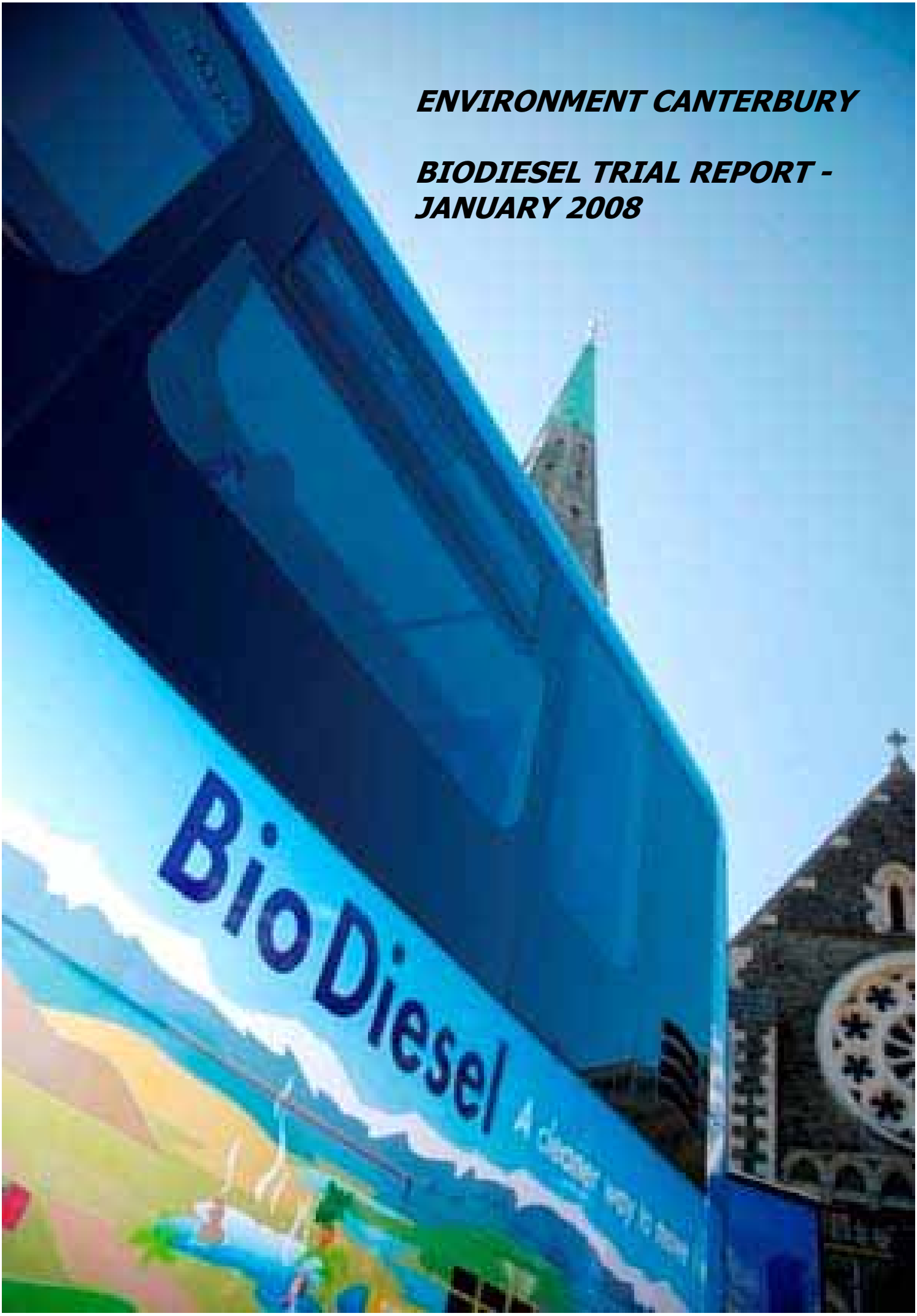


ENVIRONMENT CANTERBURY

BIODIESEL TRIAL REPORT - JANUARY 2008

BIODIESEL TRIAL

Environment Canterbury has urban bus contracts in place with 3 companies in Christchurch. These companies are Redbus Ltd, Leopard Coachlines Ltd, Christchurch Bus Services Ltd. In addition Environment Canterbury also has a ferry contract in place with Black Cat Group Ltd.
Buses on contracted services in Christchurch currently cover an average of 51,000km each day. Based on fuel consumption of 3.08km per litre the fleet uses 6.05 million litres of fossil derived diesel each year. Using these figures total Carbon Dioxide (CO^2) emissions equate to 16314 tonnes per annum.

Biodiesel is a diesel replacement fuel that is manufactured from vegetable oils, recycled cooking oil, or animal fats (tallow). Because plants produce oils from sunlight and air, and can do so year on year, these oils are considered to be renewable. Animal fats are produced when the animal consumes plant matter and they too are considered to be renewable.
The biodiesel manufacturing process converts oils and fats into chemicals commonly referred to as methyl esters.
The vegetable oil or animal fat is reacted with methanol or ethanol and a catalyst, such as sodium hydroxide, to produce the methyl ester (biodiesel). The methanol or ethanol and the catalyst used in the process are recovered and can, if needed, be re-used. The bi-product of biodiesel production is glycerine, which can be used for other purposes such as the making of soap. This process can be conducted with a batch or continuous cycle process.

The key advantages of biodiesel are:

- It reduces CO^2 emissions. Animals and plants both take CO^2 from the atmosphere to grow and live. After the oil is extracted it is converted to biodiesel and is burned producing CO^2 which then returns to the atmosphere. This cycle does not add to the net CO^2 concentration in the atmosphere whereas 100% of the CO^2 emission from fossil diesel adds to the net CO^2 concentration.
- It reduces exhaust pipe particulate matter (PM), hydrocarbon, and carbon monoxide emissions.
- It improves lubricity and in doing so reduces wear on internal engine parts.
- It is non toxic.

