# Biodiesel at Sea

## An abstracted report from the Biofuels for the Fishing Industry project

prepared for:

The Sea Fish Industry Authority

*with support from:*


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## Executive Summary

This document provides a non-technical summary of sea trials in a ~10 m class potting vessel running comparative fuel consumption tests using red (fossil) diesel and biodiesel. The vessel, FV Ma Gandole, is powered by a 20 year old Volvo MD70B 6 cylinder, normally aspirated, 120 hp diesel engine coupled to a 3:1 reduction gearbox, assumed to be fairly typical of many power plant of the Newlyn ~10 m class fleet.

The sea trials demonstrated that both fuels started the engine equally well, and the vessel was felt to handle and perform equally well with either fuel. Fuel consumption trials were conducted on 46 separate days with weather conditions ranging from flat calm to unpleasantly heavy seas. Average fuel consumption when running on red fossil diesel was measured at 3.82 litres per hour, varying between 3.48 to 4.19 litres per hour. For the biodiesel, average fuel consumption was recorded at 3.41 litres per hour, ranging between 3.45 to 3.73 litres per hour. The project team believe that the differences in average fuel consumption should not be over-interpreted. The differences in sea conditions, and the excursions to specific sites to recover pots, etc., mean that the fuel consumption of the engine between the two fuels is concluded to be 'comparable' at best. Theory predicts fuel consumption should be slightly higher for biodiesel – other things being equal.

Discussions with fishermen during the study revealed that they view reduced cost of fuel as main driver of such work although they are also aware of the environmental benefits, and the potential for increased engine life. The cost of biodiesel depends heavily on the cost of vegetable oil feedstock used to produce it. Ma Gandole was operated with self-manufactured biodiesel, prepared by the project team at a cost of 50p/litre before labour and overheads using commercial grade recovered vegetable oil. A minimum marginal cost of 23p/litre was determined using low grade locally sourced, self-collected recovered vegetable oil, including the costs of labour, maintenance, collection, power and overheads. Assuming a biodiesel self-manufacturing scenario for a fishing vessel operator leads to an estimate of annual savings of around £1,360 or £1,650 if labour is excluded.

Publicity associated with the project also led to the development of several contacts from potential marine (non-fishing) users of the fuel, seeking to add 'green credentials' to their products. These contacts are being followed up, now that the main project work has completed. Assigning 'green credentials' to seafood products caught by vessels running on biofuels has also been identified as a possible mechanism to add value through price premiums and also to increase market volume by appealing to the ethical shopper.

The general public aware of the project expressed concern that rain forests may be being cleared to make way for palm oil plantations but were relieved to hear that the feedstock used for preparing self-manufactured biodiesel used in this project was recovered vegetable oil.

This project has re-affirmed that for the class of vessel considered, the more barriers there are to change in practice, the less likely that a change will happen. A switch to biodiesel offers benefits in terms of i) minimal modifications to engines and vessel fuel tanks, ii) ready reversal to fossil diesel if necessary, iii) simplified bunkering logistics in comparision to other biofuel options. For skippers entertaining a switch of fuel, a list of practical tips, based on operational experience from Ma Gandole is presented.

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# Introduction

## Document Context

This report provides a non-technical summary of the results of sea trials in a ~10 m class potting vessel, Ma Gandole (Figure 01) running comparative fuel consumption tests using red (fossil) diesel and biodiesel. The Camborne School of Mines (CSM) is an academic department of the University of Exeter. The work was commissioned by the Sea Fish Industry Authority (SeaFISH) with the aim of providing an independent assessment of the efficacy of biodiesel in marine diesel engines for vessels of this class.

This work on sea trials with biodiesel was conducted in parallel with other work on Biofuels for the Fishing Industry, also commissioned by SeaFISH, and was reported to SeaFISH in December 2007. At the request of SeaFISH, a non-technical summary of the specific outcomes of the sea trials work are separately reported herein by means of abstracting the December 2007 report.

Thus the aim of this report is to provide a summary of the demonstration trials without the reader becoming overly burdened with technical detail, or the broader scope of the overall Biofuels for the Fishing Industry project.

Readers of this report also interested in the wider biofuels scope should obtain a copy of the full December 2007 report submitted to SeaFISH.


**Figure 01: Fishing vessel Ma Gandole**

## Attitudes of Fishermen

The cost of red diesel varies considerably, as with most commodities. Users such as fishermen tend to worry about fuel costs when they are rising and then tend to switch their attention to other matters when they are falling. However, most, if not all, fishermen are aware that fuel costs are critical to their operating margins as the marketing mechanisms for their catch do not allow them to pass on cost increases. Many are also aware that instability in the Middle East could result in a sudden and dramatic impact on both price and availability.

