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Potential of cropping for liquid biofuels in Northern Ireland

An evaluation of the market for biofuels in Northern Ireland, considering the EU Directive on the Promotion of Biofuels for Transport (2003/30/EC)

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1 Executive Summary

In this report, the implications of an EU Directive setting indicative standards that 2% of the energy content of liquid fuels for transport are to be from biofuels by the end of 2005, and 5.75% by 2010, and the UK government implementation plan for 0.3%, 2% and 5% by the end of 2005, 2010 and 2020 respectively are considered. The current size of the market for liquid biofuels in Northern Ireland was established and an allowance was made for the likely trends in fuel use up to 2020. Calculations were based on the figures for automotive diesel, which does not include gas oil used in tractors, construction machinery, trains and marine vessels. It was also recognised that a substantial proportion of diesel used in Northern Ireland is purchased in, or smuggled from, the Republic of Ireland, but no allowance for this was made in the calculations.

The conclusions drawn from this report were:

1. The size of the market for biofuels to meet the transport fuel obligations set by the EU and the UK government would create a significant market for bioethanol and biodiesel in Northern Ireland.
2. The total size of the biodiesel market will be unclear until guidance is provided on whether gas oil used in tractors, trains, construction machines and marine vessels is included and whether account should be taken of fuel purchased in, or smuggled from, the Republic of Ireland.
3. There are no fundamental climatic constraints limiting the growing of OSR or winter wheat in Northern Ireland and both crops have been grown successfully for many years, with yields similar to those obtained in England.
4. The introduction of a greater diversity of arable cropping into Northern Ireland and a reduction in grass monoculture is environmentally desirable, although a greater adoption of winter cropping is less acceptable than spring cropping.
5. Growing biofuel crops on the 3,500 ha of set-aside in Northern Ireland would provide a way of initiating the adoption of biofuel cropping without significantly changing the current arable cropping pattern.
6. Providing that suitably sized processing facilities can be constructed for bioethanol production, even the maximum increase in the wheat area of 6,500 ha could be achieved without a significant change in the overall area of arable cropping in Northern Ireland, if part of the crop is grown on set-aside.
7. The growing of OSR would be likely to displace other break crops such as peas and beans.
8. Processing OSR and wheat for biofuel would generate significant quantities of high protein animal feedstuffs which could meet the need for quality assured GM-free locally sourced protein feed, which the displaced peas and beans were also being grown for.
9. The production of biodiesel is more suited to farm-scale production than bioethanol and consideration should be given to establishing a pilot plant if those already operating in Northern Ireland for the conversion of waste vegetable oils are not suitable.

10. Any increase in the area of wheat could be matched by an increase in the area of OSR, to enable a suitable rotation to be maintained and providing the crop area to meet part of the biodiesel target, although not all of it.
11. Increasing the area of OSR in Northern Ireland to over 5,000 ha for the 2% target in 2010, and about 15,000 ha to meet the 5% target in 2020 would represent a more significant change in arable cropping than the growing of wheat for ethanol.
12. The rotational requirement of OSR to be grown no more frequently than 1 year in 3 (preferably 1 year in 5) means that it must be associated with twice its own area of cereals. In practice, therefore, only a gradual change towards such targets could be expected with the area of winter wheat and winter barley increasing in step with that of OSR.
13. The increasing demand for OSR in Europe generated by the biofuel policies of EU governments is leading to increased prices for OSR. Even without the development of biofuel processing in Northern Ireland, it is likely that the area of OSR being grown in Northern Ireland will rise.
14. Small-scale oilseed crushing facilities recently installed in Northern Ireland and in the Republic of Ireland demonstrate that the need to install such facilities should not be considered an obstacle to progressing the production of biofuel in Northern Ireland.
15. The conversion of the diesel engines in fleet vehicles such as buses would allow the use of unrefined vegetable oil now being produced in Northern Ireland (capacity 500 tonne/ annum) without conversion to biodiesel.
16. The interest of Citybus, Ulsterbus and Northern Ireland Railways in using biofuel should be exploited as a means of promoting the use of biofuel from local sources in Northern Ireland.
17. If higher targets are set for biodiesel to take account of gas oil and cross border fuel movement, then very much higher acreages of biodiesel would be required. Ultimately, the EU restriction on the ploughing up of more than 10% of permanent grassland would limit the area of land in Northern Ireland, which could be brought into arable cultivation.
18. An increase in the area of arable cropping in Northern Ireland would be likely to benefit local stock farmers who will in future, have difficulty disposing of animal manures in compliance with NVZ regulations.
19. While municipal sewage sludge can be used on land for industrial crops and this provides an income to the grower, this may not be possible on wheat and OSR, which have animal feed by-products.
20. Consideration should be given to conducting research to develop an arable rotation for annual industrial crops (e.g. biofuels, fibre crops, other biomass crops, pharmaceutical crops), which could allow for the use of low inputs, maximisation of use of organic manures and municipal sewage sludge and the adoption of other aspects of integrated crop management.
21. The possibility of growing crops for biofuels represents a valuable opportunity to diversify the rural economy of Northern Ireland and generate new income into agriculture. It may not be feasible to fully meet the targets from crops grown in Northern Ireland, but in moving part of the way towards that goal significant benefits could be gained. At a time when markets for traditional agricultural products are becoming more difficult, opportunities to develop

biofuel and industrial crops should not be missed, and given that opportunity arable farmers in Northern Ireland could undoubtedly rise to the challenge.

2 Introduction

To inform the development of an appropriate policy for renewable energy in Northern Ireland, a wide ranging study is being undertaken to investigate the potential market for, and economic and environmental sustainability of, small-scale dispersed embedded and non-networked heat and power and heat-only systems in the rural economy, and also the feasibility of crop production for biofuels for transport use. Biofuels are defined as liquid or gaseous fuels for transport produced from biomass (2003/30/EC). The study will identify the resource requirements needed to satisfy market demands, any public sector initiatives required and the potential impact on cross cutting policies, particularly in relation to rural development, the environment, Agri-Food production and forestry.

Overall, the study will quantify the potential for renewable energy production to provide viable economic and environmental opportunities for Northern Ireland up to 2020 (within a United Kingdom (UK)-wide and all-island context). From this, recommendations will be made for the Department of Agriculture and Rural Development (DARD) contribution towards a policy on renewable energy.

This report forms a part of the over all study and specifically covers the potential of cropping for biofuels in Northern Ireland. The report is divided into the two sections, which are:

Section A: - The potential market for biofuels in NI
Section B: -The potential to meet future biofuel requirements from crops grown in Northern Ireland

3 Section A

3.1 The potential market for biofuels in Northern Ireland

3.1.1 The Directive

The EU directive 2003/30/EC of the European Parliament and of the council of 8 May 2003 states:

Article 3

1. (a) Member states should ensure that a minimum proportion of biofuels and other renewable fuels is placed on their markets, and, to that effect, shall set national indicative targets.
   (b) (i) A reference value for these targets shall be 2%, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2005.

(ii) A reference value for these targets shall be 5.75%, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2010.

2. Biofuels may be made available in any of the following forms:-
   (a) As pure biofuels or at high concentration in mineral oil derivatives, in accordance with specific quality standards for transport applications.
   (b) As biofuels blended in mineral oil derivatives, in accordance with the appropriate European norms describing the technical specifications for transport fuels (EN 228 and EN 590).
   (c) As liquids derived from biofuels, such as Ethyl-tertiobutyl-ether (ETBE), where the percentage of biofuel is as specified in Article 2(2).

3. Member states shall monitor the effect of the use of biofuels in diesel blends above 5% by non-adapted vehicles and shall, where appropriate, take measures to ensure compliance with the relevant community legislation on emission standards.

4. In the measures that they take, the member states should consider the overall climate and environmental balance of the various types of biofuels and other renewable fuels and may give priority to the promotion of those fuels showing a very good cost effective environmental balance, while also taking into account competitiveness and security of supply.

5. Member states shall ensure that information is given to the public on the availability of biofuels and other renewable fuels. For percentages of biofuels, blended in mineral oil derivatives, exceeding the limit value of 5% of fatty acid methyl ester (FAME) or of 5% of bioethanol, a specific labeling at the sales points shall be imposed.

3.1.2 UK Implementation Plan of the EU Directive

The UK government announced a consultation exercise on the UK plans to implement the EU directive on liquid biofuels on 26th April 2004. In the documentation, a number of targets for liquid biofuel sales were proposed or implied. In order to provide a framework for this report, the following targets were identified in the wording of the Consultation Document: -

1. The Government propose that the biofuels target for 2005 should be 0.3% of all fuel sales by volume. The consultation exercise states this in terms of 12 million litres per month, which is equivalent to approximately 0.3% of current UK sales.

2. No formal target for 2010 biofuels was made but an indication that biofuels should make up at least 2% of total fuel sales was given. The 2% figure is the lower end of the 2% to 5% range quoted in the document.

3. Biofuels should make up 5% of total fuel sales by 2020. The documentation stated that the Government aspired towards achieving the EU targets by 2020, and that the industry believed that the 5% figure could be achieved earlier.

It should be noted to the UK government targets specify percentage of fuel sales by volume. The EU directive relates to percentage use of biofuel by energy content. For biodiesel, this makes little difference as the energy content of diesel and biodiesel are similar. However, the energy content of bioethanol is only about two thirds that of petrol and the adoption of a target by volume effectively lowers that target by one third in comparison with targets set by energy content. The figures given in the report are based on volume, but in Appendix 4 the equivalent figures on an energy basis are given.

3.1.3 Background to transport fuels in the UK

Transport demands account for more than one third of UK final energy consumption and data have shown that between 1990 and 2001, energy consumption for the transport sector in the UK (rail, water, air, road freight, road passenger) has increased by 13% (Department of Trade and Industry (DTI), 2002). As the transport industry expands, a concomitant increase in CO_2 emissions will be inevitable. It is expected that CO_2 emissions from the transport sector will increase by 50% between 1990 and 2010.

It is well recognised that hydrogen is the potential main energy carrier of the future as it offers the long term potential for full reliance on renewables (Alternative Fuels Contact Group, 2003). However, the share of hydrogen in road transport and fuels may only reach a few percent by 2020. Hybrid electric vehicle technology could also be employed in light vans, small trucks and urban buses and there are already many demonstration studies involving hybrid electric buses all over the world (DTI, 2002). Commercial and public pressure will accelerate the development of batteries and fuel cells so that they will become a technically feasible and cost effective source of electrical energy (International Association of Public Transport (UITP), 2004). It is predicted that gas to liquid diesel will be produced in remote plants and released to world markets as a premium diesel fuel, used mainly for blending purposes or in specific application cases (Alternative Fuels Contact Group, 2003). Having said this, petrol and diesel are the fuels of the moment and are likely to be the main fuels used in the transport sector up to 2020 at least. After this, synthetic diesel may remain as a potential diesel-blending component rather than remain as a mainstream fuel (Alternative Fuels Contact Group, 2003).

Within the EU directive 2003/30/EC of the European Parliament and of the council of 8 May 2003, it is stated that 2% of all petrol and diesel for transport purposes should come from biofuels and other renewable fuels by 2005 and 5.75% by 2010. The respective UK implementation plan states that 0.3% of all petrol and diesel for transport purposes should come from biofuels and other renewable fuels by 2005, 2% by 2010 and 5% by 2020. It is thought that biomass to liquid fuels could enhance the market share of biofuels beyond the EU target of 6% by 2010 and the maximum potential of biomass-derived fuels is 15% (Alternative Fuels Contact Group, 2003). Co-production of biomass to liquid fuels and hydrogen could be a cost-effective pathway to renewable hydrogen production in the future (Alternative Fuels Contact Group, 2003).

The UK government has had in place, a 20p reduction in fuel duty for biodiesel for the last two years. In February 2004, a UK scheme was approved for introducing a reduced rate of excise duty on bioethanol. The new duty will be 20p lower than the excise duty of ultra-low-sulphur and sulphur-free petrol. This scheme will apply to bioethanol producers from January 2005 to 31 December 2010 (Home Grown Cereals Authority (HGCA), 2004).

3.1.4 Current liquid transport fuel use in Northern Ireland

Liquid transport fuel includes a wide range of fuels encompassing several types of petrol, together with automotive diesel, gas oil, kerosene, marine diesel oil and fuel oil. Definitions of all the types of fuel classified by DTI are given in Appendix 1.

The statistics of the fuel market in Northern Ireland for 2003 (Table 1) provide the basic figures on which this report is based. The types of fuel for which there are possible liquid biofuel options are petrol, which can be substituted by ethanol, and diesel, which can be substituted by refined vegetable oil. It should be noted, however, that the biggest market for diesel in Northern Ireland is for heating oil, which does not come within the remit of this report but is also included in Table 1 for comparison purposes. The market for gas oil (red diesel), which is used in farm tractors, trains and construction machinery, and marine diesel oil is also very large.

The figures for the Northern Ireland road fuel market are distorted by the high proportion of diesel, and to a lesser extent petrol, which is purchased at a lower price in the Republic of Ireland or is smuggled across the border.

The UK Office for National Statistics Report (2002) state that the amount of excise duty lost to legitimate diesel purchase in the Republic of Ireland, and smuggling, may be as high as £230 m. These figures are based on custom and excise estimates. Smuggling is thought to account for about 10% of this total. Based on the £230m figure and duty at 52p/litre, some 442 million litres of diesel above official figures may be being consumed by vehicles in Northern Ireland. If this fuel demand were to come back to the Northern Ireland market, it would dramatically alter the amount of fuel required to reach the biofuel targets.

For comparison purposes, statistics for the equivalent fuel market in the Republic of Ireland are also included in Table 1.

