MB, Kapuskasing, ON and Gagnon, QC). The ARDD Steering Committee opted to limit the biodiesel blend concentration to 2% during the winter months. This concentration was raised to 5% in spring and summer along with the transition to mixed-feedstock FAME (75% canola methyl ester / 25% tallow methyl ester).

The primary objective of this demonstration was to evaluate renewable diesel performance in long-haul trucking fleets under real-world conditions, and thus assess the overall suitability of renewable diesel among the primary consumer group for on-road diesel fuel. Of particular interest was the evaluation of cold operability of 2% and 5% renewable diesel blends in the range of conditions in the Alberta market.

The ARDD also set out to build experience in blending and delivering renewable diesel blends to commercial card locks and fuel distribution infrastructure.

TIMEFRAME

Planning and partnership-building activities for this project began in early 2006, leading to the participation of sponsors and supporters in late 2006. Construction of the blending facility and preparation of card locks was completed at the end of 2007 with first renewable diesel deliveries occurring in December 2007. The official project launch was held in Edmonton, Alberta on January 23, 2008, while the on-road portion of the demonstration stretched from December, 2007 through to September, 2008, providing information from the coldest months as well as some shoulder and summer season operation.



STUDY AREA

The ARDD study area comprises southern, central and northern regions of Alberta, spanning some of the coldest zones in Canada as defined in the CGSB fuel standards. Participating vehicles fueled in Edmonton, Calgary and Lloydminster, where fuel was dispensed to meet local cloud point requirements (i.e. -37°C and -33°C in Edmonton/Lloydminster and Calgary, respectively). Some units ran as far afield as Fort McMurray and Grande Prairie, others ran to the Cold Lake/Bonnyville area (north of Lloydminster), while the balance was dedicated to regional routes in the Edmonton-Calgary corridor.

FIGURE 1: ARDD Study Area

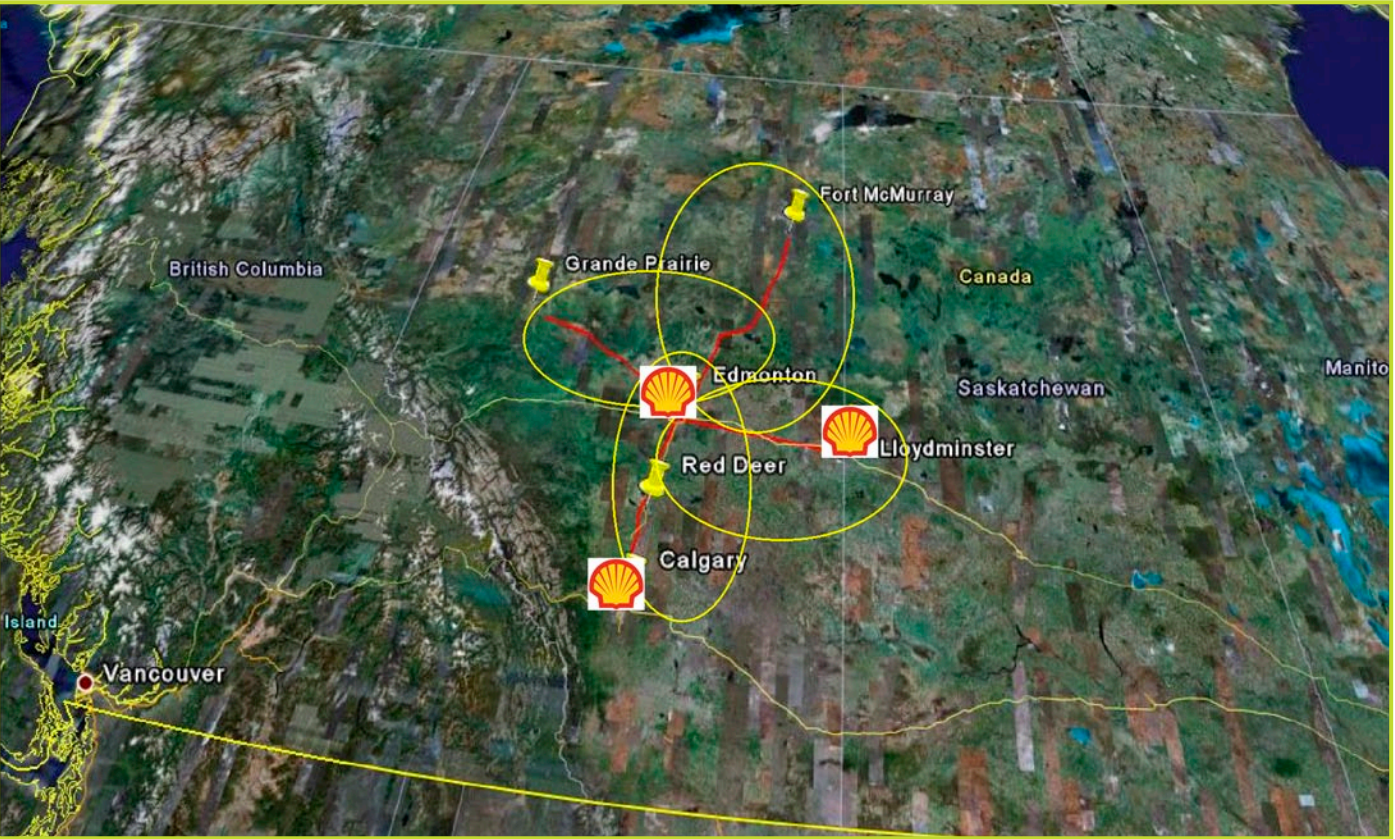


Photo Courtesy: Google Earth

PROJECT MANAGEMENT & GOVERNANCE



PROJECT SUPPORT & PROJECT MANAGEMENT

The ARDD was managed and coordinated by Climate Change Central with direction from a Steering Committee working by consensus. Funding for the ARDD was provided through Agriculture Canada's Advancing Canadian Agriculture and Agri-food program (ACAAF) and from two funds from Alberta Energy: the Biofuels Commercialization and Market Development Program (BCMDP) and the Biofuels Infrastructure Development Program (BIDP), as well as significant cash and in-kind contributions provided by industry partners. Shell Canada Ltd, being the primary industry partner, coordinated construction activities and operated the blending facility, donating its considerable management, engineering and product quality services as in-kind contributions to the ARDD. Cash and in-kind contributions were also provided by the Canola Council of Canada, the Canadian Petroleum Products Institute (CPPI) and the Canadian Renewable Fuels Association (CRFA), Canadian Bioenergy Corp., and by fuel providers Neste Oil, Milligan BioTech Inc and BIOX Corporation. Supplemental technical support was provided by Alberta Research Council (ARC).

PROJECT MANAGEMENT COMMITTEES

Steering Committee:

Climate Change Central (C3) handled day-to-day project management, financing and reporting activities for the ARDD, while a Steering Committee provided oversight and multi-stakeholder direction. The Steering Committee was made up of representatives from C3, Shell Canada Ltd. (also acting as liaison to CPPI), Agriculture Canada, Natural Resources Canada (NRCan), Environment Canada, Alberta Energy, CRFA, the Canola Council of Canada, and the Alberta Biodiesel Association. The Steering Committee met approximately bi-weekly from December, 2006 through December, 2008, providing detailed ongoing input into the design, operation and monitoring activities of the ARDD. This process ensured meaningful and continuous government and industry participation into this demonstration.

The Steering Committee reviewed and signed off on each aspect of the project, from conception to design, through to detailed fuel selection criteria, vehicle monitoring protocols, data collection mechanisms, execution plans, reporting and public outreach. Additional technical and logistical support was provided by fuel suppliers Neste Oil and Milligan BioTech Inc, BIOX Corp, BBI Biofuels Canada and Canadian Bioenergy Corporation (CBEC). The design and structure of the demonstration also directly involved the Canadian Trucking Alliance as a key stakeholder.

A supplementary Communications Committee was also struck to review key project materials and facilitate public events. The Communications Committee reported to the Steering Committee.

Technical Committee:

In addition to the Steering Committee, the ARDD struck a Technical Committee to solicit detailed technical input on issues related to fuel quality, blending and handling. This Technical Committee was made up of C3, Shell Canada (representing CPPI), Canadian Bioenergy Corporation (representing the Alberta Biodiesel Association), the Canola Council of Canada, BBI Biofuels (representing CRFA), Milligan BioTech Inc, and Neste Oil. Also participating in the Technical Committee were Environment Canada, Natural Resources Canada and Agriculture Canada.

Advisory Committee:

A broader Advisory Committee was struck to solicit input from a wide variety of stakeholders, including OEMs (engine manufacturers), trucking associations and vehicle manufacturers. The Advisory Committee was made up of representatives from the Canadian Trucking Alliance (CTA), Alberta Motor Transport Association (AMTA), British Columbia Trucking Association (BCTA), Canadian Vehicle Manufacturers Association (CVMA), Engine Manufacturers Association (EMA), Association of International Automobile Manufacturers of Canada (AIAMC), Caterpillar, Cummins, Detroit Diesel, Navistar, and the biofuel producers, Neste Oil, Milligan BioTech Inc and BIOX Corporation.

An illustration of the Steering Committee, Technical Committee, Advisory Committee and fleet participants is provided below. Where more than one organization is presented per line, one committee member represented both organizations.

FIGURE 2: ARDD Management Committees, Stakeholders and Participants

STEERING COMMITTEE MEMBERS:	
Climate Change Central	Alberta Motor Transport Association
Shell Canada Limited / Canadian Petroleum Products Institute	Agriculture and Agri-food Canada
Canadian Renewable Fuels Association / BBI Biofuels	Natural Resources Canada
Canadian Bioenergy / Alberta Biodiesel Association	Environment Canada
Canola Council of Canada	Government of Alberta
TECHNICAL COMMITTEE MEMBERS:	
Climate Change Central	Environment Canada
Shell Canada / Canadian Petroleum Products Institute	Government of Alberta
Canadian Renewable Fuels Association / BBI Biofuels	Original Engine Manufacturers
Agriculture and Agri-food Canada	Renewable Diesel Producers
Natural Resources Canada	Alberta Research Council (3rd Party Lab)
PARTICIPATING FLEETS:	
Rosenau Transport Ltd.	Hi-Way 9 Express Ltd.
Gibson Energy Ltd.	CF Managing Movement (TransForce)
First Bus Canada Ltd. (Cardinal Coachlines)	
ADVISORY COMMITTEE MEMBERS:	
Government of Canada	Navistar
Government of Alberta	Engine Manufacturers' Association
Caterpillar	BC Trucking Association
Cummins	Canadian Trucking Alliance
Detroit Diesel	Neste Oil
Canadian Vehicle Manufacturers' Association	Milligan BioTech Inc.
Association of International Automobile Manufacturers of Canada	

OUTREACH

The ARDD involved numerous stakeholders and used a coordinated outreach strategy. The demonstration’s target audiences included project committee members and participants, government organizations, members of the fuel and trucking industries, the agricultural sector and the general public.

To raise awareness of the operability of renewable fuels under cold-weather conditions, and to build the demonstration’s profile, a variety of communication and outreach activities were engaged in throughout the demonstration.⁽²⁾ These included:

- Creating and maintaining a project website, www.renewablediesel.ca;
- Organizing and hosting a media launch event and facility tour at the Shell Canada Sherwood Terminal in Edmonton;
- Authoring and issuing news releases for major project milestones;
- Writing articles for, and interviewing with, print and broadcast media networks;
- Designing branding and marketing materials including a brochure, vehicle stickers and pump signage;
- Preparing and publicizing reports for various demonstration phases; and
- Delivering presentations to numerous stakeholder groups.

The outreach tactics used in the demonstration proved successful in generating interest among the target audiences. The website received over 14,000 hits during the nine-month duration of the project, and over 50 stakeholders and six media outlets attended the launch event. Additionally, the demonstration received local, national and international media attention, with articles being published in over 20 print publications and coverage being broadcast by over ten media outlets.

⁽²⁾ See Appendix A for full listing of outreach activities.

FLEET COMPOSITION

Commercial carrier fleets traveling across the province were targeted for participation in the demonstration. Three Shell – Flying J (SFJ) card lock stations dispensed the fuel to participating fleets in a ‘business as usual’ model, meaning that they received, dispensed and sold blended fuel in a typical commercial setting. One fleet used an in-yard tank and dispensing system (capacity of 68,000 litres) to demonstrate the fuel’s application in above-ground facilities in addition to the below-ground storage of the commercial card lock model. Such dedicated in-yard dispensing units are in common usage and helped complement the real-world profile of the demonstration.

A total of 75 vehicles participated in the demonstration: 29 units ran on methyl ester blends (FAME, commonly known as biodiesel), 30 units on blends of HDRD. The ARDD dispensed roughly equal volumes of FAME and HDRD fuel during the demonstration period (see Table 11 for details). An additional 16 control vehicles ran exclusively on ultra low sulphur diesel (ULSD) to provide an unbiased comparison group.

The participating Class 8 units comprised both long-haul and oilfield service applications, including several 2007 and 2008 model year units with new exhaust after-treatment technologies. The remainder of the fleet was made up of a range of engine and vehicle types and applications and spanned intercity delivery service (long haul and pickup & delivery), asphalt/oilfield service hauling, school buses and passenger coaches. Participating vehicles are listed in Tables 1-3 below.

