# Acceptance of the Use of Biodiesel Fuels in Vehicle and Engine Applications in New Zealand

**Andrew Campbell**
**9 September 2010**

## 1. Executive Summary

This report was commissioned by EECA to better understand the compatibility of biodiesel and biodiesel blends for use in engines and to identify which engines and vehicles were deemed by the original engine manufacturers to be compatible with the use of blends with higher biodiesel content.

Responses were obtained through meetings, telephone and email communications with the New Zealand franchisees or agents of engine manufacturers. Supporting technical information was obtained through, amongst others: the author's own experience working with and testing various fuels and engines (over 25 years); literature searches; and discussions with engine development engineers, fuel test laboratory personnel, and diesel injection equipment service providers. This report collates the various responses from the engine manufacturers, using the supporting information to attempt to explain the various positions taken.

In summary, for New Zealand, engine manufacturers of light vehicles generally accept the use of blends containing up to 5% biodiesel, but often refer to the European standard for the biodiesel component (EN 14214) and not the New Zealand specification (as provided by the Engine Fuel Specification Regulations 2008).

There is a range of blend levels accepted by the engine manufacturers of heavy vehicle engines. The Japanese-origin engine manufacturers tend to limit the maximum blend level to 5% biodiesel. Some engine manufacturers accept the use of higher biodiesel blend ratios, although this acceptance is normally for specific engine models, and tends also to be for models of more recent manufacture.

There are also instances where the acceptance as judged by the New Zealand or local agent might be different to that of the parent manufacturer. For example, the local agent may only accept the use of blends with up to 5% biodiesel content even though the parent manufacturer appears to support the use of higher biodiesel content blends (for same model engines). Some local agents have also accepted the use of higher biodiesel content than normally accepted by the parent engine manufacturer.

Because of the engine model specificity (as well as biodiesel specification specificity) and the varying stances, it will be necessary for potential users to refer to the compatibility statements from the New Zealand agents or local agents.

There are many examples of where blends with higher biodiesel content than those recommended by the engine manufacturer have been used. Discussion is provided on the risks involved in this practice.

Because engine manufacturers frequently refer to the European standard for biodiesel, this was compared to the New Zealand biodiesel specification. This comparison found there to be a small number of property limits for which the European standard was more stringent, and differences in some test methods. With regards to the first, biodiesel produced from the feedstocks commonly used in New Zealand should already meet the more stringent European limits (which are more restrictive on feedstock). As for the second, those test methods that were found to be different were sufficiently equivalent to provide assurance that fuels meeting the specifications of one would meet the specifications of the other. All in all, New Zealand manufacturers should not face a more difficult task in assuring compliance to the European standard than they do in providing assurance that their biodiesel meets the New Zealand requirements.


Version:

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|---|---|
| December 2009: | Provided to EECA as draft. |
| March 2010: | Provided to BANZ and NZ new motor industry through MIA. |
| 23 March 2010: | Additional responses from NZ engine manufacturers included. |
| 27 April 2010: | Addition of “Draft” and additional notes on draft status of material. |
| 5, 7, 11 May 2010 | Additional edits based on new information from engine manufacturers. |
| 12 May 2010: | Additional edits at request of some engine manufacturers. |
| 30 June 2010: | Addition of comments from overseas experts and a comparison of European and New Zealand specifications. |
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## 2. Background and Introduction to Work

Methyl esters, more commonly known as biodiesel (because of their biological source and ability to be used as a diesel substitute), offer New Zealand an indigenous and more sustainable fuel option than the use of fossil diesel. With these and other drivers, it is projected that New Zealand may see a reasonable increase in the use of fuels containing biodiesel at some time.

One of the hurdles to the uptake of biodiesel is knowing when biodiesel blends can be used with confidence. Many potential users are likely to seek the vehicle or engine manufacturer's viewpoint on this, even when the engine is out of warranty. For this reason, the responses of many of the manufacturers supplying vehicles and engines to New Zealand have been collated and are listed in tables at the end of this report.

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Yet there are many vehicles and engines that use fuels containing higher biodiesel content than those recommended by the engine manufacturers[1]. Section 3 considers the risks involved in doing so.

To this end, this report contains:

- technical information on the differences between biodiesel and mineral diesel (to explain why there may be concerning properties);
- how these differences may manifest themselves as concerning issues, in vehicle and engine use;
- how to reduce the risks involved;
- various viewpoints on the subject provided by engine manufacturers (Section 4);
- detail on the differences between the European specification for biodiesel (that specification most referred to by the New Zealand representatives of the engine manufacturers) and the regulated specification for biodiesel in New Zealand (Section 5); and
- tables that summarise the compatibility statements received from the New Zealand representatives of engine manufacturers.

The benefits of using biodiesel also deserve mention, and these are discussed – albeit briefly, as they are not the focus of this report – in Section 6.

As part of this stage-setting, it deserves mention that:

- There are four important factors involved with the operation of an engine:
    - the engine design (which includes that of the exhaust catalyst system, where fitted, as it is typically an integral component of the "engine package");
    - the quality of the fuel;
    - the application (i.e., in particular, how the engine is operated including load profile and operating temperatures); and
    - the supporting servicing and maintenance provided.
- Changes to any one of these four can result in the engine not achieving desired performance.
- Engine manufacturers usually only have direct control over the first, although they may have influence over the others during the warranty period. Engine manufacturers must also <u>consider</u> the operation of their engines on fuels that fall out of specification, but design can only be taken so far in this regard[2].
- Various quality check programmes in the United States have at times found that a high proportion of the biodiesel tested does not meet the standards in place[3].
- There have been significant changes in engine technology over the last 10 years, brought in to simultaneously address local air quality emissions, fuel economy, driveability, reliability and servicing requirements. These performance criteria are still prime drivers for engine manufacturers today and

[1] For the remainder of this report, "vehicle manufacturer" and "engine manufacturer" are taken as synonymous.
[2] Advice from a UK-based engine development engineer.
[3] A US National Renewable Energy Laboratory (NREL) study in a 2005-2006 test programme found around a 40% failure rate in samples tested. Lower failure rates have been found in more recent NREL test programmes, but these programmes still rely on voluntary supply of samples, which does question the robustness of the conclusions drawn.

further significant changes are expected in engine technology over the next 10 years.

