Environmental Protection Agency

The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

The EPA is an independent public body established in July 1993 under the Environmental Protection Agency Act, 1992. Its sponsor in Government is the Department of the Environment, Heritage and Local Government.

OUR RESPONSIBILITIES

LICENSING

We license the following to ensure that their emissions do not endanger human health or harm the environment:

- waste facilities (e.g., landfills, incinerators, waste transfer stations);
- large scale industrial activities (e.g., pharmaceutical manufacturing, cement manufacturing, power plants);
- intensive agriculture;
- the contained use and controlled release of Genetically Modified Organisms (GMOs);
- large petrol storage facilities.

NATIONAL ENVIRONMENTAL ENFORCEMENT

- Conducting over 2,000 audits and inspections of EPA licensed facilities every year.
- Overseeing local authorities' environmental protection responsibilities in the areas of - air, noise, waste, waste-water and water quality.
- Working with local authorities and the Gardaí to stamp out illegal waste activity by co-ordinating a national enforcement network, targeting offenders, conducting investigations and overseeing remediation.
- Prosecuting those who flout environmental law and damage the environment as a result of their actions.

MONITORING, ANALYSING AND REPORTING ON THE ENVIRONMENT

- Monitoring air quality and the quality of rivers, lakes, tidal waters and ground waters; measuring water levels and river flows.
- Independent reporting to inform decision making by national and local government.

REGULATING IRELAND'S GREENHOUSE GAS EMISSIONS

- Quantifying Ireland's emissions of greenhouse gases in the context of our Kyoto commitments.
- Implementing the Emissions Trading Directive, involving over 100 companies who are major generators of carbon dioxide in Ireland.

ENVIRONMENTAL RESEARCH AND DEVELOPMENT

- Co-ordinating research on environmental issues (including air and water quality, climate change, biodiversity, environmental technologies).

STRATEGIC ENVIRONMENTAL ASSESSMENT

- Assessing the impact of plans and programmes on the Irish environment (such as waste management and development plans).

ENVIRONMENTAL PLANNING, EDUCATION AND GUIDANCE

- Providing guidance to the public and to industry on various environmental topics (including licence applications, waste prevention and environmental regulations).
- Generating greater environmental awareness (through environmental television programmes and primary and secondary schools' resource packs).

PROACTIVE WASTE MANAGEMENT

- Promoting waste prevention and minimisation projects through the co-ordination of the National Waste Prevention Programme, including input into the implementation of Producer Responsibility Initiatives.
- Enforcing Regulations such as Waste Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS) and substances that deplete the ozone layer.
- Developing a National Hazardous Waste Management Plan to prevent and manage hazardous waste.

MANAGEMENT AND STRUCTURE OF THE EPA

The organisation is managed by a full time Board, consisting of a Director General and four Directors.

The work of the EPA is carried out across four offices:

- Office of Climate, Licensing and Resource Use
- Office of Environmental Enforcement
- Office of Environmental Assessment
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet several times a year to discuss issues of concern and offer advice to the Board.

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil agus Rialtais Áitiúil a dhéanann urraíocht uirthi.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail.

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain.
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce.
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

EPA STRIVE Programme 2007–2013

eDiesel – Barriers and Benefits

(2005-ET-DS-18-M3)

STRIVE Report

End of Project Report available for download on http://erc.epa.ie/safer/reports

Prepared for the Environmental Protection Agency

by

energy solutions

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Table of Contents

Executive Summary

Introduction

Energy use for transport comprises a significant and ever increasing proportion of energy use in Ireland. From 1990 to 2005, the transport sector's share of the total final energy consumption increased from 27.8% to over 40%. Final energy use in the transport sector has grown by 151% (6.3% per annum on average) between 1990 and 2005. The transport sector is also the sector most dependent on imported fossil fuels with resultant impacts on security of fuel supplies and exposure to oil price fluctuations.

CO_2 emissions from the transport sector in 2005 were 15 270 kilotonnes, representing over 33% of total energy-related CO_2 emissions.

Using biofuels reduces dependency on imported oil and the environmental impacts of transport energy use, in particular greenhouse gas emissions. Using biofuels also creates national and local economic benefits by creating an indigenous biofuels industry.

The EU Biofuels Directive (2003/30/EC) requires that national targets for the use of biofuels should be set and suggests a non-binding 'reference value' for these targets of 2% for 2005 and 5.75% for 2010. To date, use of biofuels in Ireland has been limited although use is expected to rise to 2.24% of total fuel use in 2008 due to exemptions granted under the government's biofuels excise relief scheme. Additionally, the government has recently signalled the introduction of a biofuels obligation that would require biofuels to comprise 5.75% of the fuel market by 2009 and 10% by 2020.

Ethanol–Diesel Biofuel Blends

The principal biofuels used in Ireland are pure plant oil (PPO), biodiesel, biodiesel blends and bioethanol–petrol blends. The potential for ethanol–diesel blends is being largely ignored.

Unlike petrol, which is miscible with anhydrous ethanol, diesel is immiscible with ethanol and blends must be created using copolymer surfactants. In addition, potential effects on fuel characteristics such as flammability, cetane number and lubricity must be considered. A number of blending agents have been developed which allow stable mixtures or emulsions of diesel and ethanol to be blended and which ensure that the essential characteristics of diesel fuel from an engine performance perspective are not adversely affected.

Eight companies have developed and trialled ethanol–diesel blending technologies which are at various stages of deployment. Two technologies are being widely deployed and taking part in the EU Bioethanol for Sustainable Transport (BEST) project, while one is no longer being developed. The technologies are broadly similar, with levels typically ranging from 7.7% to 15%, but blends of up to 30% can be achieved without engine modification, and of up to 95% in customised engines.

Technical Characteristics

A number of technical characteristics must be accounted for when blending and using eDiesel:

- Engine Performance
  Substituting mineral oil with bioethanol, an oxygenate containing 35% oxygen, improves engine efficiency and reduces emissions. The improved performance is offset by the reduced calorific value of ethanol compared to diesel and the net fuel consumption and power output for eDiesel is similar to that for diesel. Lubricating agents are added to blending agents to maintain lubricity.
- Mobilisation of Debris
  Ethanol in fuel acts as a solvent and can loosen any accumulated deposits in the fuel system. Cleaning fuels tanks before switching to eDiesel and replacing fuel filters addresses this.