TABLE 1: Participating FAME Trucks

Manufacturer (Make)	Model	Year	Engine	Quantity
Freightliner	Bus	2003	CAT 3126	3
Freightliner	Cascadia	2008	Det S 60	3
Freightliner	CL 120	2007	C15 CAT	4
Freightliner	CL 120	2004	Mercedes 4000	1
Freightliner	CL 120	2006	Mercedes 4000	2
Freightliner	FL 112	2004	Mercedes 4000	1
Freightliner	Safetyliner	2006	Mercedes MB 900	3
International	9200	2007	Cummins ISX	1
International	9200	2002	Detroit	2
International	CE 300	2008	Maxxforce 7	3
Kenworth	T600	2007	Cummins ISX	1
Kenworth	T800	2007	Cummins ISX	2
Kenworth	W900	2007	Cummins ISX	1
Volvo	VN	2007	Volvo VED12	2
Total Vehicles				29

TABLE 2: Participating HDRD Trucks

Manufacturer (Make)	Model	Year	Engine	Quantity
Freightliner	CL 120	2007	C15 Cat	1
Freightliner	CL 120	2004	Mercedes 4000	1
Freightliner	CL 120	2006	Mercedes 4000	2
Freightliner	CL 120	2007	Mercedes 4000	1
Freightliner	Columbia	2003	CAT	1
Freightliner	Columbia	2005	Detroit MB 4000	2
Freightliner	Columbia	2006	Detroit MB 4000	1
Freightliner	Columbia	2007	Detroit MB 4000	1
Freightliner	FL 112	2004	Mercedes 4000	1
Freightliner	M 2	2008	Cummins ISB	2
Freightliner	M 2	2006	Mercedes 900	4
Freightliner	M 2	2007	Mercedes 900	1
International	9200	2007	Cummins ISX	1
International	9200	2008	Cummins ISX	1
Kenworth	T600	2008	Cummins	1
Kenworth	T800	2005	CAT	1
Kenworth	T800	2007	CAT	3
Kenworth	W900	2005	C13 Cat	2
Kenworth	W900	2006	C15 Cat	1
Volvo	Conv	2006	Volvo	1
Volvo	VN	2007	Volvo VED12	1
Total Vehicles				30

TABLE 3: Participating Control Trucks

Manufacturer (Make)	Model	Year	Engine	Quantity
Ford		2002		3
Freightliner	Cascadia	2008	Det S 60	1
Freightliner	CL 120	2007	C15 Cat	1
Freightliner	CL 120	2004	Mercedes 4000	1
Freightliner	CL 120	2006	Mercedes 4000	1
Freightliner	M 2	2006	Mercedes 900	2
Freightliner		2002		3
International	4000	2002	International	1
International	9400	2005	Cat C 15	1
Kenworth	T 600	2007	Cummins ISX	1
Kenworth	T800	2007	CAT	1
Total Vehicles				16

FUEL SYSTEM OVERVIEW

FUEL DISTRIBUTION SYSTEM IN WESTERN CANADA

Canada’s downstream fuel distribution system is characterized by four ‘orbits’ serviced by clusters of refineries, one serving British Columbia and the prairies, one covering Ontario, one covering Quebec and one serving the Atlantic provinces. The province of Alberta is served primarily by three refineries clustered east of Edmonton in Fort Saskatchewan: Imperial Oil (ESSO), Petro-Canada and Shell Canada. These refineries serve customers in Alberta through five major terminals (three in Edmonton and two in Calgary).

FIGURE 3: Fuel Distribution Orbits and Refineries in Canada

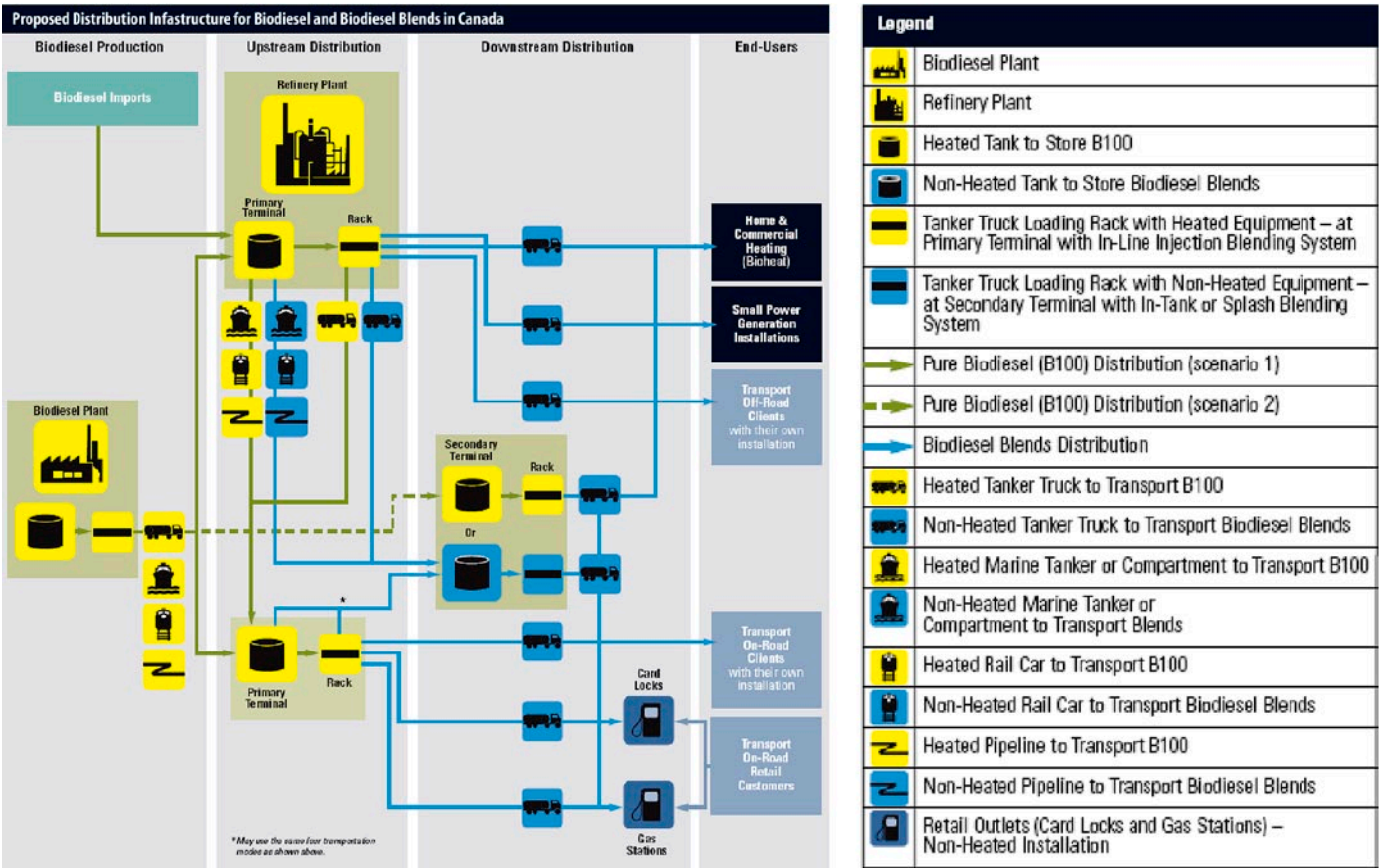


Source: NRCan, 2005

A fuller description of Canada’s fuel distribution system and points for inclusion of renewable content into the diesel stream are discussed in **Sine Nomine’s “Assessment of the Biodiesel Distribution Infrastructure in Canada” published in 2007.**

Figure 4 below illustrates the potential logistical pathways for incorporating biofuels into the petroleum distribution system in Canada at the terminal, bulk plant or end user level.

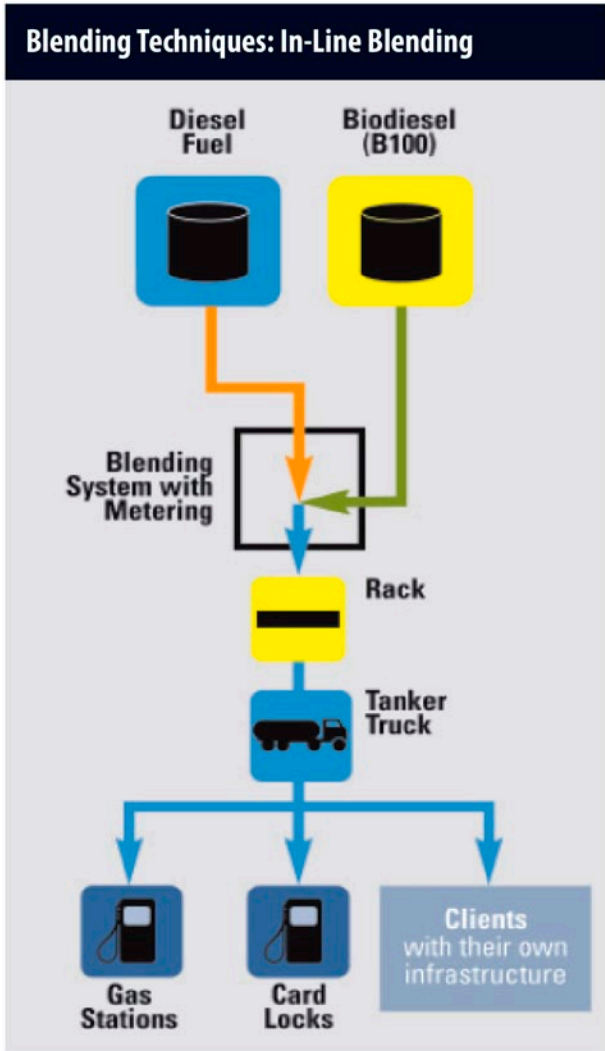
FIGURE 4: Biodiesel Introduction Points



Reproduced with permission from **Sine Nomine**, 2007.

For the ARDD, two types of renewable diesel (FAME and HDRD) were introduced at the primary terminal level (Sherwood Marketing Terminal in Edmonton) as blending components at the rack. Finished, blended fuel was loaded at the terminal into Shell-Flying J tanker trucks and shipped to card locks and yard tanks for retail or dispensing to participating fleet vehicles. As shown below, homogenous, fuel blends containing FAME or HDRD were arrived at using proper metering and in-line blending units.

FIGURE 5: In-Line Blending



Reproduced with permission from Sine Nomine, 2007.

This model of fuel blending was chosen because it reflects preferred current industry practice for blending additives and base components of finished fuel at the rack level. In this model, renewable content is added upstream of the point of taxation, suggesting that renewable content could be handled commercially like bulk transfers of unfinished fuel between refiners, or akin to additives.

In addition to accomplishing accurate blend ratios, terminal-level blending minimizes handling steps that present opportunities for fuel contamination. All components were piped to the point of injection in controlled conditions, ensuring a homogenous finished product that could be handled at the loading rack the same way petroleum diesel is currently handled.

BLENDING FACILITY

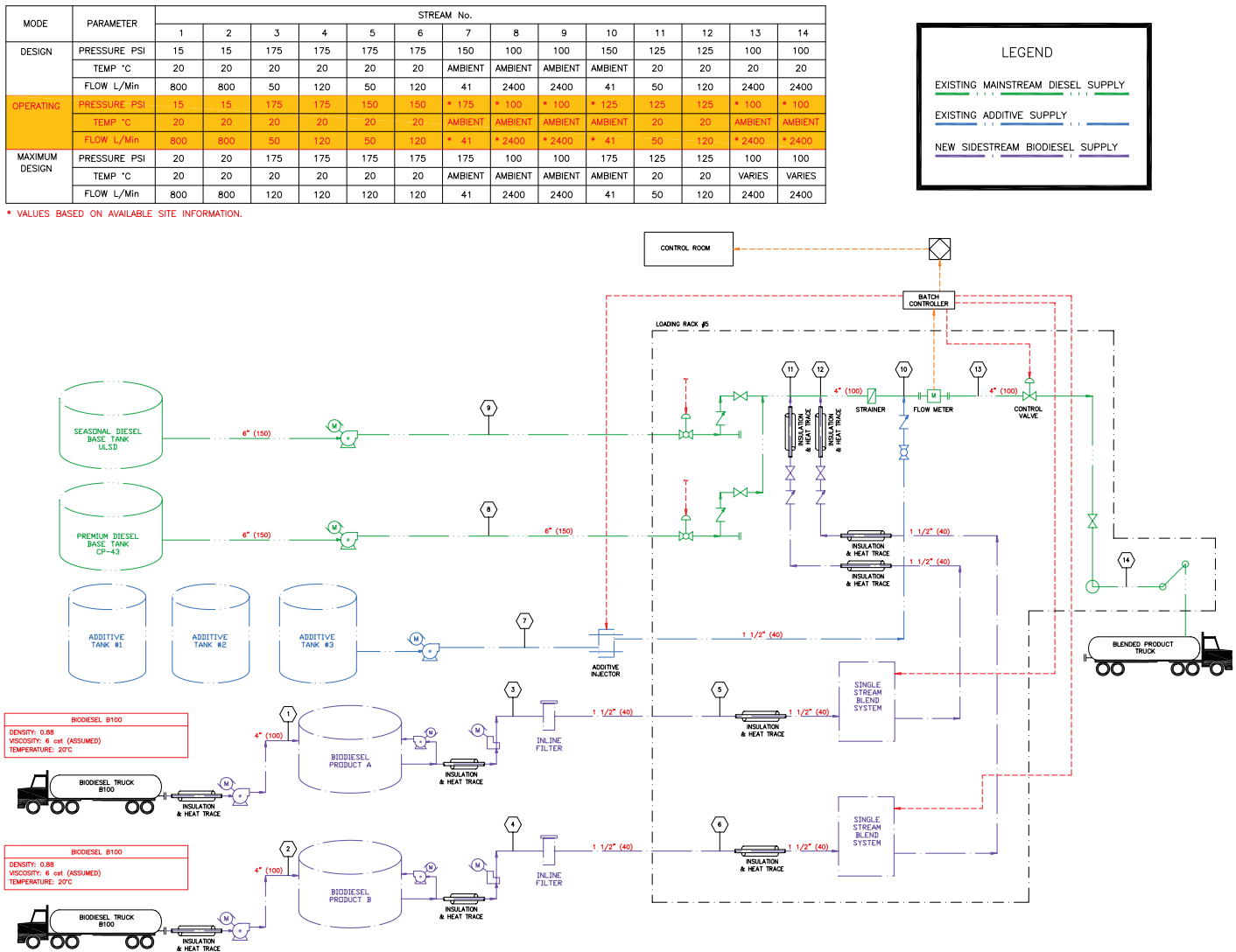
One of the reasons for carrying out this project was to demonstrate an inline blending system for creating the 2% and 5% blends that would be created at a major marketing terminal under an RFS scenario. The blending system was chosen to provide the automated and precisely controlled blending typical of diesel and gasoline 'racks' or bulk terminals. Built with storage capacity of approximately 10% of a full build-out system, the blending facility constructed at Shell's Sherwood Marketing Terminal was designed to mimic the technologies, patterns and procedures that might be anticipated in the Canadian market in the case of a fully-deployed Renewable Fuel Standard.

FIGURE 6: Facility Location: Sherwood Marketing Terminal, Edmonton, AB



A dual-stream blend system was supplied to Shell's Sherwood Marketing Terminal to accommodate separate streams for FAME and HDRD fuels (see Figure 7). This type of system was chosen because it was seen as a likely type of blending system to be used when integrated into a bulk diesel terminal. Blend formulation was designed to produce accurate volumetric blends of base seasonal diesel, renewable diesel and ultra low sulphur kerosene to the desired proportions. At time of print, the ARDD was Canada's only demonstration to include ultra low sulphur kerosene for adjustment of cloud points to meet CAN/CGSB 3.520 fuel standard.

