Waste Vegetable Oil Recycling for Bio-diesel Production in Essex & Cambridgeshire

WasteWISE Overview Report 2 MAY 2003

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Executive Summary

- It is estimated that 75,000 tonnes of waste vegetable oil arise from catering and industrial sources annually in the UK. Estimates for Essex and Cambridge are 1,850 tonnes and 750 tonnes respectively. In addition, up to 3 times this amount of waste oil may be available from households.
- Only a small fraction of this is currently recycled. Current use to manufacture animal feed will soon be prohibited within the EU as a result of BSE transmission control.
- Vegetable oil can be efficiently converted to bio-diesel using a simple process. The estimated annual quantities of waste oil produced in Essex and Cambridge could produce around 2.4 million litres of fuel.
- Bio-diesel provides a cleaner burning, more environmentally friendly substitute to ordinary diesel. No vehicle modifications are necessary.
- A WasteWISE scheme is proposed in which bio-diesel is manufactured from waste vegetable oil at a VAT inclusive cost of around 50p per litre. This could generate a large surplus if sold slightly below the current pump price of around 80p per litre for normal diesel.
- The WasteWISE scheme could create at least 10 jobs in Essex and Cambs for a 20% collection rate. The number of jobs could be doubled by collecting ca. 8% of domestic waste oil or purchasing extra catering waste.

- **Next Steps (more in para 8 below)**
  – Improve this report through discussion/consultation
  – Undertake detailed feasibility study/financial analysis in catchment area(s) likely to deliver most economic and successful recycling.

1. Background

It is estimated that between 50,000 and 100,000 tonnes of waste vegetable oil (WVO) arise from catering and industrial sources annually in the UK, of which only a fraction is collected. An even larger amount of collectable household waste is also probably available but the quantities involved are more difficult to estimate. An EU study in 1997 revealed an average per capita usage of fats and oils of 42 kg per year, from which estimates of between 5 to 13 kg per capita per year of collectible waste oil were deduced. Waste oil cannot be land-filled and had to be collected by licenced operators. Up until recently, 90% of collected oil has been used to make animal feed but thus will shortly be prohibited within the EU due to the risk of BSE transmission. It can be used to make detergents but interest is now focused on the use of recycled vegetable oil (RVO) to make bio-diesel.

Vegetable oils, including filtered waste oil, can be used directly in diesel engines without processing to form bio-diesel – often referred to as straight vegetable oil or SVO - but they are likely to leave gummy deposits and acidic residues which can affect engine warranties. They also usually need to be pre-heated or mixed with thinning agents such as white spirit to reduce viscosity so usually require conversion kits. Since they attract the same amount of duty and VAT as bio-diesel it is probably not worth considering this as an option.

Bio-diesel is one of the most promising of the alternative fuels, which include bioethanol and hydrogen. It is produced from vegetable oil using fairly simple chemistry (see Appendix 1). It is non-toxic and rapidly biodegrades. It can be produced from either new or waste oil and offers good performance together with a number of environmental benefits compared to ordinary petroleum diesel (see Appendix 2-3). If all the the estimated quantity of waste vegetable oil were collected and converted to bio-diesel, *ca.* 0.5% of the total *ca.* 17 million tonnes of petrodiesel consumed in the UK could be replaced, saving *ca.* 225,000 tonnes of carbon dioxide emissions as well as other pollutants.

This would represent a far greater percentage of vehicles than currently run on LPG.

2. Estimated Quantities Available for Recycling

Table 1 shows estimated annual quantities of cooking oil available for recycling in Essex and the regions. These have been derived from simple proportional calculations for the various regional populations taking the average estimated UK total quantity of catering and industrial (Business) waste oil as 75,000 tonnes (various sources) and the total collectable waste oil at the bottom of the EU range at 5 kg per capita per year (Teagasc 1997, Mittelbach 2002)). Populations for Essex from the '01 census and for Cambridge and the regions from the '00-'01 Waste Collection Statistics have been used.