The commonly cited disadvantages of biodiesel are:

- It contains less energy than fossil diesel.
- It is susceptible to gelling and filter plugging at low temperatures.
- There are a number of ethical questions surrounding feedstock used for manufacturing of biodiesel.

Biodiesel can be used in either B100 form (100%) or as a blend with fossil based diesel (eg. B5, or B20)

1. BACKGROUND

In January 2006 Environment Canterbury staff started work toward conducting a biodiesel trial on buses operating on urban bus contracts.
In March 2006 it was decided to incorporate a biodiesel trial into a sustainable transport education programme. The concept was to incorporate the Passenger Services, Education, Energy and Regional Land Transport sections into the project.

The key aims of the project were:
- ✓ To create an awareness of alternative modes of transport within the community
- ✓ To create an awareness of the use of biofuels
- ✓ To ascertain any issues with use of biodiesel in the bus fleets
- ✓ To verify emissions benefits associated with use of biodiesel
- ✓ To assess the winter running qualities of tallow based biodiesel through a Christchurch winter
- ✓ To use the trial to give bus companies confidence in the use of biodiesel

In April 2006 a Request For Proposal (RFP) was sent out to all companies operating the Christchurh urban contracts. This RFP called for proposals for the 'Sustainable Transport Bus Programme' on the basis of a fully branded bus powered by a B5 (5%) blend of biodiesel. The RFP was based on 12 month trial period.
An RFP was also sent out at the same time to 10 prospective biodiesel suppliers for the same trial period.

Both Leopard Coachlines Ltd and Christchurch Bus Services Ltd submitted conforming proposals and a 12 month contract was entered into. Redbus Ltd were unwilling to participate in the biodiesel trial.

The contract for biodiesel supply was awarded to Biodiesel Oils NZ Ltd on the basis of the quality of their plant, ability to meet NZ Standard 7500:2005, and their price per litre.

2. TRIAL PREPARATION

Risk minimisation and cost effectiveness were the two major drivers in the trial preparation phase. To ensure the trial was successful in both regards the following preparation activities were undertaken:
- Sponsorship to offset the high cost of testing
- Logistics, particularly transportation and storage
- Testing, both B100 testing and blended testing
- Oil Sampling
- Heating of the B100 biodiesel on receipt in Christchurch
- Distribution of the biodiesel to the bus company depots from a central storage point
- Securing appropriate emissions testing apparatus
- Setting up holding tanks at the bus company depots with ancillary pumps and hoses.

2.1 SPONSORSHIP

Biodiesel Testing During the preparation phase it was discovered that the major cost of the biodiesel trial would be testing of the B100 and blended samples.

- To ensure that quality was not compromised during the trial each batch of B100 biodiesel was to be tested to ensure that it met NZ Standard 7500:2500. The cost of the B100 test was found to be $2800.
- To ascertain the storage qualities of the B100 biodiesel a control Intermediate Bulk Container (IBC) was stored in Christchurch and tested periodically.
- Blended testing was also important and each 1000litre IBC received in Christchurch was to be tested. The cost of blended testing was also $2800.

Environment Canterbury sought sponsorship for the B100 testing and BP agreed to provide testing and technical advice for no charge. The value of this sponsorship during the initial 12 months of the trial was approximately $40,000.

Environment Canterbury sought sponsorship for the blended testing from Caleb Brett, fuel companies and IPL (Independent Petroleum Laboratory). IPL agreed to provide the testing for no charge providing that they had agreed profile on the back of the buses and in all written promotional material. The value of this sponsorship during the course of the trial was approximately $30,000.

- Shell became a sponsor of the trial from May 2007. Shell provided all blended testing from that point as well as density testing of the Leopard tank and technical support. The value of this sponsorship was approximately $30,000

Biodiesel Biodiesel Oils NZ Ltd provided sponsorship in kind by holding the original agreed price in the face of significant increases in tallow price during the 12 month contract term, assisting with the sourcing of freight companies, sourcing empty IBCs, and providing technical feedback as required.

Logistics Environment Canterbury sought sponsorship for the storage, distribution and blending of the biodiesel. Two companies, Minitankers and Petrotec both expressed interest in sponsoring the trial. Petrotec was chosen and agreed to provide logistics for no charge in return for sponsorship on the back of the buses and in all written promotional material. The value of this sponsorship was approximately $15,000.

When the trial was extended in May 2007 Leopard Coachlines volunteered to take over the logistics role from Petrotec.

2.2 TRIAL SCHEDULE AND PROJECT PLAN

A project schedule was developed which allowed the bus companies to ease into the trial. Developing bus company confidence was a key consideration in the formative stages of the trial. Discussion with the two bus companies involved in the trial revealed that their preference was to begin with a low blend quantity of vegetable or used cooking oil based biodiesel.

Biodiesel Oils NZ Ltd was reluctant to undertake a trial with used cooking oil based biodiesel and had no consistent source of vegetable oil for vegetable oil based biodiesel. The company had experienced some difficulty with used cooking oil based biodiesel previously and thought it to be a path of significant risk. They also believed that tallow was the only feedstock that was realistically going to offer them a viable business going forward under the government Sales Obligation which at this stage was legislated to begin in April 2008.

Environment Canterbury negotiated with Biodiesel Oils NZ Ltd to secure supply of used cooking oil based biodiesel for the initial stages of the trial.

Contracts for logistics and testing were implemented and an initial meeting with all parties took place.

A project plan was developed around a start date of Sept 11 2006. The critical path to achieving the timeline depended on BP undertaking successful B100 tests of the initial batch, IPL undertaking successful blended test of the initial delivery and Petrotec installing storage IBCs and pumps in each of the depots. Each activity had delivery constraints and Petrotec became the greatest risk. The installation of the IBC's and pumps required greater than anticipated Environment Canterbury time however 2 weeks prior to the project start all infrastructure was satisfactorily in place and the first delivery of biodiesel had been received.