- There have been significant changes in fuel formulation to match the changed performance requirements of the modern diesel engine. Fuel quality is paramount when considering operation in modern diesel engines, and it is the quality of the fuel as received by the engine that is important, and not just the quality of fuel that is delivered to the fuel tank or to the service station tank.
- Engines can be subject to extremes in load profiles and extremes in ambient conditions. The skill base of vehicle and engine operators is also quite diverse. Some duties and methods of operation will test the performance of the engine more than others.
- Similarly, a wide variety of servicing and maintenance is to be expected in the marketplace, to the point that both can be unreliable, especially as an engine nears the end of its life.
- Some engine manufacturers produced B100-compatible[4] vehicles in the 1990s, whereas the same manufacturers today recommend only low-proportion biodiesel blends for same marque vehicles. This is not a retrograde step in terms of the engine technology involved. In fact, to the contrary, it is a function of the take-up of more modern engine technology, where manufacturers can be certain that the performance of their engines has been proven only on fuels with low biodiesel content.
- Engine manufacturers have every reason to be protective of their brand and of their customers, including beyond the warranty period.
- The number of engines that may be exposed to fuels containing high proportions of biofuels is increasing, but it is still a minority in the total world engine market. And, as a result, a high proportion of development money is expected to target the development of "major market" engines operating on the straight mineral fuels or low-proportion biofuel options. Hence, what may appear to some as a slow response from engine manufacturers to take on higher proportion biofuel blends may simply reflect market conditions.

It is clear from this that the subject is both diverse and complex, and that opinion and knowledge is varied. The following sections aim to clarify these issues.

## 3. Fuel Performance Differences

Biodiesel is produced by a simple reaction which transforms fats and oils into different esters that are more similar in many of their physical properties to mineral diesel. Although similar, the properties of the resulting "biodiesel" still differ from those of mineral diesel, and this presents a risk that differences will be found when used in an engine. The concerns or risks arising from these differences are listed below, as are the methods to reduce those concerns or risks where applicable.

### 3.1. Energy Content:

Biodiesel has around 7% lower energy content on a litre-for-litre basis than modern mineral diesels and, unless compensated for, the use of B100 is expected to bring about a noticeable decrease in engine power, all else being equal. However, often all else is not equal, as there are many other engine- and combustion-related variables that come into

[4] i.e., vehicles designed to operate on 100% biodiesel. This includes some early models of Audi and Volkswagen vehicles.

play and the actual decrease in power may well be quite different to the theoretical 7% decrease based on the differences in the fuel's volumetric energy content alone. The overall result may range from a negligible change in power to a significantly greater decrease in power than the theoretical 7%, depending upon the particular engine involved.

A decrease in power would not be too discernible for applications where full power is seldom used (for example, typical generator applications and some vehicle applications), but this could also bring about engine instability where the load requirements and engine power are closely matched[5]. Loads that closely match the output power of the engine should therefore be avoided if switching to B100 (unless the pump setting is also changed, which is not a recommended practice).

At a B20 blend level, the difference in energy content from straight mineral diesel is not significant – there are larger differences between different batches of mineral diesel. As has been mentioned, there are also engine-related and other variables that can have a more significant effect[6].

### 3.2. Viscosity:

Biodiesel has higher viscosity than mineral diesel[7], which is more evident when operating at lower temperature. This has the potential to change the metering of fuel and also to cause an increase in the stresses on fuel injection components. The differences involved are negligible for low-proportion biodiesel blends. At higher biodiesel blend proportions, the difference in viscosity can be minimised by the use of the standard good-operator practice of warming up the engine before using it at full power.

Similar to engine power, the difference in fuel viscosity is expected to be small for most applications where blends contain 20% biodiesel or less.

### 3.3. Hydroscopic Nature:

Biodiesel is more hydroscopic than mineral diesel, meaning it will seek out, absorb and hold more water (and in fact the use of biodiesel can dry out fuel systems containing water, far more so than for mineral diesel). This is not a concern if the amount of water stays within the amount that the fuel can absorb. However, any present over that amount becomes "free water" and this can lead to physical damage to fuel injection equipment. Free water also provides sites for chemical and microbial degradation.

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[5] For example, for hydraulically-driven machinery, where the pump's load demand is closely matched to the engine's power curve; or for marine applications, where the propeller's load demand is closely matched to the engine's power curve.

[6] For example, for older technology engines, changes in injection timing advance may occur due to small differences in the physical properties of the fuel, which can give rise to noticeable changes in engine performance. Some engine manufacturer representatives also report a greater tendency for the exhaust catalyst to block when using fuels with higher biodiesel content (although this is likely to be in combination with a high proportion of low-load operation, as tests also show a lower blocking tendency with the use of biodiesel containing fuels under most other operating conditions). Lower power is expected as the restriction across the exhaust catalyst increases. There can also be driver-perceived performance differences, because they are looking for them. Many drivers have reported improved engine performance with the use of B20 (e.g. Truck drivers at the New Vale Mine, Southland, and some operators from the Queenstown Biodiesel Consortium, for use of B20).

[7] Kinematic viscosity at 40°C of around 5.0 $mm^2/s$ for B100 vs around 3.0 $mm^2/s$ for typical mineral diesels, from laboratory testing.

On the last point, various strains of air- and water-borne bacteria can give rise to microbial degradation of fuel. The bacteria causing microbial degradation of biodiesel are often collectively referred to as "diesel bug". They can enter a fuel system through open tanks and tank breathers, or by a fill with contaminated fuel.

Diesel bug is a concern for mineral diesel as well. The products of such microbial degradation of fuel include acids and deposits (sludges) that can interfere with the operation of the diesel injection equipment, to the point that affected systems tend to require major rebuilds by the time that the problem is first noticed[8].

Whether using straight mineral diesel fuels or biodiesel blends, diesel bug should not occur, or at least not pose a problem, if even only the most basic of fuel housekeeping practices are maintained[9]. However, there are numerous diesel bug-related engine failures each year in New Zealand[10], suggesting that some current fuel-handling practices for mineral diesel are inadequate. Because of the tight tolerances involved and precision of fuel metering required, modern "common rail" diesel injection systems are far more at risk than the older-style diesel injection systems. As there will be greater take-up of common rail engine technology over time, a greater number of diesel bug-related breakdowns are to be expected unless there are improvements made to how some ordinary diesel is handled in New Zealand.

Unless controlled by additives, fuels containing biodiesel are expected to degrade at a greater rate than ordinary fuels if active diesel bug is present – a function of the more susceptible chemical structure of biodiesel to such bacterial attack[11]. The greater rate of degradation is often promoted as an advantage in the case of spills in sensitive environments, as the biodiesel component is expected to break down more quickly.

The use of additives can provide biodiesel blends with greater resistance to microbial degradation, but the fuel would then not break down as quickly.