- Compatibility with Components

  Some engine components, such as nitrile rubber seals, may not be compatible with the ethanol in eDiesel blends and should be replaced with compatible alternatives.
- Flash Point, Flammability and Fuel Handling

  Diesel, classified as a combustible liquid, has a relatively low explosion risk compared with petrol and requires simple fuel-handling facilities. Adding ethanol to diesel increases the fire and explosion hazard to that of a flammable liquid – such as petrol. eDiesel therefore must be stored, handled and used as petrol would.
- Reliability, Maintenance and Warranties

  In general, engine manufacturers do not provide warranties for engine operating on non-standard fuels, i.e. diesel that does not meet the EN 590 diesel standard. This will obviously affect the market for non-standard biofuels in new engines, but, in theory, should not affect their use in engines where the warranty has expired.

Emissions

Much research has been carried out worldwide into the use of ethanol–diesel blends which has concluded that eDiesel emits significantly less NO_x, particulate, smoke, CO and SO_2 emissions than diesel. In contrast, pure plant oil and biodiesel produce higher levels of NO_x emissions than diesel. A review of the published ethanol–diesel literature found the following emission reductions reported (compared with diesel):

- Smoke emissions have been shown to be reduced by between 20% and 70%.
- Particulate matter (PM_{10}) emissions have been demonstrated to be reduced by between 15% and 30%.
- CO_2 emissions are reduced by an estimated 10% for a 15% eDiesel blend.
- CO emissions ranged from a 50% increase to a 40% reduction. The average impact in all the trials reviewed was a 20% reduction.
- NO_x emissions ranged from a 7% increase to a 18% reduction. The average impact in all the trials reviewed was a 10% reduction.

The use of eDiesel therefore presents an opportunity to significantly reduce emissions from existing diesel engines without modification to engines.

Market Analysis

An information sheet on eDiesel and a questionnaire was sent to 81 companies, representing 71 separate organisations, to determine the extent of centrally fuelled captive fleets and the potential market for eDiesel. Responses were received, and phone interviews conducted with 33 of the organisations surveyed. The highest response rate was from local authorities with the lowest being in general fleet operators and logistics/haulier companies.

By extrapolating the fuel consumption in each of the sectors surveyed, the public passenger services sector was identified as having the largest fuel consumption.

Table E.1 Fuel Consumption by Sector and Total Fuel Consumption

Sector	Number of Organisations	Number of Responses	Operate Own Fleet	Central Fuel Storage	Total Fuel Consumption (000 litres)
Building materials	7	2	2	2	27 600
General fleet	4	0	–	–	–
Local authority	34	20	20	15	10 800
Logistics	6	4	2	1	12 000
Public passenger services	7	3	3	3	69 600
Waste	13	4	3	3	3 220
Total	71	32	29	23	103 220

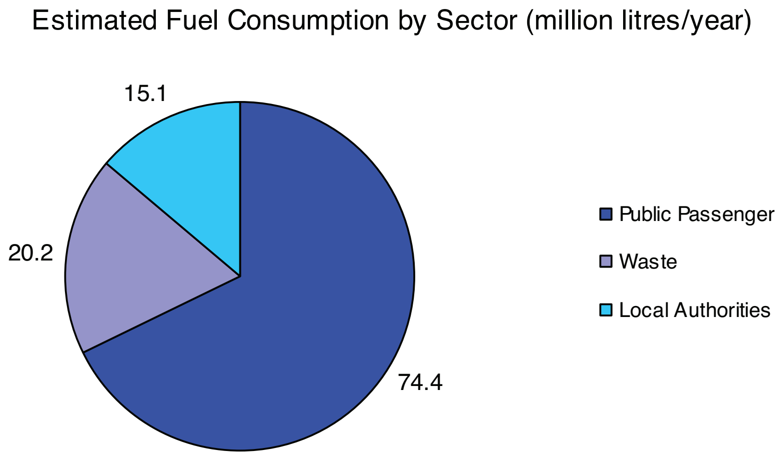


Figure E.1 Estimated Fuel Consumption by Sector

Only two responses were received from companies in the building materials sector and it was not possible to extrapolate the consumption for the sector on this basis. However, it is readily apparent that the fuel consumption and opportunity for the use of eDiesel is significant in this sector.

Based on the sectors likely to have captive fleets from whom a reasonable response was received, we estimate that captive fleets (the likely eDiesel market) use around 110 million litres a year.

This is a small proportion of the overall diesel consumption for road freight, public services and other uses of 72 PJ or approximately 2 billion litres per annum.

The principal reasons for this are considered to be:

- A zero response rate from general fleet operators.
- A small response rate from logistics companies, coupled with the fact that many of the companies that did respond do not operate their own vehicles.
- A low response rate from the building materials sector.

It is notable that two companies in the building materials sector accounted for a usage of 27 million litres per annum and that the estimated overall usage in this sector may be as high as 800 million litres per annum, indicating that this is a significant potential market.

Discussions with general fleet operators and logistics companies reveal that they tend not to operate centrally fuelled fleets, and where companies do operate their own fleets, they primarily refuel at general fuel stations.

The survey responses and subsequent phone conversations with the respondents demonstrated that there is a positive attitude towards the use of biofuels among the respondents: 35% of respondents are currently using, or trialling the use of, biofuels and 81% would consider using biofuels, 63% of which would consider using eDiesel.

The survey demonstrates that there is significant diesel use in centrally fuelled captive fleets and that operators are favourably disposed towards the use of biofuels and eDiesel.

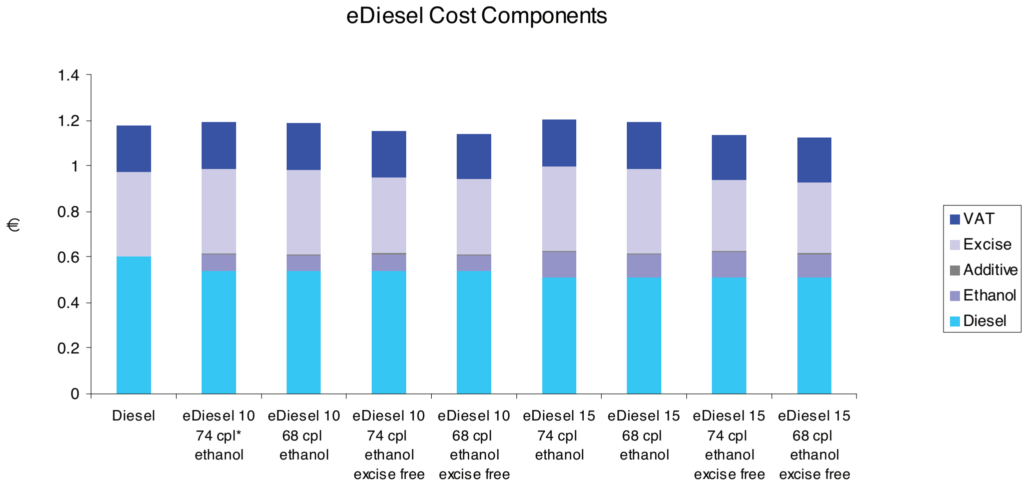
Economics

The cost of ethanol–diesel blends will be determined by the cost of diesel, the cost of bioethanol, the cost of the blending agent and the cost of blending facilities.