Table 1 Current fuel market in Northern Ireland and the Republic of Ireland

2003 '000 litres	Northern Ireland	Republic of Ireland
Petrol	333,071	2,109,174
Auto-motive Diesel	240,074	2,268,047
Gas Oil & Marine Diesel Oil*	473,611	1,704,941
Fuel oil	153,212	1,187,550
Kerosene – Air Transport Fuel	71,101	-
Other oils	131,370	-
Total transport fuel	*1,402,439*	
Cross border estimate (Derv)	*442,000*	
Heating Oil	*806,484*	-

Data from www.detini.gov.uk and Department of Communication, Marine and Natural Resources (DCMNR), Oil Supply Division. *Includes red or green diesel for tractors (unknown figure) and diesel used for rail, 7,700,000 litres in Northern Ireland and 43,216,000 litres in the Republic of Ireland

3.1.5 Trends in transport fuel use

Before arriving at an estimate of the amount of fuel required to meet the targets set within the UK Implementation plan, it is necessary to estimate the likely rate of change in the usage of each of the fuels. Information from a variety of sources has been gathered to provide the main trends, which are described in the following section. Based on these local and national trends, future fuel use in Northern Ireland is estimated in Table 2.

Table 2 Estimated future Northern Ireland market for transport fuels in 2005, 2010, 2015, and 2020*

'000 litres	Current total	Rate of change	2005	2010	2015	2020
	'000 litres	% per annum	'000 litres			
All road Derv	240,074	+1.94	252,078	273,684	300,093	319,298
Petrol	333,071	-0.41	326,410	316,417	303,095	309,756
Gas oil & Marine diesel	465,911	+1.80	482,684	524,616	566,548	608,480
Rail Derv	7,700	+3.51	8,240	9,590	10,940	12,290
Citybus Derv	4500	+1.00	4,590	4,815	5,040	5,265
Ulsterbus Derv	24,000	+1.00	24,480	25,680	26,880	28,080

*35% increase in diesel use for rail by 2013; *10% increase in diesel use for Citybus and Ulsterbus by 2013; *1.8% yearly growth rate of marine gas oil and marine diesel oil (BeicipFranlab Report, 2003)* UK Road transport projections for DERV (National Atmospheric Emissions Inventory, 2002)

3.1.5.1 Trends – Northern Ireland (Rail and Bus)

- Diesel use for rail (red diesel) will increase between 20-50% over the next 10 years
- Diesel use for buses (ultra low sulphur diesel) will increase between 0-10% over the next ten years
- Translink are keen to have access to biodiesel in the future, most suitably to use as a 'fuel-extender', where it is added to conventional fuel at 5%-10%
- Ulsterbus, Citybus and Northern Ireland Rail control and manage their own fuel stores with on-site tank capacities typically for 30,000-100,000 litres and could receive bulk biodiesel deliveries and mix on site. (Personal communication, Mr Mal McGreevy, General Manager, Rail services, Translink)

3.1.5.2 Trends – United Kingdom (Department for Transport (DFT), 2003)

- Bus patronage declined except in London. Total number of journeys made by bus in Great Britain fell by 19% between 1982 and 2002/2003 from 5,512 to 4,452 million
- Rail travel increased by 38% since the mid 1990's and continues to rise
- The amount of freight moved increased by 45% between 1980 and 2002, from 175 to 254 billion tonne kilometers
- Road freight now accounts for 62% of all goods moved, compared with 53% in 1980
- Freight moved by water has increased from 54 billion tonne kilometers in 1980 to 67 billion in 2002. It's share of all goods moved is now just over one quarter
- Goods moved by rail declined slightly in the mid 1990's, but has since risen to reach nearly 19 billion tonne kilometers. Rail freight now accounts for 7% of all goods moved, compared with 10% in 1980
- Government have set targets in the 10 year plan to achieve a significant increase in rail freights share of the freight market by 2010
- Freight moved by pipeline has remained stable over the last 20 years, at 11-12 million tonne kilometres. It's share of goods moved is now 4%, compared with 6% in 1980
- Car traffic has increased by 83% since 1980, from 215 to 392 billion vehicle kilometers

We would assume that these trends seen in the past would be uninterrupted and continue for the next few years.

- The number of cars with diesel engines increased in the 1990's. In 1990 there were 19 million cars with petrol engines and 0.6 million cars with diesel engines registered in the UK. By 1999, these figures were 20 million and 2.8 million respectively, representing an increase in cars with diesel engines by more than four fold

- In the future, the use of lightweight materials, for example, aluminium, plastic, magnesium, carbon fibre, and metal matrix composites should allow manufacturers to produce transport vehicles with greater fuel efficiency than current transport vehicles (DTI, 2002). However, using the fact that the fuel efficiency of cars remained relatively constant in the 1990's (DTI, 2000), the assumption was made that fuel efficiency of vehicles will remain unchanged
- It is evident that diesel fuel use will continue to grow in the near future as diesel engines continue to take market share from petrol power for private cars (East of England Development Agency (EEDA), 2003). The decline in petrol demand in recent years can also be attributed to higher fuel duties
- The BeicipFranlab Report (2003) shows a yearly growth rate of 1.8% of marine gas oil and marine diesel oil in the UK, with figures of 1,138 '000 tonnes in 1990 to 1,433 '000 tonnes in 2001. This yearly growth rate (1.8%) was used to project biodiesel requirements for the gas oil and marine sector in 2005, 2010, 2015 and 2020, using details of the current fuel market in NI

3.1.5.3 Trends – Republic of Ireland

- Decrease in new private cars licensed (20,084 in February 2004 and 20,182 in February 2003-a decrease of 0.5%) (Central Statistics Office (CSO), 2004)
- Decrease in new tractors licensed (261 in February 2004 and 280 in February 2003) (CSO, 2004)
- Decrease in new goods vehicles licensed (3,298 and 3,344 for February 2004 and February 2003 respectively) (CSO, 2004)
- The majority of new private cars are run on petrol (Table 3)
- Diesel use for rail was 44,083 '000 litres in 2003. The predicted figures for 2004, 2005, 2006 and 2007 are 48,249, 47,564, 48,659 and 48,893 '000 litres respectively (Irish Rail, Chief Mechanical Engineering Department 5 year forecasts)

Table 3 New vehicles in Republic of Ireland by class and type of fuel, February 2004

Taxation class	**Type of fuel**			
	Petrol	**Diesel**	**Other**	**Total**
Private cars	16,564	3,504	16	20,084
Goods vehicles	19	3,279	0	3,298
Tractors	2	259	0	261
Motor cycles	326	0	0	326
Exempt vehicles	301	142	1	444
Public service vehicles	17	104	0	121
Machines or contrivances	0	121	0	121
Other classes	3	37	0	40
Total	**17,232**	**7,446**	**17**	**24,695**

(Central Statistics Office, 2004)

3.1.6 Quantities of biofuel required for Northern Ireland to meet targets set by UK implementation plan

Using the projected figures for Northern Ireland transport fuel use from Table 2, the quantities of biofuel required to meet the UK Implementation plan targets for 2005 onwards are given in Table 4. The rail and bus figures are given separately so that if schemes were implemented to use biofuel in these services, the scale of such schemes would be known.

Table 4 Quantity of biofuel required in Northern Ireland to meet the UK Implementation plan by 2005 (0.3%), 2010 (2%), 2015 (5%) and 2020 (5%) by volume.

Year		**2005**	**2010**	**2015**	**2020**
Target %	**Biofuel**	**0.3%**	**2%**	**5%**	**5%**
			'000 litres		
All road Derv	Biodiesel	756	5,474	15,005	15,965
Petrol	Bioethanol	979	6,328	15,155	15,488
Gas oil & Marine diesel	Biodiesel	1,448	10,492	28,327	30,424
Rail Derv	Biodiesel	25	192	547	615
Citybus Derv	Biodiesel	14	96	252	263
Ulsterbus Derv	Biodiesel	73	514	1344	1,404

It is not clear from the information obtained so far, whether gas oil should be included within the calculations or not. As no road fuel tax is paid on gas oil, it has a much lower price than road fuel and against which biofuels could not currently compete. If gas oil use is included within the targets, then biofuel use of automotive derv and petrol would have to be proportionately higher to compensate.

It has also been assumed that fuel oil and kerosene figures should not be included, although no clear guidance on the subject has been available.

Similar quantities of biofuel would be required to meet the targets for petrol and road derv, rising from below 1 million litres for the 2005 target to about 16 million litres to meet the 2020 target. If gas oil is included, the figure for derv is effectively tripled to over 46 million litres.

3.2 Overview of current world liquid biofuel production

Biofuels are defined as liquid or gaseous fuels for transport produced from biomass (2003/30/EC).

The two biofuels of interest to this study are biodiesel and ethanol. Natural renewable resources, such as vegetable oils and recycled restaurant oils can be chemically converted into clean burning biodiesel fuels, for use in unmodified diesel vehicle engines. Commercial production of biodiesel is occurring in many places all over the world, including Europe.

The other principal liquid biofuel is ethanol, which is produced by the fermentation of sugar or starch from crops such as sugar beet, wheat, potatoes or maize or from fruit and vegetable waste. Ligno-cellulosic materials such as wheat straw, cornstalks and waste paper can also be enzymatically degraded to fermentable materials, from which ethanol can be produced. However, as the technology for the production of ethanol from lingo-cellulosic materials has yet to be proven commercially, this report does not consider the possibility of ethanol production in Northern Ireland from this type of feedstock.

3.2.1 Biodiesel

In Europe, oilseed rape (OSR) oil is the principal raw material used in the production of biodiesel. Production figures for biodiesel within the EU for 2003 are shown in Table 5.

Table 5 EU production of Biodiesel (2003)

Country	**(‘000 tonnes)**
Germany	715
France	357
Italy	273
Austria	32
Spain	6
Denmark	41
United Kingdom	9
Sweden	1
Total	*1,434*

(European Biodiesel Board)

After the oil is extracted from the OSR, approximately 10% methyl alcohol is added and trans-esterification takes place. During this process, glycerine is displaced and extracted as a by-product. The technical term for the end product is rapeseed oil methyl ester (RME) or biodiesel.

The RME can be used in most diesel engines without modification (except for certain older engines which might require some modification). Biodiesel, which is non-toxic and biodegradable, can be used as a substitute for conventional diesel, or it can be added in any proportion. However, biodiesel has a lower energy content than diesel, leading to a higher fuel requirement of about 15% on a weight basis. The production of RME also leads to certain by-products: glycerine, which can be marketed in pharmaceutical quality, and rape meal, a high-quality protein fodder.

Germany Biodiesel has been produced for the German market since 1999 and is now commercially available throughout Germany, which has some 82 million inhabitants, who consume in the order of 27 million tonnes of diesel fuel annually.

In 2001, about 460,000 hectares (ha) of rapeseed were cultivated in Germany for non-food purposes. These yielded some 470,000 tonnes of oil, of which about 300,000 tons were used for biodiesel production - equivalent to about 1% of Germany's diesel fuel consumption. The processing capacity of the trans-esterification plants is significantly higher though, and biodiesel production is increasing. Biodiesel is now available at about 1,500 filling stations throughout the country.

Biodiesel is exempt from the mineral oil tax, giving it a slight pump price advantage over regular diesel. At the time of writing, the price of biodiesel was about 0.76 Euro/litre (2.67 US$/gallon), compared to 0.79 Euro/litre (2.77 US$/gallon) for regular diesel. This economic advantage does not reflect the production costs, which are significantly higher for biodiesel than for regular diesel. Hence, the market viability of biodiesel depends heavily on government support policies.

The production and utilization of biodiesel is facilitated firstly through the agricultural policy of subsidizing the cultivation of non-food crops. Secondly, biodiesel is exempt from the mineral oil tax. The resulting loss of tax revenues is partially offset through other tax effects of the biodiesel production chain.

France Biofuel production is a major alternative to non-food set aside representing approximately 70% of the 410,000 ha of crops on set aside land. Tax incentives are in place in France for the use of biofuels for plants that have official agreements.

Belgium Almost all rapeseed is produced in Wallonia, with a production capacity of 540,000 tonnes each year. The Vlaamse Instelling voor Technologish Onderzoek (VITO) conducted a two-year project, examining the use of biodiesel for running a total of five cars on RME, where the biofuel was produced in the Flanders. Results from the study showed that the cost of biodiesel was too great to run the cars, but that emissions were lowered by using biodiesel.

The Netherlands Biofuel use for the transport industry commenced some years ago, where there were two experimental pilots on public transport buses, one using rapeseed products and the other using bioethanol. In the Netherlands, the biodiesel is imported from France because there is not enough land available to produce non-food crops.

Spain The use of biodiesel for the transport industry commenced recently, using public transport buses and captive fleets, fuelled by rapeseed derivatives. Currently, there is no production plant in Spain that is capable of supplying biodiesel for these studies and as a consequence, methyl ester is imported.

Republic of Ireland A group of farmers in Co. Wexford have installed a crushing facility for OSR, for the production of rapoleum-oilseed fuel (i.e. unrefined vegetable oil) (Irish Farmers Journal, 2003). This facility is currently processing 1,500 tonnes seed/year (35-40 tonne/week), giving 500,000 litres of rapoleum-oilseed fuel. A new press is on order from Germany and will have a capacity of 4,500 tonne/year. The rape cake derived from the process is sold directly to local farmers (Personal communication, Mr John Barron). Further details of this plant are described in Appendix 3.

United Kingdom The BEAM Project (1994) examined the potential for a biodiesel plant in West Wales using rapeseed. An independent, comprehensive and rigorous evaluation of the comparative energy, global warming and socio-economic cost and benefit of producing biodiesel from OSR in the UK was assessed in The Sheffield Hallam Report (Mortimer *et al.*, 2003). In this report, it was found that there were significant savings in net CO_2 emissions by growing OSR to produce biodiesel as tailpipe emissions from vehicles using biodiesel are balanced by CO_2 absorbed during the growth of OSR. The UK's first multi-feed biodiesel plant is planned for Humber, costing £10m and having the capacity to produce 100,000 tonnes of biodiesel per year. This plant will be capable of using both 'fresh' rapeseed oil in addition to waste oil from the catering industry (www.edie.net/news/archive/8300.cfm)

Australia The Australians have launched biodiesel from canola oil. The fuel achieves 80% CO_2 reductions when it is mixed with LPG, which increases the power output of the engine. (www.renewingindia.org/newsletters/ethanol/current/news_vol1_11.htm)

3.2.1.1 Biodiesel from waste material

A new £15 m biodiesel plant at Newarthill, Motherwell, **Scotland** has recently been announced (Farming Life, 2004). This plant will have the capacity to produce 50 million litres of biodiesel annually, providing almost 5% of Scotland's diesel requirements by using waste cooking oil produced by the fast food and catering industry. The Interactive European Network for Industrial Crops and their Applications (IENICA, 2000) report in part, examines the potential of waste material for biofuels in **Ireland**. It concluded that in Ireland, waste vegetable oil is a low cost raw material, but the cost of production of bioethanol will need to be more competitive as cereals and sugar beet will always be expensive raw materials for producing bioethanol. Furthermore, the capability of producing ethanol from lingo-cellulosic crops would reduce raw material costs, but there is a need to examine the availability and low value outlet of suitable ligno-cellulosic crop residues in Ireland.