Putting these together, there are times when the presence of biodiesel can offer an advantage: its presence is expected to reduce the occurrence of free water in the first place, which should reduce the occurrence of active diesel bug. There is also evidence to suggest that the use of biodiesel has removed the free water existing in tanks before its use and that the drying out stopped further fuel degradation by this mechanism[12]. There are also times when the presence of biodiesel is expected to be a disadvantage, as a greater degradation of fuel is expected in a shorter time (when active diesel bug is present). However, any presence of diesel bug is serious and good housekeeping practices should be in place regardless of the fuel used.

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[8] Personal communication with a diesel injection service person at Diesel and Turbo, Wellington and as also observed from the author's own various investigations of diesel injection system failures, where diesel bug was believed to be present.

[9] For example, by keeping the fuel and fuel systems dry.

[10] As judged by the estimated number of believed diesel bug-related repairs carried out each year by two diesel injection workshops contacted.

[11] *Anaerobic Metabolism of Biodiesel and Its Impact on Metal Corrosion*, Deniz et. al., Energy Fuels, 2010, 24 (5), pp 2924–2928.

[12] Author's personal observation from quality-related inspections of field tanks: deposits found in the bottom of two tanks inspected indicated the presence of diesel bug, and the deposit colour indicated that it had occurred before filling with biodiesel blends had begun. No other treatment had been provided to eradicate the diesel bug.

Because of the risks involved, the fuel distribution system through to the vehicle tank should be examined and controls or solutions applied to any weaknesses found before biodiesel is introduced. Many of the controls are likely to centre on keeping the water content low. For fuel suppliers, this may mean internal standards that are far stricter than regulated specifications and the use of desiccant-type breathers on fuel tanks. It would also be wise for those customers with their own tank to be well informed on the correct procedures for storing and handling fuel.

In a similar vein, water ingress should be avoided at the end-use application as well – fuel caps should be checked to ensure they are in good condition (and that they are not the old, open-vent type), the refuelling port should be protected during refuelling in poor weather, refuelling equipment stored in a weather-protected place, etc.

### 3.4. Cleaning Properties:

Biodiesel can loosen dirt and other material, pulling this through to the fuel filter where it may cause a blockage to fuel flow. Old or poorly maintained equipment is most at risk in this regard. The difference in cleaning properties should not be evident at a B5 level. It may also not be evident at a B20 level, but awareness is required nonetheless. The added cleaning properties are expected to quite evident at higher blend levels.

Due to risk of loose material making its way into the fuel, it was common practice to replace the fuel filter soon after the first use of B20 or higher-proportion biodiesel fuels. However, a number of recent switchers to B20 have not replaced the fuel filters and no problems with blocked fuel filters were reported[13].

### 3.5. Material Compatibility:

***Flexible materials***

Materials in contact with fuel may interact differently when exposed to biodiesel. Most flexible materials used for fuel hoses and seals absorb hydrocarbons[14] to some and varying extents, depending upon the material and hydrocarbons involved. This can lead to hardening or softening of the material, and/or leakage. Such differences have been demonstrated with various changes to the quality of mineral diesel over the last eight years (brought about by successive changes to more stringent fuel specifications). For example, there are reports of increased numbers of fuel pump seal leaks occurring at around the time that the sulphur and aromatic content of diesel fuels was lowered in the early and then the mid 2000s[15].

In many respects, these changes in diesel specification have already tested the compatibility of the fuel system. However, this is not the same as saying that no further incompatibilities will be found. For example, nitrile rubber is sometimes used in automotive applications and has occasionally been found to be affected by biodiesel. Elastic material parts that are old or in poor condition might also be at risk, as their flexibility has already been well exercised and they may no longer have the tolerance to cope with further change.

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[13] For example, Gull with retail sales of B20 in Western Australia (i.e., for use in a wide range of light and heavy, new and old vehicles), and use in mine-related vehicles in New Zealand.

[14] "Hydrocarbons" – a generic name often used for compounds containing carbon and hydrogen including those compounds found in biodiesel and mineral diesel.

[15] Diesel & Turbo, Wellington, and diesel injection workshops.

Care is also required that any replacement of fuel system parts is made with compatible components. This should be standard practice for most commercial operations but it is a risk nonetheless, particularly for remote or near the end of life applications (where correct parts may not always be available in the timeframe required). Providing examples of practice in the field, inspection of some vehicles has found hardened fuel lines from the use of cheap PVC tubing (due to the leaching from the tube of the materials that provide the flexibility)[16]. Some sealed, cheap plastic bottles and containers used to store samples of biodiesel have also been found to have contracted, believed to be from the loss of biodiesel out through the plastic, much like hydrogen leaks through a balloon[17]. The point of this discussion is to emphasise that there is clear evidence to show that biodiesel is not compatible with some materials, but that this should not be a concern where good practices are in place and with the engine manufacturer business-as-usual upgrade of materials used in automotive applications.

The follow-on from this is that the risk of a material incompatibility fault occurring can be reduced through checking and replacing hoses and seals that appear to be in poor condition or, if the material they are made from is known, checking the compatibility of that material. A comprehensive list of the compatibility of different elastomers with biodiesel can be found in the *Biodiesel Handling and Use Guide*, published by the US National Renewable Energy Laboratory[18].

Also, as with other differences in properties between biodiesel and mineral diesel, the risk of a fault occurring can also be reduced by diluting the differences – by keeping to low biodiesel blend levels.

***Metals***

The presence of certain metal types can catalyse fuel degradation reactions, causing the formation of sludges and other undesirable products. It is for this reason that the specification for biodiesel demands low levels of certain metals that may get introduced as part of biodiesel's production.

It is also for this reason that "yellow" metals – such as brass and copper – should be avoided in fuel systems where higher-proportion biodiesel fuels are to be used, and it is claimed that the presence of lead, tin and zinc should also be avoided[18]. This puts at risk vehicles fitted with terne-plated fuel tanks, a common production method for fuel tanks used in light vehicles before around the mid 1990s.

Additives can be used to protect against the metal-catalysed degradation of fuel and it would be advisable to use such additives in at-risk applications (for example, for marine vessel applications, as they tend to use copper for fuel lines).

[16] Author's personal experience in inspecting vehicles, one in a commercial operation.
[17] Author's personal experience handling small samples of different fuels.
[18] *Biodiesel Handling and Use Guide*, US National Renewable Energy Laboratory NREL/TP-540-43672, Revised December 2009. http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/43672.pdf

### 3.6. Distillation Curve:

Biodiesel has a higher boiling point distillation curve compared with mineral diesel[19]. The repercussions are:

- There is greater risk that fuel will remain unburnt, particularly under idling, part-load or under cold engine operation. Engines using late injection of fuel to regenerate the exhaust emission catalysts systems are at particular risk in this regard (these engines will be fitted with modern common rail injection systems). The unburnt fuel that passes to the exhaust oxidation catalyst (if fitted) can cause the catalyst to overheat and degrade prematurely[20].
- A proportion of the unburnt fuel is also expected to make its way to the lubricating oil, and once there it is less likely to be evaporated off compared to diesel fuel in the lubricating oil. Hence a higher degree of lubricating oil dilution is expected with the use of biodiesel (and has been found to be the case in practice in a number of field trials and laboratory tests overseas). This in turn can result in "sludging" which causes the oil to thicken, and thinning of the oil in other circumstances. Both can result in the loss of the oil's lubrication properties.
- The presence of excessive biodiesel in the lubricating oil can itself result in a breakdown in lubricity of the lubrication oil.
- Engine damage can result.