FIGURE 7: Schematic of Blending



Source: Associated Engineering, 2007

The blending facility consisted of an offloading area, two double-wall storage tanks for the renewable diesels with spill containment, recirculation pumps, filters, interstitial space heaters and immersion heaters, a cabinet with fuel blenders installed at the diesel rack, and ancillary piping that was heat-traced and insulated to ensure the product was maintained above its cloud point.

Deliveries of renewable diesel were unloaded as per normal industry practice through standard four inch hose at the unloading station and pumped into the appropriate storage tank. The FAME product was intended to be stored at least 15°C above its cloud point, while the HDRD product was intended to be

stored at least 5°C above its cloud point. These temperature values were chosen by the Steering Committee based on industry consultations for successful performance in the Canadian market (to ensure 100% homogeneous liquid phase renewable diesel in storage) and do not reflect or represent a legislated requirement.

The neat renewable diesel offloading rack was also heat traced and insulated to provide protection from the elements along the entire path of the renewable diesel handling system. Likewise, because the blending facility incorporated tanks with only enough heating capacity to maintain their contents at a constant temperature (i.e. not able to quickly raise the temperature of fuel in storage), neat renewable diesels were delivered at approximately the same temperature ranges. Immersion heaters were specified for the B100 tanks but not operated in some cases due to design constraints.

The recirculation pumps and filters were located inside the protective shed enclosures attached to the B100 tanks. As such, neat FAME and HDRD were normally filtered at approximately 15°C and 5°C respectively. As per Shell standard practice, filtration was present on the card locks' dispensing pumps.

FIGURE 8: Storage Tanks for Neat Renewable



FIGURE 9: Filters on Neat Renewable Diesel Tanks





FIGURE 10: Insulated and Heat-Traced Offloading Station

BLENDING TECHNIQUES

Neat renewable diesels were blended by precisely-controlled inline blenders to provide uniform, consistent blends. The design of the blending system allowed for late-stream blending with cloud point-adjusted seasonal diesel upstream of additive injection.

The blending system installed allowed for blends of up to 5% renewable product, as this was the maximum blend level contemplated in this demonstration.



FIGURE 11: Close-Up of Micro-Blenders for FAME and HT Fuels

Heated storage or delivery was not required of blended fuels, as they were formulated to perform during the coldest periods (i.e. to meet the same cloud point requirements as petroleum diesel for the same location).

FUEL RETAIL LOCATIONS

To maintain segregation of the dispensing systems for blended fuels, the ARDD required card locks with separate (as opposed to manifolded, or interconnected) underground storage tanks. In addition, these card locks were required to fit with the participating fleet’s logistics geographically. The ARDD’s four fuel dispensing sites are outlined below:



FIGURE 12: Designated Fuelling Card Lock Location #1 – Shell – HDRD Blended Fuel
Edmonton South - 1820 76th Avenue



FIGURE 13: Designated Fuelling Card Lock Location # 2 – Shell – FAME Blended Fuel
Calgary - 2525, 23rd Street NE

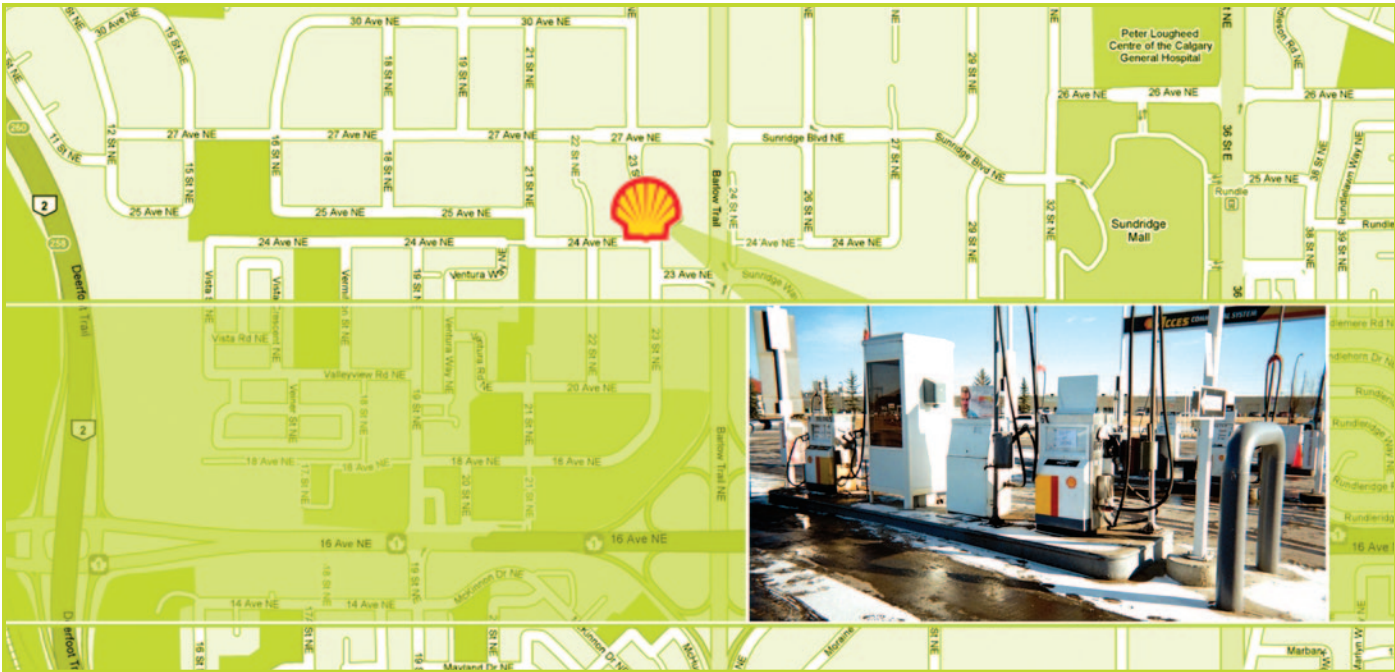
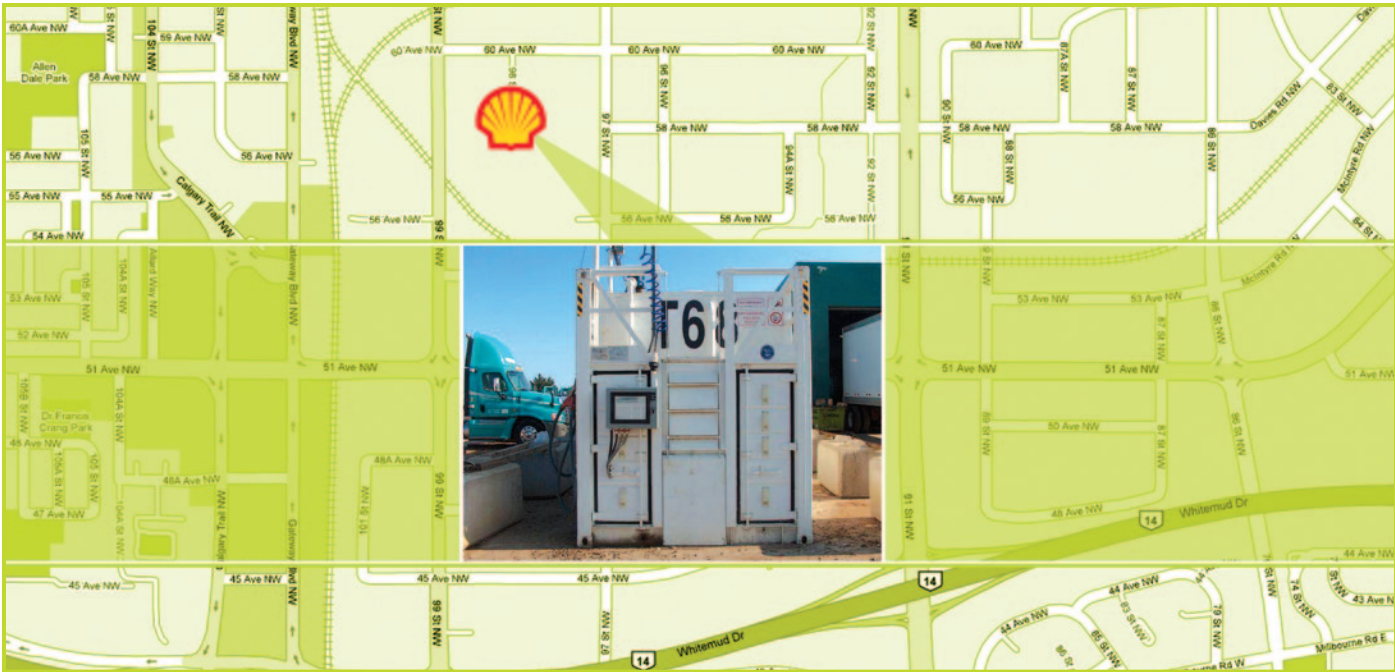


FIGURE 14: Designated Fuelling Card Lock Location # 3 – Shell – HDRD Blended Fuel
Lloydminster - 5109 63rd Avenue



FIGURE 15: Designated Fuelling Location # 4 – Rosenau Transport Yard Tank – FAME Blended Fuel
Edmonton - 5805 98 Street



As per Shell standard practice, all SFJ card locks were fitted with dispensing pump filters to remove the potential of any particulate matter at the dispensing level. The Rosenau yard tank dispensing system was commissioned with a strainer only and did not have any supplementary filtration installed. No special requirements were stipulated for filter types; typical 10-30 micron cellulose paper filters were used. Although the ARDD did not specifically address filter suitability with blended fuel, there were no positive or negative effects noted from the presence or absence of supplementary filters at dispensing sites or at the terminal.

Contracts for fuel procurement were drafted as per normal fuel sales contracts, with clauses covering price, volume, delivery options, quality specifications, handling requirements, liability and indemnity, currency and payment terms, point of sale, handling and testing instructions, etc. For the purpose of this demonstration, all procured biofuels (FAME and HDRD) were tested and met the appropriate ASTM and CGSB specifications at time of receipt. For the biofuel blends, Shell Canada provided the same warranty of quality and fit for purpose that is offered on its normal ULSD fuel. Agreements were signed between Shell and each of the participating fleets to make explicit this fuel quality guarantee for renewable diesel-blended fuels, restricted to the ARDD.

FUEL PROPERTIES

During the winter months—mid-December 2007 to mid April, 2008—a 2% blend was used, while a 5% blend was used from mid April until the end of the trial on September 30, 2008. All blends of renewable diesel were blended with seasonal diesel and ultra low sulphur kerosene also known as CAN/CGSB-3.517 Type A fuel (which is similar to Number 1 diesel in the US) to produce fuels whose cloud points would meet the requirements of the CAN/CGSB 3.520 fuel standard. Fuel suppliers were solicited to supply fuel samples of renewable diesel by an invitation process and selected through consensus of the ARDD Steering Committee based on quality, cold weather performance, and some social and environmental criteria. A suite of fuel testing work was carried out as a precursor to the ARDD in a sister study known as the Renewable Diesel Characterization Study (RDCS). Results of the RDCS are available via www.climatechangecentral.com or www.renewablediesel.ca.

FUEL HANDLING

Guidelines for handling biodiesel (B100) and blended FAME fuel (Bxx) have been published by the **US National Renewable Energy Laboratory (NREL)**, the **Alberta Biodiesel Association** and the **Sine Nomine Group’s Assessment of the Biodiesel Distribution Infrastructure in Canada** (for Natural Resources Canada). Please click on the highlighted text for web links to the referenced documents.

Throughout the project, Shell handling guidelines were followed in order to maintain the quality of fuel. In the ARDD, because carriers of neat renewable diesel were not necessarily dedicated diesel fuel carriers, for each load of neat biofuel, the prior load in the truck was required to be diesel or jet fuel, otherwise a certificate of cleanliness or wash/dry certificate was required to prove that the hold was clean. Blended

fuel was transported following current Shell handling guidelines for diesel fuel.

Trusted carriers were used in all cases to haul the neat biofuel deliveries, specifically haulers with experience hauling jet fuel or that had acceptable fuel handling procedures in place. The ARDD requirement to deliver neat renewable diesel fuels at specified temperatures required carriers of B100 to have insulation and/or heating capability such as steam coils or heat exchangers. To warm the product to desired temperature (approximately 20-30°C, or at least 15°C



FIGURE 16: Flying J Fuel Hauling

above the cloud point), carriers warmed the hold using steam from off-site service providers. No such requirements were needed for carriers of blended fuels, which were formulated to remain liquid under the ambient temperatures. Samples were retained prior to shipping and upon receipt at Shell’s Sherwood Marketing Terminal. Note: the first B100 FAME delivery to the ARDD was rejected due to excess steaming after arriving at the terminal in an ‘overheated’ state (above 80°C). Subsequent tests confirmed a reduction in oxidative stability (by EN 14112) from over 6.5 hours to approximately 3.3 hours (still meeting specification but a significant reduction). To preserve project integrity, a fresh batch was procured for on-road use.

The steps taken in the ARDD represent one of many approaches that may achieve quality control, but does not exclude other approaches, handling systems or blending strategies from also achieving reliable quality control.

FUEL SELECTION

The ARDD worked with Shell Canada Ltd as a project partner and service provider. As such, the petroleum fuel used in the demonstration was from Shell’s Scotford Refinery in Alberta. Shell’s seasonal diesel and low cloud point diesel were used exclusively in the ARDD. A selection of characteristics of the base petroleum diesel fuels illustrative of fuels used in the demonstration are presented in Table 4 below.

TABLE 4: Characteristics of Base Diesel Fuel

Test	Units	Method	Limits		Summer	Seasonal To warm the	Low Cloud
			Min	Max			
Cetane Number		ASTM D613	40		41.3	42.8	41.5
Cloud Point	°C	ASTM D5773	As Required		-16.3	-35.2	-43.6
Flash Point	°C	ASTM D93 procedure A	40		56.0	54.0	53.0
Density	Kg/m3	ASTM D4052	As Required		844.2	839.5	833.8
Pour Point	°C	ASTM D5949 or ASTM D97	Optional		-45	-54	-58
Cold Filter Plugging Point	°C	ASTM D6371	Optional		-21	-31	-40
Low Temperature Flow Test	°C	CAN/CGSB-3.0 No 140.1	Optional		Not reported	-32	-37

*Cold Filter Plugging Point is not an allowed spec in CGSB.

For renewable content, a selection of renewable diesel fuels (FAME and HDRD) was made based upon the quality testing done in the RDCS and a list of additional indicators ranging from sustainability and environmental balance, social benefit, security of supply during the demonstration and cost-effectiveness. Milligan BioTech Inc. was chosen as the supplier for canola methyl ester, BIOX Corporation as the supplier of tallow methyl ester, and Neste Oil as the supplier of hydrogenation derived renewable diesel (which can be made from a combination of tallow, palm, and rapeseed/canola feedstocks).