In **England**, an innovative industry has been established in Norfolk, where biodiesel is made and used from waste vegetable oil. The use of this biodiesel in heavy duty vehicles has shown that it exhibits very low levels of smoke pollution (EEDA, 2003). The UK's first straw-fired power station, Elean Power Station, costing £60 m is now located at Sutton, near Ely in Cambridgeshire. This is the world's largest and most efficient straw-fired power station. It generates approximately 270GWh of electricity per year, which is enough to meet the energy requirements of 80,000 homes or the equivalent of two towns the size of Cambridge. The VITO in **Belgium** have commenced a study using mineral diesel and used vegetable oil methyl ester to run two cars and three garbage trucks. In **Austria**, Südsteirische Energie und Eiweissgenossenschaft (SEEG) have been running a biodiesel plant for 10 years. It now runs a 6,000 tonne plant, where amongst other vehicles, approximately 50 city buses of the city of Graz run on this biodiesel, produced from used vegetable oil and rapeseed oil (www-och.uni-graz.at/pr/biodiesel). In **America**, a group of biochemists are examining the possibility of using soya oil and traditional jet fuel to run aircrafts (New Scientist, 2004). Australian Renewable Fuels Pty Ltd. (ARF) has committed to order the first biodiesel plant at Birkenhead, South Australia (www.amadeusenergy.com/files/announcements/cd040504.pdf). The Australian renewable fuels Adelaide plant will be the largest producer of biodiesel in Australia, at 45 million litres/year, using low-grade tallow and vegetable oil. This is the first of five plants planned for establishment all over Australia.

3.2.1.2 Biodiesel from a range of sources

In the USA, soyoil is the largest available product for biodiesel production, representing approximately 58% of total oil and fat production. However, canola, palm, peanut, sunflower, off-quality and rancid vegetable oils, animal fats and used cooking oils from restaurants are also used for biodiesel production. The Philippine Coconut Authority has formed an agreement with the UK-based firm D1 Oils, Ltd. on jointly establishing a biodiesel industry in The Philippines and on increasing Philippine export earnings from coconut (www.soyatech.com). It is hoped that the Philippines will be the biodiesel production centre in the Asia-Pacific region.

3.2.2 Bioethanol

Bioethanol can be produced from a variety of sources, which may be cellulose-based, such as lignocellulose, cornstalks or waste paper and sugar/starch-based including potatoes, waste potatoes, wheat, sorghum, maize, sugarcane and fruit and vegetable waste. For Northern Ireland, the possible sources of bioethanol are likely to be wheat, potatoes and potato waste.

3.2.2.1 Bioethanol from wheat and corn by malting and fermentation

The process for producing ethanol from wheat is similar to that of other methods for producing bioethanol by fermentation, but an initial milling and malting (hydrolysis) process is necessary. The grain is first crushed or milled. In its passive form, malting is a process by which, under controlled conditions of temperature and humidity, enzymes present in the wheat break down starches into C_6 sugars. However, this process is very slow and the commercial process introduces artificial enzymes to break down the starch into sugar. These sugars are washed out of the wheat with water, whilst the left over residue can be sold for animal feed. The C_6 sugars are then fermented using yeast at between 32 °C and 35°C and pH 5.2. Ethanol is produced at 10-15% concentration and the solution is distilled to produce ethanol at higher concentrations. The current conversion efficiency of the process is about 0.55 GJ of ethanol/GJ wheat (Reith, 2002) or 1 GJ/0.9 GJ (Levington Agriculture Report, 2000). The process is well established, so there is limited scope for enhanced efficiency or improvements. The Levington Agriculture Report (2000) states that one tonne of wheat grain, upon processing, yields 276 kg ethanol with an energy value of 30 MJ/kg. An additional 35 kg bran by-product is also produced from processing, which can be used as a fertiliser, once composted (project underway at Levington Agriculture funded by EU/HGCA).

3.2.2.2 Bioethanol from cellulose
Ethanol can be fermented from cellulosic biomass feedstocks using acid hydrolysis, enzymatic hydrolysis and thermo chemical hydrolysis. Of these three processes, acid hydrolysis is deemed the more popular.

Cost effective methods for producing ethanol from cellulose have only recently started to emerge in the USA. The most dilute acid hydrolysis processes have a limited sugar recovery of about 50%. However, ethanol from cellulose has great potential due to the availability, abundance and low cost of cellulosic material (Janick and Whipkey, 2002).

3.2.2.3 Bioethanol from potato waste
Ethanol can be made from the waste at potato processing plants. The waste is ground into small particles, heated and the pH is adjusted. The slurry formed is treated with enzymes to reduce starch to dextrins, producing a mash, which is further cooled and treated with another enzyme to reduce the dextrins to sugar. The sugars are then fermented into alcohol by yeast and the alcohol is distilled to remove water. The ethanol produced is then dehydrated and denatured, ready for sale. The residue remaining is further processed to reduce water content so it can be sold as an animal feed.

Potato waste from chip processing plants yields approximately 37 litres ethanol/tonne, while whole potatoes can yield more than 74 litres/tonne fresh weight. Other studies have examined the fermentation of potato starch to ethanol by using *Aspergillus niger* and *Saccharomyces cerevisiae* (Abouzied and Reddy, 1986).

3.2.2.4 Bioethanol from waste paper
Data from a study by the EEDA (2003) showed that production costs for ethanol derived from waste paper are almost four times that of wheat straw (27.68 p/litre and 7.26 p/litre respectively for cost of collection, preparation and transport). The cost of collection is borne by the ethanol producer. It was concluded that the potential of waste paper for producing bioethanol requires more work and is unlikely to be a feasible option for several years (www.parliament.the-stationery-office.co.uk).

3.2.2.5 Ethanol from sugar cane
Brazil is the largest producer of ethanol in the world, with more than 300 ethanol plants. 45% of Brazil's total fuel consumption is from bioethanol, amounting to 12 million litres (Institute of Biology, 2002). The ethanol industry in Columbia has

increased substantially in the past five years, current production being approximately 900 million litres/year. The headquarters of British Sugar in Peterborough are examining the feasibility of ethanol production from wheat and sugar beet (***e****ⁿ*cluster Environmental Enterprise, 2003). France produced 90,440 tonnes of ethanol in 2002, with 70% being from sugar beet and 30% from cereals.

3.2.2.6 World production of ethanol and bioethanol

World ethanol production data are given in Table 6. The feedstocks, and hence the production processes by which ethanol can be produced are diverse. Fermentation alcohol may be produced from grain, molasses, fruit, wine, whey, cellulose and numerous other sources. Synthetic alcohol may be derived from crude oil or gas and coal. Both fermentation and synthetic alcohol are, however, chemically identical.

Table 6 World Ethanol Production (1,000hl) (2001)

France	8,000	China	30,900
Germany	2,950	India	17,800
Italy	1,900	Indonesia	1,650
Spain	2,250	Japan	1,360
UK	4,300	Saudi-Arabia	3,900
Other EU	2,221	Thailand	1,500
EU	**21,621**	Other Asia	2,485
		Asia	**59,595**
Czech Republic	900		
Hungary	510	Australia	1,540
Poland	1,580	New Zealand	174
Russia	11,700	Other Oceania	80
Ukraine	2,200	**Oceania**	**1,794**
Other Europe	3,023		
Europe	**41,534**	Malawi	120
		South African CU	3,852
Argentina	1,530	Zimbabwe	293
Brazil	119,000	Other Africa	1,059
Canada	2,380	**Africa**	**5,324**
Cuba	850		
Ecuador	627		
Guatemala	600		
Mexico	701		
USA	75,800		
Other Americas	4,180	**World**	**313,915**
Americas	**205,668**		

(Berg, 2001)

On a global scale, synthetic feedstocks play a minor role as only 7% of overall output is accounted for by synthetic feedstocks. Approximately 60% of world ethanol production is from sugar crops, both cane and beet. Most of the remainder comes from grain, with maize playing a dominant role. The ethanol of commerce contains ~5% water, hence the term "hydrous (water-containing) alcohol." If the last traces of water are removed, "anhydrous alcohol" (water-free or "absolute") may be obtained. Ethanol which is used for the production of spirits is usually heavily taxed, but it is also sold in an untaxed "denatured" form, unfit for human consumption but suitable for many other purposes. Denaturing is accomplished by the addition of a small percentage of foreign materials, which are not easily removed.

Non-denatured ethanol is the alcohol contained in beverages, thus the expression "potable alcohol". It also finds wide use as an industrial solvent. Furthermore, it is the starting material for the preparation of a long list of industrial organic chemicals.

The history of ethanol as a fuel dates back to the early days of the automobile. However, cheap petrol (gasoline) quickly replaced ethanol as the fuel of choice, and it was not until the late 1970's, when the Brazilian government launched their "Proalcool" programme, that ethanol made a come back to the market place. Today, fuel ethanol accounts for approximately two thirds of world ethyl alcohol production.

In the **USA**, there are currently 73 plants in operation, with a further 14 under construction. The total production capacity by the end of 2003 was 11.7 billion litres. By the year 2010, it is expected that ethanol production in the US could consume over 20% of the entire nations corn production. 1% of the US total fuel consumption per year is from bioethanol (approximately 3.5 million tonnes of ethanol) (Fuelling for the Future 3. Biofuels. 2002). **Canada** only produces 238 million litres of ethanol per year. The ethanol industry in **China** is only emerging. There are currently two major plants under construction, each producing in excess of 800 million litres/year and employing 800 people. The feedstocks used for these plants will be corn and cassava.

The **USA** also has several plants producing ethanol using the waste from potato processing. These tend to be on a smaller scale than plants producing ethanol from corn.

Of the 2 billion litres of ethanol produced in the **EU,** less than 5% is used as fuel. France opened a plant producing ethanol from sugar beet in 1993 and several others have been opened since, with a total output capacity of over 300 million litres per year. Spain produces 80,000 tonnes ethanol per year and an additional plant is under development at Salamanca, where 200 million litres of ethanol will be produced using cereals and lignocellulose.

While the **UK** has several plants where synthetic ethanol is produced by the petro-chemical industry, there are no facilities in the UK for the production of bioethanol.

In the very long term, the estimated bioethanol world potential of 2 billion tonnes per year could lead to a global world contribution of CO_2 savings in the region of 4.5 billion tonnes per year, just from bioethanol use alone (www.jxj.com).

3.2.3 Energy conversion efficiency of biofuels

This report does not consider the relative efficiencies of energy conversion for the various biofuels in any detail. However, Table 7 provides comparative data which may be used to inform on the relative merits of biofuels.

Table 7 Conversion efficiency of ethanol production

Fuel type	Process	Conversion Efficiency (original units)	2002 Efficiency (GJ biofuel per GJ feedstock)
Biodiesel	Oilseed esterification	28-30 % [CSIRO, 2000]	0.29
Bioethanol	Wood – acid hydrolysis	47% [Reith, 2002]	0.47
Bioethanol	Straw – acid hydrolysis	40% [Reith, 2002]	0.40
Bioethanol	Wheat	55% [Reith, 2002] 349 l/tonne [IEA, 2002] 305 kg/tonne [NDDC, 2002]	0.55 0.53 0.59
Bioethanol	Corn – wet milling	2.682 gall/bu [USDA, 2002]	0.56
Bioethanol	Corn – dry milling	2.636 gall/bu [USDA, 2002]	0.55
Bioethanol	Sugar cane	80 l/tonne [Stakeholder]	0.38
Bioethanol	Sugar beet	85 kg/tonne [NDDC, 2002]	0.12

(www.dft.gov.uk/stellent/groups/dft_roads/documents/source/dft_roads_source_024054.doc) (Reith, 2002)

3.3 Discussion of the potential market for biofuels in Northern Ireland

In many countries of the world, substantial production of biodiesel and bioethanol is already taking place as a result of the implementation of policies, which promote their production and use. The technologies for the production of these biofuels from a range of crop products are well understood, although the production of ethanol from lingo-cellulosic materials is not, as yet, commercially proven.

The cost of production of both biodiesel and bioethanol is greater than that of their fossil fuel equivalents and therefore their adoption is largely dependent upon the tax and support policies of governments. However, the acceptance by the governments of countries within the EU, of the liquid biofuel obligations means that measures required to develop the market to meet set targets will have to be implemented.

A substantial market for liquid biofuels will be created within Northern Ireland during the process of moving towards achieving the UK government or EU targets for liquid biofuel use for transport. It is not clear as yet, whether some categories of fuel, such as gas oil and marine oil, will come within the targets or not and this could make substantial differences to the targets which should be achieved.

The movement of fuel across the border between Northern Ireland and the Republic of Ireland also substantially affects the amount of biodiesel that should be within the target. If there were no price differential, the figure for diesel purchased in Northern Ireland would be substantially higher.

In terms of energy efficiency, biodiesel production is less efficient than most forms of bioethanol production (Table 7). Thus, given equal opportunities to develop biodiesel or bioethanol, preference should be given to bioethanol production. However, in terms of meeting the liquid biofuel market in Northern Ireland, both bioethanol and biodiesel are required. Substitution between the two could take place, but 10% of petrol would need to be replaced by bioethanol to meet the full liquid biofuel requirement for Northern Ireland (excluding gas oil and cross border movement).