It is for these reasons that many engine manufacturers recommend that oil change periods are reduced when using higher-proportion biodiesel blends. This may result in reasonable additional expense.

Simply stipulating more frequent oil change periods does not take into account the different duties that a particular engine may see. For example, an engine that is operated cold, or at idle or light load for a significant proportion of time is expected to present a far greater loading on the lubricating oil than fully warmed, high-load engine operation. An appropriately managed and executed lubrication oil test programme should provide a lower-cost option of equal or better protection. This option was discussed with some engine manufacturer representatives, but was not favoured because it was not the method accepted by the parent engine manufacturer. The accuracy of the method used to assess the condition of the oil was also questioned.

The concerns over added oil dilution with the use of biodiesel fuels do demand caution and the high-risk applications that should be avoided – or at the very least, added controls put in place to avoid consequential repercussions – include:

- Where the engine is subject to long periods of idling or low-load operation, including at high speed (for example, where a generator is lightly loaded).
- Where the engine is fitted with an exhaust system that uses late injection of fuel for exhaust catalyst regeneration.

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[19] The main components of mineral diesel distil (evaporate) at temperatures ranging from 200°C to 300°C, whereas the majority of biodiesel first distils at above 300°C (Biodiesel*, The Comprehensive Handbook*, Mittelbach and Remschmidt, 2004, ISBN 3-200-00249-2).

[20] New Zealand representative of an engine manufacturer, personal communication.

### 3.7. Gelling at Cooler Temperatures:

B100 made from tallow, unless winterised[21], can exhibit filter blocking tendencies at temperatures of 10$^{o}$C[22]. Poor quality biodiesel may even exhibit cold temperature filter blocking tendencies at 14-16$^{o}$C[23]. This characteristic would render these fuels unsuitable for general use, in their neat form, in many parts of New Zealand.

Vegetable oil-derived biodiesel has far more favourable properties in this regard, with filter blocking tendency not showing itself until around or below -5$^{o}$C for biodiesel derived from used, canola-based, cooking oil[24], and reports of far lower temperatures still for virgin canola oil-derived biodiesel[25]. Biodiesel New Zealand reports that the cold filter plugging point[26] of their B20 fuel will at least match or better that of the mineral diesel blendstock used to make the B20. Thus "-15$^{o}$C performance" (i.e., fuel with a cold filter plugging point of maximum -15$^{o}$C, a limit for diesel mineral diesel provided in Otago and Southland during the winter months) can be achieved with a B20 blend where "-15$^{o}$C" mineral diesel is used as the blendstock. Whether additives were required to achieve this performance was not disclosed.

At some point, with higher biodiesel blend proportions, the performance under cold temperatures takes on the characteristics of the B100 used in the blend. This tends not to have the cold temperature performance of the base diesel and this may limit the winter use of such blends. Marine applications may offer an exception to this, due to the more moderate temperatures experienced when operating on and close to large masses of water.

### 3.8. Contaminant levels:

As has been mentioned, certain metal contaminants in biodiesel can compromise its stability by catalysing polymerisation and oxidation reactions. Such contaminants can be introduced as part of the production process and remain in the biodiesel if not finished adequately. As a result, all recognised biodiesel standards stipulate low values for the common contaminant metals.

Some biodiesel feedstocks can also possess naturally-occurring phosphorous. Phosphorus is known to compromise the performance of some of the catalysts used in modern exhaust systems, and all internationally-recognised biodiesel standards stipulate a low value for phosphorous also. Recent concern has resulted in the most recent version of the European standard, EN 14214:2009, requiring a maximum value of 4 ppm rather than the limit of 10 ppm as in earlier versions. The US standard, ASTM 6751, currently has a limit of 10 ppm.

### 3.9. Thermal stability:

Thermal stability concerns the degradation of fuel as a result of exposure to higher temperatures.

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[21] That is, taken through additional processes or other to avoid the fuel crystallising or gelling at cooler temperatures.
[22] Testing by Fuel Technology Limited.
[23] Author's personal observation on biodiesel provided for testing.
[24] Testing by IPL for Fuel Technology Limited.
[25] A cold filter plugging point of -15$^{o}$C for rapeseed oil-derived biodiesel, Biodiesel: The Comprehensive Handbook, Mittelbach and Remschmidt, 2004, ISBN 3-200-00249-2).
[26] The name of one test used to indicate a fuel's cold temperature operability.

In theory, biodiesel requires temperatures to the order of 250-300°C for substantial thermal degradation reactions to occur[27]. This has also been observed in practical tests considering the engine compatibility of biodiesel blends[28]. Fuel does not tend to be exposed to such high temperatures in an engine, apart from that fuel taking part in combustion (which is not of concern on this occasion). Even that fuel around the injector tip is not expected to be exposed to such temperatures for a normally working injector. Thus straight or blends of biodiesel are not expected to exhibit any thermal degradation for normal engine operation.

On a related topic, incomplete combustion of any fuel can leave residues that build up over time and these can compromise engine performance and life. For example, build-up around the piston ring pack can cause the piston rings to stick, which can lead to a number of repercussions including poor engine performance and engine damage. The risk of this occurring is indicated by the parameter known as "carbon residue", for which there is a reasonably tight specification for biodiesel[29], as there is for mineral diesel.

### 3.10. Oxidation stability:

The chemical nature of biodiesel makes it more susceptible to oxidation than for mineral diesel. The products of oxidation can cause a number of problems, from filter blocking to chemical attack on components. Experience in the field and in laboratory testing has called for greater oxidation stability, which now typically requires the use of additives to achieve it.

The oxidation stability of stored B100 will likely decrease over time, even if it has been prepared and stored carefully. This is a further reason why biodiesel should not be stored for long periods, say no longer than 4-6 months, unless this and other quality aspects have been carefully considered and monitored.

Similar to water content, fuel suppliers may opt for an oxidation stability specification that is more stringent than regulated for in order to provide a fuel that is better suited to the particular circumstances (for example, where longer storage times may be incurred).