Probably for the reasons outlined above, there has been overwhelming support from fishermen in both Padstow and Newlyn for the bio-diesel trials. Discussions with fishermen have reinforced the view that the potential key selling feature of bio-diesel would be a cost advantage over red diesel. Whilst fishermen generally appreciate that bio-diesel offers environmental advantages over fossil diesel, there has been no indication that fishermen perceive this to be a factor in their potential choice of fuel.

It should be recognised that different forms of fishing follow different economic models, the main distinction being between static fishing and trawling/dredging. As the bulk of the Cornish fleet fall into the under 10m category, which is dominated by boats operating static gear, this was the sector around which the bio-diesel project was conceived.

## Public Attitudes

### *Positive Perceptions*

The general public attitude towards renewable energy in general is positive. This seems largely to be driven by general concern about climate change. However, attempting to justify a project of this nature on the grounds that it is part of a strategy to mitigate climate change would be ill-advised. Sceptics could justifiably point out that the scale of the issues affecting climate change are such that only a total change in culture would have any significant impact.

Publicity associated with the project has stimulated considerable positive public interest, principally from people wanting information about their own potential uses of bio-diesel. Several contacts have been received from potential marine users with other contacts from commercial road vehicle users.

The use of recovered vegetable oil seems to be particularly well received, as it fulfils public desires for recycling as well as being seen as an environmentally friendly fuel.

On 14th July 2006 the European Commissioner for Energy visited Cornwall. As a part of this visit he was given a demonstration of a small jet engine running on bio-diesel and was shown around the bio-diesel test vessel, Ma Gandole. He expressed his strong support for the work being done here.

**Figure 02: Project Manager, and Ma Gandole skipper Neill Wood (LHS) and Project Engineer David Parish (RHS) explaining the operation of a small jet engine running on biodiesel to EU Energy Commissioner, Andris Piebalgs (Orange tie).**

### *Negative Perceptions*

There has been considerable publicity surrounding the destruction of rain forest to make way for palm oil plantations. In the minds of some people, all bio-diesel is produced from palm oil and all palm oil comes from questionable sources. This is clearly untrue, even to the extent that palm oil is far from the best oil to use for bio-diesel destined for use in temperate climates. However, there is a small but well organised group of people determined to undermine the use of bio-diesel on these grounds.

### *Consequences of Publicity*

Publicity connected with the project has resulted in numerous contacts initiated by third parties. The majority of these contacts have come from other marine fuel users interested in the possibility of using bio-diesel. The motivation behind these contacts was invariably a desire to establish "green" credentials for the organisation involved.

The association of this project with the Regenatec project attracted a very large number of identical e-mails calling for a stop to the use of imported oils from sources where de-forestation is an issue.

## Approaches to Compatibility and Logistics

When considering alternative fuels there are two basic approaches: to adapt the fuel to suit current engines and fuel systems with little or no modification, or to adapt the engines and/or fuel systems to suit a chosen fuel. The choice of approach is critical to the probability of take-up in the intended application.

Bio-diesel is generally derived from vegetable oil by a process of transesterification. Clearly it would be cheaper to use the unprocessed oil as a fuel without the added cost of processing. However, the main distinction between vegetable oil and bio-diesel in practical terms is that bio-diesel has a viscosity that is likely to be compatible with most diesel engines at ambient temperatures whereas vegetable oil probably would not be. In the context of a small fishing vessel this distinction is significant. Installing the additional fuel tank(s) and heat exchange equipment that would probably be required to run on straight vegetable oil would be difficult or impossible on most under 10m boats due to lack of space.

Irrespective of the practicalities of installation, the primary driving force behind a change of fuel would be economics. Installing a heat exchanger and additional fuel tank(s) represents a significant capital cost. This expenditure could only be justified on the basis of reductions in fuel costs, so the fuel to be used would have to be significantly cheaper than red diesel and used in substantial volumes. These factors mean that vessels fishing static gear would see a much longer payback period from such a conversion than trawlers or scallop dredgers where the fuel cost to catch ratio is much higher.

The more barriers there are to a change in practice, the less likely it is that change will happen. The ability to change fuel type without substantial effort or cost represents a low barrier to change. The fact that a change of fuel could just as easily be reversed (i.e. vessels could readily revert to running on red diesel) eliminates another potential barrier to change.

As well as considering the vessels themselves, bunkering logistics cannot be ignored. A straight replacement for fossil diesel presents few problems for quayside bunkering installations, whereas bunkering for more viscous fuels is likely to require more intensive capital investment, something that would tend to be unattractive to smaller ports.

The combination of installation practicalities and pay-back period suggests that a straight replacement for fossil diesel is likely to be the most attractive option for smaller vessels fishing static gear.