3.4 The UK Government Consultation Documents

In many counties, trial projects have involved the adoption of biofuel by transport fleets under the control of governments or local authorities, and this is also possible in Northern Ireland. However, this could prove relatively expensive as Northern Ireland Railways do not pay transport fuel tax and Citybus and Ulsterbus have their transport fuel tax refunded.

While in world terms, the potential market for liquid biofuels in Northern Ireland will be small, it still represents a significant challenge at a local level as to how it can be met, particularly if it involves enlisting the support of the relatively small arable sector of Northern Ireland Agriculture. The scale of that challenge will be made clear in Section B of this report.

While many biofuel production plants are of a large scale, there are examples of farm scale plants for both biodiesel and bioethanol which may be more suited to the Northern Ireland scenario. Consideration should also be given to cross-border collaboration in developing appropriately sized biofuel production units.

The encouragement of either biodiesel from OSR or ethanol production from wheat in Northern Ireland could lead to the substantial production of high protein animal feed by-products, such as brewers grains and rape meal. Such by-products could reduce the dependence of Northern Ireland on imported animal feeds.

Some countries with a small agricultural base have opted to import biofuels from neighbouring larger producers. However, with as yet, very limited biofuel production taking place in Great Britain and Ireland, the cost of importing biofuel into Northern Ireland could be relatively high.

4 Section B

4.1 The potential to meet future biofuel requirements from crops grown in Northern Ireland

The development of biofuel crop production to meet the stated obligations could make a significant impact on farming practices and land use in Northern Ireland. This section of the report will consider the potential to meet the requirements for the 2005, 0.3% and the 2010, 2% and possibly 5% by 2020 biofuel targets for transport use in NI. Analysis of available data and projected trends in future road and total transport will also provide an estimation of predicted biodiesel consumption and land requirements to meet these.

Crops and Fuels

The liquid biofuels ethanol and biodiesel are derived from different cropping sources, ethanol by the fermentation of sugar or starch-based crops and biodiesel from vegetable oil extracted, mainly extracted from OSR. The potential for each of these biofuels in Northern Ireland therefore needs to be considered separately. Descriptions of the processes involved in the manufacturing of bioethanol and biodiesel are contained elsewhere in the report.

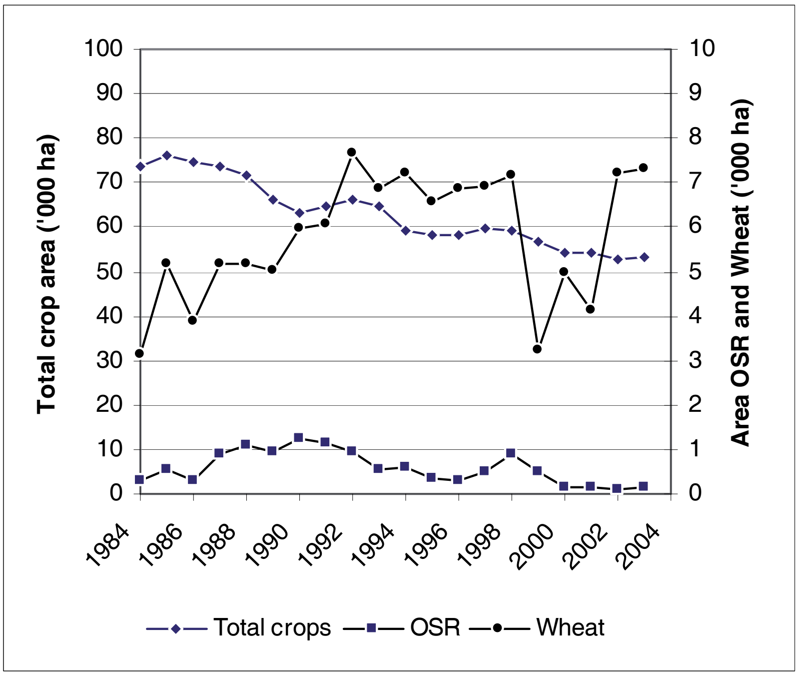
4.1.1 Biodiesel

Oilseed rape (*Brassica oleracea*) is the third most widely grown crop in the UK (CropGen, 2002). Rapeseed is the third leading source of vegetable oil in the world, after Soya and Palm (IENICA, 2002) and it is regarded as the only viable crop for large-scale biofuel oil production in the UK.

Over the last 20 years, the area of OSR grown in Northern Ireland has fluctuated from less than 100 ha and over 1200 ha, depending upon market prices and the EU support system in place at the time (Figure 1). In the UK as a whole, OSR has formed a more significant proportion of the arable area due to relatively large areas of the crop in England and Scotland (Figure 2). Over the last 10 years, the area which has fluctuated between 400,000 ha and 550,000 ha, has been between 8% and 12% of the total cropping area.

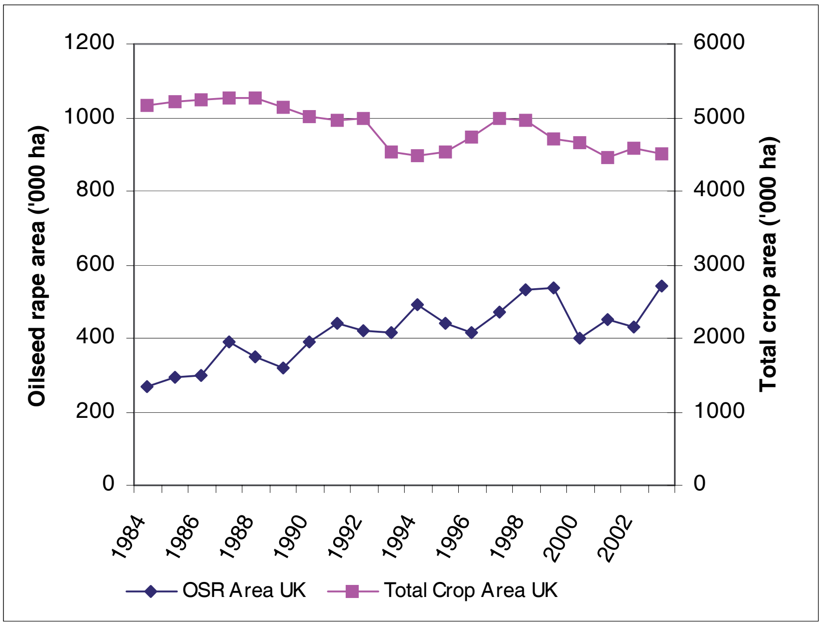
The production of OSR in the Republic of Ireland fluctuated widely between 2000 ha and 6000 ha in the 1980's and 1990's as shown in Figure 3, but has remained at the lower level in recent years.

Figure 1 Land use in Northern Ireland for oilseed rape, wheat and total crops



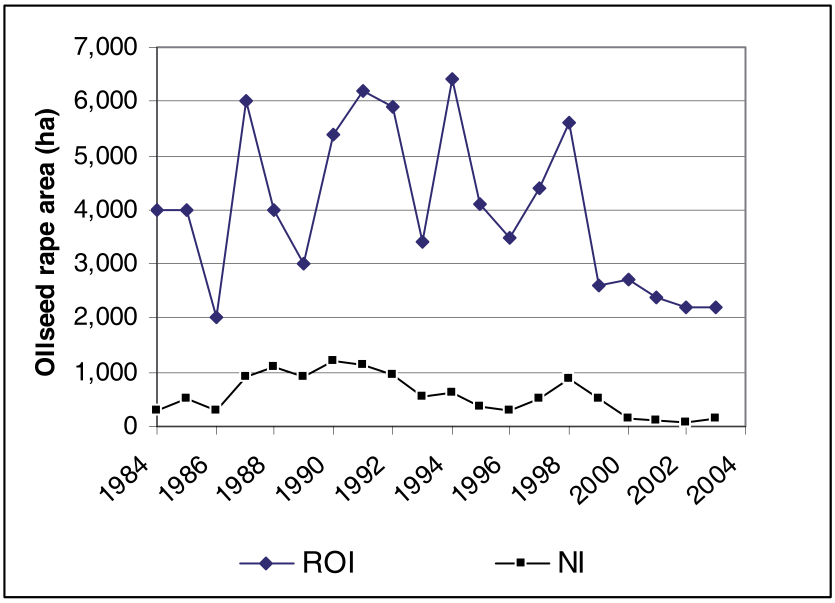
(Department of Agriculture and Rural Development, 2004)

Figure 2 Land use in United Kingdom for oilseed rape and total crops



(Department of Environment Food and Rural Affairs, 2004)

Figure 3 Land use in for oilseed rape in Northern Ireland and the Republic of Ireland



(Department of Agriculture and Rural Development, 2004; Teagasc, 2003)

Average yields from DARD statistical data (Table 8), obtained from field trials conducted at the Agricultural Research Institute of Northern Ireland (Table 9) are close to 3 tonne/ha, which is similar to the average yield published for the UK as a whole. Although HGCA variety trials (HGCA, 2004a) indicate that yields of about 4.5 tonne/ha can be expected from well-managed crops, the figure of 3 tonne/ha is taken as the yield expected under average conditions in this report.

Table 8 Average Northern Ireland and United Kingdom yield of oilseed rape (tonne/ha at 9% moisture)

Year	Northern Ireland	United Kingdom
1994	2.5	2.5
1995	2.9	2.8
1996	3.0	3.4
1997	3.1	3.2
1998	2.8	2.9
1999	3.0	3.2
2000	2.9	2.9
2001	2.6	2.6
2002	3.4	3.4
2003	3.4	3.3
Ten year average	*2.95*	*3.02*

(Department of Agriculture and Rural Development, 2004; Department of Environment Food and Rural Affairs, 2004)

Table 9 Oilseed rape yield from Reduced Input Systems of Cropping (RISC) trial at ARINI, Hillsborough (Personal communication, Lindsay Easson)

Year	**Yield (tonne/ha)**
1992	3.5
1995	3.2
1998	2.4
Average	***3.0***

However, the Levington Agriculture Report (2000), contends that The Energy Technology Support Unit (ETSU) and Agricultural Research Council (ARC) yield figures for UK rapeseed are substantially lower than those actually obtainable, and that yields above 4 tonne/ha are possible, based on field trial evidence using improved seed varieties and tailored fertiliser regimes. A comparison of OSR yields from various sources are given in Table 10.

Table 10 Comparison of oilseed rape yields

Seed Yield	**ARINI**	**ETSU**	**ARC**	**LEVINGTON**
tonne/ha	3.0	3.2	3.6	4.08

If achieved, a 25% increased crop yield as reported in these trials would lessen the land requirement *pro rata*. The British Association for Biofuels and Oils ((BABFO), 2002) believe the Levington data suggests that with such improved yields and lower inputs, the energy balance for biodiesel from OSR is enhanced by >70%.

Although OSR contains about 40% oil, only approximately 30% can be readily extracted using conventional screw presses (Beam Project, 1994). Further extraction of up to 33% is possible but uneconomic. In this report, calculations are based on an extraction rate of 30%, giving a yield of 0.9 tonne oil/ha. Each tonne of pure vegetable oil is capable of being converted into approximately one tonne of biodiesel. The conversion factor for changing from litres to tonnes of auto diesel is 1,186 litre/tonne. Thus, 0.9 tonne biodiesel is equivalent to 1,067 litres.

Data in Table 11 provide a sensitivity analyses in which the effect of variations in seed yield and oil extraction percentage on yield of biodiesel (‘000 litre/ha) are calculated.

Table 11 Effect of rapeseed yield and oil extraction percentage on the yield of biodiesel/ha

Yield (tonne/ha)	Oil extraction (%)						
	27	28	29	30	31	32	33
				litre/ha			
2.0	640	664	688	712	735	759	783
2.2	704	731	757	783	809	835	861
2.4	769	797	825	854	882	911	939
2.6	833	863	894	925	956	987	1,018
2.8	897	930	963	996	1,029	1,063	1,096
3.0	961	996	1,032	**1,067**	1,103	1,139	1,174
3.2	1,025	1,063	1,101	1,139	1,177	1,214	1,252
3.4	1,089	1,129	1,169	1,210	1,250	1,290	1,331
3.6	1,153	1,195	1,238	1,281	1,324	1,366	1,409
3.8	1,217	1,262	1,307	1,352	1,397	1,442	1,487
4.0	1,281	1,328	1,376	1,423	1,471	1,518	1,566

4.1.2 Area of oilseed rape to meet Northern Ireland biofuel targets

In Table 12, data on the area of OSR that would be required to meet the various targets, based on an assumed yield of 1,067 litres biodiesel/ha, are presented. The area of crop required would vary widely, depending on which target is chosen, and which fuels are included. To meet the 0.3% 2005 target for road derv would require only 709 ha of OSR and this would rise to over 14,000 ha to meet the 2015, 5% target. If the estimates of cross-border diesel are accurate, then twice as much diesel in Northern Ireland is derived from this source (both legitimately and by smuggling) than is purchased legitimately within Northern Ireland. Taking this into account would triple the OSR area required to over 42,000 ha, while the inclusion of tractor and construction machinery fuel would further increase the area to over 71,000 ha.

Table 12 Projections for quantities of biodiesel and hectares of oilseed rape to meet UK implementation plan targets for Northern Ireland

Year	**2005**	**2010**	**2015**	**2020**
Target %	**0.3%**	**2%**	**5%**	**5%**
'000 litres				
All road Derv	756	5474	15,005	15,965
Gas oil & Marine diesel	1,448	10,492	28,327	30,424
Rail Derv	25	192	547	615
Citybus Derv	14	96	252	263
Ulsterbus Derv	73	514	1344	1,404
Cross-border	1,392	10,078	27,625	29,393
Oilseed rape hectares *				
All road Derv	709	5,130	14,063	14,963
Gas oil & Marine diesel	1,357	9,833	26,548	28,514
Rail Derv	23	180	513	576
Citybus Derv	13	90	236	246
Ulsterbus Derv	68	482	1,260	1,316
Cross-border	1,305	9,445	25,890	27,547

* Assuming yield of 1,067 litres biodiesel/ha

4.1.3 Agricultural impact of changes in the oilseed rape area in NI

The fluctuations in the OSR area in Northern Ireland in recent years have shown that arable farmers here are prepared to take up new arable crop options, when they are financially viable, but also move out of them when they are not. Oilseed rape is a combinable crop, which can be sown, sprayed, harvested and dried using essentially the same equipment as for grain crops. A specialist swathing machine can improve harvesting, but is not essential. Oilseed rape is also an excellent break crop within predominantly cereal rotations, reducing the carry over of soil borne cereal infections. It normally follows winter barley as the relatively early winter barley harvest date allows for the sowing of the OSR by the optimum date in mid-September. Northern Ireland's cereal farmers currently have relatively few financially viable break crops and so OSR would be an attractive option, were there to be a consistent and suitably priced local market.