Table 1

	Household (tonnes)	Business (tonnes)	Total (tonnes)
Essex	5,400	1,850	7,250
Cambridge	2,100	750	2,850
E & C	7,500	2,600	10,100
Eastern Region	17,900	6,300	24,200

The total quantity of catering and industrial waste oil in Essex (1,850 tonnes) would be sufficient to produce *ca.* 1.7 million litres of bio-diesel per year, assuming densities of 0.92 g/cm^3 for the waste oil, 0.87 g/cm^3 for bio-diesel, 10% unconvertable waste/sludge and an 80% conversion yield. For Cambridge and the Eastern Region, the corresponding figures are 0.7 million litres and 5.7 million litres, respectively.

3. Financial Overview

Government has created new start-up funding for effective community recycling projects. WasteWISE will assist organisations to win funding for

projects in the two counties, including in Thurrock, Southend and Peterborough. There is plenty to bid for, including: New Opportunities Funding: 'Transforming Waste', SEED funding, Fair Share projects and the planned Government £100 million/year sustainable waste funding package. This funding would be used to assist start up as the recycling of waste cooking oil can then be developed as a sustainable business.

4. Social Employment Opportunities

WasteWISE aims to create 50 reuse and recycling jobs in Essex and Cambs by 2005, including a significant percentage for people who currently have difficulties finding jobs.

An analysis of the costs and surpluses involved in a WasteWISE bio-diesel manufacturing scheme is presented in Appendix 2. For a 100% collection rate of catering and industrial waste, the amount of oil in Essex would be enough to sustain 20 two-man social enterprises – 40 people in total - each producing over 80,000 litres of bio-diesel per year. A waste collection rate of only *ca.* 20% would provide employment for 8 people in Essex, 4 in Cambridge and 28 over the Eastern Region. It is suggested that the enterprises are limited to two-man teams with this level of production to avoid the VAT threshold. Biofuel.Org.UK and The Bio-power UK Ltd network also favour this approach. These estimates could be doubled if ca. 8% of household waste oil could be collected. Operating costs for the most efficient scenario assume the use of automatic equipment and assume one quarter of the time is spent manufacturing bio-diesel. Full allowance is made for purchasing waste oil from existing collectors but the remaining time could be used for collecting waste oil using bio-diesel fuelled vehicles. Electrical power for processing could be generated using bio-diesel once production is up and running.

Any social enterprise collecting waste oil will have to obtain a Waste Carriers' Licence from the Environment Agency (EA) costing around £150. A licence may not be necessary if waste oil is delivered, either to the premises or to community bring banks. In addition, an IPPC (Integrated Pollution Prevention and Control) licence is required by the EA, costing between £5,000 and

£30,000 and currently involving a 4 month lead time.

5. Environmental Issues

It is illegal to dispose of waste oil down drains – although it is biodegradeable and far less of a problem than mineral oil, it can solidify, blocking drainage systems and pollute sewage systems and waterways. Precise figures are unavailable but the indications are that only a small percentage of waste cooking oil is currently recycled. This is either used to manufacture animal feed (*ca.* 90%), for detergent manufacture or incinerated. There is a proposed EU-wide ban on use for animal feed in 18 months' time due to the possibility of transmission back into the human feed chain of BSE prions from incorporated animal fats. The UK does no have any robust procedures for waste oil disposal. It is likely that substantial volumes enter land fill sites in containers, though the EU directive now prohibits such deposit of liquids. Conversion to bio-diesel therefore offers a good solution. It produces less environmental damage than ordinary diesel and is less harmful to human health, as detailed in the Appendix. While no internal combustion engine can ever be regarded as clean burning and the term long term goal must be to use fuel cells powered by hydrogen produced from renewable sources or other clean alternatives, in the short term it is important to curb emissions from existing vehicles.

6. Potential Partner Organisations

- WASTEWISE and WISE - WISE provides detailed development and management training for recycling/other social enterprise managers in Essex, Cambridgeshire and neigbouring areas.
- Recycling social enterprises and community/environment groups
- Essex and Cambs county councils, district and unitary councils, and joint waste strategy and recycling initiatives. Councils may agree to use bio-diesel in refuse collection vehicles.
- Essex ReMaDe, London ReMaDe and other initiatives/umbrella organisations
- External partners, e.g. Biofuel.Org.UK Ltd, Bio-power UK Ltd.
- Local recycling, waste and other businesses.