Since supply of blended biodiesel to the Christchurch depots was ahead of schedule the B5 used cooking oil based trial was started one week early to allow the bus companies to 'get a feel' for the use of the fuel prior to the official promoted trial start date.

		Used Cooking Oil based B5	**Tallow based B5**	**Used Cooking Oil or Tallow based B20**
Stage 1	**Sept 06 – Dec 06**	4 buses	nil	nil
Stage 2	**Dec 06 – Mar 07**	2 buses	2 buses	nil
Stage 3	**Mar 07 – Jun 07**	1 bus	1 bus	2 buses
Stage 4	**Jun 07 – Sept 07**	2 buses	2 buses	nil

In order for the trial to be credible control vehicles were essential. Leopard Coachlines had generously offered four brand new MAN powered buses for the purposes of the trial. Two were designated as biodiesel trial buses and two were designated as control buses. Christchurch Bus Services offered four of their existing Cummins powered buses, again two were designated as biodiesel buses and two were control buses. The role of the control buses was important in terms of both emissions testing and in terms of oil sampling. Had there been any reliability problems these buses would also have been equally important.

The stance of the relative engine manufacturers was an important consideration in the formative stage of the trial.
Although MAN in Germany had trialled tallow based biodiesel (Fatty Acid Methyl Ester, FAME) successfully with the RETHMANN/SARIA Group since 2001 their official stance remained that they would allow a up to a 5% blend of Rape seed oil Methyl Ester (RME) only. Leopard Coachlines conducted a thorough independent investigation into the use of biodiesel, and the possible risks associated with it, prior to trial commencement. Following this investigation they decided that the risk was sufficiently minimal that they could supply 2 new MAN buses for the trial without MAN endorsement.
Cummins advice to it's customers at the commencement of the trial that it would only allow blends up to 5% (these could be either FAME or RME). This advice was to change with Cummins allowing blends up to 20% from March 07. (refer Appendix J)

2.3 PROMOTION AND INFORMATION PROVISION

The success of the Biodiesel trial was intrinsically linked to promotion of the uniquely branded buses within the wider community. The Education and Marketing teams combined to produce promotional material. Technical information on biodiesel was sourced from within the Passenger Services team and from EECA material.

The four buses were branded in a unique livery which portrayed the Canterbury vista from South Canterbury to the Kaikouras. This unique livery was primarily driven by Sian Carvell of the Education team and was to become a key ingredient to the success of the overall project. The bus livery also included thoughtful detail in the inside of the bus which provided information to bus users as to the meaning of sustainable transport, alternative transport types, and alternative fuel types. As part of the overall 'on bus experience' an LCD display was also added to provide users with further information.

The Marketing and Information teams transferred the bus livery design to the promotional material for consistency and this proved to be effective in creating an awareness of what Environment Canterbury and partners were trying to achieve.

2.3 PRE-TRIAL EMISSIONS TESTING

Pre-trial emissions testing was carried out using a Testo 300M Exhaust Gas Analyser and Opus 50 Opacity meters.

Table 1 and 2 below contain emissions data taken from all vehicles involved in the trial including control vehicles.

TABLE 1 Exhaust Gas Analysis:

Christchurch Bus Services (Cummins engines)

Bus Number	Engine Temperature	O^2 (%)	CO^2 (%)	CO (ppm)	NO (ppm)
109	85°	18.6	1.8	39	383
110	85°	18.5	1.9	33	422
111	85°	18.4	2	39	384
112	85°	18.4	1.9	38	442

Leopard Coachlines (MAN engines)

Bus Number	Engine Temperature	O^2 (%)	CO^2 (%)	CO (ppm)	NO (ppm)
67	82°	18.4	1.9	48	359
68	81°	18.5	1.9	54	334
69	81°	18.6	1.8	53	312
70	82°	18.4	1.9	53	371

TABLE 2 Opacity:

Christchurch Bus Services (Cummins engines)

Bus Number	k (l/m)	Op (%)
110	0.54	21.0
111	0.25	10.2

Leopard Coachlines (MAN engines)

Bus Number	k (l/m)	Op (%)
69	0.24	10.0
70	0.19	8.0

All readings were taken on 18 August 2006.

2.3 PRE-TRIAL OIL SAMPLING

Gough Gough and Hamer Ltd were engaged to conduct oil sampling. All vehicles including control vehicles were sampled pre-trial for the full spectrum of element and lubricant tests.

All engines were ascertained to be in good condition.

3. TRIAL STAGE 1

The first stage of the trial began on September 11, 2006. A launch was held in Christchurch's Cathedral Square with local media covering the event.

On September 20, 2006 informal feedback was received that Biodiesel Oils Ltd were having difficulty getting the latest batch of biodiesel to conform to the NZ Standard. Official confirmation was received late in September that a sample had failed due to a low oxidation stability reading.

A meeting was held with the bus companies and it was agreed that if a solution could not be found then a transition would be made earlier than scheduled to a tallow based blend of biodiesel.

Biodiesel Oils dosed two batches of used cooking oil based biodiesel with high levels of antioxidant and samples of both subsequently failed testing in Australia. As a result the trial transitioned to a blend of tallow based B5 biodiesel in mid November 2006.

3.1 STAGE 1 ANALYSIS

Stage 1 of the trial progressed smoothly, aside from the oxidation stability testing, with no operational issues at all.

Some minor logistical issues occurred largely concentrated around timely delivery of the biodiesel to the bus company depots.

Once the trial transitioned to tallow based biodiesel heater pads were acquired from Argus Heating. Four pads were mounted beneath each IBC stored at Petrotec and temperature was regulated to a consistent 21°C.

Tables 1 and 2 below contain the emissions testing data recorded during this period. The shaded row in each table indicates the biodiesel buses.