A comparison of characteristics of the various neat renewable diesel fuels used in the demonstration is presented in Table 5 below.

TABLE 5: ARDD Neat Renewable Fuel Characteristics

Inspection Property	Test Method Number	CGSB Limit	Neat HDRD	Neat Canola Methyl Ester	Neat Composite Methyl Ester
Cetane	ASTM D613	Min 40	74	50-65	55-60
Cloud Point (°C)	ASTM D5773	As Required	-19 to -28	-2 to -3	0
Density (g/kg)	ASTM D4052	As Required	775	885	882
Oxidative Stability (hrs)	EN 14112	Min 3.0	N/A*	6 to 7	6 to 7
Flash Point (°C)	ASTM D93(A)	Min 40 (HDRD) Min 93 (FAME)	60	170	170

*EN 14112 is not part of CAN/CGSB specifications for diesel.

FUEL BLENDING

Blend formulation is specific to the characteristics of any given refiners processing capabilities, crude diet and blending capabilities. CAN/CGSB-3.517 – for petroleum diesel and CAN/CGSB-3.520 – for biodiesel blends up to 5% both include cold operability requirements that are further discussed on page 42. Industry practice is to meet this requirement by creating geographic zones with cloud point schedules that vary by half-month. Calgary is in zone (AB-1), with Edmonton & Lloydminster in a colder zone (AB-2).

Shell assured that the renewable diesel blend would meet the cloud point requirements of CAN/CGSB-3.520 by adding Ultra Low Sulphur Kerosene (ULSK) to the blends. The ULSK, as sold by Shell, has a cloud specification of –43 deg C or colder. A typical result for Shell’s ULSK would be a cloud point of –45 deg C.

Based upon the results of the RDCS and internal Shell studies it was determined that the simplest way of accomplishing this was to offset the cloud point requirement for the base diesel by 3 deg C in the case of the 2% FAME blends and by 1 deg C in the case of the 2% HDRD Blends. This approach was based upon the cloud point of FAME being -2oC to -3oC and HDRD being -16oC to -19oC. It should be noted that the blending methodology was not changed when the second shipment of HDRD arrived with a cloud point of -28oC, which would have significantly reduced the ULSK blending requirement.

This approach, of using an offset, was validated as appropriate in the ARDD project. The results are discussed later under the Blend Consistency and Accuracy Section (page 40).

After the end of March, the cloud requirements for both zones AB-1 & AB-2 were warm enough to no longer require any addition of ULSK. The “seasonal” diesel as produced by Shell in April had a cloud point of –20 deg C versus a cloud schedule requirement of –15 deg C or warmer. This 5 deg C offset exceeds the 1 or 3 deg C offset noted above and so precluded any requirement for ULSK.

From mid-April to mid-September the blends were increased to contain 5% of FAME or HDRD. During this period the quality of the “seasonal” diesel fuel produced by Shell did not require any use of ULSK in the renewable diesel blends. If deliveries from the trial had continued past mid September, ULSK blending would have been required, as well as reverting back to 2% blends to meet the lower cloud point requirements.

From the start of the trial in December until the end of March the renewable diesel blends were a blend of “seasonal” ULSD, ULSK and either 2% FAME or 2% HDRD. Table 6 on the following page shows the blend data.

TABLE 6: Blending Data Dec through March

	Required Cloud Point (°C)	FAME Results %			HDRD Results %		
		FAME	Seasonal ULSD	Kerosene (CP-45)	HDRD	Seasonal ULSD	Kerosene (CP-45)
AB-1 Zone (Calgary)							
Dec 1 – Jan 31*	-33	2	66	32	2	87	11
Feb 1 - 14	-30	2	70	28	2	88	10
Feb 15 - 28	-26	2	74	25	2	89	9**
Mar 1 - 15	-25	2	74	24	2	90	8**
Mar 16 - 31	-20	2	77	21	2	90	8**
AB-2 Zone (Edm & Lloyd)							
Dec 1 - 31	-36	2	55	43	2	84	14
Jan 1 - 31	-37	2	55	43	2	83	15
Feb 1 - 14	-34	2	64	34	2	86	12
Feb 15 - 28	-30	2	70	28	2	88	10
Mar 1 - 15	-28	2	72	26	2	89	9**
Mar 16 - 31	-20	2	77	21	2	90	8**

*Half-month periods have been aggregated where the cloud point is the same.

**Blending model was kept the same despite receipt of the HDRD with a -28oC cloud point.

Blending to correct to the cloud point schedule required ULSK addition of 21-43% of the blend for B2 FAME and 8-15% of the blend for 2% HDRD. In the coldest part of the year the 2% FAME blends required the use of 43% ULSK for use in either Edmonton or Lloydminster and 32% ULSK for use in Calgary. Similarly the 2% HDRD blends required the use of 15% ULSK for use in either Edmonton or Lloydminster and 11% ULSK for use in Calgary.

The ARDD did not estimate changes to total annual ULSK demand in Canada. However, it is relevant to note that the supply of ultra low sulphur kerosene is under limitations in Canada that vary by company, geography and season.





FUEL QUALITY MONITORING PROTOCOL

Recognizing that maintaining fuel quality throughout the chain of custody was a primary objective of this demonstration, a monitoring protocol was created to sample and test all fuels for quality and cold operability characteristics throughout the supply chain. The ARDD test protocol went beyond normal industry practice to capture a wide range of information for this demonstration.

Each incoming renewable diesel delivery was tested for quality and cold operability attributes. All renewable diesel deliveries were stipulated to be accompanied by valid Certificates of Analysis showing they met ASTM D6751 and CAN/CGSB 3.517 specifications (for FAME and HDRD respectively). Samples were retained, tested and stored for each incoming delivery of neat biofuel and each outgoing delivery of blended fuel. This is consistent with best industry practice. Third party analysis was conducted at Alberta Research Council (ARC) to verify the vendors’ Certificates of Analysis, with all lab testing carried out by ARC’s Fuels and Lubricants division in Edmonton, AB. Cold Soak Filtration Time is the time required to filter 300 ml of sample through a filter of known type under specific conditions. This test method and its corresponding limit are under development at ASTM, where limits ranging from 150 to 360 seconds have been proposed. FAME deliveries were required to report cloud point and cold soak filtration time, with all FAME deliveries required to meet a maximum cold soak filtration time test result of 200 seconds (a limit agreed to for the ARDD and not an industry standard at time of print). HDRD deliveries were also required to report cloud point.

TABLE 7: ARDD Fuel Testing Protocol Schedule

Tests Required Along Supply Chain	Full ASTM 6751 or CAN/CGSB 3.517	Clear & Bright and Density	Density, Cloud Point, Blend Level and Lubricity*	Additional testing
Neat Fuel – Producer	Each batch			Only if trouble
Neat Fuel – Delivery	Each batch	Upon delivery		Only if trouble
Blended Fuel – Delivery			Each batch	Only if trouble

*Lubricity only required on a subset of retained samples

NEAT BIOFUEL QUALITY RESULTS

Each of the four deliveries of FAME received during the ARDD met ASTM D6751 specifications. Each of the three deliveries of HDRD received during the ARDD met CAN/CGSB 3.517 specifications.

All renewable fuels were purposely requested not to be additized for stability, cold flow or any other parameter to minimize any potential interactions with additives. As a result, a project goal was set to use the FAME product within three months of receipt (about half of the typical shelf life recommended in the US NREL Guidelines) to guard against signs of fuel degradation (e.g. acid number, oxidation stability, etc). Throughout the ARDD, suitable storage and shipping containers were used at all times (e.g. steel tanks and bulk fuel carriers with non-nitrile rubber elastomer hoses).

Quality in the Lifecycle of a FAME Batch:

Proper handling and storage are critical for preserving product quality. The BQ9000 quality control program for FAME fuels provides a framework for measuring product quality at points throughout the chain of custody, and monitoring the quality of a batch or commingled shipment. The BQ9000 program does not set prescriptive guidelines but requires biodiesel producers to prove (through third party lab testing and consistent record keeping) that all biodiesel sold meets ASTM D6751 at the point of production through the handling chain to the point of sale. The ARDD followed BQ9000 principles by sampling and testing fuel at the origin of biofuel production, during transport and at the terminus of the supply chain in order to provide comprehensive data collection for tracking fuel quality in the study. (The ARDD had a BQ9000 registered marketer on its Steering Committee, and applied industry best practice to supplement BQ9000 guidelines.)

Table 7 below provides an overview of changes observed in a batch of FAME from its point of origin through shipping to the Terminal and storage over five months. Note that the final sample in this timeframe is commingled with a second delivery of FAME from the same producer using the same feedstock. Each value in Table 7 is from a single test result from a single sample.

TABLE 8 B100 (Canola Methyl Ester) – Lifecycle of a Batch

Key Inspection Properties	Test Method Number	ARDD Limit	Point of Production	Reciept at Terminal	Pumpout (commingled)
Cetane	ASTM D613	Min 40	53.6	53.0	54.3
Cloud Point (°C)	ASTM D5773	Report only	-2.6	-3.5	-2.6
Density (g/kg)	ASTM D4052	Report only	883.6	883.6	883.9
Acid Number	ASTM D664	Max 0.50	0.18	0.17	0.23
Oxidative Stability (hrs)	EN 14112	Min 3.0	6.9	4.3	3.6
Flash Point (°C)	ASTM D93(A)	Min 93	143	158	149
Total Water and Sediment	ASTM D2709	Max 0.05%	0.00	0.00	0.00
Water by Karl Fischer (Only for EN 14214)	ASTM D6304(A)	None set (500 ppm suggested)	Not reported 321	751 508	936*
Cold Soak Filtration	Under Dev.	Max 200**	147.5	100	46.5

*Note that on point of receipt, the two samples making up the commingled product in this tank were measured at 751 and 508 ppm respectively. Thus the pump-out sample did not increase in water content from 321 ppm to 936 ppm solely due to atmospheric moisture during storage at Sherwood Marketing Terminal. Results suggest that water may have been introduced in transport – see p. 33 for typical safeguards against water contamination.

**Cold Soak limit of 200 seconds was not part of ASTM D6751 during demonstration. The ARDD limit of 200 seconds was imposed as a project-specific criterion.

Like with petroleum diesel and HDRD, the handling of neat FAME can affect product quality. Because B100 has a higher propensity to absorb water than ULSD, typical precautions to safeguard against water contamination of diesel fuel should be emphasized when handling neat biodiesel. Possible precautions may include using desiccant air filters on tank vents and proper drying and/or flushing procedures to ensure no residual water is left in storage and transport containers.

As seen in Table 8, the two tests for water content (i.e. ASTM D2709 and ASTM D6304) are not directly comparable. Whereas D2709 is a measure of free water and sediment, D6304 measures total water including dissolved, suspended and free water. At time of print, ASTM D6304 is not part of ASTM D6751. Currently, CAN/CGSB 3.517 and CAN/CGSB 3.520 include a test for entrained water by visual assessment of haze at 4°C in winter and 15°C in summer.

Precautions for safeguarding product quality include general cleanliness of storage, managing ambient temperatures and humidity, and material compatibility. However, as noted in Table 8 above, water (as measured by ASTM D6304(A), also known as the Karl Fischer method), can be increased from exposure to atmospheric moisture, possible residual water in cleaned bulk truck tanks, and other sources.

FAME STORAGE

Given that the ARDD used neat and blended renewable diesel fuels over a period of several months, the inventory of neat renewable diesel fuels consisted at some points of commingled product that had been stored on site for varying periods of time. At two points in the demonstration, the neat FAME tank was emptied: once at the end of the winter period on April 15, 2008; and once at the end of the demonstration following spring and summer operation, on November 3, 2008.

After the winter season, or B2 operation period (from project launch to April 15, 2008), the B100 FAME tank contained a mixture of canola methyl ester from two deliveries that had been in storage for 4.5 months and 2.5 months, commingled. As shown in Table 8 below, while lab analysis showed that some oxidation had occurred, the fuel removed from this tank met ASTM D6751 specifications for all specified quality parameters.

TABLE 9: B100 (Canola Methyl Ester) - Changes from Storage

Inspection Properties	Test Method Number	ARDD Limit	FAME 1	FAME 2	FAME Out
Cetane	ASTM D613	Min 40	54.8	53.0	54.3
Cloud Point (°C)	ASTM D5773	Report only	-2	-4	-3
Density (g/kg)	ASTM D4052	Report only	883.8	883.6	883.9
Acid Number	ASTM D664	Max 0.50	0.21	0.17	0.23
Oxidative Stability (hrs)	EN 14112	Min 3.0	4.5	4.3	3.6
Flash Point (°C)	ASTM D93(A)	Min 93	160	143	149
Cold Soak Filtration	Under Dev.	Max 200**	128.5	100.0	46.5
Total Water and Sediment	ASTM D2709	Max 0.05%	0.00	0.00	0.00
Water by Karl Fischer***	ASTM D6304(A)	None set	751	508	936

*Note that none of the Canola B100 fuels were additized for oxidative stability, cold flow or any other parameter, and were stored without desiccant air filters on tank vents.

**The 200 second limit for cold soak test was imposed as an ARDD project specification, and did not represent an official ASTM or CGSB specification at time of print.

***Only for EN 14214; not part of ASTM D6751 at time of print. Note: EN 14214 is a standard for FAME as a pure fuel whereas ASTM D6751 is a standard for FAME as a blending component.

Following the B5 operation period (with 75% canola methyl ester / 25% tallow methyl ester), the tank was once again emptied, providing an opportunity to analyze B100 fuel of mixed feedstock that had been in storage for approximately 5.5 months and 2.5 months (commingled). Each value in Table 9 is from a single test result from a single sample.

TABLE 10: B100 (Composite Methyl Ester) - Changes from Storage

Inspection Properties	Test Method Number	ARDD Limit	FAME 3	FAME 4 (commingled)**	FAME Out
Cetane	ASTM D613	Min 40	54.7	59.6	56.3
Cloud Point (°C)	ASTM D5773	Report only	0	0	-0.1
Density (g/kg)	ASTM D4052	Report only	882.1	867.7	882.3
Acid Number	ASTM D664	Max 0.50	0.18	0.43	0.23
Oxidative Stability (hrs)	EN 14112	Min 3.0	6.9	4.7	3.3
Flash Point (°C)	ASTM D93(A)	Min 93	173.0	165	169
Cold Soak Filtration	Under Dev.	Max 200***	73.0	151	136
Total Water and Sediment	ASTM D2709	Max 0.05%	0.00	0.00	<0.005
Water by Karl Fischer****	ASTM D6304(A)	None set	345	624	432

*Note that none of the Canola B100 fuels were additized for oxidative stability, cold flow or any other parameter, and were stored without desiccant air filters on tank vents.