Oilseed rape, however, is subject to rotational restrictions and should not be grown more frequently than one year in three, or preferably one year in five. Farmers likely to grow OSR will be those growing winter wheat as their preferred crop. A three-year rotation might therefore be winter wheat, winter barley, OSR. In recent years, the winter wheat area in Northern Ireland has been in the region of 7,000 ha, and this would put a natural limit of about 7,000 ha on the area of OSR which could readily be fitted into the current arable system in Northern Ireland, assuming most other break crops were displaced. Currently, oats, peas, beans and short-term leys are the principal break crops.

It can be concluded that meeting the 0.3% target for 2005 could be achieved without any change to current agricultural practices. The 2% target for 2005, while representing a significant change in the pattern of break crops, would not pose undue difficulties. The loss of some protein crops, for example would be compensated by the additional supply of rape meal.

If the 5% road biodiesel target was to be met by arable farmers in Northern Ireland, this would require an OSR area of over 14,000 ha, which in a 1 in 3 rotation, would represent a total arable area of 42,000 ha under cereals and OSR, compared with the current total of 38,000 ha, including 24,000 ha of spring barley, much of which is grown on non-arable farms. This would represent a very significant change in the pattern of arable farming in Northern Ireland. The trend of declining arable areas in Northern Ireland would be reversed and the total area under arable cropping would return to what it was about 20 years ago.

If the higher target figures including gas oil or cross border movement of biodiesel are taken into account, then only the 0.3% target could be achieved without significant change, while the 2% and 5% targets would require relatively large shifts in the pattern of agriculture as a whole. The 5% target would necessarily result in a reduction in the area of temporary grassland, with knock-on effects for dairy and beef enterprises.

4.1.4 Factors likely to affect the uptake of oilseed rape in Northern Ireland

4.1.4.1 Economic factors

Typical costs for growing OSR are presented in Table 13. The area of OSR in Northern Ireland would only increase if it were profitable for farmers to grow the crop. Although this report is considering the situation after the mid-term review of the CAP, the detailed implementation of the mid-term review and how it will affect Northern Ireland are not fully decided.

For the purpose of this report, the following are assumed:

1. The single payment received by a farmer would not be affected by any decision to increase his/her area of OSR
2. As the set-aside requirement will remain, OSR could be grown as an industrial/energy crop on set-aside, providing the regulations for industrial crops are adhered to
3. Providing any increase in the overall Northern Ireland area of OSR results in less than a 10% reduction of permanent pasture in Northern Ireland, then there would be no effect on the single farm payments to farmers
4. Oilseed rape would have to be a profitable crop in its own right, without specific area payments

Where OSR has been grown in the past, it has been by the larger arable growers who have been practicing a cereal rotation and using OSR as a break crop to reduce take-all in the following wheat crop and improve the performance of the rotation as a whole.

When arable aid was introduced, OSR received a higher area payment, provided the grower was in the full scheme (with set-aside). Growers in the 'Simplified Scheme' received the same payment for OSR as for cereals, making the crop unattractive to them. Thus, OSR was only grown by larger arable farmers who could claim the higher rate aid. From 1996, however, the EU reduced the area aid for OSR down to the same as for cereals and so the area of OSR grown in Northern Ireland fell to a very low level.

Table 13 Cost of growing and harvesting Oilseed rape

	£/ha
Seed	35
Fertiliser	100
Herbicide	56
Fungicide	10
Slug pellets	9
Desiccant	35
Ploughing	32
Cultivation	22
Sowing	17
Harvesting	60
Drying	12
Total	***388***

(Department of Agriculture and Rural Development, 2004)

Oilseed rape has not been grown by the majority of spring barley growers whose cereal enterprise is secondary to their grass-based enterprises, and a small amount of industrial rape has been grown on set-aside in Northern Ireland. The OSR area can therefore be linked to the winter cereal area, which in 2003 in Northern Ireland was about 11,400 ha (7,300 ha wheat and 4,100 ha barley) 2002/03.

At present, there are no large-scale processing facilities in Northern Ireland. However, the first oil crushing plant in Northern Ireland was recently installed on a farm in Waringstown, capable of processing about 1,500 tonnes of rapeseed/year, producing about 500 tonnes of oil.

This unit is similar in capacity to the one installed by a group of farmers in Co Wexford. A number of other farmers or farmer groups in Northern Ireland are considering installing similar oil-pressing facilities.

4.1.4.2 Farm size

The Northern Ireland Agricultural census (DARD, 2003) shows that 457 farms grew cereals in 2002/3 as their primary enterprise. Of these, some 261 were classed as very small, 163 small, 25 medium and 8 large. This total represents less than 2% of all listed farming enterprises in Northern Ireland. The area of cereals (2003/4) on farm is shown in Table 14.

Table 14 The average area of cereals on arable farms in Northern Ireland

Crop	Area '000(ha)
Winter Wheat	7.3 ha
Oats	2.5 ha
Winter Barley	4.1 ha
Spring Barley	23.6 ha

(Department of Agriculture and Rural Development, 2004)

In theory, to meet the 5% target area of OSR, each of the 457 cereal growers would have to grow approximately 35 ha of rape and to provide for the rotational requirements of the rape, the cereal area would also have to increase. The OSR would be likely to replace other break crop options such as potatoes, peas, short-term leys or oats.

Referring to the costs (Table 13) for growing and harvesting OSR, at £388/ha, it is clear that both improved yields and relatively high prices are needed to obtain a margin of profit (Table 15), particularly if conacre rent is included in the calculation (Table 16). Even at very high yield level and with the energy crop supplement, price is critical to sustain margins (Table 17).

Table 15 Margin over costs assuming cultivations, sowing and harvesting carried out by contractor

Price ex- farm (£/tonne)	Yield (tonne/ha)							
	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5
	Margin over cost (£/ha)							
130	-76	-37	2	41	80	119	158	197
135	-64	-24	17	58	98	139	179	220
140	-52	-10	32	74	116	158	200	242
145	-40	4	47	91	134	178	221	265
150	-28	17	62	107	152	197	242	287
155	-16	30	77	123	170	216	263	39
160	-4	44	92	140	188	236	284	332
165	8	58	107	157	206	256	305	355
170	20	71	122	173	224	275	326	377
175	32	85	137	190	242	295	347	400
180	44	98	152	206	260	314	368	422
185	56	112	167	223	278	334	389	445
190	68	125	182	239	296	353	410	467

Table 16 Margin over costs assuming cultivations, sowing and harvesting carried out by contractor, plus conacre rent (£250/ha)

Price ex-farm (£/tonne)	Yield (tonne/ha)							
	2.40	2.70	3.00	3.30	3.60	3.90	4.20	4.50
	Margin over cost (£/ha)							
130	-326	-287	-248	-209	-170	-131	-92	-53
135	-314	-274	-233	-193	-152	-112	-71	-31
140	-302	-260	-218	-176	-134	-92	-50	-8
145	-290	-247	-203	-160	-116	-73	-29	15
150	-278	-233	-188	-143	-98	-53	-8	37
155	-226	-219	-173	-126	-80	-33	13	59
160	-254	-206	-158	-110	-62	-14	34	82
165	-242	-193	-143	-94	-44	6	55	105
170	-230	-179	-128	-77	-26	25	76	127
175	-218	-166	-113	-61	-8	45	97	150
180	-206	-152	-98	-44	10	64	118	172
185	-194	-139	-83	-28	28	84	139	195
190	-182	-125	-68	-11	46	103	160	217

Table 17 Income per hectare from oilseed rape (with £30/ha energy crop incentive), minus £250 conacre rent and costs, at a range of yields

Price £/tonne	Yield 3 tonne/ha	Yield 3.5 tonne/ha	Yield 4 tonne/ha	Yield 4.5 tonne/ha	Yield 5 tonne/ha
120	-248	-188	-128	-68	-8
150	-158	-83	-8	27	142
180	-68	22	112	212	292
210	22	127	232	337	452

4.1.4.3 Availability of equipment, labour etc. and farm practice

Farming and agricultural contracting has sufficient capacity to deal with the area necessary for the 2005 and 2010 projections for road transport demands. However, to deal with the huge increase OSR, crop production if gas oil and marine diesel are included in the target of 5% by 2020, (43,400 ha), it is likely that a considerable capital investment would be needed. Production at this sort of level could also result in job creation in the sector. The DFT (2004) report gives figures for possible job creation in biofuel, as being 2-5 jobs created (or retained in crop substitution) for every 1,000 tonnes of biofuel produced. Some 60-80 could result for a 100,000 tonne processing plant, with a further 500+ jobs in agriculture.

4.1.4.4 By-products and uses

If OSR were grown and also crushed in Northern Ireland, this would increase the availability of rape meal after the extraction of the oil. Therefore, although OSR might displace grain legumes grown to provide a local traceable source of protein for animal feeds, the increased supply of rape meal would counterbalance this and provide an alternative solution to the demand for locally sourced protein feed.

Approximately two thirds of the rapeseed remains after processing and one hectare would produce about 2 tonne of pressings suitable for rape meal production. This is a high fat, high protein feedstuff, which presently attracts a premium price (£134/tonne) in Northern Ireland. Although it has a high nutritional value, it is classed as relatively unpalatable but as a feedstock, compares well with other sources. A generalised comparison of feed value with maize silage and hay is shown in Table 18.

Table 18 Comparison of rapemeal with other feedstuffs

Feed type	Rapemeal Concentrate	Soyameal Concentrate	Maize Silage	Hay Forage
Dry Matter (%)	88.0	88.0	30.0	87
Dry Matter Analysis (%)				
Crude Protein (CP)	38.5	51.0	9.0	10.4
Digestible CP	32.0	50.0	6.0	6.0
Starch	5	5	22	3
Sugars	9.5	11	3	11
Protein	38.5	55	9	10.4
Oil	3.5	2.5	3.5	2
Inclusion in dairy cow diet (%)	25	35	75	100

(Ewing, 1998)

4.1.4.5 Limits on use in rations – Current size of market for such feeds
Importantly though, limits exist on the types of rapeseed suitable for use as a ruminant dietary supplement and also the quantities which can be readily fed to stock. Only double-low (00) rape varieties produce cake suitable as feed. This is because most OSR strains naturally contain high levels of glucosinolates, which have a deleterious effect on animal performance.

Rapemeal with low glucosinolate can acceptably be fed to most cattle and pigs at rates of at 150 g/kg/day and can be used with or as a replacement for other concentrate feeds (HGCA, 2003).

This could become a valuable market for OSR producers, giving added value to the crop and improving margins. Table 19 gives generalised average winter feed (silage) intake requirements for various housed cattle.

Table 19 Winter-feed intake of cattle in Northern Ireland

Cattle class	Average Feed (tonne/month)	6 month Intake (tonne)
Dairy Cow (milking/dry)	1.75	10.5
Suckler Cows (calving)	1.25	7.5
Other cattle	1.0	6
Average	1.3	8

(Department of Agriculture and Rural Development, 2002)

Given that the Northern Ireland 2003 dairy herd alone was recorded as 291,700 animals, the feed requirement at this consumption level for winter cattle is over 2 million tonnes. The potential to include even a small proportion of the concentrates as 15% rapemeal would offer a very considerable market for the by-product of OSR, providing it was from suitable low glucosinolate varieties. It can also be included as a feed for broilers (up to 200 g/kg), but is rarely used for feed to laying flocks as egg flavour taint can result, though steam processing can reduce this effect.

4.1.4.6 Effect on farming practices in Northern Ireland
There is a rotational restriction on OSR due to the risk of soil borne infections such as club root. Oilseed rape should not be grown closer than 1 year in 3, and 1 year in 5 is recommended. As rape grows satisfactorily on a wide range of soil types, other than the lightest soils, there is no reason to suppose that any increase would be on less suitable ground in Northern Ireland.

4.1.4.7 Existing crop displacement
The total area of arable crops which could be classified as 'break crops' including potatoes, oats and grain legumes is about 12,000 ha. Thus, it might be reasonable to suggest that an increase in OSR to about 4,000 ha could be included in the rotation of the current arable area, by a reduction in these other break crops and also in less profitable cereals such as spring barley. The 2005, 0.3% area of 709 ha could be easily incorporated in this scheme.

Any further increase in OSR in Northern Ireland above 4,000 ha is more likely to require a displacement of temporary or permanent grassland in the more arable areas of the province.

Based on the current winter cereal area (16,400 ha) and working this out on a 1 year in 3 frequency, an area of 5,460 ha of OSR could easily be supported, and with a ratio of 1 year in 5 an area of 3,280 ha supported. If it assumed that these larger cereal growers also include spring barley for 1/3 of their cereal area, this would increase the potential area of OSR, which would be included in the rotation, to 8,550 ha (1 in 3) or 4,275 ha (1 in 5).

The 2% target for road diesel, requiring 5,130 ha, could be met with a small degree of change in farming practices at the 1:3 rotation. For the 1:5 rotation, this would require some displacement of grass-based activities, and a marked change.

4.1.4.8 Displacement of grass-based enterprises
Any increase above the 2% level would necessitate greater changes in the balance of farming enterprises in Northern Ireland and to meet the 5% target for 2015 and beyond, over 14,000 ha will be needed.

If 10,000 ha comes from grass less than 5 years old (rotational grass), this still represents only bringing the arable area back up to the amount in 1992 (47,000 ha). This would represent a reversal of the steady decline in the arable area, which has been taking place in Northern Ireland for many years.