By far the greatest determinant in the cost is the cost of diesel and the cost of bioethanol. The retail cost of diesel is currently €1.17/litre, having risen steadily from a cost of 83 c/litre in January 2003. The current cost comprises a diesel cost of 60.3 c/litre, excise at 36.8 c/litre and 20.4 c/litre VAT.

Bioethanol is an internationally traded commodity and bioethanol production in the EU has increased ninefold from 60 million litres in 1993 to 526 million litres in 2004. Fuel ethanol costs varied from 27 c/litre to 33 c/litre from Brazil and 53 c/litre to 60 c/litre Free on Board (FOB) from Rotterdam.

For indigenous biofuels the typical bioethanol delivered cost excluding excise duty and VAT is €0.74/litre which compares to typical biodiesel delivery costs of €0.80/litre. When these costs, together with storage, handling and distribution costs are included, the estimated cost of bioethanol from Brazil is €0.68/litre, which compares with estimated costs from Rotterdam of €0.82/litre.



* cpl = cents per litre

Figure E.2 eDiesel Costs

Considering a cost for bioethanol of €0.74/litre (with no excise relief) eDiesel 15 costs 2.3% more than diesel, whereas eDiesel is 4.5% cheaper with excise exemption and €0.68/litre bioethanol. Application of excise duty on the bioethanol is therefore the main influencing factor on the relative cost of eDiesel.

In the absence of excise relief, eDiesel is more expensive than diesel fuel, but, in a biofuel obligation scenario it is competitive with other biofuel alternatives. In the future, second generation bioethanol sources (e.g. from wastes or lingocellulosic materials) offer a significant potential for cost effective alternative to mineral oils.

Benefits and Barriers

The use of ethanol–diesel blends in the transport fleet would provide another alternative biofuel for use in centrally fuelled diesel engines which would complement the existing alternative fuels: PPO, biodiesel and EN 590 biodiesel blends. Like other biofuels, it offers the potential to reduce CO_2 emissions from transport and reduce dependency on imported fossil fuels while fostering an indigenous biofuels industry.

eDiesel offers the benefit of easy use in existing engines without modification, and can directly replace (i.e. is fungible) diesel, allowing operators to fill eDiesel trucks with diesel from forecourts.

An important differentiation factor between eDiesel and other biofuels is the reduction in smoke, particulate and NO_x emissions from engines that is achieved due to the oxygenation effect of the fuel. This is an important benefit in terms of air quality and national emission inventories, but very few of the fleet operators surveyed viewed this as a significant benefit.

A significant barrier to eDiesel is fleet operators’ concerns about engine warranties, reliability and maintenance costs. Like other non-standard fuels (PPO, biodiesel), the use of eDiesel voids the engine manufacturer’s warranty. However, this will not be an issue where eDiesel is used in older engines that are out of warranty.

The market survey carried out as part of this study demonstrated that there is a significant potential market for eDiesel in local authorities, public passenger services and building materials sectors. These sectors have a large fuel consumption and in discussion with operators a positive attitude towards the use of biofuels was in evidence.

In contrast, logistics companies, hauliers and operators of general fleets are less disposed to the use of biofuels, and were mainly concerned with the potential effects on engine reliability.

There are a number of technical issues around the use of eDiesel such as effect on lubricity, cetane number, and potential vapour lock due to the lower vapour pressure of ethanol. These technical issues are addressed by the additive suppliers through the addition of cetane improvers and lubrication agents to the blending agents.

1 Introduction

1.1 Energy Use in Transport

Energy use for transport comprises a significant and ever increasing proportion of energy use in Ireland. From 1990 to 2005, the transport sector's share of final energy consumption increased from 27.8% to over 40%.[1] Final energy use in the transport sector has grown by 151% (6.3% per annum on average) between 1990 and 2005, the fastest growth rate of all sectors. Growth of 8% was recorded in 2005, which is higher than growth in any other sector.

As well as using more energy than any other end-use sector, the transport sector is also the sector most dependent on imported fossil fuels which comprise over 99% of the energy used in the transport sector, with resultant impacts on security of fuel supplies and exposure to oil price fluctuations.

CO_2 emissions from the transport sector in 2005 were 15 270 kilotonnes, representing over 33% of total energy related CO_2 emissions.

Within the sector, the increased demand is due to increased demand in all transport modes: private car, air, public passenger and road freight. Fuel consumption by road freight increased by 264% over the period, which was the highest growth, followed by public passenger services (149%), aviation (129%) and private car (107%).[1] These modal trends are also reflected in the fuel splits, with diesel having an increased share of overall transport fuel consumption. There was a 5.1% increase in petrol consumption in 2005 and an 8.2% increase in diesel consumption.

While all areas of the transport sector need to contribute to reduce fuel consumption and emissions, road freight and public passenger services show the highest growth, and present an opportunity to replace diesel with biofuels.

In 2005 there were 286 548 road freight vehicles using 1208 ktoe of fuel or an estimated 1380 million litres of diesel. The public passenger services sector has a lower consumption of 131 ktoe or an estimated 149 million litres of diesel per annum. (This is assuming that all fuel used in these sectors is diesel. However, as taxis are included in public passenger services, it is likely that petrol accounts for some of the use in this sector.)