7. Key Issues for Further Analysis/Discussion

(i) Efficient strategies for Waste oil collection.
(ii) Evaluation of gains/losses involved in glycerol disposal and methanol recovery.
(iii) Quality control issues – for example testing to BS EN 14214 standard.

8 Next Steps/Detailed Financial Analysis

Processing cost issues are discussed in Appendix 2. In summary, the best scenario shows that bio-diesel could be produced from waste oil for around 43p per litre ex VAT. If this is sold for around 69p per litre, the turnover from making and selling *ca.* 80,000 litres of biodiesel per year (one 400 litre batch per day) would be around £55,000 - just below the VAT threshold. The surplus would easily cover the cost of production and subsidise collection costs for a two-man social enterprise. It is suggested that a number such enterprises are set up in Essex and Cambridgeshire.

Our standard two stage approach at WasteWISE is, with partners, to

a Consult on discussion drafts like this, then improve and publish a final 'overview report'

b To then undertake a detailed feasibility study and financial analysis with partners on a real potential scheme covering a defined catchment area that is projected to deliver economic and successful recycling. This will normally cover at least three council districts in Essex and/or Cambs, and the study will be overseen by the creation of a 'task and finish' project group including key partners.

In the case of bio-diesel, the issues to be costed in detail include:

A FIXED COSTS (* costs reduced by partnerships/links)

Capital investment

- recycling banks appropriate to waste oil (most efficient option to be determined)
- * collection vehicle and systems for bulking oil and reactants
- * premises/bulking/external storage
- * processing equipment/blender/delivery pump
- * IPPC and Waste Carriers' licences

* Operating costs
– business rates, phones etc
– Quality control/contamination prevention
– Promotion/media

B VARIABLE COSTS PER LITRE

Staff costs
- Waste oil collection
- * Filtering/processing/blending/quality control
- * Delivery/transport to market

Operating costs
- Reactants/electricity/waste product disposal
- Quality Control
-

C INCOME

Price per litre
Recycling credit per tonne (household waste oil)
Financial support from local authority/potential business partners
Staffing contribution re: placing people with learning disability
Potential one-off assistance from industry
Local partners interested in reprocessing outputs
Potential grant aid and start up funding.

9. Contacts / Information Sources

Contacts

Martin Brook, Biofuel.Org.UK Ltd. 54, Lambs Lane, Cottenham, Cambridge CB4 8TA. Tel: 07970 979 646 Fax: 01954 204330
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Appendices

Appendix 1 presents some additional technical information, including details about bio-diesel manufacture, emissions and performance.

Appendix 2 presents estimated biodiesel manufacturing costs for WasteWISE projects. Four scenarios are considered which include the use of bought waste oil, use of manual or automatic equipment and a back-up using fresh rapeseed or sunflower oil.

1.Technical information

Bio-diesel has been used in other countries for over 10 years. For example, the US mail and other government departments operate its fleet with it and it is currently being tested in buses in Montreal. In Kyoto, refuse collection trucks are running on it. Minnesota has just implemented a state-wide ruling that all diesel is sold as a 2% bio-diesel mix and is investigating the use of waste-derived ethanol/biodiesel mixes (EB diesel). Asda supermarkets in the UK are currently testing a scheme using the 140,000 litres of waste oil and chicken fat generated annually from its canteens, rotisseries and restaurants to produce bio-diesel for its delivery lorries.

Bio-diesel is normally manufactured from fresh oil. Any oil can be used – normally rapeseed in Europe and soybean in the USA. Animal fats such as lard and tallow can also be used, so the mix of vegetable oils and animals fats normally found in waste cooking oil shouldn't present a major problem, other than the fact that the resulting fuel might solidify more readily in winter – a factor which must also be taken into account with pure vegetable derived bio-diesel, which begins to form a sludge at around 2^0 C compared to around -15^0 C for pure petroleum diesel. This factor can be compensated for by using additives or, more generally, by mixing bio-diesel with ordinary diesel. Bio-diesel can be mixed with ordinary diesel in any ratio – a 20% bio-diesel, 80% petro-diesel mixture, referred to as B20, is commonly used in the USA, whereas a 5% bio-diesel mixture (B5) is normally used in Europe. Pure bio-diesel is referred to as B100.