## Potential Benefits

### *Potential Cost Benefits*

It is evident that the primary motivation for a change to bio-diesel would be economic benefit. All fishermen are interested in reducing operating costs, and fuel represents a substantial proportion of operating cost for all but the smallest vessels.

If it assumed that a typical 10 metre vessel fishing static gear would run for 1,200 hours per year using an average of 5 litres per hour, the annual fuel usage would be 6,000 litres. At 50 pence per litre, this equates to an annual operating cost of £3,000. Every penny per litre that could be saved through cheaper fuel would reduce annual costs by £60.

For inshore trawlers, the fuel usage and therefore the potential savings are an order of magnitude greater. Thus even a small cost advantage over red diesel would make bio-diesel an attractive option for a trawler, whilst larger savings would probably be required in order to tempt a static gear vessel into making a change.

### *Marketing and Catch Value Benefits*

The general mood in the fishing industry is that there are issues of sustainability to be addressed. In part this is driven by “real” sustainability issues linked to stock levels and environmental damage attributed to the fishing industry. However, it is also driven by the marketing potential of seafood that is in some way branded as sustainable. Several such schemes are already in operation and appear to have been well received. The benefit of "sustainable" branding is twofold: firstly, suitably branded product has been shown to commend premium prices and secondly, the potential market volume may be increased by mollifying the concerns of some consumers that attempt to shop ethically.

There is a clear opportunity for at least elements of the fishing industry to boost its environmental credentials by publicising its use of bio-diesel. Identifying seafood as '*caught using bio-diesel'* has the potential to significantly increase the value of the catch. This potential was explored with a company called Falmouth Bay Oysters. This company supply seafood to premium outlets all over the country, mostly restaurants. They expressed considerable enthusiasm for seafood that could be marketed as *caught using bio-diesel* on the basis that it would provide a competitive advantage. A small quantity of shellfish caught during the trials was provided to Falmouth Bay Oysters to test actual consumer reaction, with strongly positive feedback.

A branding scheme of this nature could be modelled on that currently used in Cornwall to identify line caught bass and pollack, where a tag is attached to the product that not only identifies its nature but allows consumers to look up the fisherman on a website. It would be most appropriately used by static gear vessels landing shellfish or premium quality whitefish. For this category of vessel, the potential increase in the value of the catch could be far more significant than the potential fuel savings. For example, pollack tagged as line caught attract a premium of 30 – 50 pence per kilo whilst bass attract an additional 50 pence to £1 per kilo (source: Cornwall Fisheries Resource Centre). This scale of premium represents an increase of around 10% in gross income. The feedback from Falmouth Bay Oysters suggests that it may be possible to replicate this scale of benefit for shellfish caught using bio-diesel.

If the anticipated marketing benefit of using bio-fuel is realised, then the calculation determining the economically viable cost of bio-diesel versus red diesel would be fundamentally changed. It would no longer be necessary for bio-diesel to be cheaper than red diesel in order to yield a net economic benefit. It is the potters that would be most likely to benefit from this scenario, especially in relation to lobster. This is because lobster is largely destined for the upper end of the restaurant market where the consumer is most likely to be willing to pay premium prices for a premium product.

## SWOT Summary

**Strengths**

Switching between bio-diesel and red diesel is straightforward

Pollution potential is lower relative to red diesel

Flash point is higher than for red diesel

No resistance encountered from insurers

**Weaknesses**

Poor availability of fuel

Bio-diesel is an efficient solvent for natural rubber

May require injection timing alteration if engine is to be heavily loaded

**Opportunities**

Potential cost saving relative to red diesel

Potential for enhancing value of the catch

**Threats**

Image of bio-diesel tarnished by threat to rain forests from palm oil plantations

Availability and cost of fuel is influenced by government policy

## The Application of Bio-Diesel in Ma Gandole

### *Preparations*

Ma Gandole, the test vessel, is of wooden carvel construction and was built in France in 1976. She is just under 30 feet in length and is registered at 6.3 tonnes. She is decked, and rigged as a crabber with a small wheelhouse aft and a hydraulic hauler mounted forward on the starboard side. The engine, located under the wheelhouse, is a Volvo MD70B approximately 20 years old, coupled to a 3:1 reduction gearbox. The MD70B engine is a normally aspirated, 6 cylinder design rated at 120 hp. It is understood to be based on the Volvo F7 truck engine.

At the outset of the trials, the vessel was fitted with twin steel fuel tanks amidships, mounted on wooden bearers either side of a small hold accessed through a deck hatch. The fuel tanks had originally been further aft, either side of the engine but had been relocated several years previously to provide more space around the engine and to give the vessel better balance.