**The 200 second limit for cold soak test was imposed as an ARDD project specification, and did not represent an official ASTM or CGSB specification at time of print.

***Only for EN 14214; not part of ASTM D6751 at time of print.

The analysis of FAME 4 was conducted on a sample taken after delivery and recirculation of the fourth batch of B100 and the remaining inventory from the third B100 delivery in the neat biodiesel tank at Sherwood Marketing Terminal. This method of sampling was chosen to reflect the quality of the overall product in the B100 tank. FAME 3, by contrast, was sampled upon arrival without any commingling, recirculation, mixing or filtration. The variation in water content by ASTM D6304 and acid number by ASTM D664 between ‘FAME 4’ and ‘FAME Out’ do not trend as expected, and may suggest a sampling issue with the FAME 4 sample. Each value in Table 10 is from a single test result from a single sample.

HDRD STORAGE

Similar to the handling of neat FAME, the HDRD product stored at Sherwood Marketing Terminal was tested upon receipt and upon emptying the tank when decommissioning the temporary blending facility.

TABLE11: Quality of HDRD in Storage

Test	Units	Method	Limits		Seasonal ULSD	HDRD on Receipt	HDRD Pumpout
			Min	Max			
Acid Number	Mg KOH/g	ASTM D974	0.10		0.00 to 0.003	0.00	0.00
Cetane Number		ASTM D613	40		42.8	74-75	76.7
Cloud Point	°C	ASTM D5773	As required			-19 to -29	-20.1
Carbon Residue	Mass %	ASTM D524 & ASTM D86		0.15	0.07	0.02 to 0.04	0.02
Flash Point	°C	ASTM D93 procedure A	40		54.0	60 to 64	62
Density	Kg/m3	ASTM D4052	As required			775 to 777	775.7
Pour Point	°C	ASTM D5949 or ASTM D97	Op-tional		-54	-21 to -36	-27
Sulphur	Mass ppm	CAN/CGSB-3.0 No. 16		15	4.5	<1 to 3.1	<1
Water and Sediment	Volume %	ASTM D1796		0.05	0	0	0
Cold Filter Plugging Point	°C	ASTM D6371	Op-tional		-31	-20 or not reported	Not re-ported
Low Tempera-ture Flow Test	°C	CAN/CGSB-3.0 No 140.1	Op-tional		-32	-18 or not reported	Not re-ported

*Cold Filter Plugging Point not part of CGSB tests.

During the course of the ARDD three deliveries of HDRD were received at Sherwood Marketing Terminal. As shown in Table 11, the quality of remaining product inventory of HDRD was not significantly affected by storage and handling in typical infrastructure. The values above are representative of three HDRD samples.

VOLUME OF DISPENSED FUEL

During the winter phase of the demonstration (December, 2007 to mid-April, 2008), the ARDD dispensed nearly 650,000 litres of B2 blended fuel, comprising approximately 250,000 litres of FAME B2 and 400,000 litres of 2% HDRD. In the shoulder and summer seasons of the ARDD (April16 to September 30), over 540,000 litres of B5 FAME and nearly 425,000 litres of 5% HDRD were dispensed. In total, the ARDD dispensed over 1.6 million litres of blended fuel.

TABLE 12: Fuel Volumes Dispensed by Phase and Location of ARDD

Total Fuel Lifted	B2 FAME	2% HDRD	B5 FAME	5% HDRD	Total
Lloydminster		177,117		220,816	397,933
Calgary Barlow	100,440		163,941		264,381
Edmonton South		226,161		203,683	429,844
Rosenau Yard	145,132		376,126		521,258
Total	245,572	403,279	540,067	424,498	1,613,416

BLEND CONSISTENCY AND ACCURACY

Results from analysis of FAME blends showed that blend levels were within 0.1% of the target for all measured samples. HDRD blends could not be tested for blend concentration, as the HDRD molecules are similar to petroleum diesel. The cloud points of both types of blended samples remained relatively consistent at each step of the cloud point schedule. Graphical representations of the cloud points of FAME and HDRD blended fuels are provided in Table 13 (from December 15, 2007 to February 15, 2008 representing the coldest period), and Figure 17 and Figure 18 for both B2 and B5 periods of operation.

TABLE 13: ARDD Blended Renewable Fuel Characteristics

Inspection Properties	Test Method Number	CGSB Limit	B2 FAME	B5 FAME	2% HDRD	5% HDRD
Cloud Point (°C)	ASTM D5773	Report only (schedule)	-38.3*	-31.7***	-37.9*	-33.2****
Density (g/kg)	ASTM D4052	Report only	833.2	840.7	828.1	834.5
Lubricity (um)	ASTM D6079	Max 460**	260	290	520**	540**

*2% blend results taken January 22, 2008, the coldest period of Edmonton’s cloud point schedule.

**ASTM D6079, or HFRR, is one of five criteria that can be used to determine lubricity. Shell Canada qualifies its fuels using a pump rig test to determine fuel lubricity.

***B5 FAME results taken from April 21, 2008

****5% HDRD results taken from May 28, 2008.

The values in Table 13 are from single samples of each fuel (variation between samples was low). As shown in the figures on the following page, the cloud points for each delivery met or exceeded the required cloud point for all but one HDRD sample that was measured within 1°C of the cloud point requirement.

FIGURE 17: FAME Cloud Points of Blended Fuel Deliveries and Cloud Point Requirements

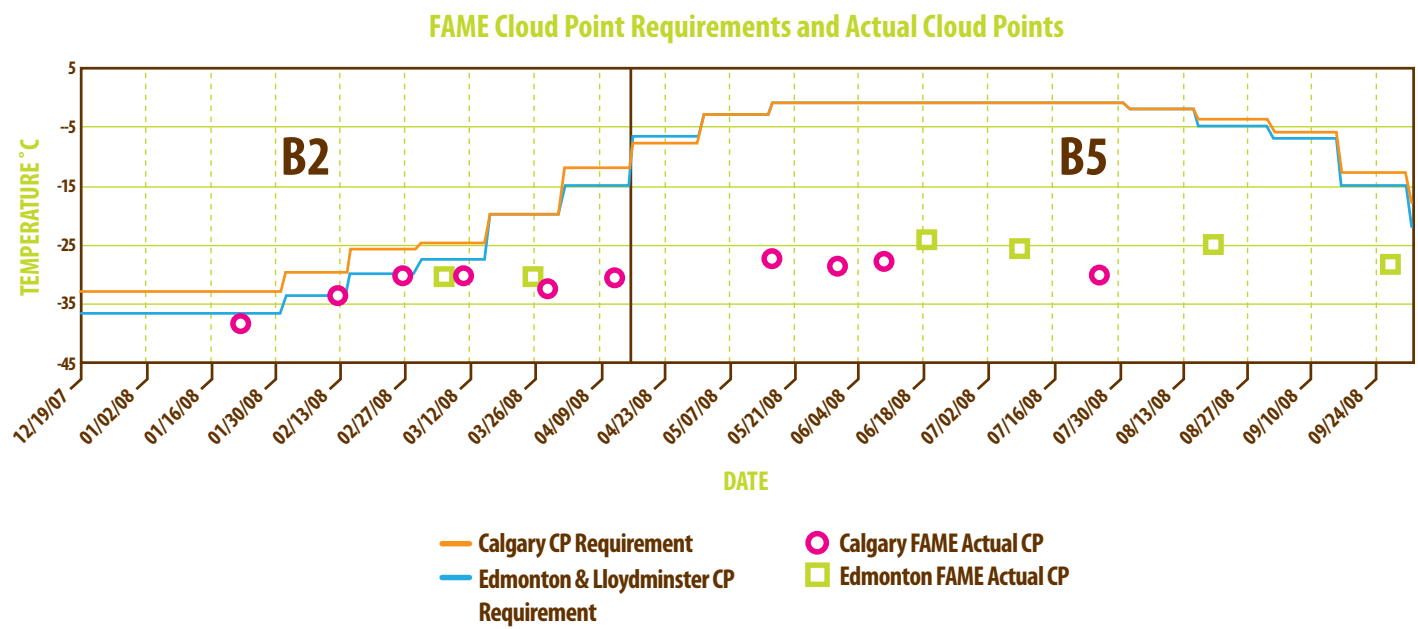
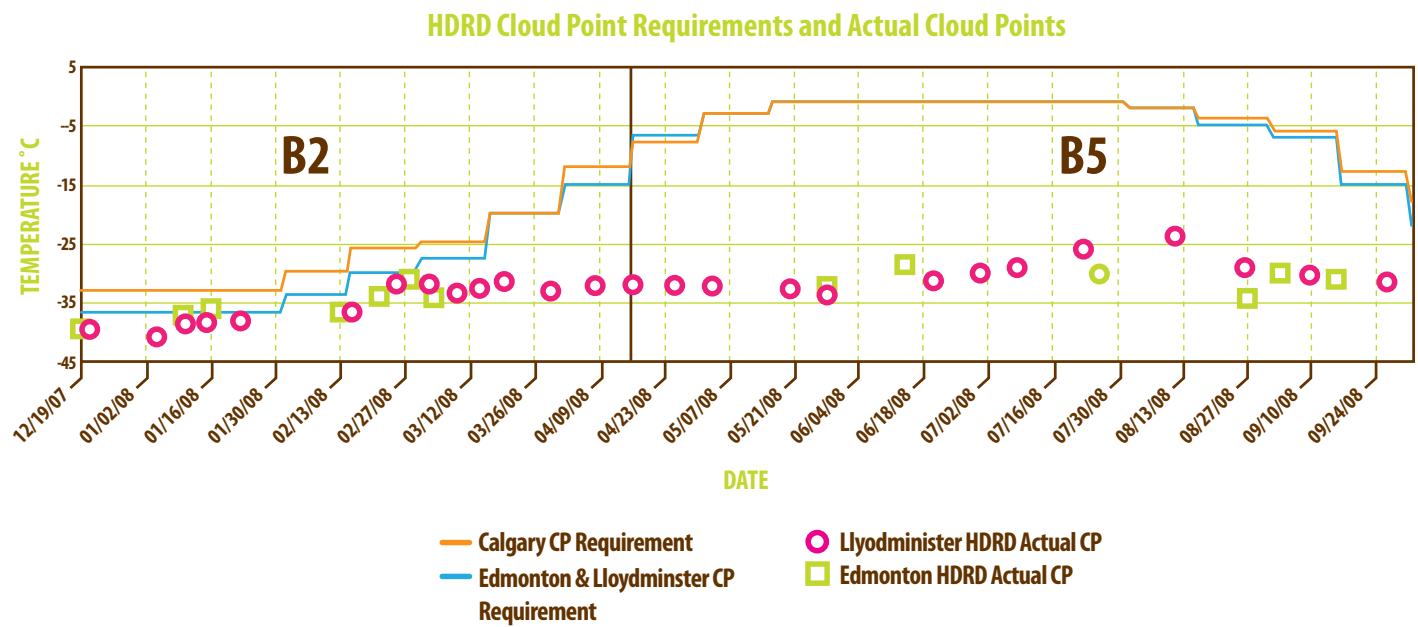


FIGURE 18: HDRD Cloud Points of Blended Fuel Deliveries and Cloud Point Requirements



Results from analysis of blended fuels showed that all fuel quality parameters were maintained at all times. Blend concentrations and blend formulation were observed to be satisfactory for all quality criteria and cloud point targets in the ARDD.

PROJECT MONITORING



MONITORING PROTOCOL

The ARDD collected data on fuel use, distance traveled, daily ambient temperatures, operating hours (when available), oil change and fuel filter change intervals and maintenance/operational observations. All data were gathered in aggregate monthly tallies from participating fleets. As such, the ARDD only gathered quantitative information about operability and general fuel performance (see Appendix B).

SEASONAL MONITORING

Staggered Launch:

Participating vehicles were launched in a staggered fashion, allowing the fleets to fuel at their next natural opportunity after notification of renewable diesel availability at the designated card lock. Fleets were asked to change the engine oil and oil filter, as well as fuel filter prior to taking on test fuel, but otherwise were asked to follow business as usual for fueling and maintenance practices.

Winter Period Observations:

From December, 2007 to February 16, 2008 (i.e. when ambient temperatures twice reached local CGSB cloud point specifications), the ARDD fleet increased in size reaching 19 trucks on FAME blends and 30 units on HDRD blended fuel. More units were launched after February 29, bringing the total number of trucks to 29 on FAME blends and 30 on HDRD blends, with another 16 trucks as control vehicles, operating on normal petroleum-based ULSD fuel. No fleets reported any fuel-related loss of service or mechanical operability challenge (save one early filter change, noted on page 46 below).

In Edmonton, for two consecutive nights in late January the overnight low temperatures fell below -40°C. During the same period temperatures fell across the province, reaching below -33°C in Calgary and to -40°C in Lloydminster. It should be noted, however, that during this extreme cold snap eight vehicles were operating on the FAME fuel from the Calgary card lock. Throughout the cold snap, B2 fuel was stored in the Edmonton yard tank but was not dispensed. During the extreme cold snap, monitoring systems for the yard tank could not be installed due to weather hazard and as a result the Edmonton yard tank was not commissioned until early February, when the extreme cold temperatures subsided.

Throughout the demonstration period, some units experienced difficulty accessing test fuel due to fuel card difficulties (card lock system access). In some cases, contrary to project protocols, drivers were forced to take on ULSD in order to continue doing business. While not anticipated, this situation provided the observation that units alternating between renewable diesel blends and normal ULSD did not experience operational difficulty in the ARDD, nor did units running exclusively on blends. For details, see Appendix B.

For broader context of winter temperatures in the study area, Figure 20 below shows the daily maximum and minimum temperatures in Edmonton, Lloydminster and Calgary as measured by Environment Canada.