Germany is the largest producer, with an annual output of *ca.* 0.75 million tonnes that is projected to rise to 2 million tonnes in 2010. In July 2002, Lurgi Life Science GmbH opened a new plant in Marl with an annual production of 100,000 tonnes of bio-diesel and 12,000 tonnes of pharmaceutical grade glycerin. In contrast, bio-diesel production in the UK for '02 – '03 was only 3,500 tonnes. This is mainly been due to the unfavourable tax position. In most of Europe bio-diesel is untaxed, whereas in the UK the full amount of 45.82p per litre duty was applied until July 2002. For example, in Belgium, Germany, Spain, Italy, Sweden and Norway there is 100% tax relief and in Austria there is 95% relief. The recent reduction of 20p per litre in fuel duty compared to Ultra Low Sulphur Diesel (ULSD) from 45.82p to 25.82p has helped the fledgling UK industry but is still barely sufficient to make bio-diesel production from fresh oil economic because the cost of the raw materials (*ca.* 40p per litre) is generally around 3 times greater than the pre-tax cost of petrodiesel. The rate of production has only increased from barely zero in '01 to a rate of around 10,000 tonnes per year as of May '03. As a further slight hindrance, it was announced in the April '03 budget that the rate of duty applied to bio-diesel will increase from 25.82p to 27.1p per litre on the 1/10/03 – an increase of almost twice the rate of inflation or almost double the percentage increase in duty for ordinary diesel. It was also announced that a special duty reduction of *ca.* 0.6p per litre would be introduced for the newer sulphur free diesel and that the rate of duty for ethanol, another biofuel, would be set at 20p per litre below the sulphur free diesel rate as from 1/1/05. However, the Government seems oblivious the sulphur free nature of bio-diesel and the 20p per litre rate reduction for this is still pegged to the ULSD rate, as opposed to the sulphur free rate.

The current British standard BS EN 14214 has to be strictly adhered to obtain the reduction in duty. The European bio-diesel draft standard is prEN 14214:2001 and the future British standard is expected to follow this. Blends of 5% bio-diesel have to meet the current BS EN 590 standard. Global Commodities, based in Thetford, Norfolk, have been selling 100% bio-diesel – "driveECO" - in around 10 garages in the Norfolk area since March '02. Greenergy/Globaldiesel started selling bio-diesel in Holbrook in July '02. This is a 5% blend (B5) of rapeseed-derived bio-diesel mixed with ultra low sulphur diesel (ULSD). Envirodiesel Ltd., based near Doncaster, sell pure bio-diesel manufactured from waste cooking oil in 1000 litre batches for 73p per

litre. Martin Brook (Biofuel.Org.UK Ltd) is currently setting up his own bio-diesel manufacturing business in Cambridge and is participating in the WISE programme. John Nicholson in Caernafon is attempting to set up a network of biofuel producers (Biopower UK Ltd). LILI (Low-Impact Living Initiative) based at Redfield Community, Winslow, run weekend courses showing how to make bio-diesel.

Manufacture

Vegetable oils belong to a chemical group known as triglycerides. These are compounds formed from fatty acids and glycerol. Three fatty acid molecules link with each glycerol molecule – hence the triglyceride term. The link is a bond between two oxygen atoms, known as an ester link. Vegetable oils are tri-esters. Glycerol (also known as glycerin) is a type of alcohol which is a skin emolient and useful additive for the cosmetics industry. The triglyceride molecules are large compared to those in petrodiesel – each fatty acid comprises a chain consisting of around 18 carbon atoms in the case of rapeseed oil, for example, making 54 carbons in addition to the 3 in the glycerol. Petrodiesel, in contrast, contains carbon chains averaging around 12-14 atoms in length. This difference in molecular size is one of the main reasons for the unsuitably high viscosity of vegetable oil for use as a fuel. During bio-diesel manufacture, the oil is split into smaller carbon chains by a process known as transesterification.