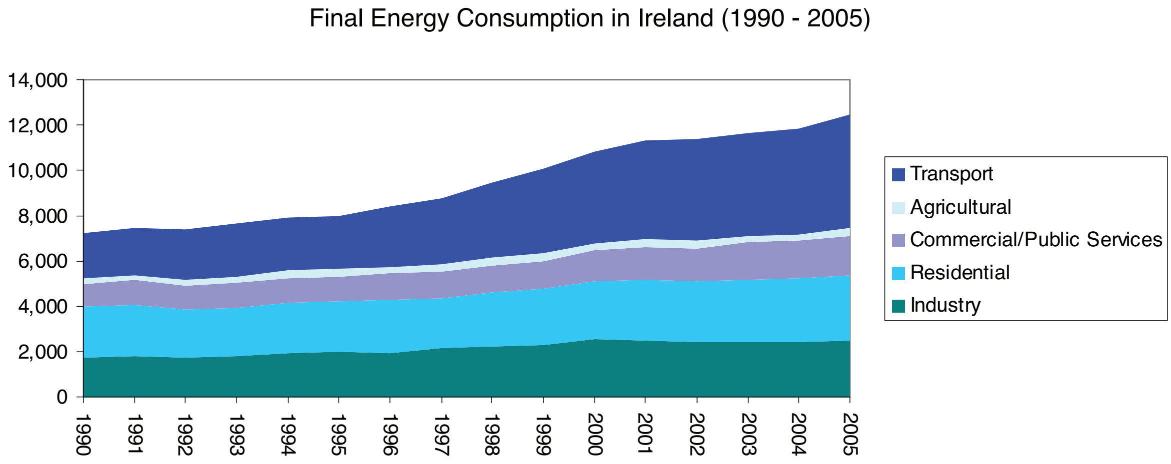


Figure 1.1 Final Energy Consumption in Ireland by Sector

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[1] *Energy in Ireland 1990–2005 – Trends, issues, forecasts and indicators.* SEI EPSSU. 2006.

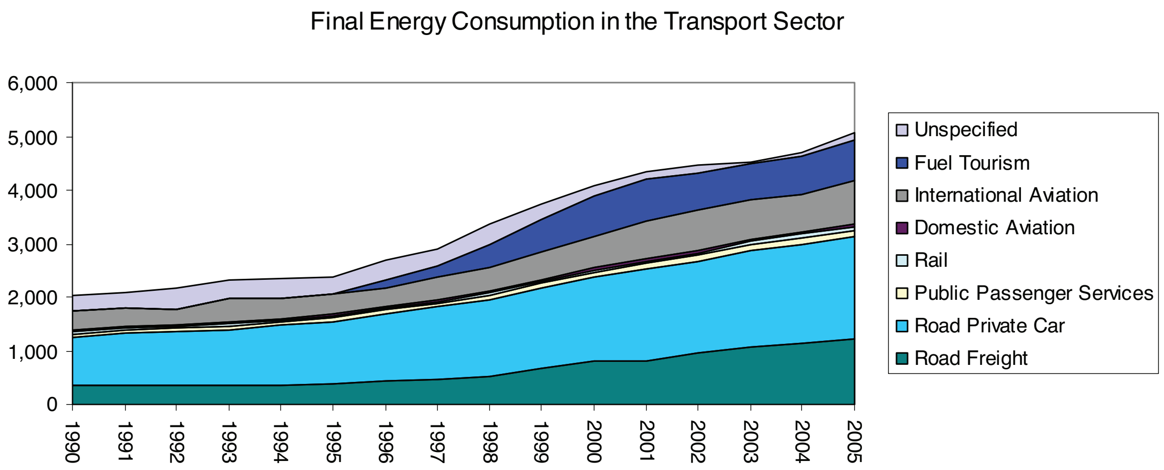

Figure 1.2 Final Energy Consumption in the Transport Sector

1.2 Policy and Resource

The use of biofuels meets two key strategic objectives: reduced dependency on oil and a reduction in the environmental impacts of transport and, in particular, greenhouse gas emissions. Biofuels can help to reduce greenhouse gas emissions and improve energy security, while yielding national and local economic benefits through the creation of an indigenous biofuels industry.

A number of EU and national policy measures have been put in place to promote the use of biofuels in recognition of the role that biofuels have in meeting future energy needs and in reducing the environmental impacts of energy supply and use.

The EU Biofuels Directive (2003/30/EC) requires that national targets for the use of biofuels should be set and suggests a non-binding ‘reference value’ for these targets of 2% for 2005 and 5.75% for 2010. In a report to the European Commission, Ireland submitted an initial indicative target of 0.06% by the end of 2005, rising to 1.14% in 2006. These initial targets are based on the government’s scheme for excise relief on pilot biofuels projects.

Teagasc, Ireland’s agriculture and food development authority, estimates that achieving the 5.75% EU target by focusing on ethanol, will require 115 000 ha of cereals and 40 000 ha of rapeseed. In comparison, around 360 000 ha of land is currently in tillage in Ireland.

Table 1.1 Biofuels Targets (EU and Ireland)[2]

Year	EU Target (%)	Irish Target (%)	Irish Actual (%)
2005	2.00	0.06	0.045[3]
2006	–	1.14	
2007	–	1.75	
2008	–	2.24	
2009	–	5.75	
2010	5.75	–	
2020	10.00	10.00	

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[2] http://ec.europa.eu/energy/energy_policy/doc/factsheets/renewables/renewables_ie_en.pdf

[3] Department of Communications, Marine and Natural Resources. *Report on measures taken to promote the use of biofuels or other renewable fuels to replace diesel or petrol.* 2006.

2 Biofuels Policy and Resource Studies

2.1 Resource Studies

In 2004 Sustainable Energy Ireland (SEI) commissioned a consortium of Ecofys, Teagasc and the Fraunhofer Institute to conduct a major study into the strategy for the use of biofuels in Ireland. This study concludes that the potential biofuels resource is sufficient to meet the reference value target for 2005 (i.e. 2%) but that the 2010 target can only be met by diverting food crops for energy use and by using biofuels that do not meet the current gasoline directive (98/70/EC)[4] regarding ethanol or the current diesel standard (EN590:2003).[5]

The report, however, recognises that the use of lingocellulose material to produce biofuels offers the potential to produce large quantities of biofuels without competing with food crops. The production of second generation bioethanol via acid hydrolysis or enzymatic hydrolysis offers the potential for the production of large quantities of bioethanol.

The report considered a range of biofuels or blends, whose use does not require any adaptations to the common transportation fleet, including fatty acid methyl esters (FAME) and petrol–ethanol blends. The study did not consider the use of fuels that may require adaptation of vehicles such as pure vegetable oils or, as it is investigated in this study, the potential for the use of ethanol–diesel blends (eDiesel).

The Irish government's Mineral Oil Tax Relief Scheme for biofuels provides excise relief for a number of biofuel producers. The fuels supported under the scheme include bioethanol, fuels in captive fleets and biodiesel. The alternative diesel fuels are used in captive fleets or in private cars centred around local distribution centres while bioethanol is distributed for use in flexible fuel vehicles in a number of fuel forecourts around the country.

Biodiesel and plant oil are the principal alternative fuels for use in diesel engines. The use of eDiesel could provide an alternative transport fuel for diesel engine vehicles in captive fleets, substituting diesel with ethanol and creating a market for bioethanol which would justify and facilitate the construction of an indigenous bioethanol production capacity.