As originally conceived, the project was to have been based on a smaller vessel. At the request of Seafish, the specification for the test vessel was amended to require a 120hp engine. Ma Gandole was selected on the basis that there were very few vessels available within the project budget.

Ma Gandole was leased to the project. This was important to the trials as it allowed access at any time and there was no conflict between the project and fishing operations. There was also no risk that fishing operations could be hindered in the event of mechanical problems attributable to the project. The absence of potential conflict proved to be extremely helpful.

The vessel was brought to Newlyn for the trials. This was a logical choice given the proximity of Newlyn to the University campus, the good standard of the facilities at Newlyn, and the number of other vessels operating out of Newlyn. The Harbour Master was very supportive and local fishermen were cooperative.

As a test vessel, Ma Gandole had a number of limitations. The bilges were constantly wet. The engine bay was cramped, which combined with the generally wet and dirty conditions made for a challenging working environment. The engine smoked quite heavily, although it ran smoothly. However, the intention was to perform the precision testing on the rig at Holman's Test Mine with the test vessel being used to demonstrate the use of bio-diesel in 'real' conditions.

Since bio-diesel is an efficient solvent for natural rubber, one of the first checks on the vessel was to identify any rubber components. The fuel lines were found to be synthetic hydraulic hose and there were no rubber engine mountings so no areas of concern were identified.

As a precaution, the fuel priming system on the engine was upgraded to a more modern arrangement. This was not done out of concern for potential damage, but was motivated by a desire to improve the efficiency of fuel priming in the event of problems at sea.

When switching from fossil diesel to bio-diesel in road vehicles it is widely advised to change the fuel filters shortly after making the change. This is because bio-diesel tends to dislodge accumulated deposits from the walls of the fuel tank and fuel lines. Once the system has been cleaned out by the action of the bio-diesel there is no further hazard, but it is wise to take precautions in the first instance.

Inspection of the fuel tanks on Ma Gandole was difficult due to poor access, but one of the tanks was emptied so that the fuel line and valve could be removed. This enabled scrapings to be taken from the lower part of the tank. The tank was found to contain a substantial quantity of heavy, oily deposits with some particulate contamination embedded in it. Given that the intention was to evaluate bio-diesel rather than to evaluate the contamination in the fuel tanks, the decision was made to replace the tanks with plastic tanks. The original fuel lines were retained. The plastic tanks eliminated the major potential sources of fuel contamination and also made it easier to make visual checks on the condition of the fuel (colour and clarity) and to record fuel consumption.

### *Use on Ma Gandole*

With 2 fuel tanks available, one was dedicated to red diesel whilst the other was dedicated to bio-diesel. At no time was fuel deliberately mixed in a tank as this would have infringed the regulations laid down by H.M. Customs and Excise. It should be noted that some very small quantities of fuel would have been transferred from one tank to another when the fuel types were switched, this being the volume of fuel trapped in the fuel lines and not consumed by the engine.

By retaining an uncontaminated tank of red diesel at all times, there was an additional level of assurance that the vessel would be able to return to port safely in the event that fuel problems were encountered at sea.

Each fuel tank had a valve at its outlet, feeding into a common fuel line to the engine. Switching fuels was achieved by closing the valve on the tank in use before opening the valve on the other tank. The return line was then moved from one tank to the other and a check was made to ensure that the tank breather was open and clear.

Fuel was brought to the vessel in 25 litre plastic containers. Different colours of container were used to readily distinguish between the types of fuel. A fill level was clearly marked on each tank and the first fill was made to this level. Subsequent re-fuelling was done manually, using a large measuring jug to record the quantities of fuel going into the tank. This gave a simple but reliable measure of fuel consumption.

No special protective measures were taken during re-fuelling. No skin irritations or other ill effects were observed. Both polyurethane boots and PVC oilskins appeared to be unaffected by contact with the bio-diesel. However, spillages needed to be wiped up effectively as they proved to be extremely slippery.

Spare fuel, both red diesel and bio-diesel, was retained on board in the 25 litre plastic containers, often for several weeks at a time. These were stored below deck.

Shortly after the first use of bio-diesel, the engine was serviced including a change of fuel filters. This was purely precautionary, in accordance with good practice. The chances of fuel filter blockage had been greatly reduced by changing the fuel tanks but there was still scope for debris to have been dislodged from within the fuel lines.