(i) Filtering, neutralisation and drying

The waste vegetable oil needs to be filtered to remove any food particles which may clog up fuel lines. Free fatty acids, which are present in higher concentration in used oil than fresh, then need to be neutralised with alkali. Finally, the oil must be dried as water reduces the efficiency of the transesterification.

(ii) Transesterification

The oil is reacted with about a fifth by volume of methanol and a small amount of sodium hydroxide (caustic soda). This results in a break-up of the triglyceride molecules and formation of the fatty acid methyl esters (FAME)

which comprise bio-diesel. Bio-diesel made from primarily rapeseed oil is known as rapeseed methyl ester, for example. Glycerol is also formed as a useful by-product. Ethanol can be used as a less toxic alternative to methanol to form fatty acid ethyl esters (FAEE). This process is popular in the US as ethanol can be formed from biomass, whereas methanol is still largely produced from oil, although alternative production methods from biomass and natural gas do exist. Performance and emission characteristics of FAME and FAEE bio-diesel appears similar so in the longer term it would be preferable to manufacture FAEE fuel. Current barriers include the need for extremely dry ethanol for the reaction to occur cleanly.

(iii) Washing and drying

The bio-diesel then needs to be washed to remove the residual methanol (about a tenth by volume) and soapy deposits. The glycerol settles out as a separate layer in a procedure facilitated by using a sand bed. It should be possible to sell the glycerol to soap and cosmetics manufacturers for purification to pharmaceutical grade glycerol. Alternatively, it may be possible to use it within local soap-making enterprise. The glycerin at this stage is coloured as it contains dyes from the waste oil – this is removed commercially by filtration through charcoal. Finally the bio-diesel is dried by heating or passing through a salt bed.

(iv) Equipment

Equipment for automated bio-diesel production can be obtained fairly cheaply. For example, Savoia Power in Argentina make a unit for ca. £2,400 (the BIO 4) which produces 400 litre batches. A smaller, 200 litre unit (the BIO 2) is also available for £1,400. They also make an accessory for filtering and vacuum drying waste oil prior to conversion (the BIO-D2. This has a throughput of 200 litres per hour and costs £1,600. The Chemical Engineering Department at Cambridge University are developing a continuous flow system which is expensive but would be the best option for a large scale operation. A third “supercritical” method could be applied, which uses extremely high pressure and dispenses with the catalyst, but this involves extremely expensive equipment which is difficult to manufacture on a large scale.

Emissions

Carbon dioxide emissions are reduced because bio-diesel is essentially carbon neutral – as much carbon dioxide is absorbed from the air during plant photosynthesis as is released by burning. It is often claimed that replacing a tonne of petrol diesel with the same quantity of bio-diesel reduces CO_2 emissions by 3 tonnes. This is true for bio-diesel produced from waste oil but the saving is reduced to around 2.5 tonnes when using new oil because of the energy used in fertiliser production and conventional diesel burnt during agriculture. Sulphur emissions are also virtually zero – even less than ultra low sulphur diesel (ULSD). A recent draft report issued by the US Environment Protection Agency concludes that exhaust emissions of particulates and carbon monoxide are reduced by almost 50% and unburned hydrocarbons by over 65% when B100 manufactured from fresh oil is used in heavy goods vehicles. Similar results appear to be obtained from waste oil, although fewer experiments have been conducted.

Particulates (microscopic carbon particles) are reasonably considered to be carcinogenic. It has recently become apparent that the size of these may have has a more important effect than their mass. Very small particles, especially ultrafine particles less than 0.1 μm in diameter are considered critical in their effect on human health as they become deposited in the pulmonary alveoli. A range of particle sizes are found in both conventional diesel and bio-diesel exhaust, but initial tests have demonstrated that the fraction of ultrafine particles in bio-diesel exhaust comprises a much smaller component of the more dangerous sub-micron size particles – only 2% have a diameter smaller than 0.125 μm compared to 44% for conventional diesel. Many of the hydrocarbons in exhaust are toxic and are absorbed into the body attached to the surface of the particulates. Petroleum-derived diesel contains a cocktail of toxic hydrocarbons including benzene which is carcinogenic. Even low benzene diesel can contain up to 0.8% benzene which translates to 8 ml per litre or 1.6 litres in a 200 litre tank.