## 4. The Perspective of the Engine Manufacturers

### 4.1. Background

The factors that must be considered when assessing the use of a particular fuel in a particular engine are (from Section 2):

- the engine design;
- the quality of the fuel;
- the application (meaning load cycle, ambient conditions in which it is used, etc.); and
- the servicing and maintenance support provided.

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27 Characterization Of Biodiesel Oxidation And Oxidation Products, Waynick et al.,
CRC Project No. AVFL-2b, Task 1 Results SwRI Project No. 08-10721, August 2005.

28 Tests carried out by IPL for Fuel Technology Limited at IPL – using IP 440 testing of blends held near 250°C for 3 hours. No polymerisation was detected.

29 Maximum of 0.05% (for undistilled sample)

If all of these factors are simultaneously and appropriately met at all times, for the particular fuel and engine in question, then there would be very little risk of faults occurring.

However, the engine manufacturer has little control over these factors apart from the first. Yet their engines are expected to deliver reliable performance despite the many unknowns.

Engine manufacturers may also carry out extensive testing on a particular fuel. But which fuel should be used to represent "biodiesel", as biodiesel can be derived from a number of animal fat and vegetable oil feedstocks and each fuel derived from different feedstocks can yield different results when used in an engine[30]? Additives or other changes to the fuel specification may also be used to accelerate or otherwise force durability tests which can give rise to uncertain response in field use[31].

Recent testing by engine manufacturers has also found significant issues with the latest low-emission engine technology under development. There are real concerns that the exhaust catalyst systems are not sufficiently durable with use of other than fuels with low biodiesel content[32] in such (yet to be put into production) engine technologies.

In the face of doubt, a responsible approach to protecting their clients would be for an engine manufacturer to only recommend what has been proven to be compatible. This has led to many engine manufacturers recommending the use of biodiesel only in low content blends.

And yet some vehicle models that have only been approved for use with a maximum biodiesel content of 5% here in New Zealand have been approved for the use of up to B30 in Europe, where various control requirements have been met. This does suggest that there is some opportunity for higher blend ratios to be approved for use in New Zealand for existing engine technologies, as long as the necessary control requirements could be also assured at all times here (and approval is granted for the specific application by the engine manufacturer).

### 4.2. Summary Position of Engine Manufacturers

New Zealand agents and franchisees of engine manufacturers were asked to provide a statement on the compatibility of their engines with biodiesel blends.

In summary, for New Zealand, engine manufacturers of light vehicles generally accept the use of biodiesel blends containing up to 5% biodiesel, but often refer to the European standard for biodiesel (EN 14214) and not the New Zealand specification (as provided in the Engine Fuel Specification Regulations 2008 [EFSR 2008] which govern fuel quality in New Zealand).

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[30] *Biodiesel: the Comprehensive Handbook*, Mittelbach and Remschmidt, First Edition, 2004, ISBN 3-200-00249-2, and *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions, Draft Technical Report*, US EPA, EPA420-P-02-001, October 2002.

[31] Personal communication with a vehicle test engineer working in an overseas engine and vehicle test laboratory.

[32] New Zealand representative of one of the engine manufacturers: personal communication.

As will be discussed in Section 5, the New Zealand and European specifications for biodiesel do differ, and this could be grounds for European manufacturers to decline to accept the use of fuel that only meets the New Zealand specification. However, the differences were found to be minor in practice, to the point that manufacturers producing biodiesel that meets the New Zealand specification from feedstocks commonly used in New Zealand should have little trouble also assuring compliance with the European standard. And it is suggested that the New Zealand producers opt to report compliance to both.

BMW has moved to be consistent with a recent change in the European standard for diesel (EN 590:2009), and accepts the use of blends containing up to 7% biodiesel.

There was a range of acceptance from the manufacturers of heavy vehicle engines. The Japanese-origin engine manufacturers tended to limit the maximum blend level to 5%. Some other engine manufacturers accepted the use of blends with higher biodiesel content for some model-specific engines. These tended to be for engines of more recent model.

There are also instances where the acceptance as judged by the New Zealand or local agent might be different to that of the parent manufacturer. For example, the local agent in New Zealand may only accept the use of blends with up to 5% biodiesel content, even though the parent manufacturer appears to support the use of higher biodiesel content blends (for same model engines). Some local agents have also accepted the use of higher biodiesel content than normally accepted by the parent engine manufacturer.

As for light vehicles, the European standard for the biodiesel fuel component was quite often referred to rather than the New Zealand specification.

Because of this engine model and fuel specificity, potential users are recommended to check with the pertinent compatibility statements from individual engine manufacturers.

In more detail:

### 4.3. Light Vehicles

The majority of engine manufacturers responded that their New Zealand vehicles were compatible with blends containing up to 5% biodiesel, so long as the biodiesel met EN14214 (the European specification for biodiesel) and the fuel met EN 590 (the European specification for automotive diesel). Note that this same acceptance was often provided for Japanese-origin vehicles as well, as the engines of many modern Japanese-origin diesel vehicles are of European origin.

The New Zealand specification for diesel (a component of the EFSR 2008) allows the sale of diesel containing up to 5% biodiesel without notice, so long as the biodiesel and mineral diesel components meet the relevant specifications and the blend also meets the specification for diesel. Engine manufacturers supply vehicles to New Zealand knowing the specification of fuel that is in place. By implication, selling a vehicle that is fit for common purposes in this country without providing notice of the potential incompatibility with the use of up to 5% biodiesel would therefore seem to oblige engine manufacturers to honour their warranty for the use of fuel up to B5, provided it meets the EFSR 2008.

However, the other side of this is that suppliers of engines and vehicles to New Zealand can normally only supply models that are produced for other markets – apart from some heavy vehicle applications, the size of the New Zealand market makes it impractical to do otherwise. Hence importers are dependent upon the Government to direct the fuel specification so that the fuels available in this country are compatible with the vehicle requirements. And in the main, the fuel specifications in New Zealand are well aligned with recognised international specifications. However, even small differences can be a concern to engine manufacturers because of the uncertainty this creates.

The latest European standard for diesel, EN 590:2009, allows for the use of up to 7% biodiesel (with that biodiesel meeting EN 14214:2009), signalling that the European engine manufacturers also accept the use of this biodiesel blend (rather than the former limit of up to 5% biodiesel for retail sales). It appears that, apart from BMW, the position of the engine manufacturers for light vehicles in New Zealand has yet to move with this increase, although there is little reason to do so whilst the New Zealand fuel quality regulations allow only a maximum of 5% biodiesel for retail sales.