TABLE 1 Exhaust Gas Analysis:

Christchurch Bus Services (Cummins engines)

Bus Number	Engine Temperature	O^2 (%)	CO^2 (%)	CO (ppm)	NO (ppm)
109	82°	18.6	1.8	27	324
110	81°	18.6	1.8	24	332
111	85°	18.4	1.9	25	334
112	82°	18.9	1.6	24	309

Average CO reading of control engines vs average CO reading of biodiesel engines equates to a decrease in CO emission of 3.92%.

Leopard Coachlines (MAN engines)

Bus Number	Engine Temperature	O^2 (%)	CO^2 (%)	CO (ppm)	NO (ppm)
67	81°	18.8	1.8	35	235
68	82°	18.7	1.8	39	249
69	82°	18.7	1.7	34	268
70	82°	18.4	1.8	25	290

Average CO reading of control engines vs average CO reading of biodiesel engines resulted in a decrease in CO emission of 20.27%.

TABLE 2 Opacity:

Christchurch Bus Services (Cummins engines)

Bus Number	k (l/m)	Op (%)
110	0.51	20.0
111	0.24	9.5

A comparison between pre-trial test and Stage 1 test for the CBS biodiesel buses demonstrated an average Opacity decrease of 5.8%

Leopard Coachlines (MAN engines)

Bus Number	k (l/m)	Op (%)
69	0.24	9.3
70	0.19	7.6

A comparison between pre-trial test and Stage 1 test for the Leopard biodiesel buses demonstrated an average Opacity decrease of 6%

All readings were taken on 17 October 2006.

Oil sampling took place in October. The Christchurch Bus Services buses showed good results while the Leopard Coachlines buses showed soot and silica levels increasing. Gough Gough and Hamer explained that there was no cause for alarm in the result and that further monitoring would ascertain if there was any trend.

4. TRIAL STAGE 2

A tallow based B5 blend of biodiesel was used from November 2006 through to February 2007. During this timeframe there were no issues noted.

4.1 STAGE 2 ANALYSIS

Tables 1 and 2 below contain the emissions testing data recorded during this period.

TABLE 1 Exhaust Gas Analysis:

Christchurch Bus Services (Cummins engines)

Bus Number	Engine Temperature	O^2 (%)	CO^2 (%)	CO (ppm)	NO (ppm)
109	82°	18.3	2	26	339
110	85°	18.1	2.1	25	336
111	82°	18.6	1.7	22	288
112	82°	18.6	1.8	22	354

Average CO reading of control vehicles vs average CO reading of biodiesel vehicles equates to a decrease in CO emission of 2.08%.

Leopard Coachlines (MAN engines)

Bus Number	Engine Temperature	O^2 (%)	CO^2 (%)	CO (ppm)	NO (ppm)
67	84°	19.1	1.4	37	184
68	81°	18.8	1.6	41	215
69	80°	18.9	1.6	32	228
70	84°	18.5	1.9	34	246

Average CO reading of control vehicles vs average CO reading of biodiesel vehicles equates to a decrease in CO emission of 15.39%.

TABLE 2 Opacity:

Christchurch Bus Services (Cummins engines)

Bus Number	k (l/m)	Op (%)
110	0.48	18.0
111	0.26	9.3

A comparison between pre-trial test and Stage 1 test for the CBS biodiesel buses demonstrated an average Opacity decrease of 11.55%

Leopard Coachlines (MAN engines)

Bus Number	k (l/m)	Op (%)
69	0.23	9.2
70	0.18	7.6

A comparison between pre-trial test and Stage 1 test for the Leopard biodiesel buses demonstrated an average Opacity decrease of 6.5%

All readings were taken between 25 January and 8 February 2007.
Oil Sampling continued throughout Stage 2 and this sampling verified that the high incidence of soot and silica discovered by Gough Gough and Hamer in Stage 1 (on the Leopard buses) was an aberration. Sampling in Stage 2 revealed levels of both soot and silica to be normal. The reason for the higher levels in Stage 1 was determined to be due to the engines of the Leopard buses being within their running in period.

5. TRIAL STAGE 3

From mid February 2007 Leopard Coachlines began operating their buses on a B20 blend of tallow based biodiesel. The confidence of the representatives of both companies had increased over the course of the trial and whilst Brent Early (Managing Director) from Leopard Coachlines still had some reservations over the use of tallow he elected to trial both Leopard Coachline's two biodiesel buses on a B20 blend.

Leopard Coachline's acceptance of B20 blends was a calculated risk based on abundant data available from overseas which indicated that the risk was limited to possible winter fuel gelling.
Environment Canterbury made contact with Société de transport de Montréal (STM) who had conducted an extensive trial of vegetable oil and tallow based biodiesel in their 'Biobus' trial in 2003. The 'Biobus' trial had been conducted in much lower winter temperatures (-15°C) than those likely to be experienced in Christchurch and STM provided useful feedback to enable Environment Canterbury to better manage any risk associated with winter running.

Once the transition to B20 had been made the trial continued without any issue noted. Due to the greater logistical need associated with the higher volume of biodiesel used there were some issues associated with supply and distribution. These were largely overcome but there was a need for more advanced planning and active management.

Christchurch Bus Services continued to operate their two buses on a B5 tallow based blend of biodiesel during Stage 3 of the trial. This was due to the stance of Cummins NZ who at that time were not actively encouraging higher blend levels. Cummins NZ were to change their minds about higher blend levels just 4 weeks later following a decision by Cummins in the US to allow blend levels of up to 20%. Even after the decision by Cummins, Christchurch Bus Services though elected to continue to use a B5 blend.

5.1 STAGE 3 ANALYSIS

Volumes of biodiesel B100 used increased from 100 litres per week to 260 litres per week once the B20 trial got underway. Each batch continued to be rigorously tested to ascertain compliance with the NZ Standard.