This literature review and desk study aims to assess the opportunities and costs for ethanol–diesel blends. It describes the fuel in detail and the development history. It considers the technical benefits and modifications needed to use eDiesel in vehicles and quantifies the potential market for eDiesel.

2.2 Biofuels Policy

Renewable energy policy is a function of Ireland's Department of Communications, Energy and Natural Resources (DCENR), and policy for biofuels also overlaps with the Department of Agriculture and the Department of Environment, Heritage and Local Government.

A number of policy measures have been introduced by these departments to promote the production, supply and use of biofuels.

2.2.1 Biofuels Excise Relief Scheme 1

In 2005, the Department of Communications, Marine and Natural Resources (DCMNR) launched a pilot biofuels Mineral Oil Tax Relief Scheme which provided two years (2005–2007) of excise relief (valued at €6 million) for pilot biofuels projects. Of the 34 applications received 8 were approved and the DCMNR announced the successful projects in August 2005 as shown in Table 2.1.

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[4] Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Directive 93/12/EEC.

[5] IS EN 590:2004. *Automotive Fuels – Diesel – Requirements and Test Methods*. NSAI. 2004.

Table 2.1 Mineral Oil Excise Relief Scheme 1 Projects

Category	Company
EN 590 (diesel)	Conoco Phillips, Whitegate Refinery
	Eco Ola
	Greyhound Recycling and Recovery Ltd
Bioethanol (petrol)	Maxol Ltd
Pure plant oil	Biogreen Energy Products Ltd
	Recycled Products Ltd
	Eilish Oils Ltd
	Kilkenny Cereals Ltd

These projects are expected to produce 16 million litres of biofuels in the two-year, excise-free period comprising 12 million litres of pure plant oil, 2 million litres of EN 590 (diesel) biofuel and 2 million litres of bioethanol. This compares with petrol consumption of 8.074 billion litres and diesel consumption of 6.588 billion litres.[6]

2.2.2 *Biofuels Excise Relief Scheme 2*

Following on from the first scheme, the DCMNR announced a second round of excise relief in July 2006. This scheme provides excise relief for five years (2006–2010) and is valued at €213 million. Excise relief will be provided to projects producing biodiesel complying with EN 590, ethanol blends of 5–85%, PPO and biofuels in captive fleets.

Proposals were requested in July 2006, 102 proposals were submitted in August 2006 and the DCMNR announced in November 2006 that 16 proposals were approved. The successful companies are listed in Table 2.2.

Projects resulting from this scheme are expected to be operating in 2008, producing 163 million litres of biofuels, to achieve 2.2% of the fuel market and Ireland's 2008 biofuels target. It is also expected to displace 1.2 million tonnes of CO_2.

Table 2.2 Mineral Oil Excise Relief Scheme 2 Projects

Category	Company
EN 590 (diesel)	Biodiesel Production Ireland Ltd
	Conoco Phillips, Whitegate Refinery
	Green Biofuels Ireland
	Irish Food Processors
Bioethanol (petrol)	Cooley-Clearpower Ltd
	Maxol Ltd
	One51 Ltd
	Topaz Energy Ltd
Captive fleets	Bord na Mona
	Eco Fuels
	Eco Ola
	Emo Oil
	Greyhound Recycling and Recovery
	Biogreen
Pure plant oil	Eilish Oils/Glanbia
	Goldstar Oils

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[6] O' Leary, F., Howley, M. and Gallachóir, B. Ó. *Energy in Transport: Trends and Influencing Factors – 2006 Report*. SEI EPSSU. 2006.

2.2.3 Vehicle Registration Tax Relief for Flexible Fuel Vehicles

The 2006 budget has reduced vehicle registration tax (VRT) for 2006 and 2007 by 50% for cars which accept biofuels comprising at least 85% biofuels. The 2006 Finance Act extends the existing 50% VRT relief for hybrid electric vehicles to the end of 2007.

A number of companies have now launched flexible fuel vehicles on the Irish market and 200 of these vehicles were introduced as of March 2007.[8]

2.2.4 Energy Crops Scheme

In 2005 the Department of Agriculture and Food agreed 268 contracts with farmers under the EU energy crops and non-food set-aside schemes.

The EU Energy Crops Scheme is valued at €45/hectare and this has been topped up by the Irish government by €80/hectare for a total of €125/hectare for a maximum of 37.5 hectares/producer.[9] Assuming all the land meets this criteria, the scheme incentives total €210 125 in 2005. Energy Solutions understands that energy crops on set-aside are entitled to the Irish subsidy (€80/hectare) but not the EU subsidy (€45/hectare). Energy crops grown on active land are entitled to both subsidies.

2.2.5 Future – Biofuels Obligation

The Irish government expects to implement a biofuels obligation in 2009. Current research by Sustainable Energy Ireland and Ecofys is looking at nine other EU member states who have brought in a biofuels obligation. In particular, Ireland will focus on the UK's experience with a biofuels obligation.

Table 2.3 Projected Biofuels Use (Million Litres) under the Excise Relief Scheme[7]

Year	Biodiesel (EN 590 Blends)	Bioethanol 5–85% Blend	Pure Plant Oil	Captive Fleets	Total
2006	44	11	0	9	64
2007	57	40	3	12	112
2008	60	85	6	12	163
2009	60	85	6	12	163
2010	60	85	6	12	163

Table 2.4 2005 Energy and Non-Food Set-aside Crops

	Energy Crops	Non-food Set-aside	Total
Oilseed rape planted (hectares)	1 681	819	2 500
Wheat planted (hectares)	0	136	136
Total planted (hectares)	1 681	955	2 636
No. of agreed contracts	136	131	268

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[7] *Energy in Transport – Trends and Influencing Factors*. SEI EPSSU. 2006.

[8] BioEnergy Action Plan for Ireland. DCMNR. March 2007.

[9] Department of Agriculture, Fisheries and Food, *Minister Coughlan Announces Details Of New Bioenergy Initiatives*, available at: http://www.agriculture.gov.ie/index.jsp?file=pressrel/2007/18-2007.xml, last accessed: 26 July 2007.

Under an obligation scheme, fuel supply companies have to account for their fuel mix on an annual basis and pay a fixed amount penalty per litre of target not achieved if they do not reach the obligated limit.

On 12 February 2007, the Minister for Communications, Marine and Natural Resources announced the introduction of a biofuels obligation that would require biofuels to comprise 5.75% of the fuel market by 2009 and 10% by 2020.

The DCMNR has invited feedback for the stakeholder consultation it is conducting in 2007 on a possible biofuels obligation.