For light vehicles in Europe, Peugeot, Renault and Citroen provide an exception to the maximum biodiesel content of 5%-7%: approved, customised validation may permit the use of up to B30. This appears to be limited to captive fleets purchasing fuel from approved suppliers. This arrangement does not appear to have occurred in New Zealand to date, but perhaps may become relevant in the future.

Stated in a recent release by JAMA[33], "except for vehicles specially designed and operated by fleet users with special vehicle management qualification, JAMA does not recommend exceeding 5% FAME content" (where FAME is fatty acid methyl ester, another name form biodiesel).

A summary of the compatibility statements received for light vehicles, provided in direct communication with the New Zealand representatives for the engine manufacturers, is provided in Table 2.

Note that the information provided by the manufacturers of light vehicles, or their agents or franchisees, tends to be for across their fleet and generic. However, some engine manufacturers have accepted the use of higher biodiesel blend proportions in the past, for specific vehicle models. For example, the manuals for some older Audi and Volkswagen diesel-engined vehicles refer to acceptance of the use of B20 and even B100. This indicates that these particular vehicles were indeed built for use with such fuels at the time, and it is expected that no additional problems would be found when using the approved fuels today in these older-technology vehicles (as long as they are still in appropriate condition). However, it is stressed that the engine technology involved would be quite different to that of their modern counterparts available today.

### 4.4. Heavy vehicles:

The use of blends with medium biodiesel content (B20 to B30) up to high biodiesel content (including B100) has been tested and accepted by some engine manufacturers for

[33] *News from JAMA Asia*, Japanese Automobile Manufacturers' Association. Volume 38/February 2010.

use in some specific heavy duty engines. For example, the following biodiesel fuels have been approved for use:

- Up to 20% biodiesel for specific Caterpillar and Deutz engines
- Up to 30% for specific Cummins and Volvo engines, and
- Up to 100% biodiesel for specific Scania and Daimler engines.

However, there are also instances where the acceptance as judged by the New Zealand or local agent might be different to that of the parent manufacturer. For example, the local agent may only accept the use of blends with up to 5% biodiesel content even though the parent manufacturer appears to support the use of higher biodiesel content blends (for same model engines).

Any acceptance of the use of biodiesel blends is normally guarded by reference to minimum fuel quality standards, and may also be guarded by required changes to service periods and mandatory parts replacement.

Customised acceptance is sometimes provided by engine manufacturers, agents or franchisees, which may extend the accepted biodiesel content of blends that can be used, or otherwise extend leniency in the manner in which they can be used. This approval of specific engine applications generally requires good relationships between the end user, the fuel provider, the engine manufacturer's New Zealand representative, and the parent engine manufacturer.

A summary of the compatibility statements for heavy vehicle engines, as provided in direct communication with the New Zealand agents and franchisees of the engine manufacturers concerned, is listed in Table 3.

As for light vehicles, some manufacturers of heavy vehicle engines have also accepted the use of blends with higher biodiesel content in the past. Owners should therefore also refer to any fuel specification-related documentation that may have come with the engine concerned.

### 4.5. Industrial and Marine Engines

Similar to heavy vehicle engines, some engine manufacturers accept the use of higher-proportion biodiesel blends in industrial and marine engines, and this acceptance is typically specific to certain engine models.

Industrial and marine engine applications in the past have had the advantage that the exhaust emission requirements tend to be far less stringent than for on-road applications, and the simple exhaust system technology involved tends to be more tolerant of the use of fuels different to diesel. Despite this, some base engine models are shared with automotive applications and a first reference point for the compatibility of these engines is the detail provided in the engine manufacturer's information accompanying this document.

### 4.6. Summary Engine Compatibility Statements

Tables at the end of this report, Tables 2 and 3, list the compatibilities for different marques of engine and vehicle based on information received from the respective New Zealand representatives. The preferred contact point, as at the time of the most recent update, is also provided.

Not all marques are listed. It is hoped that additions and new information will be added from time to time as the tables are revised. A more recent version can be recognised by a more recent date in the footnote of the page. If a marque is not listed, a contact point might be found by checking on the Motor Industry Association's website (www.mia.org.nz), or through search engines using the marque name and "New Zealand".

## 5. Comparison of the New Zealand Specification and European Standard for Biodiesel.

The vast majority of the New Zealand representatives of engine manufacturers refer to the European standard for biodiesel (EN 14214) and not the New Zealand specification as provided by the EFSR 2008. This section considers the technical differences between the two sets of specifications in regard to the biodiesel fuel (noting that EN 14214 also contains other information on labeling, etc.).

Also, the comparison made here refers to EN 14214:2009, the current European standard for biodiesel. Some engine manufacturers still refer to an earlier version (EN14214:2003)[34]. The main technical difference is a reduction of the maximum phosphorus content from 10 mg/kg to 4 mg/kg (a change described in the EN 14214:2009 standard as "a first reasonable step towards meeting the needs of the latest technology engines")[35]. The 2009 amendment also updates the test procedures and includes a note on good housekeeping[36].

Further amendment to EN 14214 is expected in 2011, which may see a further decrease in the allowed phosphorous content to 2 mg/kg, an increase in the oxidation stability from the current 6.0 hours to 8.0 hours, and perhaps further decreases in the allowed content of at-risk metals[37]. Beyond this, there are a number of groups currently investigating alternative test procedures, including procedures to better assess the storage stability of biodiesel and cold operability properties. This work will be required if the global industry is to reach agreement on a single standard for biodiesel.

The differences between the specifications are of two types: difference in the test method used; and difference in the limit used.

For the first: the test methodologies referred to in EN 14214 are all recognised tests described by European standards. Some of the New Zealand specifications refer to these European test standards but some refer to American Society for Testing and Materials (ASTM) standards. Some of these test procedures are identical.

[34] Amendment of the European biodiesel standard EN 14214 was approved by the European Committee for Standardisation (CEN) on 25 October 2008 and EN 14214:2009 was published in 2009. It superseded EN 14214:2003, and exists in parallel with EN 590 (the EN standard for diesel).

[35] Phosphorous is known to compromise the performance of some catalysts used in modern exhaust systems.

[36] ÖNORM EN 14214, Edition: 2009-03-01 https://www.astandis.at/shopV5/Preview.action%3Bjsessionid=64535227F30E231B48F68CE1223A8782?preview=&dokkey=325771&selectedLocale=en

[37] Extracts from the UFOP – Union zur Förderung von Oel- und Proteinpflanzen (UFOP) report, http://www.ufop.de/downloads/RZ_UFOP_Biodiesel_E_NEU.pdf

For those that are not, there appears to be sufficient similarity between the differently sourced test procedures that there is either near equivalence in them or, for an alternative test option provided by the New Zealand specification for carbon residue determination, very good correlation between the results[38]. This means that where the New Zealand specification has been met by even a small margin (to take any minor variation into account), the fuel will also meet the European standard.