B20 biodiesel inherently has less energy than standard fossil based diesel and it was expected that there would be some increase in fuel consumption, possibly by as much as 3 to 5%. Leopard Coachlines monitored fuel use during this stage of the trial and found no noticeable increase in fuel consumption. The

range of fuel consumption for both B5 and B20 blends was within that of different drivers using a standard fossil diesel powered bus. Environment Canterbury had no accurate way to assess any increase in fuel consumption other than that employed by the bus companies who measured no quantifiable difference.

Oil sampling results for both Christchurch Bus Services and Leopard Coachlines buses were good during Stage 3 of the trial with no abnormalities detected.

Tables 1 and 2 below contain the emissions testing data recorded during this period.

TABLE 1 Exhaust Gas Analysis:

Christchurch Bus Services (Cummins engines)

Bus Number	Engine Temperature	O^2 (%)	CO^2 (%)	CO (ppm)	NO (ppm)
109	80	18.4	2	31	457
110	82	17	2.9	27	717
111	80	18.2	2	26	433
112	84	18.2	2	31	458

Average CO reading of control vehicles vs average CO reading of biodiesel vehicles equates to a decrease in CO emission of 14.52%.

Leopard Coachlines (MAN engines)

Bus Number	Engine Temperature	O^2 (%)	CO^2 (%)	CO (ppm)	NO (ppm)
67	81	18.3	2	50	340
68	82	18.4	1.9	47	323
69	82	18.5	1.9	43	316
70	80	18.5	1.8	43	322

Average CO reading of control vehicles vs average CO reading of biodiesel vehicles equates to a decrease in CO emission of 11.34%.

TABLE 2 Opacity:

Christchurch Bus Services (Cummins engines)

Bus Number	k (l/m)	Op (%)
110	0.54	18.3
111	0.27	9.6

A comparison between pre-trial test and Stage 3 test for the CBS biodiesel buses demonstrated an average Opacity decrease of 9.37%

Leopard Coachlines (MAN engines)

Bus Number	k (l/m)	Op (%)
69	0.22	9.4
70	0.18	7.5

A comparison between pre-trial test and Stage 3 test for the Leopard biodiesel buses demonstrated an average Opacity decrease of 6.13%

Exhaust Gas Analysis readings were taken on 13 April 2007 and Opacity readings were taken between 8 April and 30 April 2007.

Oil sampling results for both Christchurch Bus Services and Leopard Coachlines buses were good during Stage 3 of the trial with no abnormalities detected.

6. TRIAL STAGE 4

Stage 4 of the trial between June and September 2007 was perceived to be the period of greatest risk in the 12 month trial. At the outset of the trial some concern was expressed that a B20 blend of tallow based biodiesel would not be able to be used through a Christchurch winter. The Cold Filter Plugging Properties (CFPP) of tallow based biodiesel were thought to indicate that it would not cope well in a climate in the negative temperature range. Ample evidence from overseas though suggested that the risk was limited in the temperature range typically experienced in a Christchurch winter.

The B20 buses operated without issue throughout the winter with the two coldest recorded days being the 8th and 9th of July at -7°C and -8°C respectively. These temperatures were independently recorded at an amateur weather station located within 1km of the Leopard Coachlines depot. The temperatures recorded differ slightly from those recorded at the NIWA weather station at Christchurch Airport (Appendix A) and it is considered that this difference may be explained by geographical location. Initially it was thought that the residual heat in the engines may have been the reason that no issues were experienced but this was quickly discounted as one of the buses was not used at all prior to the cold days.

Additional heating was required to ensure that the B100 stayed fluid and Leopard Coachlines overcame this by utilising a kerosene blower heater directed at the IBC in addition to the heater pads. The best solution to the gelling was only discovered later in the winter with immersion heaters sourced from Argus Heating.

Stage 4 of the trial held a surprise outcome when Brent Early from Leopard Coachlines decided to trial the entire fleet of Leopard Coachlines buses on a B5 blend of tallow based biodiesel. From May 18, 2007 all Leopard Coachlines 42 urban buses and all tour coaches based in Christchurch were running on a B5 blend.

Shell, as Leopard Coachlines fuel supplier, effectively began to sponsor the trial and took over all blended testing. Leopard Coachlines took over logistics for the trial from Petrotec and the biodiesel was pumped directly into the Supervault main tank through a tee junction in the supply line at Leopard Coachlines facility. This required close co-ordination with Shell's distributor Alexanders but worked well.

Issues experienced at the beginning of the fleet trial were limited to logistical ones. Tanker compartment sizes had previously been largely variable and Alexanders agreed to make these more consistent to enable better control of blend quantity. Shell set up top, middle and bottom tank sampling apparatus to enable adequate mixing to be confirmed. Samples were taken and the density of the fuel was measured. The sample taken from the bottom of the tank tended to indicate a higher density than the other samples but was within limits.

Stage 4 of the trial was also extended to include 3 diesel vehicles from the Environment Canterbury fleet based at Kainga. This was not a planned extension to the trial, but was easily managed. Two bunded IBC

tanks and pumps were installed on site at Kainga and the 3 Ranger vehicles began operating on a B10 blend of tallow based biodiesel in early June.

6.1 STAGE 4 ANALYSIS

Aside from the variation between top and bottom density in the Leopard Coachlines tank the only issue experienced during Stage 4 was one associated with water.

Leopard Coachlines pump housed a gel type filter which blocked early in the fleet trial. The filter was removed pending the discovery of a solution. Another conventional filter existed in the line so there was no risk. The reason for the pump filter blockage was found to be water which caused the gel to expand thereby blocking the flow. Samples were taken from the dispenser to ensure that water was not entering the vehicles in the fuel. It was confirmed that no water was entering the vehicles and further tests revealed that the Supervault tank was carrying some water in its base. No suitable alternative filter was found and Shell is continuing to investigate the issue.

Tables 1 and 2 below contain the emissions testing data recorded during this period.