2.2.6 Biofuels (Blended Motor Fuels) Bill 2007

The Biofuels (Blended Motor Fuels) Bill 2007 was introduced on 7 February 2007 and referred to a select committee on 14 February.[10]

The bill will ensure that all motor fuels that comprise mineral oils are blended, at least in part, with biofuel, a fuel that is made from biodegradable and renewable biomass sources. The bill does not define the proportion of the fuel to be substituted by biofuel, which allows the government flexibility to increase the proportion of biofuel.

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[10] Tithe An Oireachtais, *Biofuels (Blended Motor Fuels) Bill 2007*, available at: http://www.oireachtas.ie/viewdoc.asp?DocID=6942&&CatID=59, last accessed: 26 July 2007.

3 Ethanol–Diesel Biofuel Blends

3.1 Ethanol–Diesel Blending Technologies

There are a number of reasons for blending diesel with bioethanol, the principal of these being the opportunity it provides for the use of biofuels in existing fleet vehicles with little or no modification to engines, irrespective of the age of the engine. Further, unlike other diesel substitute biofuels, ethanol provides an oxygen component to the fuel, improving combustion characteristics and reducing emissions from the engine.

Unlike petrol, which is miscible with anhydrous ethanol, diesel is immiscible with ethanol and potential effects on fuel characteristics such as flammability, cetane number and lubricity must be considered. A number of copolymers and emulsifying agents have been developed which allow stable mixtures or emulsions of diesel and ethanol to be blended and which ensure that the essential characteristics of diesel fuel from an engine performance perspective are not adversely affected. All these technologies create emulsions of ethanol in diesel fuel by the use of surfactants, although there are various proprietary agents used and cetane and lubricity improvers are also a common feature with all the blending agents.

Companies which actively promote or have promoted such technologies are listed in Table 3.1.

In a range of trials, these additives have proved successful in producing stable eDiesel mixtures and emulsions.

We carried out an exhaustive literature review and contacted companies supplying ethanol–diesel blending agents to compare the different technologies and performance of ethanol–diesel blends.

Suppliers have not disclosed the composition of their additives; however, Pure Energy has stated that its additive comprises just carbon, oxygen and hydrogen.

3.1.1 Lubrizol

Lubrizol have developed and trialled an eDiesel additive. However, they have now put their eDiesel activities on hold[11] and are no longer actively involved in this area to allow them to focus on other alternative fuels including biodiesel and E85.

The additive is blended into the ethanol and the ethanol is then blended into the diesel. Lubrizol conducted trials of their eDiesel additive which showed that blending together multiple additives can give eDiesel the properties it requires to be used in diesel engines but that improper blends can create pump wear problems while passing lubricity bench tests.

Table 3.1 eDiesel Additive Suppliers

Additive	Supplier
O2D05	O2Diesel
Beraid 3540	Akzo-Nobel Surfactants
DMX-10011	GE Water and Process Technologies
Puranol	Pure Energy Corporation
Lubrizol	Lubrizol
Dalco	Apace Research
Etamix D3	Sekab Svensk Etanolkemi AB
AEP-102	Ecomat

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[11] Corkwell, Keith. Fw: Ethanol Diesel Blend Additive. Personal email. 22 May 2007.

3.1.2 Sekab – Etamax D

The use of ethanol–diesel blends has been trialled extensively in Sweden and a Swedish company Sekab Svensk Etanolkemi AB (Sekab) markets Etamix D3,[12] a mixed fuel with 15% ethanol, diesel and emulsifier.

Sekab, in conjunction with the engine manufacturer Scania, is developing Etamax D, a neat bioethanol fuel for use in customised diesel engines. Scania and Sekab have trialled 95% ethanol, mainly in buses. It consists of ethanol (92.2% by mass), ignition improver (5%), Methyl Tertiary Butyl Ester (MTBE) (2.3%), isobutanol (0.5%) and a corrosion inhibitor (90 ppm).[13]

Etamix D3 is currently being trialled in buses in La Spezia, Italy and Biofuel Region, Sweden as part of the EU-funded Bioethanol for Sustainable Transport (BEST) project.[14]

3.1.3 O2Diesel

Formerly known as AAE Technologies Inc. and founded in the UK in 1997, the company is now called O2Diesel Corporation, based in Newark, Delaware, USA and traded on the American Stock Exchange.

O2Diesel markets an eDiesel blending agent known as O2Diesel. They have trialled the product in buses in Sao Paulo, showing that using eDiesel reduced particulate (PM_{10}) emissions by 20–31%, nitrogen (NO_x) emissions by 1.6–3%, carbon monoxide (CO) by 12–23% and smoke by 50–70%.[15] These reductions are matched in their product claims except for particulates where 20–46% reductions are claimed and nitrogen with reductions of 1.8–8.5%.[16] O2Diesel has recently started supplying 50 000 buses in India with their ethanol–diesel blending technology. The O2Diesel technology typically uses a 7.7% ethanol blend together with 1% blending agent and offers the advantage of the possibility for in-line blending at the point of delivery and also for in-tank mixing of O2Diesel and diesel.

In January 2007, O2Diesel acquired 80% of ProEco Energy, who are developing a 379 million litre/year ethanol plant in South Dakota, USA, expected to be completed in 2008.

O2Diesel is currently being trialled in buses in Rotterdam, Netherlands as part of the EU-funded Bioethanol for Sustainable Transport (BEST) project.[17]

3.1.4 Akzo Nobel Surfactants

Formerly Akzo Nobel Surface Chemistry, Akzo Nobel market an eDiesel additive called Beraid ED10, which allows anhydrous ethanol to be mixed with diesel. Beraid comprises three components and has the following properties.

1 It creates a stable blend of ethanol and diesel.
2 It improves lubricity and corrosion protection.
3 It increases the cetane number to counter the effects of the ethanol.

Akzo Nobel conducted a field trial of Beraid on two Scania trucks in Denmark between October 2001 and May 2002. One truck was converted to run eDiesel while the other truck used standard diesel as a reference. Emissions data from this trial were used to calculate the life-cycle emissions of eDiesel. Section 5 summarises the results from this and other trials.

3.1.5 GE Water and Process Technologies

GE Water and Process Technologies market an eDiesel additive developed by BetzDearborn, who were bought by GE in 2001. DMX-10011 is used to stabilise the emulsion of fuel ethanol (99.6+%) in diesel fuel and also provide lubricity, stability and corrosion inhibition.

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[12] Nylund, N-O. *Alcohols/Ethers as Oxygenates in Diesel Fuel: Properties of Blended Fuels and Evaluation of Practical Experiences*. TEC Transenergy Consulting/Befri Consult, 2005.