The differences between the EFSR 2008 and EN 14214:2009 limit values for biodiesel are listed in Table 1 (listing only those where the limit values are different):

**Table 1: Technical Specifications for the EFSR 2008 and EN 14214:2009, where the limit values are different.**

| Property | EFSR 2008 | EN 14214:2009 |
|---|---|---|
| Kinematic Viscosity at 40$^o$C ($mm^2/s$) | 2.0-5.0 for B100<br>2.0-6.0 for where biodiesel is used in any blend of biodiesel and diesel. | 3.50-5.00 |
| Flashpoint ($^o$C) | Min 100 | Min 120 |
| Carbon residue (on 100% distillation residue) (%mass) | Offered as an alternative to the ISO 10370 procedure (which is based on 10% distillation residue). | Allows use of the ISO 10370 procedure only (which is based on 10% distillation residue). |
| Oxidation stability, 110$^o$C (hours) | Min 10.0 if used for retail blends up to B5<br>Min 6.0 otherwise. | Min 6.0<br>Min 8.0 proposed. |
| Iodine value (g iodine/100g) | Max 140 | Max 120 |
| Phosphorous (mg/kg) | Max 10 | Max 4 |

Discussing these differences in the order that they appear in Table 1:

The minimum viscosity limit of 2.0 $mm^2/s$ as given in the EFSR 2008 is the same as that for mineral diesel (for both EN 590 and the EFSR 2008). This seems to be an unnecessary extension of the allowance provided by the EFSR 2008, as biodiesel manufactured from the commonly available feedstocks in New Zealand is expected to exhibit viscosities in the range of 4.0 to around 5.0 $mm^2/s$[39]. A maximum limit of 5.0 $mm^2/s$ is also the viscosity specification for EN 14214:2009 and for the EFSR 2008 where the biodiesel is used as B100.

In addition, the EFSR 2008 provides a maximum viscosity limit of up to 6.0 $mm^2/s$ for biodiesel where used in a blend with mineral diesel, which provides for the use of palm oil-derived biodiesel (which typically has a viscosity of around 5.7 $mm^2/s$)[39]. The viscosity of biodiesel derived from some cooking oils may also just tip over 5.0 $mm^2/s$. These feedstocks would be in the minority in New Zealand, and hence the vast majority

[38] Findings of a commission given to Intertek, Singapore, as a component of this compatibility study. Intertek is a company of independent test laboratories that provide fuel testing services. Note that this finding is quite different to a comparison of vehicle emissions testing (with which engine manufacturers are more familiar) – there is normally a very poor correlation between the emissions results from testing vehicles to emission tests from different jurisdictions.
[39] *Biodiesel: The Comprehensive Handbook*, Mittelbach and Remschmidt, 2004, ISBN 3-200-00249-2).

of biodiesel derived from common New Zealand feedstocks is expected to meet the EN 14214 specification limit for viscosity.

Biodiesel that meets all other quality specifications should also meet the more stringent EN 14214 specification for flashpoint. Therefore adopting the EN 14214 specification limit should not impose any additional burden.

The New Zealand specification provides for the option to use a different carbon residue test to the one specified in EN 14214. The two tests have been shown to yield matching results when their different scales are taken into account[39] and therefore the use of the optional test method, if chosen, should not be of concern.

The EFSR 2008 stipulate a more stringent oxidation stability specification using the same test method. Therefore biodiesel meeting the New Zealand specification will also meet EN 14214:2009. This will remain the case should the currently proposed, more stringent EN 14214 amendment come into force in 2011.

The iodine number is a measure of the number of double bonds in biodiesel, which provides an indication of its chemical stability. Biodiesel made from common New Zealand feedstocks is expected to meet the EN 14214 specification for iodine number. Biodiesel derived from soybean oil may not meet this specification and biodiesel made from sunflower oil is unlikely to meet this specification[39]. The New Zealand specification of an iodine number of 140 rather than 120 allows for the use of biodiesel derived from sunflower and soybean oils.

Phosphorous in biodiesel can be feedstock- or process-derived. Test results from testing biodiesel from a range of producers in New Zealand indicate that they already meet the more stringent EN 14214 specification for phosphorous[40].

In summary, biodiesel that is produced from common New Zealand feedstocks and that meets the EFSR 2008 specifications for biodiesel should already comply with the technical specifications of EN 14214:2009. The tests used by the independent test laboratories typically engaged by New Zealand biodiesel producers are also identical or nearly equivalent to those specified in EN 14214. As a result, there should be no additional burden or costs for a producer to provide assurance that their biodiesel meets EN 14214:2009, over and above the requirements they use to assure compliance to the EFSR 2008.

## 6. Benefits of using Biodiesel

It's not to be forgotten that the use of biodiesel also has a number of advantages, including reduced greenhouse gas emissions compared to the use of mineral diesel (for the feedstocks and production methods commonly available in New Zealand), less damaging effects in the case of spills (where stabilizing or biocide additives are not used), generally good combustion-related properties, good lubricity, and generally lower local air quality-related emissions. There may also be greater national fuel security in using biodiesel.

[40] For testing carried out by independent laboratories on tallow-, used cooking oil- and rapeseed oil-derived biodiesel produced by different producers in New Zealand.

Table 2: Engine Manufacturer Indicated Compatibility of Light Vehicles  Note that the “Max B%” value does not infer across all engines.