An attempt was made to supplement the fuel usage data gathered with instantaneous measurement using in-line turbine flow meters. Simple, low cost turbine flow meters were obtained and tested in the laboratory where their performance was satisfactory. Installation on the vessel was more problematic. They were used to determine the proportion of the fuel flow returning to the tank over a period of several minutes. However, they proved to be unreliable as a source of instantaneous net fuel flow measurement, with highly unstable readings being observed. It is thought that this may have been due to pulsing within the system, with pulses affecting the feed line and the return line differently. Further development effort would be required in order to derive a reliable reading of fuel consumption in real time. It should be noted that the fuel flow measurement system used for the onshore test rig was of a totally different nature but was two orders of magnitude more expensive than the low cost turbine flow meters.


**Figure 03: Instantaneous fuel flow meter installed on Ma Gandole bridge**

### *Observations*

With the definitive quantitative data coming from the onshore test rig, the first question to be answered at sea was whether it was possible to "feel" any difference between the fuels at sea. In practice, it proved impossible to tell which fuel was being used other than by the smell of the exhaust fumes. Both fuels started the engine equally well, even on cold mornings (although being

Newlyn, no severely cold weather was encountered). The vessel was felt to handle and perform equally with either fuel.

An area of potential concern was whether the bio-diesel would degrade in the tank, especially during periods of cold weather. No evidence of fuel deterioration was observed, even after the vessel had not been started for periods of 2 weeks during the winter. With the fuel tanks located below deck and below the waterline, they would have been protected from any extremes of cold that may have caused the larger molecules to crystallise. It is possible that the rocking motion of the boat on its mooring would also provide some movement in the fuel to inhibit crystallisation.

With the engine running, it was observed (using the, rather unreliable, in-line flow meters) that over 90% of the fuel delivered to the engine was returned to the tank. This large volumetric flow would have kept the fuel reasonably well agitated as well as warming it, thus keeping the bio-diesel in good condition.

Several attempts were made to obtain direct torque measurements from the propellor shaft. The nature of the required installation made this an extremely difficult operation. The large diameter of the propeller shaft meant that there was a very substantial mass of stainless steel acting as a heat sink which made soldering of the leads to the strain gauges very difficult. After several trials, the first of which is shown in Figure 40, eventually an installation was achieved and some data was obtained. However, maintaining sufficiently dry conditions for the torque sensor to operate reliably in proved to be extremely challenging, to the point where continued operation of the torque sensor became impossible.

**Figure 04: Ma Gandole torque sensor after initial installation on 14th December 2006.**

Being an aging vessel, the engine and other mechanical parts were quite high maintenance. Typical faults encountered were a leak of gearbox oil, failure of the engine shut-down solenoid, starter motor problems and corrosion of a hose tail on the intake strainer resulting in a seawater leak. However, no failures were encountered that could reasonably have been attributed to the fuel.

### *Data*

The fuel consumption test runs were preceded by some basic reliability trials. It was realised that whilst the skipper had confidence that bio-diesel would perform adequately as a fuel for a fishing vessel, the fact that it was unproven in these conditions was thought to have an impact on the way in which the vessel was used. The skipper observed that when first using bio-diesel, he instinctively altered hid behaviour. This was particularly noticeable in the use of the throttle where it was observed that speed increases were made more cautiously and that cruising revolutions per minute were reduced. These instinctive alterations in behaviour appeared to make little difference to the performance of the vessel but made fair comparison of fuel consumption impossible until confidence in the fuel was fully developed. As time went on, it was found that the skipper became far less conscious of which fuel was being used and behaviour patterns converged.

During the summer of 2007, fuel consumption runs were carried out on 46 separate days with weather conditions ranging from flat calm to unpleasantly heavy seas. The testing area in and around Mounts Bay is subject to strong tides. Fuel consumption test runs were designed to replicate the activities of a potter, with a run of about half an hour to the fishing area, followed by periods of idling as strings of pots were hauled.

On fuel consumption test runs, 71 hours were logged using red diesel for baseline purposes, during 3 blocks of test runs. During these tests 271 litres of red diesel were consumed giving an average fuel consumption rate of 3.82 litres per hour. However, average fuel consumption for each block of test runs varied from 3.48 to 4.19 litres per hour, suggesting that fuel consumption at sea can be highly variable.

In comparative test runs, 3 blocks of trials were performed using bio-diesel. The total hours logged during these runs was 66 during which time 225 litres of bio-diesel was consumed, giving an average fuel consumption rate of 3.41 litres per hour. However, across the blocks of tests the average fuel consumption ranged from 3.45 to 3.73 litres per hour.