FIGURE 19: Environment Canada daily temperature ranges

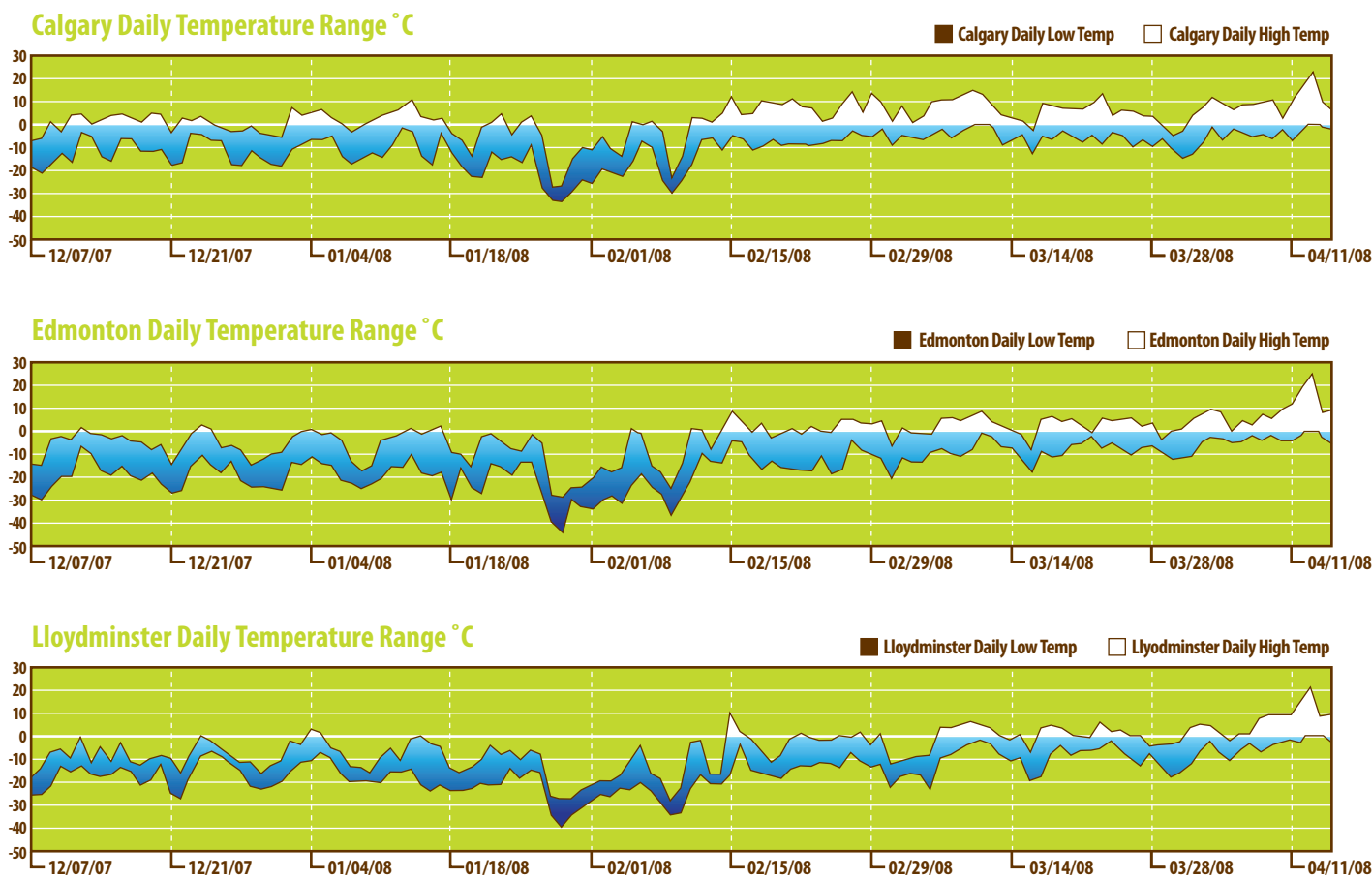


FIGURE 20: Overview of Fleet Launch for B2 FAME Fuel:

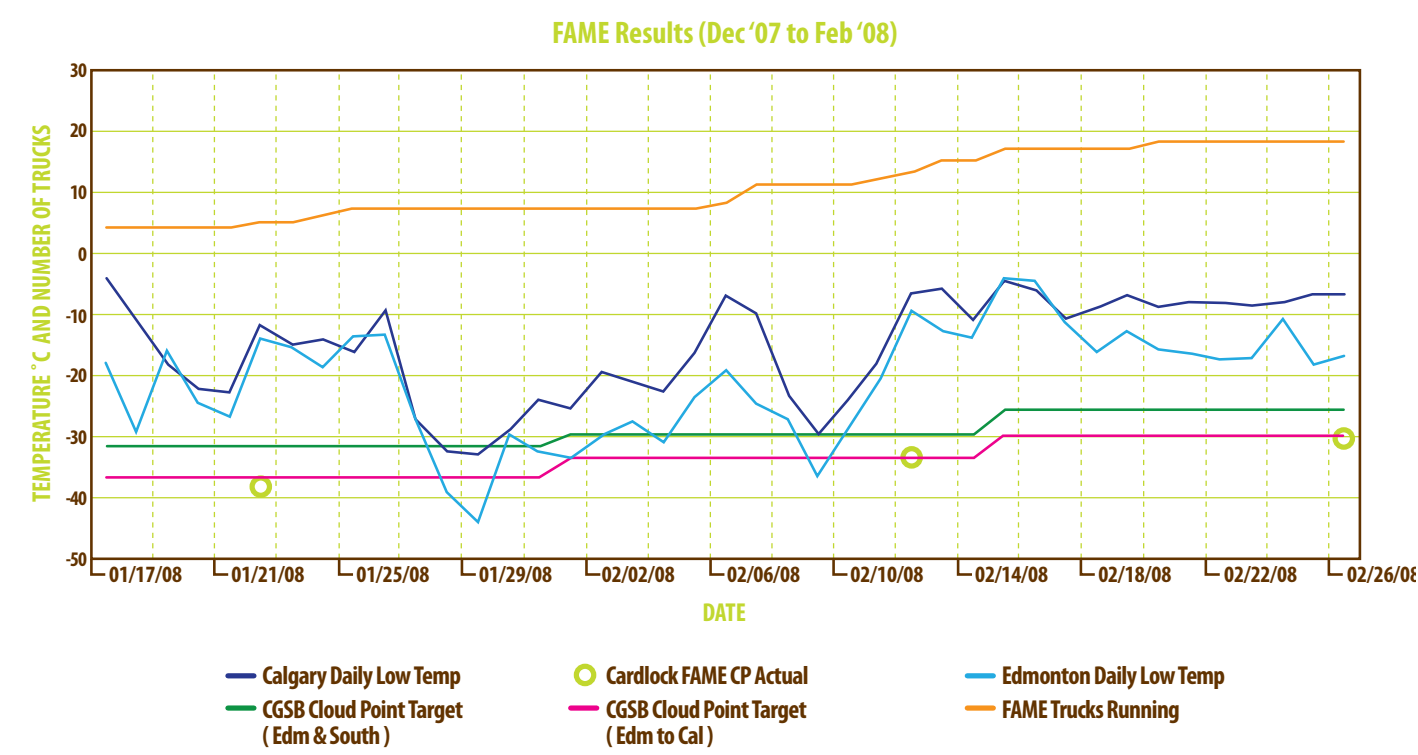


Figure 20 above provides an overview of the cold winter period (January 24 - February 15) for trucks running on FAME blends. The red line illustrates the number of trucks running on that test fuel, reflecting the staggered launch mentioned above. As of January 24, 2008, there were nine units running on B2 FAME in Calgary. As of February 7, 2008 eleven units were running on B2 FAME (comprising at least six class 8 trucks spanning CAT C15, Mercedes 4000, Volvo VED12 and Cummins ISX engines, five of which were 2007 models). The pink and dark blue lines represent the daily low temperatures for Edmonton and Calgary. The light blue lines represent cloud point specifications for CAN/CGSB 3.520 compliance. The CGSB cold operability or cloud point schedule is set to meet the 2.5th percentile low end design temperature for the location and half-month period (i.e. temperature at which ambient temperature does not fall below that value for more than 9 hourly readings in a 15 day period as calculated over four decades of historical climate data). For the Calgary region, the coldest period requires -33°C, while the requirement for the Edmonton region in the coldest periods is -37°C. The yellow triangles on the chart show the measured cloud point of samples of blended fuel taken from one of the participating card locks. Their measured cloud points all met or exceeded the CGSB requirement (note: some results varied within the repeatability of the test method from the required temperature).

FIGURE 21: Overview of Fleet Launch for 2% HDRD Fuel:

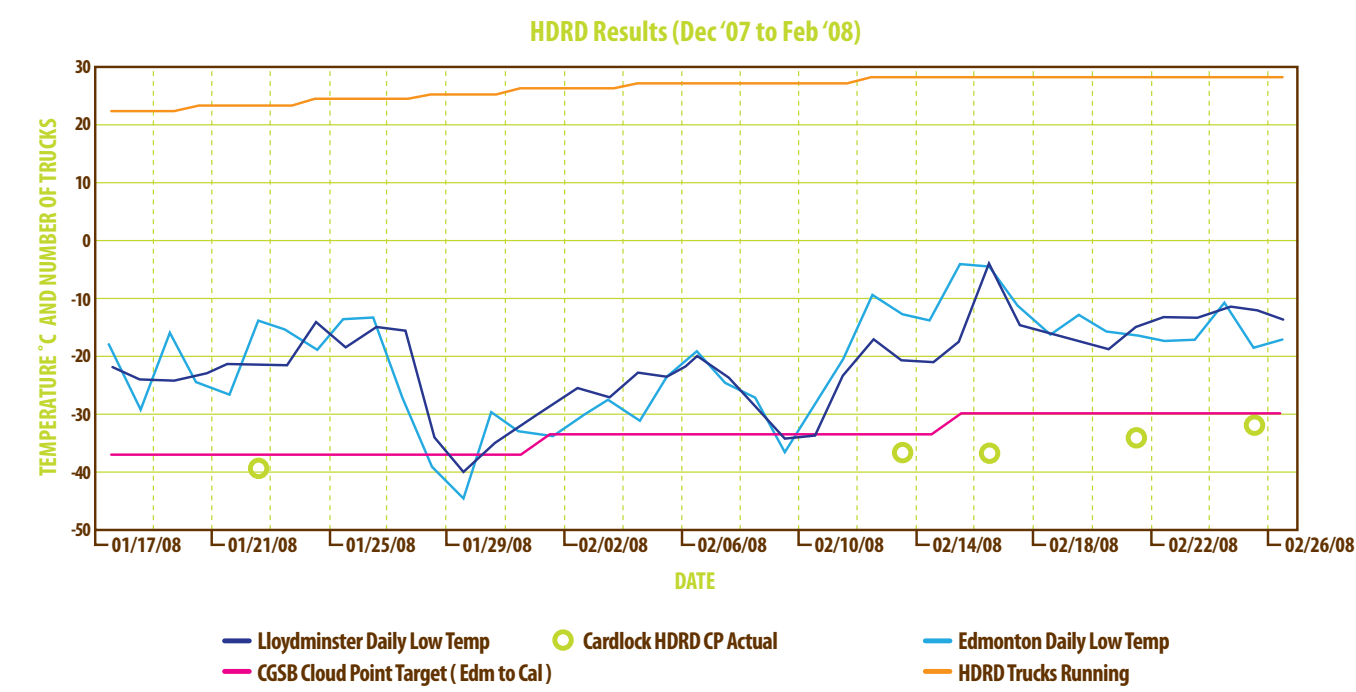


Figure 21 provides an overview of the launch of trucks running on HDRD blends. The red line illustrates the number of trucks running on this test fuel, reflecting the staggered launch mentioned above (the majority of trucks launched in the early part of January, 2008). The pink and dark blue lines represent the daily low temperatures for Edmonton and Lloydminster respectively. The light blue line represents cloud point specifications for CAN/CGSB 3.520 compliance. For the Edmonton region the coldest CGSB cloud point specification for this period is -37°C.

The dark blue diamonds on the chart represent the measured cloud point of samples of blended fuel taken from participating card locks on the dates shown. All test fuels met CGSB cloud point requirements.

Spring / Summer Period Observations:

From April 15 to September 30, 2008 the ARDD fleet operated on 5% blends without any reported loss of service or loss of operability. None of the fleets reported any need to change their maintenance schedules or to make any unscheduled fuel filter changes. All fuel dispensed in the ARDD met CAN/CGSB 3.517 or CAN/CGSB 3.520 standards as appropriate (i.e. for FAME blends and HDRD blends respectively).

HANDLING AND DELIVERY

The ARDD followed handling guidelines for FAME and HDRD were informed by BQ9000 and best industry practice. The project demonstrated that product quality can be maintained for renewable diesel blends during shipping and storage activities, and can generally be accomplished with existing tankage and fuel hauling infrastructure. However, as with all diesel products, each transfer or storage event in the chain of custody introduces the potential for contamination. Furthermore, any product with a high cloud point requires shipping, storage and piping infrastructure to be capable of maintaining or raising product temperature above the product's cloud point. In the ARDD, new receipt facilities, tanks and blending systems were constructed at the terminal to meet this need.

Deliveries of renewable diesel for the ARDD were made in insulated containers or truck holds with steam coils, with steam provided by off-site facilities. However, as observed in the ARDD, care should be taken to minimize the potential for contamination from prior loads and water. Handling and delivery were successfully accomplished by these means.

Handling of blended fuels was done successfully and without incident using the same handling procedures as for petroleum diesel. Downstream handling (from the rack or terminal to the card locks) was done using standard trucks, tanks and dispensing infrastructure.

TERMINAL OPERATION

The temporary blending facility constructed for the ARDD successfully facilitated the unloading and storage of neat FAME and HDRD, and blending and loading of cloud point adjusted 2% and 5% blends with FAME and HDRD in all encountered temperatures. Blend ratios, as measured in finished fuel samples en route to card locks reflected consistent and accurate blending. The insulated and heat traced piping from the offloading area to the B100 tanks and from the tanks to the loading rack performed as expected, maintaining all products above their respective cloud points.

Moisture in fuel tanks is an issue to be managed for all types of diesel. The hygroscopic nature of neat FAME (higher propensity to absorb atmospheric moisture) is the primary reason that moisture is managed carefully for B100 storage. Total water and sediment content is a part of the ASTM specification for FAME, as is visual observation of haze. However a parts-per-million standard has not been included in ASTM D6751 at time of print. The two 48,000 litre tanks used to store neat biofuels in the ARDD were not designed with desiccant air filters; inclusion of such filters could aid in minimizing entrainment of moisture in neat and/or blended fuel and are in use in FAME storage in some settings. Further moisture management could be undertaken by requiring truck carriers of B100 to rinse the hold with diesel or FAME after washing/drying or by stipulating diesel fuel as a prior load.

The B100 storage tanks were fitted with immersion heaters and interstitial space heaters (heating the air between the double containment walls of the tank). During the extreme cold weather in January and February of 2008, the immersion heater in the FAME B100 tank failed and product temperature dropped from the target storage temperature of about 15°C to about 8°C. To arrest the product temperature from falling near or below the cloud point, terminal staff covered the tanks with large insulating tarps. The interstitial heater was then able to maintain product temperature at the desired level until the immersion heater could be replaced. Fuel was blended and loaded during this cold snap with no ill effects observed in the operation of the terminal or the trucks.