TABLE 1 Exhaust Gas Analysis:

Christchurch Bus Services (Cummins engines)

Bus Number	Ambient Temp	Engine Temperature	O^2 (%)	CO^2 (%)	CO (ppm)	NO (ppm)
109	12	80	18.3	2	30	442
110	10	78	18.2	2.1	26	462
111	11	80	18.1	2.1	22	458
112	10	81	18.1	2.1	33	488

Average CO reading of control vehicles vs average CO reading of biodiesel vehicles equates to a decrease in CO emission of 23.81%.

Leopard Coachlines (MAN engines)

Bus Number	Ambient Temp	Engine Temperature	O^2 (%)	CO^2 (%)	CO (ppm)	NO (ppm)
67*	13	80	18.5	1.9	49	302
68	13	80	18.4	1.9	45	312
69	8	82	18.5	1.8	40	285
70	8	80	18.4	1.9	42	322

Average CO reading of control vehicles vs average CO reading of biodiesel vehicles equates to a decrease in CO emission of 12.77%.

* With LPG injection fitted

TABLE 2 Opacity:

Christchurch Bus Services (Cummins engines)

Bus Number	k (l/m)	Op (%)
110	0.40	16.0
111	0.27	12.6

A comparison between pre-trial test and Stage 4 test for the CBS biodiesel buses demonstrated an average Opacity decrease of 0.14%. The Opacity reading for bus 111 at the time of the Stage 4 test was greater than the reading taken pre-trial. At the time of writing this report the bus remains scheduled for retest to ascertain whether the Stage 4 reading is accurate.

Leopard Coachlines (MAN engines)

Bus Number	k (l/m)	Op (%)
69	0.22	9.8
70	0.18	7.3

A comparison between pre-trial test and Stage 4 test for the Leopard biodiesel buses demonstrated an average Opacity decrease of 5.38%

Exhaust gas Analysis readings were taken on 2nd and 3rd of August 2007. Ambient temperature was recorded to try and ascertain whether ambient temperature was impacting NO results.

7. EXECUTIVE SUMMARY

The first 12 months of the biodiesel trial were a resounding success. The confidence of both operators involved in the trial is now assured and there is ample evidence that any logistical issue can be overcome. The trial has also enabled access to a greater knowledge of biodiesel for a number of fuel companies ahead of the Sales Obligation which is now scheduled to commence in July 2008. Importantly the trial has also proven that winter running is possible in Christchurch at higher biodiesel blend levels.

Public awareness of biofuels, in particular biodiesel, has increased measurably during the course of the trial.

Tallow based biodiesel was considered to be a major risk by many and there is now ample evidence that this concern is unfounded in the temperature ranges experienced in a Christchurch winter. Aside from the need for heating when stored tallow based biodiesel has presented no issue at all throughout the trial duration.

Environment Canterbury did not have the funds available to purchase complex testing apparatus and conduct in depth scientific analysis of emissions. In addition no rolling road with the ability to withstand the weight of a bus exists locally in Christchurch so all emissions tests were conducted when the vehicle was stationary and not under load. While this is not ideal the emissions results have sufficiently demonstrated reductions in both CO (Carbon Monoxide) and Opacity (Particle Matter).

The other emissions measured, Nitric Oxide (NO) and Carbon Dioxide provided inconclusive results. For detailed reference to Exhaust emissions related to Tallow based biodiesel blends in buses refer Appendix I of this document.

The biodiesel trial and the Sustainable Bus programme have both been extended for another 12 months. During this period Environment Canterbury will look to have the injectors of the B20 vehicles checked to identify any erosion or deposits. The additional year will also be useful in understanding whether there are any other longer term impacts of running a B20 blend of tallow based biodiesel. Overseas data suggests that there is no longer term risk but the continued trial will serve a useful purpose in confirming this.

There have been no mechanical issues associated with the buses involved in the trial. The extension of the trial by an additional year will serve to provide further confidence in this regard. Data obtained from long term trials conducted overseas suggests that there is no ill effect on engine life at higher biodiesel blend levels (up to B20) provided regular maintenance is undertaken.

Operator confidence is now assured amongst the two Christchurch urban bus companies involved in the trial. Leopard Coachlines is continuing their fleet trial and Christchurch Bus Services has committed to work with their fuel supplier Mobil to do the same. A Chrstchurch Bus Services fleet trial could have commenced at the same time as the Leopard Coachlines fleet trial but Environment Canterbury perceived the risk to be too great during the winter. The Christchurch Bus Services main tank is a double metal skinned air insulated tank as opposed to the Leopard Coachlines Supervault tank which is a concrete insulated tank. Concrete insulated tanks have the same internal temperature characteristics as inground tanks. Knowledge gained over the winter months of the trial has been sufficient to give confidence that an air insulated tank would not represent too much of a risk. Providing sufficient support was given by Mobil, Christchurch Bus Service's fuel supplier, a winter trial is possible during the second year of the trial.

7.1 FEEDBACK

David Stenhouse of Environment Canterbury led the project and received 449 email or phone queries related to the trial during the first 12 months of the trial.

Many of the queries were from the public offering support for the trial and use of biodiesel. Some were directly related to people wanting to source biodiesel. A number (15) were from companies wanting to supply biodiesel to Environment Canterbury. Of these 2 were from Malaysia, 1 from the Phillipines, 1 from Singapore, 1 from China, and 1 from the Ukraine. The remainder were from companies based in Australia or NZ.

During the first 12 months of the trial Environment Canterbury only received 11 feedback comments that were negative.

- 4 of these comments related to the fact that the people concerned did not believe that the biodiesel blend quantity was enough. All believed that a blend quantity of greater than B20 was preferable.
- 1 person was very much against the trial using tallow as he was a vegetarian.
- 1 person was concerned that Environment Canterbury's biodiesel supply was not from within Canterbury.
- 1 person complained that they had seen a Sustainable bus smoking and wanted to sell Environment Canterbury an LPG kit to rectify it..
- Once the Leopard Coachlines fleet trial was underway 1 person complained that they had seen a bus with a biodiesel sticker on it smoking.
- The remaining 3 people all complained that some of the technical information on the website was factually incorrect.