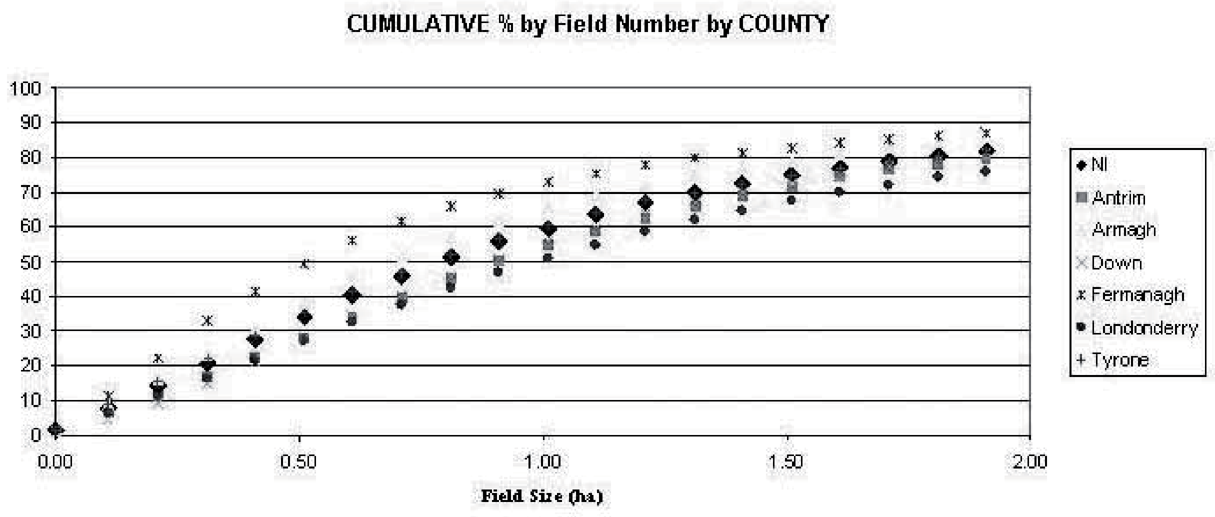
A more significant change would be required if there was a requirement to meet the higher targets including gas and marine oil, and also taking account of cross border fuel movement. Whether the area of OSR required is 45,000 ha or 70,000 ha is almost immaterial as both are beyond what could be reasonably considered for Northern Ireland. When the rotational restriction of 1 year in 3 is considered, the area under the plough would have to rise to 135,000 ha and 210,000 ha respectively. While a large part of this might come from short-term grass leys, currently 137,976 ha in Northern Ireland, a significant area of permanent grassland would inevitably be brought under the plough. The EU regulation under the mid-term review agreed to allow for a decline of up to 10% of permanent grassland (80,000 ha in Northern Ireland), although some derogation for energy crops may be permitted. Nevertheless, such a large-scale change is not considered to be practical.

4.1.4.9 Other issues relating to the expansion of arable cropping

Field size

One of the major limiting factors in economic tillage farming in Northern Ireland is small field size (Figure 4). Over 50% of fields are less than 1 ha in area and it should be said that field shapes are defined historically, not rationally. These play against economies of scale for crop production for many farmers and seriously hinder competitiveness due to increased cost loadings.

Figure 4 Field size in Northern Ireland



4.1.4.10 Crop management factors

Fertilisers
The recommended fertiliser rates to attain current yield levels of 3 tonne/ha in Northern Ireland are 180 kg/ha N, 50 kg/ha P and 40 kg/ha K. This amount of fertiliser input is less than that normally applied to grassland and the environmental impact may be less as the input is targeted closely to the crop needs and losses are lower. Grazed grassland may receive dressings of 200-250 kg/ha N per season, though the new directives regarding NVZ will affect application rates in the future. The likely imposition of phosphate limits for preventing water pollution and reducing eutrophication in our water systems will also be pertinent, though many farmers already apply zero P fertilisers as their ground is P saturated.

A possible outcome of enlarged areas of OSR production might be to allow for disposal of the manure and slurry excess that is now inherent, following the restrictions on nutrient inputs to farm soils. A larger area of soils able to bear the surplus nutrients could help alleviate this problem and reduce artificial fertiliser costs for the grower.

Pesticides
As with most cereal crops, OSR is intensively produced with high demands for crop protection from pests and diseases. Weed control measures for growing OSR include perennial grass weeds, which should be controlled from the previous crop, soil-acting residual herbicides, which are usually applied pre or post-emergence and herbicides will control a range of annual dicots and grasses. Pests, such as the flea beetle and pollen beetle are usually controlled by seed treatments or sprays. This necessitates regular spray applications with a range of chemical pesticides including herbicides, insecticides and fungicides. Different companies offer a range of products that the cereal producer then selects according to his/her needs or preferences. There are literally dozens of proprietary chemicals possible for use on OSR and among these are the chemicals normally used locally (Table 20).

Table 20 Possible pesticide use for oilseed rape

Chemical compound	Spray type	Sprays/Crop
Glyphosate	Herbicide	One
Metazachlor	Pre-emergent	One
Tluazifop-p-butyl	Post-emergent	One
Chlorpyrifos+dimethoate	Insecticide	One/Two
Carbendazim	Fungicide	One/Two
Bipyridal	Dessicator	One
	Total sprays	Six or Eight

The above listed pesticides may not all be required and as an example (Personal communication, Mr Malachy Mason), one local grower last year applied only one pre-emergent, one fungicide and a desiccant spray. Where OSR would be a displacement in break crop rotation, even intensive spraying regimes might not be likely to add to the overall spray load. But where it would involve introduction of unsprayed pasture and ley ground to cultivation, then the environmental implications of additional amounts of agricultural chemicals could cause concern. Total spray applications may range from 5-8 kg/ha of product and the loading at 6kg/ha spray to 705 ha (0.3%) and 14,956 ha (5%) could be in excess of 4 tonne and 90 tonne respectively. The latter figure in particular, would represent a large introduction of chemicals to the local environment. Currently, OSR crops in Northern Ireland encounter few disease risks, but this is liable to change if a larger area is grown. A budget for the use of fungicides therefore needs to be taken into account if considering planting a larger area of land with OSR. The same applies to insect control.

4.1.4.11 Public reaction

It is not difficult to predict that this huge amount of a single crop in the small area of Northern Ireland would have a very significant effect on the landscape. The flowering season in particular, would be the most noticeable visually, with seemingly large areas of bright yellow and iridescent flowers. Public perception of this would be hard to gauge, though most people are probably now more generally amenable to the precepts of green energy. The environmental aspects of these probabilities are discussed later in this report.

For the higher projections of over 46,000 ha by year 2020, we might assume that demands for more and larger fields could entail hedgerow removal and field ditch piping and back filling. The impact of this upon the landscape would be significant and probably considered by many to be detrimental to wildlife and visual amenity. The possibility that the cross border fuel market might some day return to the North would add half as much again to the required land area. How might this play upon public acceptance?

Health concerns are also a possible factor for consideration where large areas of OSR are likely to be grown. Oilseed rape pollen is cited by many as a causative factor in the upsurge in hay fever incidence, though this is an area of dispute and counterclaim. Natural OSR contains erucic acid, which can be toxic to humans in large doses, but can also be used as a food additive in smaller doses.

Investigations for comparison with mineral diesel into tailpipe emissions of greenhouse gases and the discharge of particles (especially M10 (soot) particles) from biodiesel are currently underway. M10 particles are less than 10 micromeres in size and are carried in tailpipe emissions from diesel vehicles. They have been shown to lodge deep in the lung tissue (Bunn *et al*., 2001) and have been linked to respiratory disease and are thought to be carcinogenic. A new generation of exhaust emission clean-up systems is hoped to provide solutions for dealing with a high percentage of these and other discharged particulates. The BABFO (2002) provide figures which indicate that life cycle emissions of all the major pollutants are considerably less from biodiesel than from mineral diesel.

4.1.4.12 Potential biodiesel markets

Translink state that they could take and hold considerable quantities of biodiesel that they would blend to their own requirements. They also state that they see diesel as being the most likely and only feasible road transport fuel for the next twenty years.

4.1.5 Conclusions – Biodiesel

Oilseed rape is a crop which has been grown successfully in Northern Ireland for a number of years, although the economics of the crop and the lack of local crushing facilities have, until now, restricted it to a small area on few of the larger arable farms. The yield performance of the crop in Northern Ireland has been similar to that in England, where it is by far the most important non-cereal crop and the proximity to crushing facilities has made the crop more economically viable.

However, the economics of OSR are not as attractive as those of wheat and in the light of the changes taking place in the mid-term review, rapeseed prices consistently higher than those of recent years, together with the achievement of higher yields, will be necessary to make the crop profitable. Analysts of the futures market are indeed suggesting that the widespread demand for biodiesel in Europe will continue to maintain the higher prices seen in recent months, and proponents of the OSR crop are suggesting that yields of 4 to 5 tonne/ha are achievable.

In the past, some OSR in Northern Ireland has been grown as an industrial crop on set-aside, although there appeared to be very little financial advantage from doing this and a great deal more bureaucracy was involved. The introduction of an additional payment for energy crops could help to make the OSR for biofuel more financially viable whether on set-aside or not. Many farmers dislike set-aside in principle, because it leaves their land unproductive and so the introduction of a financially viable energy crop alternative, which can be grown on set-aside, will be attractive to them.

An increased use of OSR as a break crop could displace some of the other protein crops, which are being grown to provide a home-grown source of protein concentrate of known province. The rape meal produced as a by-product from rape crushing could also fulfil this need.

In terms of the arable farming pattern in Northern Ireland, a growth in the area of OSR to about 4,000 ha could be incorporated into rotation with the current area of winter cereals, without any real change in cropping systems. An area of this size would require a crushing capacity of about 12,000 tonne/annum or 36 tonne/day. The recent installation of an oil-press with an annual capacity of 1,500 tonne on a farm in Waringstown gives an opportunity to evaluate now, the local potential for biodiesel production, or for the use of the unrefined oil in vehicles with modified engines. Modification of standard diesel engines in cars and light goods vehicles costs in the region of £1000 and so with a relatively small outlay, a demonstration of the system could be evaluated using a number of vehicles.

Facilities for the conversion of vegetable oil to biodiesel exist in Bangor, Co Down, which are currently used for the manufacture of biodiesel from waste vegetable oil (Conservation Volunteers, 2004). Again, these facilities could be used in the evaluation of the production of biodiesel from the locally produced rape oil.

A greater area of OSR in Northern Ireland would have a pronounced effect on the appearance of the countryside in late April and May, when the bright yellow crops would be very noticeable. The pollen from OSR crops can cause allergies such as hay fever, although, even with the maximum areas of OSR mentioned in this report, the proportion of OSR would remain much lower than is currently grown in areas of England.

With the low arable base area in Northern Ireland, there is no question of considering a large-scale biodiesel facility unless it was to be in an all-island context. Although there will clearly be economies of scale with a larger plant, it may be that the development of several smaller scale biodiesel production facilities as farm/co-operative ventures would allow gradual development, enabling farmers to buy into the market as it grows and add value to their product, bringing a new source of income into the rural economy. If achieving the highest 5% biodiesel target for Northern Ireland were to be accepted, it would have to represent a reversal of the gradual decline in arable cropping that has been a consistent feature of Northern Ireland agriculture for many years. Such a change is possible, and may in fact be desirable, providing the new enterprises are seen to be more consistently profitable than those they are replacing, are more in tune with the demands of society, are reliable within the constraints of our climate and contribute towards solving some of the difficulties that the agriculture industry is currently facing in terms of slurry disposal and excess production of traditional agricultural products.

4.2 Bioethanol

Although bioethanol can be produced from a wide range of agricultural crops, those which could be considered currently as having potential in Northern Ireland, are cereals and potatoes. Of the cereals, winter wheat is the highest yielding and most profitable although there is no technical reason why barley could not be used. In this report, winter wheat is the only cereal considered in detail.

4.2.1 Estimate of wheat area to meet biofuel targets

Differing figures for the quantity of bioethanol, which can be manufactured from a tonne of grain, are quoted in the literature. For this report, the lowest figure quoted of 336 litre/tonne (Energy Systems Research Unit (ESRU), 2002) is used, although Levington Agriculture Report (2000) quotes 370 litre/tonne. Wheat yields in Northern Ireland over the last 10 years have averaged just over 7 tonne/ha, which is about 0.7 tonne/ha lower than for the UK as a whole (Table 21). For the purpose of this report, the Northern Ireland wheat yield is taken to be 7 tonne/ha, and so the potential bioethanol production per hectare can be calculated as 2,352 litre/ha.

Table 21 Average wheat yields for the UK and Northern Ireland

Year	United Kingdom	Northern Ireland
1994	7.35	7.78
1995	7.70	7.54
1996	8.15	7.02
1997	7.38	6.94
1998	7.55	6.76
1999	8.05	7.26
2000	8.01	6.23
2001	7.08	6.51
2002	8.00	7.17
2003	7.78	7.02
Average	***7.71***	***7.02***

(DARD, 2004; DEFRA, 2004)

The area of wheat required to meet the bioethanol targets rises from just over 400 ha in 2005 to over 6,500 ha in 2020 (Table 22). These figures can be compared with the 2004 winter wheat area of just over 8,000 ha.

Table 22 Land area required to meet bioethanol targets from wheat, based on data from Table 4

Target Year	Target % of petrol	'000 litres required	Hectares
2005	0.3	969	412
2010	2.00	6,328	2,690
2015	5.00	15,155	6,443
2020	5.00	15,488	6,585

4.2.2 Effect of wheat biofuel area on arable cropping in Northern Ireland

If the area of winter wheat for ethanol production were met by replacing the wheat currently grown for animal feed, then this would result in no change, although it is more likely that a large part of the area of wheat for ethanol would be in addition to the current wheat area. When considered in relation to the current winter wheat area of about 8,000 ha and total cereals of 34,000 ha, an additional area of 412 ha to meet the 0.3% target and 2,690 ha to meet the 2% target would not represent a significant shift in the pattern of arable farming, particularly if it was achieved by a reduction in the area of spring barley. The increase of over 6,000 ha to meet the 5% target would represent a more significant change, bringing the total area of winter wheat up to more than15,000 ha.