**Table 1: Fuel consumption on Ma Gandole when fuelled with red (fossil) diesel**

**Ma Gandole - Fuel Usage Record**

**Red Diesel**

| Date | Hrs End | Hrs Start | Hrs Run | Notes | Fuel | l/hr |
|---|---|---|---|---|---|---|
| 15/05/2007 | 9604 | 9603 | 1 | moderate swell | | |
| 22/05/2007 | 9609 | 9604 | 5 | calm - exhaust leak in engine bay | | |
| | | | | Added 25 litres (22 litres to mark + 3 litres) | 25 | |
| 05/06/2007 | 9610 | 9609 | 1 | pontoon run | | |
| 06/06/2007 | 9612 | 9610 | 2 | potting, moderate swell | | |
| 07/06/2007 | 9613 | 9612 | 1 | filled with 9 litres | 9 | |
| 08/06/2007 | 9617 | 9613 | 4 | Potting & lining - calm | 14 | |
| 10/06/2007 | 9620 | 9617 | 3 | potting, moderate swell | | |
| 12/06/2007 | 9623 | 9620 | 3 | | 9 | |
| 14/06/2007 | 9625 | 9623 | 2 | heavy swell | 9 | |
| 15/06/2007 | 9629 | 9625 | 4 | moderate swell | 12 | |
| 03/07/2007 | 9632 | 9629 | 3 | | 23 | |
| | | | **29** | | **101** | **3.48** |
| | | | | | | |
| 07/08/2007 | 9668 | 9665 | 3 | calm | 14 | |
| 09/08/2007 | 9671 | 9668 | 3 | calm | 11 | |
| 10/08/2007 | 9674 | 9671 | 3 | calm | 11 | |
| 13/08/2007 | 9677 | 9674 | 3 | lumpy | 11 | |
| 16/08/2007 | 9682 | 9677 | 5 | calm | 15 | |
| 17/08/2007 | 9686 | 9682 | 4 | moderate | 20 | |
| | | | **21** | | **82** | **3.90** |
| | | | | | | |
| 28/08/2007 | 9705 | 9701 | 4 | | 22 | |
| 29/08/2007 | 9709 | 9705 | 4 | windy | 21 | |
| 30/08/2007 | 9712 | 9709 | 3 | | 15 | |
| 10/09/2007 | 9713 | 9712 | 1 | pontoon run | | |
| 11/09/2007 | 9718 | 9713 | 5 | calm sea, strong breeze, big tide | 18 | |
| 12/09/2007 | 9722 | 9718 | 4 | flat calm | 12 | |
| | | | **21** | | **88** | **4.19** |

**Table 2: Fuel consumption on Ma Gandole when fuelled with biodiesel.**

**Ma Gandole - Fuel Usage Record**

**Bio-Diesel**

| Date | Hrs End | Hrs Start | Hrs Run | Notes | Fuel | |
|---|---|---|---|---|---|---|
| 13/04/2007 | 9590 | 9588 | 2 | Pontoon run, no problems | | |
| 20/04/2007 | 9592 | 9590 | 2 | easy start after cool weather, cruised Mounts Bay | | |
| 22/04/2007 | 9594 | 9592 | 2 | easy start, cruised Mounts Bay. 6.5 kts @1400 rpm | | |
| 02/05/2007 | 9595 | 9594 | 1 | shot pots, rough sea | | |
| 03/05/2007 | 9597 | 9595 | 2 | potting, fair weather | | |
| 04/05/2007 | 9600 | 9597 | 3 | potting, fair weather | | |
| 05/05/2007 | 9603 | 9600 | 3 | potting, calm - filled with 44 litres | 56 | |
| | | | **15** | | **56** | **3.73** |
| | | | | | | |
| 06/07/2007 | 9634 | 9632 | 2 | pontoon run | | |
| 08/07/2007 | 9637 | 9634 | 3 | potting, calm | | |
| 10/07/2007 | 9640 | 9637 | 3 | breezy, some chop | | |
| 16/07/2007 | 9643 | 9640 | 3 | potting, lumpy! | 25 | |
| 17/07/2007 | 9646 | 9643 | 3 | very lumpy | 20 | |
| 24/07/2007 | 9648 | 9646 | 2 | slight swell | | |
| 25/07/2007 | 9650 | 9648 | 2 | lumpy | | |
| 26/07/2007 | 9652 | 9650 | 2 | horrible sea conditions | | |
| 27/07/2007 | 9655 | 9652 | 3 | fairly calm | | |
| 30/07/2007 | 9658 | 9655 | 3 | calm | | |
| 31/07/2007 | 9661 | 9658 | 3 | | 40 | |
| 03/08/2007 | 9665 | 9661 | 4 | heavy seas | 29 | |
| | | | **33** | | **114** | **3.45** |
| | | | | | | |
| 21/08/2007* | 9688 | 9686 | 2 | horrible sea conditions | | |
| 22/08/2007* | 9692 | 9688 | 4 | windy & choppy | 11 | |
| 23/08/2007* | 9697 | 9692 | 5 | wind & swell | 44 | |
| 24/08/2007* | 9701 | 9697 | 4 | fair | | |
| | | | **15** | | **55** | **3.67** |

* Self manufactured biodiesel from the project batch reactor.