[13] Rutz, D., Janssen, R. *Overview and Recommendations on Biofuel Standards for Transport in the EU*. WIP Renewable Energies, 2006.

[14] Ericson, Jonas. *Sv: Vd: Results of e-Diesel Trials*. Personal email. 9 May 2007.

[15] Afonso, P. *Use of O2DieselTM Fuel in Sao Paulo City's Urban Fleet*. 2004, p.5.

[16] O2Diesel. *A Cleaner Burning Diesel Fuel For the World of Commerce*. p.5.

[17] Rae, Allen. Personal email. 26 July 2007.

According to GE: 'DMX-10011 effectively treats blends of ethanol in diesel fuels to prevent phase separation when the fuel is exposed to low ambient temperatures or water contamination. DMX-10011 also effectively stabilizes blends of ethanol in highly hydro-treated diesel. The product also helps provide superior lubricity. DMX-10011 allows ethanol and diesel to be blended "in situ", and should allow fuel blends to be made at existing blending facilities.'

GE emphasise that their product improves the lubricity of the blended fuel and that it would be required even if the conditions are not present for separation of the ethanol and diesel. GE's DMX-10011 additive requires fuel grade (i.e. anhydrous) ethanol.[18]

3.1.6 Pure Energy

Pure Energy Corporation was founded in 1992. Pure Energy has developed and markets an eDiesel additive called Puranol. An elemental analysis of Puranol shows that it comprises just carbon, hydrogen and oxygen.

The recommended blend mix for Puranol is 80–84% diesel, 15% ethanol and 1–5% (typically 2%) Puranol additive. Pure Energy have conducted trials on Puranol in four Mack Trucks in Decatur, Illinois, USA in November 1998 and another trial on 30 buses for the Chicago transit authority (15 on eDiesel, 15 on diesel). This trial demonstrated that eDiesel can substitute diesel, and highlighted that preventing water contamination is important to maintain fuel quality.

In July 2006, Pure Energy (50%) entered into a joint venture with Green Star Products Inc. (25%) and Bio-Clean Fuels (25%). The joint venture, known as Green Star International, aims to develop biorefinery projects in the USA with integrated biodiesel and ethanol production.

Blends are created with Puranol through splash blending, where the different components, i.e. the diesel, ethanol and Puranol, are mixed by adding the correct proportions to a storage tank.

3.1.7 Apace Research

Australian-based Apace Research Limited was founded in 1980 and has developed an eDiesel technology based on the use of azeotropic ethanol rather than anhydrous ethanol. Apace claim to have conducted engine test cell and field trial evaluations of their eDiesel additive with industry organisations in Australia and overseas.

The product from Apace is unique in that it uses azeotropic ethanol rather than anhydrous ethanol, and so requires less processing and energy. Apace also claim that eDiesel based on azeotropic ethanol is more stable and does not destabilise with water contact, in contrast to eDiesel based on anhydrous ethanol which destabilises when contacted with small amounts of water (from the atmosphere or ingress during storage).[19]

This form of ethanol–diesel blend must be pre-blended and stored as the blend in storage tanks.

3.1.8 Ecomat

Ecomat (Ecologica Mato Grosso) are based in Brazil and have developed an additive called AEP102. When AEP102 is blended with diesel, the blended product is known as MAD8 and comprises 89.4% diesel, 8.0% anhydrous ethanol and 2.6% AEP102 additive.

AEP102 was tested on two Mercedes buses in Curitiba between February 1998 and May 1999, each bus covering 100 000 km. Field performance, drivability and ignition were found to be satisfactory and fuel consumption rose by 2–4%.

In March 2001 Ecomat opened a plant which produces 14 000 tonnes/year of AEP102.[20]

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[18] GE Infrastructure, Water and Process Technologies, *DMX-10011 Product Fact Sheet*.

[19] Personal Communication from Dr Russell Reeves.

[20] Azevedo, Gil Floro Popoire and Andrade, Edilson Bernardim. 2002. *Biofuels: Alternative Technologies for Ethanol Fuel – Brazilian Mission in India*. Presentation slides. 2002.

3.1.9 Summary of Technologies

The different blending technologies and the typical ethanol proportions that are achieved with the technologies are summarised in Table 3.2. In terms of ethanol levels in the ethanol–diesel blends, the technologies are broadly similar with levels typically ranging from 7.7% to 15%, with the exception being the Apace technology which can use blends of up to 30% and the Sekab Etamax D technology which is a fundamentally different technology and is essentially pure ethanol with an ignition improver which runs in customised engines.

The majority of these additives are based on anhydrous (99.8%) ethanol–diesel blends, although the emulsifier developed by Apace Research is designed for use with either anhydrous or azeotropic (95%) ethanol, which reduces the sensitivity of the eDiesel to separation due to contamination by water and would reduce the production costs and the energy required to produce the bioethanol.

Table 3.2 Emulsifier Mixing Details

Emulsifier Producer	Preferred Ethanol Level (by Volume) (%)	Emulsifier Level (by Volume) (%)	Ethanol
O2Diesel	7.7, 10	0.5	Anhydrous
Akzo-Nobel Surfactants	10–1	1–4	Anhydrous
GE Water and Process Technologies	5, 10, 15	0.25, 0.35–0.75, 1	Anhydrous
Pure Energy Corporation	5–15	1–5	Anhydrous
Sekab – Etamix D3	15	(Inc. in ethanol)	Anhydrous
Sekab – Etamax D	92.2 (by mass)	7.8% (by mass)	Anhydrous
Apace Research	15–30	Variable	Azeotropic
Ecomat	8	2.6	Anhydrous

The different technologies vary in terms of ease of blending: Puranol blends can be created by splash blending, O2Diesel blend by in-line, point of delivery blending, while the Apace technology requires pre-blending and storage of the blend. The ease of blending will have an impact on the ease of access to the potential market.

Another distinction between the technologies is the sensitivity of the blend to moisture. Anhydrous ethanol is highly hygroscopic and will absorb moisture from the air which could affect the stability of blends. For example, Pure Energy Corporation acknowledges that higher concentrations of Puranol may be required in wet climates and that wet climates may limit the ethanol level that can be used. Other technologies (O2Diesel, GMX-1011 and the Apace technology) are less sensitive to moisture and the Apace technology is the only one that can be used with azeotropic ethanol.

The different technologies are also at various stages of commercial deployment, with, for example, both the Sekab Etamix D3 and O2Diesel technologies participating in the Bioethanol for Sustainable Transport (BEST) project and Lubrizol having ceased to be active.