As an industrial crop, wheat grown for ethanol production could be grown on set-aside. In Northern Ireland, the current area of set-aside is approximately 3,500 ha. Set-aside is mostly associated with the larger arable farms and therefore already favourably situated for industrial cropping use. It is therefore likely that a high proportion of the set-aside area could be used for wheat for ethanol. By supplying up to half of the area of wheat needed, this would minimise the change in the pattern of arable cropping while at the same time, giving the farmer an economic income from set-aside.

4.2.3 Environmental implications

An increase in the area of intensively managed winter wheat in Northern Ireland could be seen as undesirable from an environmental view, if it represented a move away from spring cereals. However the situation in Northern Ireland is very different to than in Great Britain. Any move away from grass monoculture in Northern Ireland represents a move back towards a more mixed farming system creating greater diversity.

4.2.4 Scale of processing facilities

While ethanol production from corn in the USA and from sugar in Brazil and Europe is mostly from large scale processing facilities, farm scale processing plants for ethanol production are available (http://www.journeytoforever.org/biofuel_library/Butterfield/butterfield1.html). In Minnesota, a number of farmer owned co-operatives have been established for ethanol production at farm scale. A plant capable of processing 3 tonne/day of grain, equivalent to about 1,000 tonne/year could be supplied by an area of about 150 ha of wheat and would produce about 265,000 litres of ethanol per year (200 tonne). A potential advantage of such systems would be the generation of the grain residue (equivalent to brewers grains) as a high protein wet animal feed, which could be supplied locally.

However, it has been suggested that a plant producing 100,000 tonne (74 million litres) of ethanol, and therefore using 300,000 tonne of raw material produced by agriculture would be the optimum size to start with in the UK, but that a further reduction in fuel duty of 5p per litre over that currently proposed by the government, would be required to make such a plant viable. Alternatively, £35m of capital grants (40% of the total cost) would allow the plant to be viable at the current proposed rate of duty, due to commence in January 2005 (www.saos.co.uk). Such a scale of plant would clearly be outside the scope of consideration in Northern Ireland, or even Ireland as a whole.

4.2.5 Bioethanol from potatoes

Producing fuel from potatoes and potato peelings is currently being exploited in a number of countries, particularly in the USA. The technology presently used can produce 80 litres of ethanol/tonne of potatoes. Some local companies are investigating the possibility of producing biogas from potato waste and peelings for combined heat and power generation, with the prospect of gaining a degree of self-sufficiency and reduced costs.

Yields of potato crops in Northern Ireland are in excess of 40 tonne/ha, even allowing for chats and discards. Based on the view that quality is not an issue for bioethanol production and that only dry matter yield is of concern, total yields of 50 tonne/ha are realistic. However, for this report, we believe a figure of 45 tonne/ha is a more acceptable estimate. Working on this figure, we can provide figures for potato production and land requirements to meet targets for bioethanol manufacture from potatoes. From one hectare, 45 tonnes of potatoes will yield 3,600 litres or 2.67 tonne bioethanol.

The land area of potatoes would be less than that of wheat to meet the same biofuel targets (Table 23). If this were to develop, it would in fact, return the potato crop area to that of 1981, when over 12,000 ha was grown in Northern Ireland. It is unlikely that an increase in potato growing, even to the highest level, 4,302 ha, would cause any significant problem, particularly if some of it were on set-aside.

Table 23 Land area required to meet bioethanol targets from potatoes

Target Year	Target % of petrol	'000 litres	Hectares
2005	0.3	969	270
2010	2.00	6,328	1,768
2015	5.00	15,155	4,235
2020	5.00	15,488	4,302

However, the specialist equipment for planting, harvesting, handling and storage of potatoes compared to winter wheat add much greater costs, which are normally recouped by the relatively high price of potatoes. If wheat is sold off-farm for £80/tonne for ethanol production, the equivalent price per tonne for potatoes to produce the same quantity of ethanol is £19/tonne (Table 24). Such a low price could not sustain commercial potato production in Northern Ireland, even with the adoption of a simplified crop management system without stone removal, less emphasis on management of potato quality, and greater emphasis on yield.

Table 24 Comparison of yield and ethanol production from wheat and potatoes

	Yield (tonne/ha)	DM content (%)	DM yield (tonne/ha)	Ethanol (litre/ha)
Wheat	7	85	6.0	2,352
Potatoes	45	22	9.9	3,600

Ethanol production from waste potato peelings and wastewater from the two major potato-processing facilities could be considered. At one of the two Northern Ireland potato-processing plants, there is a high charge currently being paid for the disposal of wastewater with a high starch content. A small ethanol production plant could prove economic if it allowed cleaner water to be discharged, thus reducing the charges. However, the contribution towards the liquid biofuel targets from processing potato waste in Northern Ireland would be relatively small.

4.2.6 Conclusions - Ethanol

The biofuel target for petrol is not subject to the same question marks as that of biodiesel and unless there is substitution between biofuels, would reach about 15.5 million litres for the 5% target. Assuming that suitably sized processing plants can be constructed, the areas of wheat or potatoes, which would be required to the meet the 2% target in 2010, would not require any large structural changes in arable cropping, and could more be considered as a reversal in the decline in the area of arable cropping which has been taking place over the last 30 years or more. Meeting the 5% target with an increase of 6,500 ha of wheat or 4,300 ha of potatoes would represent a more significant change, but not one that would pose any significant problems in terms of the skills base or farming structure. Those who are concerned about more intensive farming methods would see the move towards increased winter wheat negatively, but this would be offset by the improved diversity in Northern Ireland agriculture and the wider benefits of generating biofuel.

The possibility of using a substantial area of set-aside for this industrial wheat crop is particularly attractive, as it would generate additional income for the grower, bring the land into productive use and diminish the need for change in the pattern of agricultural production as a whole.

The relative efficiency of cereal sowing, harvesting and storage equipment and the low labour requirement for these operations compared to that of potatoes, makes it highly unlikely that growing potatoes purely for ethanol production would be an economic proposition. However, an ethanol plant designed for wheat can usually handle other starch-based crop materials. Thus, such a plant could provide a market for potato waste, sub-standard crops and similar surplus materials.

Farm scale or co-operative ventures in ethanol production are attractive because they encourage gradual development of the industry, without taking the greater risks involved in a large-scale plant. The commitment and support of local farmers would be more likely to lead to success, particularly if the security of the market is underwritten by government actions to support it. The production of significant quantities of animal feed by-product which, with a high protein content, would also meet the needs of local farmers who require quality assured sources of non-GM protein feeds.

Although the scale of operation it is suggested is optimum for Great Britain is larger than would be possible in Northern Ireland or even the whole of Ireland, intermediate sized plants are also possible and may be feasible at a cross-border level.

4.2.6.1 Increased employment from biofuel processing

Within the UK, it is thought that bioethanol production from wheat and sugar beet would generate 5.5 jobs/1,000 tonnes of bioethanol produced. Furthermore, additional jobs would be created during the processing of biofuel. A 100,000 tonne biodiesel plant would employ 62 staff in processing and blending industries. A bioethanol plant of similar size would employ 50-55 staff, in addition to a further 16-28 in fuel blending and transport (The United Kingdom Parliament-www.parliament.the-stationery-office.co.uk).

4.2.6.2 Implications of both ethanol production and biodiesel together

As the targets for biodiesel and bioethanol are both part of the liquid biofuel obligation, consideration must be given to the possible effect of growing crops in Northern Ireland to meet both of these obligations. Bearing in mind that OSR is an ideal break crop within cereal rotations, parallel increases in winter wheat and OSR compliment one another. Thus, at least up to the 2% target for 2010, 2,690 ha of wheat and 5,000 ha of OSR could co-exist, without imposing additional problems in addition to those already discussed for the individual crops. The likelihood that part of either the wheat or the OSR would be grown on set-aside would also minimise the overall impact of the changes.

At the 5 % target level for road diesel and petrol, this would require 6,500 ha of wheat and 15,000 ha of OSR. Clearly in this scenario, the OSR area is substantially out of step with the total cereal area in Northern Ireland currently or in the recent past. Because of the rotational requirement for OSR, the cereal area would also have to rise, and even the increase in wheat for bioethanol production would be insufficient to achieve that. Thus at the 5% target level, the OSR becomes the dominant issue against which achieving the increase in wheat area pales into insignificance.

There are many facets to the environmental advantages and disadvantages of growing more winter cereals and OSR in Northern Ireland, particularly when they are considered as industrial rather than food crops. Mention has already been made to the less desirable impact of winter-sown compared with spring-sown crops. On the other hand, introducing a greater diversity into our almost grass monoculture system is desirable. In the light of the NVZ issues facing beef and pig farmers, a substantially greater area under arable cultivation could provide more opportunities to ‘dispose of’ slurry’.

Disposal of composted sewage sludge is also a problem for local authorities in Northern Ireland who are prepared as a result, to pay substantial gate fees for disposal of the material onto eligible land. Non-food crop areas could be eligible, provided the ground is not used for food crops for several years after the last application. Where successive wheat and OSR crops are grown for industrial use only, this could be a possibility, although consideration would need to be given to how the by-products could be used cost-effectively.

5 Discussion

In recent days, world oil prices have been rising rapidly and pump prices for petrol and diesel are predicted to reach over £1 per litre unless the trend is reversed in the near future. As the production cost of biofuels is relatively unaffected by these changes, biofuels become increasingly financially attractive relative to their mineral counterparts. While this report does not in itself examine the economic aspects of biofuel production, anything that increases the financial viability of such enterprises will increase the level of interest from the local farming community.

While Northern Ireland may seem a relatively small market compared with our larger neighbours in Ireland, Great Britain and Europe, and we only have a small base of arable crops, the possible production of biofuels from arable crops in Northern Ireland is an opportunity to develop new agricultural outlets for non-food cropping, bring new money into farming, widen the range of crops from the relatively narrow base we currently have, produce more locally grown quality assured high protein animal feed and create employment in both agriculture and the associated biofuel processing.

5.1 The potential market

In the earlier section of this report, the potential size of the market in Northern Ireland for liquid biofuels is considered. Life in Northern Ireland is never as simple as it seems, and establishing the transport fuel market size is no exception. Department of Trade and Industry statistics for road fuel use in Northern Ireland are not able to take account of fuel purchased in or smuggled from the Republic of Ireland, and the large number of farm tractors which consume red diesel (gas oil) to which fuel tax is not added, may not also be officially included in the targets. As inclusions of these figures would have a very large influence on the biofuel targets (up to a 5 fold increase), it is important that clarification of which are the appropriate targets is sought.

Meeting the appropriate UK targets would necessitate firstly, either the production or the importation of biodiesel and/or bioethanol and secondly, the purchase of this fuel by road users. In this report, our efforts have been mainly concentrated on the former. It is assumed that providing the biofuel grades of petrol or diesel are either cheaper or the same price as pure mineral fuel, that the public will buy it voluntarily. Vehicle manufacturers have given approval for the use of biodiesel and bioethanol blends in unmodified modern engines and so the public can be assured that such blends are safe to use, and also that they produce a lower level of harmful emissions than pure mineral fuels.

As with other ‘green’ issues, substitution or trading of one target against another is possible and so achieving Northern Ireland’s total liquid biofuel entirely from bioethanol or biodiesel is possible, enabling a flexible approach to be taken to achieving the targets.

Future trends in the demand for diesel and petrol in Northern Ireland result in relatively small changes in the targets compared with the current situation. Only very large uptake of new technologies such as dual powered or hydrogen powered vehicles within the next ten years would give rise to significant changes in the pattern of demand for road fuel.

It is concluded from this first section of the report that it can reasonably be expected that the demand for road derv and petrol in Northern Ireland will both be in the region of 300 million litres by the end of the period being considered in this report, 2020. Demand for gas oil and marine diesel, including red diesel, may have reached over 600 million litres by then. If there were no price differential between Northern Ireland and the Republic of Ireland, the figures for petrol and diesel purchases in Northern Ireland could be substantially higher.

The possibility of meeting all or part of the liquid biofuel for transport obligations depends largely upon the size of processing plants that it is economic to run, and on the nature of the financial incentives that are put in place make the production and use of biofuels financially viable.

The fact that small oil presses have recently been installed on farms in both Northern Ireland and the Republic of Ireland demonstrates that the current lack of large-scale crushing facilities would be unlikely to be a significant obstacle if the appropriate incentives were in place. The example in the Republic of Ireland where a fleet of cars, light vehicles and tractors have been modified with grant aid to use the unrefined rape oil could also prove to be a useful model to follow in Northern Ireland, if the vehicles in the fleet were normally paying fuel prices including fuel tax and VAT. Unfortunately, this would exclude farm tractors. The interest of Citybus, Ulsterbus and Northern Ireland Railways in using biofuels would offer another opportunity to incrementally increase the usage of biofuels, raise their profile and build up public confidence in their use. However, it should be noted that neither the bus or rail companies appear to pay the full ‘road’ price for their fuel.

For more general use, the setting up of biodiesel production facilities would be necessary. The scale of such processing could be set at an appropriate level in association with the oil crushing facilities, which would be required.

Processing plants for the production of ethanol are generally large-scale and if the optimum size specified for Great Britain (100,000 tonnes output per annum) were applied here, it would rule out any possibility of it either in Northern Ireland or indeed the whole of Ireland. However, there appears to be increasing interest and adoption of smaller ‘farm’ scale ethanol plants particularly in the USA and Canada. The development of such plants in Northern Ireland could be particularly attractive as they could benefit the wider rural economy, bring a new source of income into agriculture, generate a more diverse agricultural system, encourage a wider ownership of the project and spread the financial risks.

5.2 Growing crops to meet the biofuel obligations in Northern Ireland

Although Northern Ireland has a relatively small arable crop sector, the introduction of a gradual increase in the area of OSR, cereals or potatoes would not pose any initial difficulties. The additional area of cropping of under 1000 ha to meet the 0.3%

2005 target would not significantly affect the pattern of arable cropping. Bearing in mind that growing biofuel crops is possible on set-aside ground, achieving the 2010 target of 2%, which would represent an increased arable cropping of 7,600 ha would also not pose any great difficulties, although it would represent a reversal of the trend of many years for a declining arable area.