The reduction in emissions applies in proportion to bio-diesel mixtures slightly more favourably than might be expected from the ratio in the mix - for example, B20 exhibits a *ca.* 12% reduction in particulates rather than the 10% which would be expected. The reduction in CO emissions occurs because, in contrast to petrodiesel, bio-diesel contains oxygen (two atoms per bio-diesel molecule, around 10% by weight) so the fuel is more completely burnt. On the negative side there appears to be slight increase in nitrogen oxide (NOx) emissions – ca. 10% for B100 bio-diesel, *ca.* 2% for B20, although there are numerous reports that these can be reduced or eliminated by adjusting the engine timing. Additives are also available (Clean Diesel Technologies Inc., Stamford CT USA) for reducing or eliminating NOx emissions.

Performance

Bio-diesel does not require any engine modifications. It has been used in cars, light and heavy duty goods vehicles, trains and is presently being tested for use in jet aircraft. The low flashpoint compared to kerosene is particularly useful for aircraft, however, additives have to be used to prevent solidification at the low temperatures encountered (winterisation). Performance is maintained, filtes and catalysts operate as normal and the additional lubricity of the fuel compared to petrodiesel is advantageous. There is a chance that rubber fittings in some pre-'94 engines could be affected by the use of 100% bio-diesel and the replacement of rubber hose with Viton is recommended. The energy content of plant-based bio-diesel is 7.9% lower than petroleum-derived diesel on a volume basis – ideally the duty and VAT applied should reflect this. Fortunately this doesn't result in a proportional reduction is fuel economy – an average reduction of around 4.6% is reported. Presumably this is because the fuel burns more completely.

2. Estimated manufacturing costs for WasteWISE projects.

Bio-diesel manufacturing costs on a per litre basis have been estimated for WasteWise projects (see Table 2). Four scenarios have been considered:

A. Waste cooking oil and chemicals bought and delivered from most expensive existing sources, bio-diesel manufactured by a manual, labour-intensive bucket method.

B. Waste oil and chemicals bought and delivered using cheapest sources, bio-diesel manufactured using automatic equipment.

C. Back-up scheme using fresh UK rapeseed oil to maintain supply if waste oil collections are disrupted..

D. Back up scheme using cheapest possible source of fresh oil (imported sunflower).

Costs using bought waste oil are used because it is difficult at this stage to estimate the cost of collection and reasonably priced, reliable sources of waste are available. It is anticipated that, after further analysis WasteWISE projects will set up collection systems after a consideration of various options, including community bring banks and containers installed on commercial premises and civic amenity sites. The figures quoted provide a useful guide to the target costs for these.

Table 2 shows that the main obstacle to maintaining a profitable, sustainable enterprise is the high level of duty still applied by Customs and Excise. Manual processing is uneconomic, as is production from fresh UK rapeseed oil. However, it should be possible to produce bio-diesel from waste oil using automatic equipment for a minimum ex-works price of *ca.* 43p per litre including duty, provided the cost of the premises is partly met from other sources. If VAT can be avoided, this would produce a profit of around 26p per litre if sold at 69p per litre - *ca.* 10p below normal diesel prices - representing a profit margin of around 40%. Total sales of *ca.* 80,000 litres per year would then produce a surplus of *ca.* £21,000. As the labour involved in production would only require one person half-time, most of this surplus could be used tofund time additional waste oil collection, making a total of at least two full-time posts per enterprise. A back-up operation using imported fresh sunflower oil may be worth considering to keep the operation going should waste oil

supplies become interrupted. This would cost a minimum of *ca.* 55p per litre to produce but should still return a surplus.