## Practical Tips for Skippers

The fact that no fuel related problems were encountered during testing at sea was probably due to the fact that appropriate precautions were taken when switching to bio-diesel. In summary, a sensible checklist of preparations would be as follows:

(i) Survey the vessel to identify components made from natural rubber. Any natural rubber items that may come into contact with bio-diesel should be replaced with a synthetic rubber, or effectively protected. Few modern diesel fuel systems will contain natural rubber components but engine mountings in particular could be vulnerable.

(ii) Check the fuel tank(s) for cleanliness and either replace them or thoroughly clean them before filling with bio-diesel.

(iii) Replace the fuel filters after the first trip using bio-diesel and also carry a spare set of fuel filters, plus a filter wrench.

(iv) Remember that H.M. Customs and Excise do not permit the mixing of bio-diesel with red diesel. If carrying both fuels, it is prudent to clearly identify and separate tanks and to carry spare fuel in colour coded containers.

(v) If the vessel has been left un-started for a long period of time, especially in cold weather, make a visual inspection of the fuel before starting the engine to check that the fuel remains homogenous.

## Recommendations for Further Work at Sea

This project has demonstrated that an inshore fishing vessel can be operated using bio-diesel. The remaining issues centre on the long term use of bio-diesel at sea, something that was beyond the scope of this project. A typical fishing boat engine will be expected to give many years of reliable service so it is logical that further work should be conducted to monitor the long term effects, if any, of using bio-diesel in a fishing vessel.

The ideal scenario would be to conduct a trial over several years on a vessel fitted with twin engines, preferably new engines. By running one engine on bio-diesel and the other on red diesel it would be possible to build up a history not only of relative fuel consumption under service conditions, but also of maintenance issues. There are reasonable grounds to believe that an engine running on bio-diesel may consume less oil and suffer less wear than an equivalent engine running on bio-diesel.

These trials have highlighted the fact that fuel consumption at sea is highly dependent upon a number of factors that cannot be standardised, such as wind, sea conditions and tide. By running identical engines under identical conditions these factors can be eliminated as variables to allow true comparison. If both engines are new at the start of the trial then there is a greater degree of certainty that the engines are in identical condition than would be the case with older engines.

## Cost / Benefit Analysis

Cost of bio-diesel production (per litre)

Using commercial grade recovered vegetable oil:

Feedstock: 32p
Methanol: 13p
Sodium Hydroxide: 1p
Filtration/washing: 2p
Cold weather additive: 2p

Therefore the total cost before labour and overheads is 50 pence per litre which compares unfavourably with red diesel at around 50 pence per litre. The feedstock input cost per litre of fuel output has been based on the assumption that 10% of the feedstock could not be processed (the whites) and that the process yield is 95% (1 litre feedstock oil processed > 0.95 litres bio-diesel).

Using low grade locally sourced recovered vegetable oil:

Feedstock: 0p
Methanol: 13p
Sodium Hydroxide: 1p
Filtration/washing: 2p
Cold weather additive: 2p

At 18 pence per litre before overheads and labour bio-diesel looks economically attractive. In an optimised plant, it should be possible to produce a batch of bio-diesel with a labour input of about 2 hours, although not continuously. If the assumed batch size is 400 litres and a labour value of £10 per hour is used, then the labour cost per litre of bio-diesel is 5 pence. This will clearly vary greatly according to batch size, plant efficiency and actual labour cost. The labour element of cost when using low grade feedstock may also increase as the feedstock is harder to handle at low temperatures (solid) and may require more pre-treatment. However, when producing fuel for own use there is only a true labour cost if the activity prevents money being earned from elsewhere.

Overheads are difficult to estimate as they will vary greatly from plant to plant. They would include the cost of collecting feedstock, power, maintenance and depreciation. Power costs were found to be just over 1 penny per litre of fuel produced. Collection of feedstock cost about 2p per litre in fuel for the collection vehicle. Maintenance is highly variable but 2p per litre is assumed.

In conclusion, ignoring depreciation costs on plant, the marginal cost of self-produced bio-diesel could be as low as 23p per litre, but in practice is likely to be somewhat higher.

Therefore, if a fisherman manufactures his own bio-diesel from a nil cost feedstock, he is likely to see a cost saving of 25 pence per litre compared with red diesel at 50p per litre. For a static gear vessel using 6,000 litres of red diesel per year at 50 pence per litre, the annual fuel cost would amount to £3,000. Substituting self manufactured bio-diesel and assuming an additional fuel consumption of 12.5%, the volume of bio-diesel used would be 6,750 litres at a cost of £1,687.50 (or £1,350.00 if labour is excluded) giving an annual saving of £1,359.50 (£1,650.00 if labour is excluded). If it is assumed that the realistic total labour input to produce the fuel is 1 hour per 100 litres (double the optimum) then this saving represents a benefit of over £24 per hour spent on fuel production.