It is only with the further increment taking the target up to 5% of liquid biofuel that more significant changes in the pattern of arable farming would become necessary. Increasing the wheat area by an additional 6,500 would pose less of a problem than increasing the OSR area to over 15,000 ha, which would make it second only to spring barley using current figures.

Such changes cannot be imposed and would only come about if the growing of wheat and OSR was seen as being a more profitable and secure enterprise than those it was displacing, whether they are other arable options, short term ley, set-aside or permanent pasture. Many people are of the view that Northern Ireland has a comparative advantage for growing grass, and that the weather does not suit the production of arable crops. However, gradual climatic changes are taking place, which could mean that Northern Ireland is not at quite the disadvantage it was in the past. It is not just in Northern Ireland that weather conditions, both drought and flood, have played havoc with cereal crops in some recent years and competent arable farmers in Northern Ireland succeed nevertheless in achieving their sowings and harvest.

Oilseed rape and wheat have been considered in this report as the principal options for biofuel production in Northern Ireland. Although technically capable of producing more ethanol per hectare, the high costs of potato planting, harvesting and storage would make it uneconomic to grow the crop specifically for ethanol production. If an ethanol production plant were built in Northern Ireland, however, the by-products of potato processing could contribute to the production of ethanol.

The adoption of increased areas of arable crops for biofuel production in Northern Ireland would have a number of environmental implications, some more desirable than others. Where land is used exclusively for industrial cropping, then there is the possibility of utilizing nutrient-rich waste products, such as municipal sewage sludge, which are difficult to dispose of in other ways. However, when there are animal feed by-products, as is the case with OSR and wheat, this option will not be available. Perhaps consideration could be given to developing an ‘industrial crop only’ rotation which could allow full economic and practical use to be made of the nutrient value of sewage sludge, without committing the land to plantation crops such as willows or miscanthus. For livestock farmers with insufficient land on which to spread animal manures, increased local availability of arable land could provide a means of complying with the NVZ and phosphate regulations, while for the growers of the biofuel crops, utilizing animal manures may provide a cheaper source of the required crop nutrients.

Other environmental disadvantages such as the necessary move from spring to winter crops, and the growing or greater areas of intensively managed crops need to be set against the advantage of stimulating more diverse and mixed farming providing a greater range of habitats.

6 Conclusions

1. The size of the market for biofuels to meet the transport fuel obligations set by the EU and the UK government would create a significant market for bioethanol and biodiesel in Northern Ireland.
2. The total size of the biodiesel market will be unclear until guidance is provided on whether gas oil used in tractors, trains, construction machines and marine vessels is included and whether account should be taken of fuel purchased in, or smuggled from, the Republic of Ireland.
3. There are no fundamental climatic constraints limiting the growing of OSR or winter wheat in Northern Ireland and both crops have been grown successfully for many years, with yields similar to those obtained in England.
4. The introduction of a greater diversity of arable cropping into Northern Ireland and a reduction in grass monoculture is environmentally desirable, although a greater adoption of winter cropping is less acceptable than spring cropping.
5. Growing biofuel crops on the 3,500 ha of set-aside in Northern Ireland would provide a way of initiating the adoption of biofuel cropping without significantly changing the current arable cropping pattern.
6. Providing that suitably sized processing facilities can be constructed for bioethanol production, even the maximum increase in the wheat area of 6,500 ha could be achieved without a significant change in the overall area of arable cropping in Northern Ireland, if part of the crop is grown on set-aside.
7. The growing of OSR would be likely to displace other break crops such as peas and beans.
8. Processing OSR and wheat for biofuel would generate significant quantities of high protein animal feedstuffs which could meet the need for quality assured GM-free locally sources protein feed, which the displaced peas and beans were also being grown for.
9. The production of biodiesel is more suited to farm-scale production than bioethanol and consideration should be given to establishing a pilot plant if those already operating in Northern Ireland for the conversion of waste vegetable are not suitable.
10. Any increase in the area of wheat could be matched by an increase in the area of OSR, to enable a suitable rotation to be maintained and providing the crop area to meet part of the biodiesel target, although not all of it.
11. Increasing the area of OSR in Northern Ireland to over 5,000 ha for the 2% target in 2010, and about 15,000 ha to meet the 5% target in 2020 would represent a more significant change in arable cropping than the growing of wheat for ethanol.
12. The rotational requirement of OSR to be grown no more frequently than 1 year in 3 (preferably 1 year in 5) means that it must be associated twice its own area of cereals. In practice, therefore, only a gradual change towards such targets could be expected with the area of winter wheat and winter barley increasing in step with that of OSR.

13. The increasing demand for OSR in Europe generated by the biofuel policies of EU governments is leading to increased prices for OSR. Even without the development of biofuel processing in Northern Ireland, it is likely that the area of OSR being grown in Northern Ireland will rise.
14. Small-scale oilseed crushing facilities recently installed in Northern Ireland and in the Republic of Ireland demonstrate that the need to install such facilities should not be considered an obstacle to progressing the production of biofuel in Northern Ireland.
15. The conversion of the diesel engines in fleet vehicles such as buses would allow the use of unrefined vegetable oil now being produced in Northern Ireland (capacity 500 tonne/ annum) without conversion to biodiesel.
16. The interest of Citybus, Ulsterbus and Northern Ireland Railways in using biofuel should be exploited as a means of promoting the use of biofuel from local sources in Northern Ireland.
17. If higher targets are set for biodiesel to take account of gas oil and cross border fuel movement, then very much higher acreages of biodiesel would be required. Ultimately, the EU restriction on the ploughing up of more than 10% of permanent grassland would limit the area of land in Northern Ireland, which could be brought into arable cultivation.
18. An increase in the area of arable cropping in Northern Ireland would be likely to benefit local stock farmers who will in future, have difficulty disposing of animal manures in compliance with NVZ regulations.
19. While municipal sewage sludge can be used on land for industrial crops and this provides an income to the grower, this may not be possible on wheat and OSR, which have animal feed by-products.
20. Consideration should be given to conducting research to develop an arable rotation for annual industrial crops (e.g. biofuels, fibre crops, other biomass crops, pharmaceutical crops), which could allow for the use of low inputs, maximisation of use of organic manures and municipal sewage sludge and the adoption of other aspects of integrated crop management.
21. The possibility of growing crops for biofuels represents a valuable opportunity to diversify the rural economy of Northern Ireland and generate new income into agriculture. It may not be feasible to fully meet the targets from crops grown in Northern Ireland, but in moving part of the way towards that goal significant benefits could be gained. At a time when markets for traditional agricultural products are becoming more difficult, opportunities to develop biofuel and industrial crops should not be missed, and given that opportunity arable farmers in Northern Ireland could undoubtedly rise to the challenge.

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8 Appendices

Appendix 1 - Definitions of liquid transport fuels

Aviation Spirit	All light hydrocarbon oils intended for use in aviation piston-engine power units, whether in the air, on land, or on water, including bench testing of aircraft engines.
Motor Spirit	Blended light petroleum components used as fuel for spark-ignition internal-combustion engines other than aircraft engines.
4 Star Grade	All finished motor spirit with an octane number (research method) not less than 97. This can include leaded petrol or unleaded petrol containing an alternative to lead as an anti-wear additive (lead replacement petrol LRP).
Premium Unleaded Grade	All finished motor spirit with an octane number (research method) not less than 95.
Ultra Low Sulphur Petrol	This is finished motor spirit with a specification similar to that for Premium Unleaded grade, but with a sulphur content of less than 50 parts per million.
Super Premium Unleaded Grade	All finished motor spirit, with an octane number (research method) not less than 97.
Aviation Turbine Fuel	All other turbine fuel intended for use in aviation gas-turbine power units, whether in air, on land or on water, including bench testing of aircraft engines.
Burning Oil (Kerosene)	Refined petroleum fuel, intermediate in volatility between motor-spirit and gas-oil, used for heating and lighting. White spirit and kerosene used for lubricant blends are excluded.
Gas Oil/Automotive Diesel	Petroleum fuel having a distillation range immediately between kerosene and light-lubricating oil.
Derv	(Diesel Engined Road Vehicle) - automotive diesel fuel for use in high speed, compression ignition engines in vehicles subject to Vehicle Excise Duty.
Ultra Low Sulphur Diesel	A grade of DERV fuel with less than 50 ppm sulphur (below 0.005%).

Gas Oil	Used as a burner fuel in heating installations, for industrial gas turbines and as for DERV (but in vehicles not subject to Vehicle Excise Duty e.g. agricultural vehicles, fishing vessels, construction equipment).
Marine Diesel Oil	Heavier type of gas oil suitable for heavy industrial and marine compression-ignition engines.
Fuel Oil	Heavy petroleum residue blends used in atomising burners and for heavy duty marine diesel engines (marine bunkers etc) normally requiring pre-heating before combustion, but excluding fuel oil for grease making or lubricating oil and fuel oil sold as such for road making.

Appendix 2 - Conversion factors used

(To convert fuel between weight, volume and energy content)
(from www.energyinst.org.uk)

Petrol tonnes to litres multiply by 1.34
Gas oil and marine diesel tonnes to litres multiply by 1.150
Road diesel tonnes to litres multiply by 1.186
Rail diesel tonnes to litres multiply by 1.168

Biodiesel = 35.6 MJ/litre
Diesel 36.4 MJ/litre
102 litres of biodiesel required to supply equivalent energy content of 100 litres of diesel

Petrol 32.0 MJ/litre
Ethanol 21.1 MJ/litre
150 litres of ethanol required to supply equivalent energy content of 100 litres of petrol

(Oak Ridge National Laboratory, 2004)

Appendix 3 - Details of crushing facility for oilseed rape in Co. Wexford (Personal communication, Mr John Barron)

The rapoleum oilseed fuel (unrefined vegetable oil) produced from this plant is used to run modified cars, jeeps and light vans.

Tractors can be run on the unrefined vegetable oil without being modified:

- 50% diesel and 50% unrefined vegetable oil may be used
- 100% unrefined vegetable oil can also be used but the tractor firstly needs to be started and warmed with diesel and subsequently switched to the unrefined rape oil

Sustainable Energy Ireland has funded the conversion of 100 vehicles (cars, jeeps and light vans) to use rape oil as a pilot project. These vehicles are randomly checked for emissions by the University of Limerick. People using the rape oil do not pay duty on this fuel. A finance bill is due to be signed into law for this purpose. A total of 23 vehicles have been converted with an additional 73 to follow.

The cost of modifying a truck's engine to use the rape oil is approximately €2,000, with a respective cost of €1,400-1,500 for cars. Sustainable Energy Ireland meets half of this cost, with the owner of the vehicle meeting the remaining half.

Appendix 4 - Northern Ireland biofuel targets based on energy content rather than volume

Table 1 Quantity of biofuel required in Northern Ireland to meet the UK implementation plan by 2005 (0.3%), 2010 (2%), 2015 (5%) and 2020 (5%)

Year		**2005**	**2010**	**2015**	**2020**
Target %	**Biofuel**	**0.3%**	**2%**	**5%**	**5%**
			'000 litres		
All road Derv *	Biodiesel	771	5,583	15,302	16,284
Petrol ☼	Bioethanol	1,469	9,492	22,733	23,232
Gas oil & Marine diesel *	Biodiesel	1,477	10,702	28,894	31,032
Rail Derv *	Biodiesel	26	196	558	627
Citybus Derv *	Biodiesel	14	98	257	268
Ulsterbus Derv *	Biodiesel	74	524	1,371	1,432

* 1 litre of derv equivalent to 1.02 litres biodiesel in energy content
☼ 1 litre of petrol equivalent to 1.5 litres of bioethanol in energy content

As the targets are set in terms of the energy content of the fuels, the quantities of biofuels required are calculated on the basis that 1.02 litres of biodiesel have the energy content of 1.0 litre of diesel and 1.5 litres of ethanol have the energy content of 1.0 litre of petrol.

The UK government consultation document states: -
"It should be noted that the reference values are calculated on the basis of energy content. Translating these reference values into equivalent values on the basis of sales by volume or mass is not straightforward. Biodiesel and bioethanol both contain less energy content per unit of volume than fossil fuels, but the difference is more pronounced in respect of bioethanol. Translating the 2% and 5.75% reference values into percentages of sales by volume will therefore depend, among other things, on the anticipated split between biodiesel and bioethanol sales" (DFT, 2004).

Table 2 Projections for quantities of biodiesel and hectares of oilseed rape to meet UK implementation plan targets for Northern Ireland (Energy content basis).

Year	**2005**	**2010**	**2015**	**2020**
Target %	**0.3%**	**2%**	**5%**	**5%**
'000 litres				
All road Derv	771	5,583	15,302	16,284
Gas oil & Marine diesel	1,477	10,702	28,894	31,032
Rail Derv	26	196	558	627
Citybus Derv	14	98	257	268
Ulsterbus Derv	74	524	1,371	1,432
Cross-border	1,392	10,078	27,625	29,393
Oilseed rape hectares *				
All road Derv	723	5,232	14,341	15,261
Gas oil & Marine diesel	1,384	10,030	27,080	29,083
Rail Derv	24	184	523	588
Citybus Derv	13	92	241	251
Ulsterbus Derv	69	491	1,285	1,342
Cross-border	1,305	9,445	25,890	27,547

* Assuming yield of 1,067 litres biodiesel per hectare

Table 3 Land area required to meet bioethanol targets from wheat, based on data from Table 1 (Energy content basis).

Target Year	**Target % of petrol**	**'000 litres required**	**Hectares**
2005	0.3	1464	622
2010	2.00	9492	4078
2015	5.00	22,733	9665
2020	5.00	23,232	9878

Table 4 Land area required to meet bioethanol targets from potatoes

Target Year	Target % of petrol	'000 litres	Hectares
2005	0.3	1464	407
2010	2.00	9492	2637
2015	5.00	22,733	6315
2020	5.00	23,232	6453

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