Table 2

Estimated Bio-diesel Manufacturing Costs

Cost (£ per litre)

	Scheme A	Scheme B	Scheme C	Scheme D
Waste Oil	0.120	0.063		
Rapeseed Oil			0.400	
Sunflower Oil				0.200
Methanol	0.110	0.025	0.025	0.025
Sodium Hydroxide	0.010	0.010	0.005	0.010
Energy	0.020	0.010	0.010	0.010
Misc	0.010	0.010	0.010	0.010
Labour	0.200	0.050	0.025	0.025
Equipment		0.010	0.010	0.010
Other capital costs	0.04	0.04	0.04	0.04
Gylcerin credit	-0.03	-0.03	-0.03	-0.03
Methanol recovery	-0.055	-0.0125	-0.0125	-0.0125
Duty	0.258	0.258	0.258	0.258
Sub Total	0.683	0.434	0.741	0.546
VAT	0.120	0.076	0.130	0.095
Total	0.80	0.51	0.87	0.64

Notes on calculations used to produce Table 2:

It is assumed that 1 litre of oil produces 1 litre of bio-diesel (*ca.* 80 % yield)

Scheme A is a worst case scenario assuming highest prices reported recently for waste oil, current UK price of methanol (as delivered by Albion at price of £85 per 210 litres + VAT, assuming 200 ml used per litre of oil), labour

intensive processing with buckets etc. (8 hours or each 200 litre batch @ £5 per hour). Sodium hydroxide cost assumes use of 7g/litre (£35 per 25 kg quoted by Relics, Witney). Gas heating is assumed, using 1.7 kWh/l at cost of 1.2 p/kWh. Recent report from Sheffield Hallam University quotes 1.4 kWh for new oil – an extra 0.3 kWh is added here for initial drying. Ideally, waste products could be used for heating. No working time is allowed for methanol and glycerin recovery, which may be uneconomic. Miscellaneous costs include phenolpthalein indicator used for titrations.

Scheme B assumes the best recent quote for delivered waste oil (£69 per tonne according to Martin Brook at Biofuel.Org.UK Ltd). Rotterdam spot price for methanol plus manufacture in 400 litre batches using automatic equipment (Savoia, Argentina) assuming 2 hours needed for filtering and neutralisation followed by 2 hours for processing. Electrical heating is used but the energy cost is less than in scheme A due to efficiency savings (13 kWh per 400 litre batch is claimed but this figure is taken with caution and multiplied by a factor of 5 here at a cost of 6p/kWh.) Savoia also sell a bio-diesel powered generator which is a useful totally “green” option. They also sell a unit for reclaiming methanol which could save between 1p and 6p per litre. Equipment cost of £2400 is used and 30% per annum interest and depreciation is allowed. Use 200 days per year with a single daily throughput of 400 litres is assumed.

Scheme C assumes cheapest spot methanol price and rapeseed oil bought at lowest UK bulk cost (there are reports within the bio-diesel community that this is cheaper bought at supermarkets) with manufacture using automatic equipment taking 2 hours for each 400 litre batch (only minor neutralisation anticipated). Sodium hydroxide costs assumes use of 3.5 g/litre.

Scheme D assumes use of crude sunflower oil bought at lowest European price (Bulgarian source, 5p/litre included for transport) and methanol bought at spot price. Sodium hydroxide costs assumes use of 7g/litre due to high acidity reported for crude oil.

Other capital costs: A figure of 4p per litre is used for initial consideration. This is based on a figure of 3.12p per litre derived in ’97 for Teagasc for a 3000 tonne waste oil bio-diesel plant operating with 40% grant aid. On the

one hand, the small-scale (80 tonne) WasteWISE projects might be expected to have higher unit costs, on the other hand these may be reduced if buildings are shared with other recycling and resuse projects.

Duty is charged at a flat (reduced) rate of 25.8p/litre. WISE projects could escape VAT if the annual turnover is less than £55,000. If bio-diesel is produced for 43p per litre according to scheme B and sold at ca. 10p below the normal pump price at 69p per litre this is equivalent to *ca.* 80,000 litres of bio-diesel/year (*ca.* 400 litres or 90 gallons per day). Annual profit would then be *ca.* £21,000 (40% of turnover).

Current diesel pump price (Mar '03) for comparison is *ca.* 80p/litre.

This report has been compiled to the highest accuracy using the best available information, but prospective users should check details prior to setting up a new social enterprise. The WasteWISE team requests anyone using this analysis or other assistance to set up a new enterprise to acknowledge the role/contribution of WasteWISE and other partners e.g. councils, to such projects.

RESEARCHED AND WRITTEN BY: Andrew Stevens, April 2003