| **Engine Manufacturer Compatibility Statements** | | **Across range** | | **Max B%** | **Refers to EFSR 2008** | **Refers to EN 590** | **Refers to EN 14214** | **Refers to ATSM** | **Specifics** |
|---|---|---|---|---|---|---|---|---|---|
| **Light Vehicles** | | | | | | | | | |
| Alfa Romeo | info@ateco.co.nz | y | allow | 5% | | | | | Must be EN 14214 |
| Audi | oyule@audi.co.nz | y | allow | 5% | | y | y | | Must be EN 14214 |
| BMW | Tim.Harper@bmw.co.nz | y | allow | 7% | | y | y | | Must be EN 14214, plus MINI from year 2000 |
| Citroen | info@ateco.co.nz | y | allow | 5% | | y | y | | Must be EN 14214 |
| Fiat | info@ateco.co.nz | y | allow | 5% | | y | y | | Must be EN 14214 |
| Ford | nzinfo@ford.com | no | allow | 5% | | y | y | | +2005 models, must be EN 14214. |
| Great Wall | info@ateco.co.nz | no | no | | | | | | No recommendation exists yet from manufacturer |
| Holden | greg.sillitoe@gm.com | y | allow | 5% | | y | y | | Must be EN 14214 |
| Honda | bryan.davis@honda.co.nz | Do not have diesels | | | | | | | |
| Hyundai | customerservice@hyundai.co.nz | y | allow | 5% | | y | y | | Must be EN 14214 |
| Kia | cbuckley@kia.co.nz | y | allow | 5% | | y | y | | Must be EN 14214 or equivalent specification |
| Landrover | Shane.Lawson@motorcorp.co.nz | y | allow | 5% | | y | y | | Must be EN 14214 |
| Mazda | jvelden@mazda.co.nz | y | allow | 5% | | y | y | | Must be EN 14214 |
| Mercedes-Benz | mark.atkinson@daimler.com | y | allow | 5% | | y | y | | Must be EN 14214 |
| Mitsubishi | www.mmnz.co.nz | y | allow | 5% | y | | | | |
| Nissan | sbavin@nissan.co.nz | y | allow | 5% | | y | | | Must be EN 14214 |
| Porsche | ewaanders@porsche.co.nz | y | allow | 5% | | y | y | | Must be EN 14214 |
| Peugeot | scott.bruhns@sddg.co.nz | y | allow | 5% | | y | y | | Must be EN14214 |
| Skoda | jyates@skoda.co.nz | y | allow | 5% | | y | y | | Must be EN 14214 |
| Subaru | Noel.Robinson@subaru.co.nz | y | allow | 5% | | y | | | |
| Suzuki | rbrown@suzuki.co.nz | y | allow | 5% | | y | y | | uses Peugeot and Renault engines |
| Toyota | Ph 0800 869 682 | y | allow | 5% | y | | | | |
| Volkswagen | swilson@volkswagen.co.nz | y | allow | 5% | | y | y | | Must be EN 14214 |
| Volvo | technical@volvocarsnz.co.nz | no | does not recommend | 5% | | y | y | | Must be EN 14214 |

Table 3: Engine Manufacturer Indicated Compatibility of Heavy Engines  Note that the "Max B%" value does not infer across all engines.

| **Engine Manufacturer Compatibility Statements** | | **Across range** | | **Max B%** | **Refers to EFSR 2008** | **Refers to EN 590** | **Refers to EN 14214** | **Refers to ATSM** | **Specifics** |
|---|---|---|---|---|---|---|---|---|---|
| **Heavy Vehicle, Marine and Generator Engines** | | | | | | | | | |
| Case | | n | allow | Up to 100% | | | | y | Conditional where above 5% |
| Caterpillar | Greg.McCarthy@ggh.co.nz | n | allow | up to 30% | | | y | y | See compatibility bulletin for approved models. |
| Cummins | danni.pietsch@cummins.com | n | allow | up to 20% | | | | | See compatibility bulletin for approved models. |
| Deutz | mcarthur.j@deutz.com | n | allow | Up to 100% | | y | y | y | See compatibility bulletin for approved models. |
| DAF | | n | allow | up to 100% | | y | y | | See compatibility bulletin for approved models. |
| Daimler AG | bruce.clarke@daimler.com<br>steve.mansell@daimler.com | y | allow | 7% | | y | y | | See compatibility bulletin for approved models. |
| Daimler AG | bruce.clarke@daimler.com<br>steve.mansell@daimler.com | n | allow | 100% | | | y | | |
| Detroit | | y | allow | 5% | | | | | |
| Hino | gtaylor@hino.co.nz | tbd | tbd | tbd | | | | | To be determined – Hino wish to first test fuel. |
| Hitachi | www.cableprice.co.nz | y | allow | 5% | | y | y | | Shorter service period recommended. |
| Hyundai | customerservice@hyundai.co.nz | y | allow | 5% | | y | y | | Must be EN 14214 |
| Iveco | j.cossill@nztrucks.co.nz | n | allow | 5% | | y | y | | Eurocargo and Daily only |
| Iveco | j.cossill@nztrucks.co.nz | n | allow | 30% | | y | y | | Up to 30% in E3 Cursor with modification and reduced oil drain periods. 5% in E4 Cursor only |
| Isuzu | kelly.keogh@gm.com | y | allow | 5% | y | y | y | | |
| John Deere | | y | allow | up to 20% | | | | y | According to John Deere, US. |
| Mack | jbell@mtd.co.nz | n | allow | 5% | | y | y | | Mack engines only |
| Mack | jbell@mtd.co.nz | n | allow | 30% | | y | y | | Euro V Mack engines only |
| MAN | pwilliams@man.co.nz | y | allow | 7% | | y | y | | EN 14214 biodiesel only. |
| MAN | pwilliams@man.co.nz | n | allow | up to 100% | | | y | y | For specific engines and conditions only. Check with MAN. |
| Mitsubishi Fuso | www.fuso.co.nz | y | allow | 5% | | | | | Refers to Japanese diesel fuel quality standard (est. March 2007) |
| New Holland | newhollandclub@norwood.co.nz | n | allow | up to 100% | | | | | Up to B20 or B100 depending upon model. |
| Navistar | ComerB@intertrucknz.co.nz | | | | | | | | Waiting for information from parent company |
| Nissan | Bryan.Musgrave@udtrucks.co.nz | y | allow | 5% | y | | | | |
| Perkins | neillb@transdiesel.co.nz | n | allow | up to 20% | | | y | y | See compatibility bulletin for approved models. |

Table 3, continued: Engine Manufacturer Indicated Compatibility of Heavy Engines Note that the “Max B%” value does not infer across all engines.

| **Engine Manufacturer Compatibility Statements** | | **Across range** | | **Max B%** | **Refers to EFSR 2008** | **Refers to EN 590** | **Refers to EN 14214** | **Refers to ATSM** | **Specifics** |
|---|---|---|---|---|---|---|---|---|---|
| **Heavy Vehicle, Marine and Generator Engines** | | | | | | | | | |
| Renault | jbell@mtd.co.nz | y | allow | 5% | | y | y | | |
| Renault | jbell@mtd.co.nz | n | allow | 30% | | y | y | | Specific conditions apply. Does not apply to engines with common rail fuel system. |
| Scania | www.cableprice.co.nz | y | allow | 8% | | y | y | | |
| Scania | www.cableprice.co.nz | n | allow | 100% | | | y | | See compatibility bulletin for approved models. |
| Volvo | jbell@mtd.co.nz | n | allow | 5% | | y | y | | |
| Volvo | jbell@mtd.co.nz | n | allow | 30% | | y | y | | Specific conditions apply. Does not apply to engines with common rail fuel system. |
| Yanmar Marine | | y | allow | 5% | | | y | y | |