If the fisherman also obtains a market premium of 10% on his catch through certifying it as caught using bio-fuel, the benefit of enhanced catch value would be greater than the savings in fuel costs, thereby more than doubling the net economic benefit.

For trawlers, the fuel cost savings would be substantially higher, pro-rata to their fuel usage, but there is less scope to enhance catch value through bio-diesel based marketing.

**Table 3: Summary of key costs in biodiesel self-manufacture**

| Cost per litre in pence | Commercial Grade Feedstock | Zero Cost Feedstock |
|---|---|---|
| Feedstock | 32 | 0 |
| Methanol | 13 | 13 |
| Sodium Hydroxide | 1 | 1 |
| Wash and Filter | 2 | 2 |
| Cold weather additive | 2 | 2 |
| **Total Cost of consumables(p/l)** | 50 | 18 |
| Labour | 5 | 5 |
| Power | 1 | 1 |
| Collection | 2 | 2 |
| Maintenance | 2 | 2 |
| **Total** | 60 | 28 |

## Bio-Diesel and Fuel Duty

In general, bio-diesel is subject to fuel duty in the same way that fossil diesel is, although where duty is payable the rates are lower than for red diesel (and lower than white diesel when used on the road). The actual rates vary from time to time. Users eligible for a zero rate of duty on red diesel would also be entitled to a zero rate of duty on bio-diesel.

H.M. Revenue and Customs explicitly forbid the mixing of bio-diesel with red diesel unless the full road duty rate is paid on all of the resulting fuel. They also require 7 days notice of any intention to do this.

Since 30th June 2007 a "homebrew" style of concession has applied to individuals producing bio-diesel for their own use. In these circumstances, an individual may produce up to 2,500 litres of bio-diesel per year for any use without registering as a fuel producer and without any requirement to pay fuel duty.

## Discussion, Conclusions and Further Work

There are a number of reasons to consider the use of bio-diesel in fishing vessels. For many members of the public the primary consideration would be the environmental benefits. Whilst it is fair to say that the combustion products of bio-diesel are an improvement on those of red diesel in environmental terms, there can be little doubt that technical and social changes are driven by pragmatism rather than by idealism. For bio-diesel to constitute a realistic alternative to red diesel it has to offer an economic benefit. This economic benefit does have to come solely from savings in fuel costs, but may also be derived from enhanced prices for fish certified as caught using bio-diesel.

This project has demonstrated that bio-diesel is a technically feasible direct substitute for red diesel in engines typical of 10 metre class fishing vessels. Theory predicts that the lower calorific value will result in increased fuel consumption relative to red diesel.

The central issues to the potential take-up of bio-diesel in fishing vessels will be those of economics and logistics. Of these, the economic factors will dominate as favourable economics would stimulate solutions to logistical issues. Fishing, or even general marine use of bio-diesel cannot be considered in isolation. The dominant factor in the development of the market for bio-diesel is the level of demand for road transport use, which in turn is driven by government policy. The policy of renewable obligations will artificially stimulate demand for bio-diesel for road use which is likely both to stimulate additional production capacity and to drive up market prices. The inevitable consequence will be that all bio-diesel that is certified as conforming to the requirements of BS 14214 will be sold into the road transport market as that is where the greatest profit margin will be achieved. The superior profitability of bio-diesel in the road transport market will continue for as long as supply does not excessively exceed demand and as long as the duty differential between road transport bio-fuel and fossil fuel remains.

Based upon the probable scenario for demands for bio-diesel by the road transport sector, it is logical to conclude that security of supply for the fishing industry can only be achieved if the industry has control of adequate production capacity. Furthermore, there is no benefit in having available capacity without a sufficiency of feedstock. In order to avoid competition with the road transport fuel industry, the fishing industry will need to utilise less favourable feedstock that would be unlikely to economically yield fuel that complies with BS EN14214. In terms of dynamic performance, fishing operations under marine diesels are less demanding of fuel quality than many road diesel engines. In contrast to automotive applications, marine diesels are operated at high load for prolonged periods and one result from this project is that if this high load setting is too extreme (taking account of revised engine performance curves), engine condition can deteriorate when no engine timing adjustments are made to allow for the new fuel. Under the less onerous, but typical operating conditions experienced on Ma Gandole, no issues arose from the use of fuel produced in-house, that almost certainly did not comply with BS EN14214, or externally sourced BS 14214 specification fuel.