TRUCK OPERABILITY

The ARDD sought to ascertain whether there were any operational challenges from issues such as fuel gelling or clouding, blocked filters, stalled vehicles or non-starts from an operational perspective. As such, an operability breach was defined as a fleet-identified fuel-related problem that caused reduced performance or loss of service. Meaningful fuel efficiency calculations were not part of the ARDD due to the multiple variables that could not be controlled in a business as usual demonstration (i.e. payload, engine type, idling time, driver habits etc.). Also, no comprehensive engine oil analysis was undertaken as part of the ARDD as renewable diesel blend levels were low and well understood by OEMs, and thus no impacts were expected.

The ARDD recorded one fuel filter changed in advance of regularly scheduled maintenance for a cold start on a school bus running on winter B2 FAME blend. During the extreme cold of January 28-30, 2008, the participating school bus fleet operating in Calgary changed several buses' fuel filters to aid in starting (as part of common practice for the fleet). The filter change was done for one of the nine units on test fuel and several non-ARDD units running on normal petroleum ULSD from the same fleet yard. The overnight low temperature on January 29, 2008 was recorded by Environment Canada as -33.3°C, similar to CAN/CGSB 3.520 cloud point requirement of -33°C for that region and time of year.

As per the fleet's standard practice, the fleet manager's action for all units suspected of hard starts, hesitation or frozen filters was to remove the fuel filter and replace it with a new one, topped up with fresh diesel (ULSD). Contrary to project protocols, this filter was discarded before the ARDD could sample its contents, thus it was not possible to assess whether flow was in fact restricted or whether renewable content may have been a factor. Given that eight other B2 vehicles at the same site had full operability at the recorded low temperature, that several non-ARDD buses also received filter changes, and that causality could not be associated with renewable content, this filter change was reasonably not recorded as a loss of service event. Fuel filters from the control units running on ULSD were likewise discarded before they could be analyzed, ruling out the ability to test for potential causes of filter plugging.

FUEL EFFICIENCY

Fleet data from the ARDD showed that there was no statistically significant difference in fuel mileage among FAME blends, HDRD blends and control fuel (ULSD) in winter or summer seasons. A listing of fuel economy by unit, season and fuel is provided in Appendix B.



CONCLUSIONS



The ARDD has confirmed operability of low-level ULSD/renewable diesel blends in regards to vehicle performance among Alberta commercial trucking and bus fleets under the conditions tested. By working with producers, distributors and trucking companies to test the viability of renewable diesel use in the winter, summer and shoulder seasons, the demonstration engaged stakeholders from fuel producers to commercial end users, including engine manufacturers, trucking associations and fuel distributors, providing hands-on experience in a real-world deployment scenario. The ARDD Steering Committee opted to limit the biodiesel blend concentration to 2% during the winter months. This concentration was raised to 5% in spring and summer along with the transition to mixed-feedstock FAME (75% canola methyl ester / 25% tallow methyl ester).

All fleets have incorporated the test fuels into their business as usual without any reports of breakdowns, reduced performance, or loss of business. All fuels used in the demonstration were acquired and maintained to meet quality specifications. As expected, fleet data from the ARDD showed that there was no statistically significant difference in fuel mileage among FAME blends, HDRD blends and control fuel (ULSD) in winter or summer seasons. The ARDD did not encounter any loss of service events, but did observe one filter change made on a school bus

in Calgary to aid in a cold morning start when the ambient temperature fell to -33.3°C (compared to the CAN/CGSB 3.520 specification of -33°C for that location and date).

The ARDD has shown that B2 blends of canola methyl ester and 2% blends of hydrogenation derived renewable diesel are fully operable in winter conditions in the study area when cloud points are adjusted to meet CAN/CGSB requirements. The demonstration has also shown that B5 blends can be successfully made and used in shoulder and summer seasons using a composite methyl ester (containing 25% tallow methyl ester and 75% canola methyl ester) as well as 5% blends using HDRD. All blended fuel dispensed in the demonstration met CAN/CGSB specifications.

To meet CAN/CGSB 3.520 specifications for cloud point, low cloud point diesel (ULSK) was added to the seasonal diesel to produce a base diesel with cloud point 3°C colder to accommodate B2 with canola during the coldest periods, and 1°C colder to accommodate 2% HDRD. From December to March, this required ULSK addition of 21-43% of the blend for B2 FAME and 8-15% of the blend for 2% HDRD. All blended fuel was compatible with existing infrastructure patterns, materials and handling procedures. Some precautions are noted for maintaining quality of neat renewable diesel deliveries, including the ability to heat any product that is likely to encounter ambient temperatures near or below its cloud point, and measures to prevent entrainment of moisture in neat biodiesel.

Once blended, all test fuel in the ARDD performed adequately in existing (real-world) handling, storage and usage environments. Given these observed results, the ARDD confirms operability of seasonally adjusted 2% blends with canola methyl ester or HDRD in winter and 5% blends with mixed feedstock biodiesel (75% canola methyl ester / 25% tallow methyl ester) or 5% HDRD in shoulder and summer seasons in the conditions encountered in the ARDD.

LINKS AND REFERENCES

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National Renewable Energy Laboratory, 2008. Biodiesel Handling and Use Guide, Fourth Edition. **URL:** <http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/43672.pdf>

Natural Resources Canada, 2005. Overview of the Canadian Downstream Petroleum Industry. **URL:** http://www.fuelfocus.nrcan.gc.ca/reports/2005-07/overview/overview_july2005_e.pdf

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APPENDICES

APPENDIX A: Summary of Outreach Activities

Activity	Details	Date
Website	www.renewablediesel.ca	Launched January 2008
Launch Event	The event was held at Shell Canada’s Sherwood Terminal in Edmonton and included a funding announcement by the federal and provincial governments and presentations by project sponsors, Climate Change Central, Shell Canada and the Canola Council of Canada. Following the announcements, speakers completed media interviews and there was a short bus tour of the blending facility.	January 22, 2008
News Release	Biodiesel to be Tested in Long-term Canadian Demonstration Pilot. Canada’s Largest Renewable Diesel Demonstration Launches.	December 18, 2006 January 22, 2008
Print Coverage	Truck News Canadian Driver Magazine Edmonton Sun Edmonton Journal Globe and Mail energycurrent.com greencarcongress.com Today’s Trucking online Municipal Information Network automotiveworld.com ecology.com labcanada.com Biofuel Review Magazine Sherwood Park News Fort Saskatchewan Record Process West Magazine Manitoba Cooperator Magazine Alberta Farm Express Magazine Canadian Cattlemen Magazine Alberta Biodiesel Association Magazine Farming for Tomorrow Magazine BioEnergy Canada Magazine Biodiesel Magazine	January 22, 2008 January 23, 2008 January 23, 2008 January 23, 2008 January 23, 2008 January 23, 2008 January 23, 2008 January 24, 2008 January 24, 2008 January 24, 2008 January 24, 2008 January 24, 2008 January 24, 2008 January 24, 2008 January 25, 2008 January 29, 2008 March 2008 Spring 2008 Spring 2008 Spring 2008 Spring 2008 Spring 2008 April / May 2008 April 2008

Activity	Details	Date
Print Coverage	farmcentre.com	June 2, 2008
	C3 Views Newsletter	October 2008
	Alberta Biodiesel Association Magazine	Winter 2008
	Biofuels Canada Magazine	Winter 2008
Broadcast Coverage	City News at Noon, Edmonton	January 22, 2008
	CTV News at 6, Edmonton	January 22, 2008
	CTV News Late Night, Edmonton	January 22, 2008
	CTV News at Noon, Edmonton	January 23, 2008
	CBC News at Six, Edmonton	January 22, 2008
	CBC News at Six, Calgary	January 22, 2008
	Global News Hour, Edmonton	January 22, 2008
	Global News Morning Ed., Edmonton	January 23, 2008
	Q91 Agri News, Drumheller	January 23, 2008
	CJGX-AM, Yorkton	January 24, 2008
Marketing Materials	Logo	October, 2007
	Brochure	January, 2008
	Vehicle stickers	October, 2007
	Pump toppers signage	October, 2007
Interim Report	Preliminary results and observations of the project over the winter period of operation.	July, 2008
RDCS Report	Summary of the findings of the Renewable Diesel Characterization Study (RDCS).	August, 2008
Final Report	Final results and observations of the entire project.	December, 2008
Presentations	Delivered updates to stakeholders and participants.	Ongoing
	Presented at speaking engagements to groups including:	
	Farm Progress Show	April, 2008
	Canadian Petroleum Products Institute	June, 2008
	Alberta Biodiesel Association	Ongoing
	Alberta Urban Municipalities Association	October, 2008

APPENDIX B: Supplemental Fleet Monitoring

Fuel Mileage Comparison

Participating fleets were monitored for fuel efficiency throughout the winter (2% renewable content) and shoulder/summer periods (5% renewable content). As expected, due to the lower density (and therefore energy content) of winter diesel, fuel efficiency in winter was slightly lower than that of summer. However, ARDD data showed no difference in fuel efficiency between test fuels or between

control fuel and either of the test fuels. Results of an analysis of variance (one-way ANOVA) show no meaningful difference between fuel efficiency of B2 FAME and winter ULSD, nor between B5 FAME and summer ULSD. Likewise, due to the variation between units from driver habits, payload weight, wind or other variables, there was no statistical difference in ARDD fuel economy between 2% HDRD and winter ULSD nor between 5% HDRD and summer ULSD. Participating buses were not included in fuel efficiency calculations as they were different in nature and operating duty from the target group of heavy trucks.

FIGURE 19: Winter Fuel Efficiency Data

Company Unit	Manufacture	Model	Year	Engine	Fuel Type	Litres				Kilometers	(l/100km)
						Test Fuel	ULSD	Total Fuel	% Test Fuel		
Rosenau 231	Freightliner	FL 112	2004	Mercedes 4000	FAME	6,394	2,200	8,595	74.40%	18,710	45.9
Rosenau 234	Freightliner	CL 120	2004	Mercedes 4000	FAME	13,698	14,764	28,462	48.13%	60,473	47.0
Rosenau 291	Freightliner	CL 120	2006	Mercedes 4000	FAME	6,475	13,689	20,164	32.11%	44,518	45.3
Rosenau 317	Kenworth	W 900	2007	Cummins ISX	FAME	18,910	17,184	36,095	52.39%	71,244	50.6
Rosenau 335	Kenworth	T 600	2007	Cummins ISX	FAME	23,853	13,140	36,993	64.48%	70,022	52.8
Rosenau 353	Freightliner	CL 120	2007	Cat C 15	FAME	23,920	18,318	42,239	56.63%	89,444	47.2
Rosenau 354	Freightliner	CL 120	2007	Cat C 15	FAME	22,073	17,704	39,777	55.49%	80,090	49.6
Rosenau 361	Kenworth	T 800	2007	Cummins ISX	FAME	22,390	16,428	38,818	57.68%	77,011	50.4
Rosenau 365	Freightliner	CL 120	2007	Cat C 15	FAME	18,623	7,271	25,894	71.92%	56,086	46.1
Rosenau 395	Freightliner	Cascadia	2008	Det S 60	FAME	20,761	20,695	41,456	50.08%	73,567	56.3
Rosenau 401	Freightliner	Cascadia	2008	Det S 60	FAME	9,680	1,225	10,906	88.77%	22,591	48.2
Rosenau 402	Freightliner	Cascadia	2008	Det S 60	FAME	19,445	2,244	21,689	89.66%	37,672	57.5
Rosenau 268	International	9400	2005	Cat C 15	ULSD	0	24,171	24,171	0.00%	44,819	53.9
Rosenau 290	Freightliner	CL 120	2006	Merc 4000	ULSD	0	7,946	7,946	0.00%	24,882	31.9
Rosenau 334	Kenworth	T 600	2007	Cummins ISX	ULSD	0	27,191	27,191	0.00%	57,380	47.3
Rosenau 360	Kenworth	T 800	2007	Cummins ISX	ULSD	0	29,215	29,215	0.00%	55,613	52.5
Rosenau 285	Freightliner	CL 120	2006	Mercedes 4000	FAME	7,510	3,338	10,849	69.23%	21,736	49.9
Rosenau 349	Freightliner	CL 120	2007	Cat C 15	FAME	29,531	3,671	33,202	88.94%	60,377	54.9
Rosenau 359	Kenworth	T 800	2007	Cummins ISX	FAME	8,382	1,458	9,840	85.18%	25,123	39.1
Rosenau 351	Freightliner	CL 120	2007	Cat C 15	ULSD	0	41,211	41,211	0.00%	78,601	52.4
Rosenau 397	Freightliner	Cascadia	2008	Det S 60	ULSD	0	20,065	20,065	0.00%	44,711	44.8
Rosenau 413	Freightliner	M2	2008	Cum isb	HDRD	1,407	1,031	2,438	57.73%	3,842	63.4
Rosenau 235	Freightliner	CL 120	2004	Mercedes 4000	HDRD	14,614	0	14,614	100.00%	31,218	46.8
Rosenau 241	Freightliner	FL 112	2004	Mercedes 4000	HDRD	13,215	0	13,215	100.00%	31,082	42.5
Rosenau 272	Freightliner	M 2	2006	Mercedes 900	HDRD	3,256	0	3,256	100.00%	7,099	45.8
Rosenau 279	Freightliner	M 2	2006	Mercedes 900	HDRD	4,175	0	4,175	100.00%	9,600	43.4
Rosenau 288	Freightliner	CL 120	2006	Mercedes 4000	HDRD	7,017	0	7,017	100.00%	12,835	54.6
Rosenau 294	Freightliner	CL 120	2006	Mercedes 4000	HDRD	34,180	0	34,180	100.00%	68,619	49.8
Rosenau 304	Freightliner	M 2	2006	Mercedes 900	HDRD	6,804	0	6,804	100.00%	13,258	51.3
Rosenau 305	Freightliner	M 2	2006	Mercedes 900	HDRD	9,033	0	9,033	100.00%	16,604	54.4
Rosenau 347	Freightliner	CL 120	2007	Cat C 15	HDRD	51,608	0	51,608	100.00%	89,857	57.4
Rosenau 348	Freightliner	CL 120	2007	Mercedes	HDRD	0	18,187	18,187	0.00%	32,913	55.2
Rosenau 364	Freightliner	M 2	2007	Mercedes 900	HDRD	3,962	0	3,962	100.00%	12,119	32.6
Rosenau 423	Freightliner	M 2	2008	Cum ISB	HDRD	6,901	101	7,003	98.55%	17,160	40.8
Rosenau 204	International	4000	2002	International	ULSD	0	2,302	2,302	0.00%	7,165	32.1
Rosenau 237	Freightliner	CL 120	2004	Mercedes	ULSD	0	21,907	21,907	0.00%	48,245	45.4
Rosenau 275	Freightliner	M2	2006	Mer 900	ULSD	0	6,272	6,272	0.00%	19,510	32.1
Rosenau 308	Freightliner	M 2	2006	Mer 900	ULSD	0	5,092	5,092	0.00%	10,402	48.9
Hi-Way 9 2228	Freightliner	Columbia	2006	Detroit MB 4000	HDRD	29847.50	0	29847.50	100.00%	55895.41	53.4
Hi-Way 9 2220	Freightliner	Columbia	2005	Detroit MB 4001	HDRD	19306.55	0	19306.55	100.00%	41489.05	46.5
Hi-Way 9 2233	International	9200	2007	Cummins ISX	HDRD	12794.22	0	12794.22	100.00%	28743.53	44.5
Hi-Way 9 2229	Freightliner	Columbia	2007	Detroit MB 4000	HDRD	22337.24	0	22337.24	100.00%	54481.61	41.0
Hi-Way 9 2255	International	9200	2008	Cummins ISX	HDRD	35639.65	0	35639.65	100.00%	73313.83	48.6
Hi-Way 9 2246	Volvo	VN	2007	Volvo VED12	HDRD	24529.94	0	24529.94	100.00%	48177.16	50.9
Hi-Way 9 2232	International	9200	2007	Cummins ISX	FAME	38418.62	0	38418.62	100.00%	71404.50	53.8
Hi-Way 9 2243	Volvo	VN	2007	Volvo VED12	FAME	26475.17	0	26475.17	100.00%	52701.67	50.2
Hi-Way 9 2242	Volvo	VN	2007	Volvo VED12	FAME	23355.99	0	23355.99	100.00%	48270.34	48.3
Gibsons 08552-02	Kenworth	T800	2007	Cat	HDRD	13983.00	2895.00	16878.00	82.85%	5866.00	287.7
Gibsons 08427-01	Kenworth	T800	2005	Cat	HDRD	21136.00	2545.00	23681.00	89.25%	19923.00	118.8
Gibsons 08427-02	Kenworth	T600	2008	Cummins	HDRD	28777.00	2768.00	31545.00	91.23%	27019.00	116.7
Gibsons 08502-02	Volvo	Conv	2006	Volvo	HDRD	17653.00	9706.00	27359.00	64.52%	26763.00	102.2
Gibsons 08502-03	Freightliner	Columbia	2005	Detroit	HDRD	10008.00	2947.00	12955.00	77.25%	7757.00	167.0
Gibsons 5104	Freightliner	Columbia	2003	Cat	HDRD	2241.00	270.00	2511.00	89.25%	2606.00	96.3
Gibsons 5105	Kenworth	W900	2005	C13 Cat	HDRD	2902.00	951.00	3853.00	75.32%	2345.00	164.3
Gibsons 5115	Kenworth	W900	2005	C13 Cat	HDRD	0.00	12025.00	12025.00	0.00%	12665.00	94.9
Gibsons 96590	Kenworth	W900	2006	C15 Cat	HDRD	10392.00	632.00	11024.00	94.27%	15608.00	70.6
Gibsons 96589	Kenworth	T800	2007	CAT	HDRD	13659.00	1180.00	14839.00	92.05%	22413.00	66.2
Gibsons 8384-01	Kenworth	T800	2007	CAT	ULSD	0.00	34780.00	34780.00	0.00%	33700.00	103.2
Gibsons 8968-01					ULSD	0.00	24460.00	24460.00	0.00%	25210.00	97.0
CF 038-0059	International	9200	2002	Detroit	FAME	6324.4	19148	25472.4	24.83%	44852	56.7
CF 038-0061	International	9200	2002	Detroit	FAME	11174.9	11469	22643.9	49.35%	36631	61.8