The remaining comments were all overwhelmingly positive.

4 comments were received from users who had observed that the buses running on the biodiesel blend were quieter. No decibel testing was carried out during the initial 12 months but will be carried out in the next 12 months. This observation may be illusory but biodiesel has a greater lubricity than standard fossil based diesel so mechanical noise may be reduced.

Most people giving feedback supported the trial and a large number thought it should be extended to all buses. Some gave tentative support to the trial and wanted to find out more about the feedstock we were using and whether it was sustainable in the long term.

7.2 TRIAL COST

$150,000 was budgeted for the trial. This budget was not intended to include branding of the buses or promotion of the trial. Due to the sponsorship received the actual cost was substantially lower than that budgeted at $86,000.

Table 1: Trial Cost

Payment to bus companies for loss of revenue due to full bus branding	$40,000
Branding of buses, promotional material and launch	$20,000
Biodiesel and Ancillary equipment	$26,000
Total	**$86,000**

7.3 FUTURE USE OF BIODIESEL

The trial success provides an opportunity for Environment Canterbury to build on the use of biodiesel across the Passenger Transport fleet.

The trial has conclusively proven that there is no issue with tallow based biodiesel and winter running. It has also proven that bus users and the general public would support a fleet wide initiative at a higher blend level (Appendix L).

There are legitimate concerns surrounding the use of biodiesel as follows:

- The use of vegetable oil as a feedstock requires too much energy and is not considered sustainable.
- The use of crop based biodiesel can create a situation where land area used for crops competes with food crops. This is particularly the case in developing countries.
- Palm Oil based biodiesel is derived largely from plantations in areas where there has previously been native rainforest. The destruction of this rainforest to sustain the global demand for biofuels continues daily.
- Genetically modified crop based feedstock produce approximately double the yield of hybrid seed crops but ethical (food supply contamination) and cross pollination issues have been widely publicised. The issues publicised offer serious reason for concern.

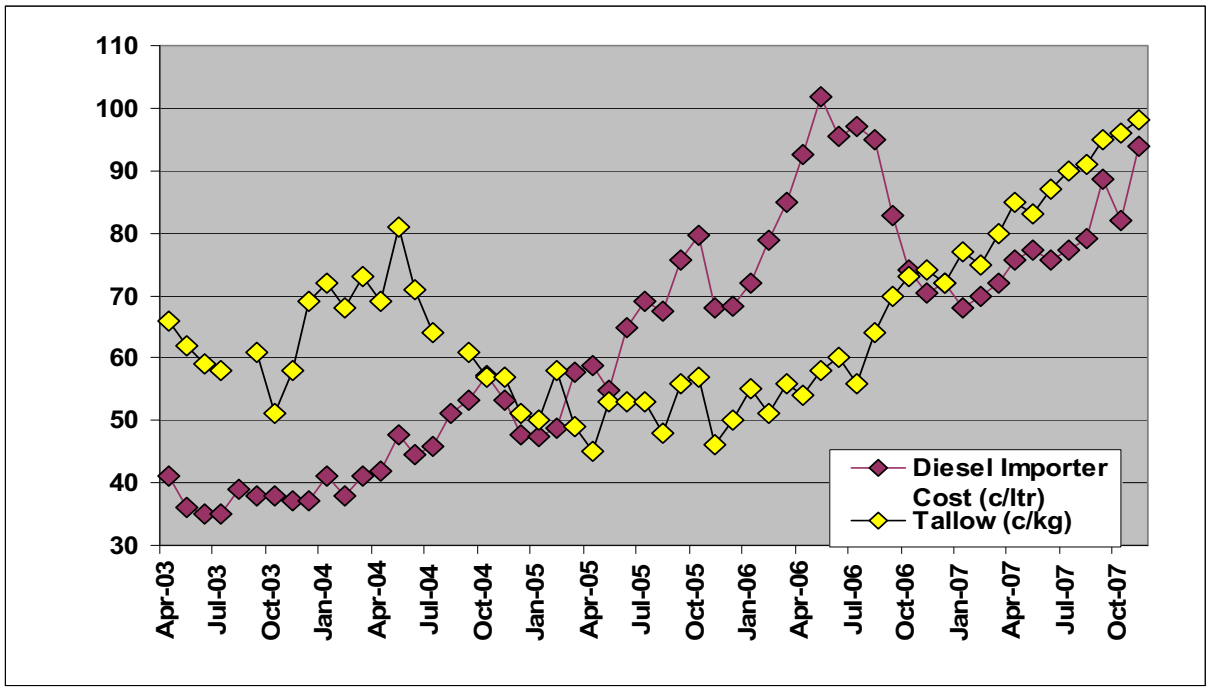
The use of tallow as the feedstock for biodiesel offers a considerable number of environmental advantages.

- ✓ Tallow is a byproduct. Livestock is not killed expressly for the purpose of making biodiesel.
- ✓ Tallow is available locally. While the supply is not infinite there is sufficient tallow available.
- ✓ At present most tallow is shipped to China for the making of soap. This outwardly appears to be an unsustainable use of the byproduct. When the price paid for tallow reaches a new biodiesel demand driven price it may no longer be feasible to ship it to China for soap production. This may mean that all tallow produced in New Zealand will be used in New Zealand for biodiesel production.
- ✓ Tallow requires minimal energy to produce unlike crop based oil.
- ✓ Tallow is completely renewable.

The price of tallow is increasing as local and global demand increases. Tallow was priced at 0.70 cents a kg when the trial commenced, in December 2007 the price of tallow was $1.02 cents per kg. The price of the B100 biodiesel has risen from 0.95 cents per litre to $1.15 per litre. This compares to a retail diesel price in December 2007 of $1.26 per litre.