FIGURE 20: Summer Fuel Efficiency Data

Company Unit	Manufacturer	Model	Year	Engine	Fuel Type	Litres		Total Fuel %	Test Fuel	Kilometers (l/100km)	
						Test Fuel	ULSD			Test Fuel	ULSD
Rosenau 231	Freightliner	FL 112	2004	Mercedes 4000	FAME	8,950	0	8,950	100.00%	25,283	35.4
Rosenau 234	Freightliner	CL 120	2004	Mercedes 4000	FAME	37,470	621	38,090	98.37%	83,167	45.8
Rosenau 291	Freightliner	CL 120	2006	Mercedes 4000	FAME	20,178	1,967	22,145	91.12%	53,199	41.6
Rosenau 317	KW	W 900	2007	Cummins ISX	FAME	43,290	201	43,491	99.54%	84,802	51.2
Rosenau 335	KW	T 600	2007	Cummins ISX	FAME	46,788	985	47,773	97.94%	105,498	45.2
Rosenau 353	Freightliner	CL 120	2007	Cat C 15	FAME	52,810	422	53,232	99.21%	112,222	47.4
Rosenau 354	Freightliner	CL 120	2007	Cat C 15	FAME	33,949	0	33,949	100.00%	71,560	47.4
Rosenau 361	KW	T 800	2007	Cummins ISX	FAME	44,027	4,853	48,880	90.07%	97,961	49.9
Rosenau 365	Freightliner	CL 120	2007	Cat C 15	FAME	33,802	895	34,697	97.42%	66,930	51.8
Rosenau 395	Freightliner	Cascadia	2008	Det S 60	FAME	27,048	1,456	28,504	94.89%	65,568	43.4
Rosenau 401	Freightliner	Cascadia	2008	Det S 60	FAME	17,617	0	17,617	100.00%	40,195	43.8
Rosenau 402	Freightliner	Cascadia	2008	Det S 60	FAME	39,752	1,248	41,000	96.96%	79,821	51.3
Rosenau 268	International	9400	2005	Cat C 15	ULSD	0	6,626	6,626	0.00%	13,899	47.6
Rosenau 290	Freightliner	CL 120	2006	Merc 4000	ULSD	0	19,000	19,000	0.00%	40,180	47.2
Rosenau 334	KW	T 600	2007	Cummins ISX	ULSD	0	24,821	24,821	0.00%	59,060	42.0
Rosenau 360	KW	T 800	2007	Cummins ISX	ULSD	0	39,790	39,790	0.00%	96,369	41.2
Rosenau 285	Freightliner	CL 120	2006	Mercedes 4000	FAME	16,368	0	16,368	100.00%	37,218	43.9
Rosenau 349	Freightliner	CL 120	2007	Cat C 15	FAME	32,247	0	32,247	100.00%	64,637	49.8
Rosenau 359	KW	T 800	2007	Cummins ISX	FAME	13,957	0	13,957	100.00%	33,658	41.4
Rosenau 351	Freightliner	CL 120	2007	Cat C 15	ULSD	0	51,919	51,919	0.00%	106,542	48.7
Rosenau 397	Freightliner	Cascadia	2008	Det S 60	ULSD	0	36,609	36,609	0.00%	71,979	50.8
Rosenau 413	Freightliner	M2	2008	Cum isb	HDRD	4,272	3,117	7,389	57.81%	13,826	53.4
Rosenau 235	Freightliner	CL 120	2004	Mercedes 4000	HDRD	16,673	0	16,673	100.00%	38,500	43.3
Rosenau 241	Freightliner	FI 112	2004	Mercedes 4000	HDRD	8,979	0	8,979	100.00%	21,972	40.8
Rosenau 272	Freightliner	M 2	2006	Mercedes 900	HDRD	3,310	0	3,310	100.00%	10,215	32.4
Rosenau 279	Freightliner	M 2	2006	Mercedes 900	HDRD	3,327	0	3,327	100.00%	9,550	34.8
Rosenau 288	Freightliner	CL 120	2006	Mercedes 4000	HDRD	12,042	0	12,042	100.00%	27,149	44.3
Rosenau 294	Freightliner	CL 120	2006	Mercedes 4000	HDRD	43,418	0	43,418	100.00%	89,206	48.6
Rosenau 304	Freightliner	M 2	2006	Mercedes 900	HDRD	13,047	0	13,047	100.00%	26,574	49.1
Rosenau 305	Freightliner	M 2	2006	Mercedes 900	HDRD	12,396	0	12,396	100.00%	26,192	47.3
Rosenau 347	Freightliner	CL 120	2007	Cat C 15	HDRD	66,564	0	66,564	100.00%	117,251	56.7
Rosenau 348	Freightliner	CL 120	2007	Mercedes	HDRD	33,982	12,827	46,809	72.60%	107,331	43.6
Rosenau 364	Freightliner	M 2	2007	Mercedes 900	HDRD	6,746	0	6,746	100.00%	21,680	31.1
Rosenau 423	Freightliner	M 2	2008	Cum ISB	HDRD	9,834	0	9,834	100.00%	31,181	31.5
Rosenau 204	International	4000	2002	International	ULSD	0	3,533	3,533	0.00%	13,319	26.5
Rosenau 237	Freightliner	CL 120	2004	Mercedes	ULSD	0	29,460	29,460	0.00%	63,929	46.0
Rosenau 275	Freightliner	M2	2006	Mer 900	ULSD	0	6,060	6,060	0.00%	22,939	26.4
Rosenau 308	Freightliner	M 2	2006	Mer 900	ULSD	0	4,332	4,332	0.00%	9,854	43.9
Hi-Way 9 2228	Freightliner	Columbia	2006	Detroit MB 4000	HDRD	30444.17	0	30444.17	100.00%	60141.99	50.6
Hi-Way 9 2220	Freightliner	Columbia	2005	Detroit MB 4001	HDRD	49093.95	0	49093.95	100.00%	111498.89	44.0
Hi-Way 9 2233	International	9200	2007	Cummins ISX	HDRD	31130.75	0	31130.75	100.00%	84346.36	36.9
Hi-Way 9 2229	Freightliner	Columbia	2007	Detroit MB 4000	HDRD	28020.56	0	28020.56	100.00%	68901.65	40.6
Hi-Way 9 2255	International	9200	2008	Cummins ISX	HDRD	56625.97	0	56625.97	100.00%	130211.38	43.4
Hi-Way 9 2246	Volvo	VN	2007	Volvo VED12	HDRD	32416.37	0	32416.37	100.00%	67674.20	47.9
Hi-Way 9 2232	International	9200	2007	Cummins ISX	FAME	60675.89	0	60675.89	100.00%	117297.52	51.7
Hi-Way 9 2243	Volvo	VN	2007	Volvo VED12	FAME	37241.83	0	37241.83	100.00%	80610.91	46.2
Hi-Way 9 2242	Volvo	VN	2007	Volvo VED12	FAME	35038.72	0	35038.72	100.00%	77441.79	45.2
Gibsons 08552-01	Kenworth	T800	2007	Cat	HDRD	0.00	18201.90	18201.90	0.00%	31795.00	57.2
Gibsons 08552-02	Kenworth	T800	2005	Cat	HDRD	19503.41	2952.90	22456.31	86.85%	17428.00	128.8
Gibsons 08427-01	Kenworth	T600	2008	Cummins	HDRD	30873.28	770.40	31643.68	97.57%	59321.00	53.3
Gibsons 08427-02	Volvo	Conv	2006	Volvo	HDRD	34271.32	6187.55	40458.87	84.71%	69507.00	58.2
Gibsons 08502-02	Freightliner	Columbia	2005	Detroit	HDRD	11091.24	10725.05	21816.29	50.84%	30430.00	71.6
Gibsons 08502-03	Freightliner	Columbia	2003	Cat	HDRD	10372.06	4294.63	14666.69	70.72%	19722.00	74.3
Gibsons 5104	Kenworth	W900	2005	C13 Cat	HDRD	5250.45	0.00	5250.45	100.00%	6894.00	76.1
Gibsons 5105	Kenworth	W900	2005	C13 Cat	HDRD	1732.29	1878.83	3611.12	47.97%	6090.00	59.3
Gibsons 5115	Kenworth	W900	2006	C15 Cat	HDRD	0.00	9011.05	9011.05	0.00%	19595.00	45.9
Gibsons 96590	Kenworth	T800	2007	CAT	HDRD	1270.02	352.43	1622.45	78.28%	1265.00	128.2
Gibsons 96589	Kenworth	T800	2007	CAT	HDRD	280.73	0.00	280.73	100.00%	484.00	58.0
CF 038-0059	International	9200	2002	Detroit	FAME	14508.46	7311	21819.46	66.49%	68894	31.6
CF 038-0061	International	9200	2002	Detroit	FAME	18606.7	5609	24215.7	76.84%	69157	35.0

TABLE 14: Winter (2% Biofuel) Fuel Efficiency Comparison

FAME	HDRD	ULSD
45.94	63.45	53.93
47.07	46.81	31.94
45.30	42.52	47.39
50.66	45.86	52.53
52.83	43.49	52.43
47.22	54.67	44.88
49.67	49.81	32.13
50.41	51.32	45.41
46.17	54.40	32.15
56.35	57.43	48.95
48.27	55.26	
57.57	32.69	
49.91	40.81	
54.99	53.40	
39.17	46.53	
53.80	44.51	
50.24	41.00	
48.39	48.61	
	50.92	

Anova: Single Factor

99%

SUMMARY

Groups	Count	Sum	Average	Variance
FAME	18	893.9458	49.66366	19.78721
HDRD	19	923.5024	48.60539	50.9538
ULSD	10	441.7328	44.17328	78.64809

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	203.0057	2	101.5029	2.277028	0.114551	5.122628
Within Groups	1961.384	44	44.57691			
Total	2164.39	46				

TABLE 15: Spring/Summer (5% Biofuel) Fuel Efficiency Comparison

FAME	HDRD	ULSD
35.40	53.44	47.67
45.80	43.31	47.29
41.63	40.86	42.03
51.28	32.40	41.29
45.28	34.83	48.73
47.43	44.35	50.86
47.44	48.67	26.53
49.90	49.10	46.08
51.84	47.33	26.42
43.47	56.77	43.96
43.83	43.61	
51.36	31.11	
43.98	31.54	
49.89	50.62	
41.47	44.03	
51.73	36.91	
46.20	40.67	
45.25	43.49	
	47.90	

Anova: Single Factor

99%

SUMMARY

Groups	Count	Sum	Average	Variance
FAME	18	833.1817	46.28787	19.11553
HDRD	19	820.9477	43.20777	53.91245
ULSD	10	420.8586	42.08586	76.335

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	141.7439	2	70.87195	1.573023	0.218858	5.122628
Within Groups	1982.403	44	45.05461			
Total	2124.147	46				

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