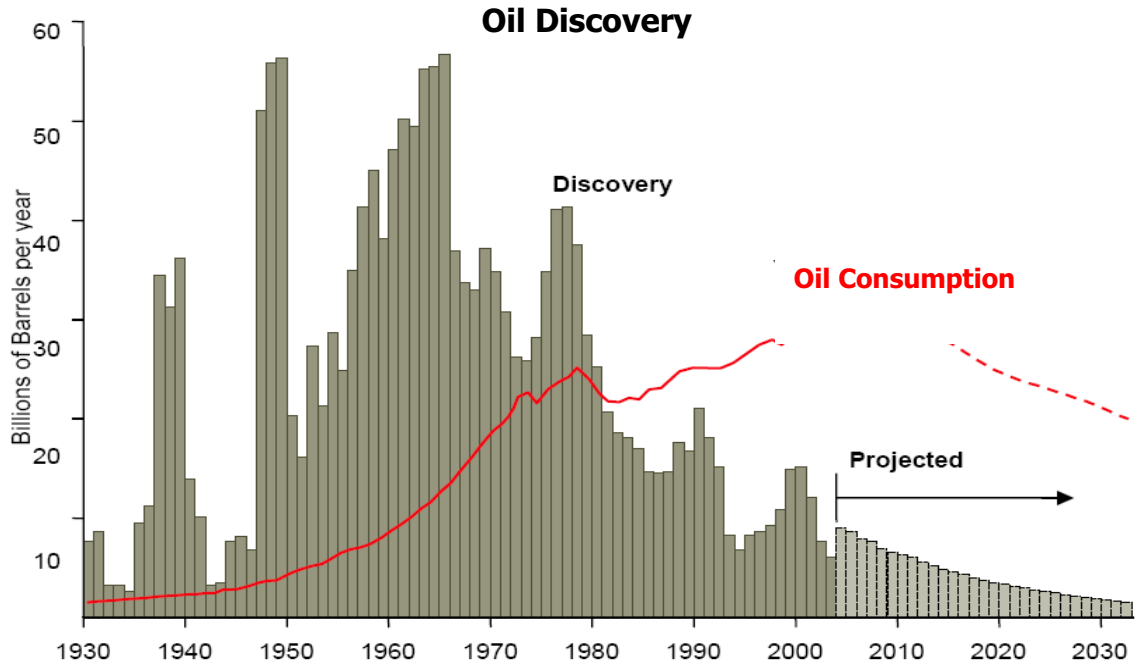
The price of tallow based biodiesel is at a record high but it seems likely that when the governments Sales Obligation comes into force in July 2008 (was originally April 2008 but has now been delayed) that fuel companies will offer a similar price break to trade customers for biodiesel as they presently do for standard fossil diesel customers.

Tallow Price vs Standard Fossil Diesel



A contract with a tallow based biodiesel manufacturer would secure both sustainability (as tallow is a byproduct) and price.

There is increasing concern that the peak of oil discovery and production occurred in 2006 and biodiesel, whilst not the ultimate panacea, is one way of offsetting the public transport system's dependence on fossil fuel use. If oil production has peaked or is close to peaking the need to look for alternatives is critical especially with rapidly rising demand in countries such as India and China. Following the peak of production it is widely expected that production rates will decline at a rate of between 2% and 8% per year.*



*EnergyWatch – Journal of the Sustainable Energy Forum, Issue 46, December 2007

7.4 CARBON NEUTRAL PUBLIC TRANSPORT

Carbon neutral status for the Christchurch public transport is achievable. Based on a price of $25 per carbon credit the annual cost of offsetting emissions would be $430,000 for B20 blend of biodiesel (14,552 tonnes of CO^2). This cost could be directly offset by a 0.03 cent increase in the network average fare (equal to a 2.67% increase in network revenue)

7.5 RECOMENDATION

Including a requirement for a B10 or B20 biodiesel blend in the next Christchurch public transport contracts would be a positive step forward in terms of creating a more sustainable public transport network.

Various options are available for the inclusion of higher blend quantity biodiesel (B10 or B20 blend) use in Environment Canterbury Passenger Services urban contracts including:

- Asking for alternative tenders from the operators for biodiesel use. This solution will be difficult to achieve in terms of suitable pricing of the advantages of biodiesel and it is also unlikely to attract the interest of all operators.
- A requirement for biodiesel use at the desired blend level in all contracts with Environment Canterbury contracting supply of B100 biodiesel on behalf of the operators. This would involve a similar arrangement of heating storage, distribution, and blending as that carried out for the duration of the trial. Leopard Coachlines have found logistical support for the fleet biodiesel trial to be quite time consuming hence this solution may require the use of a contractor.
- A requirement for biodiesel use at a desired blend level in all contracts with Environment Canterbury negotiating to take control of fuel supply for the entire passenger services fleet. This would require the agreement of all operators. This solution offers a number of advantages and could also involve a proportional arrangement whereby operators that used the greatest volume of fuel would receive the largest break in terms of price. The Bus and Coach Association has a similar arrangement for their members so there is some precedent. This solution would allow a fuel company to secure the volume for the entire fleet and therefore be able to provide the best infrastructural and logistic support.
- A requirement for biodiesel use at a desired blend level in all contracts with individual operators sourcing their own supply as they presently do for standard fossil diesel. At least two fuel companies have expressed interest in supplying higher blend levels to companies operating in Christchurch as a result of the trial. This solution is possibly the most practical but may disadvantage smaller operators who don't use sufficient volume of fuel to be attractive to the fuel companies in terms of supply or support.

It is recommended that a business case be developed for B10 or B20 tallow based biodiesel and that Environment Canterbury work toward including a mandatory requirement for biodiesel in its contracts from 2009/10.