3.2 Azeotropic and Anhydrous Ethanol

The distinction between ‘azeotropic ethanol’ and ‘anhydrous ethanol’ arises directly from the process for producing ethanol from biomass. In all commercial processes for production of bioethanol, the output from the fermentation stage is an ethanol/water mixture which normally contains less than 10% ethanol and more than 90% water. Thus, fermenter output must be processed to remove the water and concentrate the ethanol.

The first stage in the process of removing water and concentrating the ethanol is known as ‘stripping distillation’. This is followed by a second stage, known as ‘rectification distillation’.

The stripping/rectification distillation process increases the concentration of ethanol in the ethanol/water mixture to a theoretical maximum of 96.5% ethanol (by volume). This product is termed 'azeotropic ethanol'.

The remaining 3.5% of water in the azeotropic ethanol product cannot be removed by standard distillation. To remove the remaining water, a third compound termed an 'entraining agent' must be added to the azeotropic ethanol and a different distillation process, known as 'azeotropic distillation', performed. The product from the azeotropic distillation process is theoretically 100% ethanol. This product is termed 'anhydrous ethanol'.

Compared to azeotropic ethanol, anhydrous ethanol produced by either the azeotropic distillation process or a molecular sieve dehydration process has the following disadvantages associated with it:

1 A higher economic cost, due to the capital and operating costs of the additional process stage.
2 Higher greenhouse gas emissions, due to the energy inputs associated with the additional process stage.

Also, compared to azeotropic ethanol, anhydrous ethanol is hygroscopic (i.e. it absorbs water from the atmosphere and the surrounding environment). This increases the chances of fuel contamination and operation problems.

Furthermore, it is well understood that when azeotropic ethanol is used as fuel in internal combustion engines, the water content of azeotropic ethanol results in higher engine thermal efficiency and lower NO_x exhaust emissions than anhydrous ethanol.

4 Technical Characteristics

4.1 Engine Performance

Engine performance includes the impacts on engine efficiency, emissions, wear and engine lifetime. Substituting mineral oil with bioethanol, an oxygenate containing 35% oxygen (by weight), improves engine efficiency and reduces smoke, particulate, carbon monoxide (CO) and oxides of nitrogen (NO_x) emissions. Substituting diesel (which contains sulphur) with eDiesel also reduces vehicle sulphur dioxide (SO_2) emissions.

Ethanol has a lower lubricity than diesel which can increase the wear on fuel pumps and other engine components that rely on the lubricating properties of diesel. eDiesel additive suppliers mitigate this by adding a lubricating agent to their additive to give similar lubricating properties to diesel. eDiesel should therefore have no net effect on engine wear and lifetime, and is suitable for use in low- and high-pressure diesel engines

4.2 Solvent (Tank Cleaning and Fuel Filters)

Ethanol in fuel acts as a solvent and can loosen any accumulated deposits in the fuel system. This could potentially block fuel lines if impurities are entrained into the fuel. Cleaning fuel tanks before switching to eDiesel and replacing fuel filters shortly after will help reduce the likelihood of fuel system blockages.[21,22,23]

4.3 Vapour Pressure and Vapour Lock

eDiesel has a higher vapour pressure than ordinary diesel, which may allow vapour locks to occur in the engine as the fuel is heated through contact with the engine in the fuel lines (Department of the Environment and Heritage Australia, 2004). In order to prevent this, the pressure must be maintained at sufficiently high levels throughout the engine's fuel injection system to compensate for the temperature rise. The pressure in the fuel injection system depends on the engine's fuel injection system. For example, the Cummins PT fuel injection system can have low pressure and high temperature fuel in the fuel rail, particularly at low load, which makes it unsuitable for use with eDiesel without modifications, whereas the more standard Lucas/CAV and Bosch fuel pumps maintain a high pressure in the fuel rail under all operating conditions, which prevents the formation of ethanol vapour in the fuel.

For engines fitted with unsuitable fuel injection systems it would be necessary to modify the engine to prevent eDiesel being heated in the fuel rail. These modifications could include adjustments such as rerouting fuel lines to avoid warm engine areas, insulating the fuel line, shielding heated areas or installing a fuel cooler. These are relatively major modifications and would practically limit the applicability of eDiesel to engines with suitable fuel delivery systems. However, as the only fuel pumps not suited to eDiesel are proprietary Cummins pumps, and due to the limited market share Cummins have in Europe, this will not unduly limit the market for eDiesel.

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[21] Afonso, P. *Use of O2DieselTM Fuel in Sao Paulo City's Urban Fleet*. 2004. pp.31, 32.

[22] O2Diesel. *A Cleaner Burning Diesel Fuel for the World of Commerce*. p.35.

[23] Department of the Environment and Heritage. *Setting National Fuel Quality Standards: Discussion Paper on Diesohol*. Clean Fuels and Vehicles Section, Department of the Environment and Heritage, Australia, 2004. p.16.

4.4 Lubrication

Standard diesel serves as a lubrication which reduces fuel system servicing needs. Ethanol–diesel blends have poorer lubrication properties which potentially lead to equipment (fuel pump and injector) failures. However, most additives compensate for this by including additives with good lubrication properties. Overall lubricity of eDiesel blends should therefore be equivalent or better than for standard diesel.

4.5 Compatibility with Components

Some engine components, such as nitrile rubber seals are not compatible with the ethanol in eDiesel blends. Where these components are present, they should be replaced with compatible alternatives.[24] This is likely to be required in the majority of engines, but is a low cost measure (c. €50) and would not limit the market for eDiesel.

Ethanol–diesel blends can also increase the corrosion rate of fuel system equipment. However some additives mitigate this by including anti-corrosion additives in the blending agent.

4.6 Energy Content – Fuel Delivery/Injection Timing

eDiesel has a lower calorific value than diesel, due to the low calorific value of ethanol. This will reduce the energy in the fuel, mileage per tank and power from the engine. This reduction in energy content is somewhat offset by the increased efficiency due to the improved combustion resulting from the oxygenate effect of the bioethanol.

For high percentage bioethanol blends, engine power can be maintained by increasing fuel delivery and adjusting injection timing. These adjustments would need to be reversed if the engine were returned to operation on diesel for an extended period of time.[25,26] Increasing the fuel pump rate may not be permitted on emissions certified vehicles and may void engine warranties.[27] This is one of the primary reasons for limiting the ethanol content of blends, at least during the initial stage of deployment of the fuel.

4.7 Flash Point, Flammability and Fuel Handling

Flash point describes the lowest temperature at which a liquid fuel will form an ignitable mixture in air. With a flash point of around 61.5 °C, ordinary diesel presents a relatively low explosion risk compared with petrol and requires simple fuel-handling facilities. However, adding ethanol to diesel with blends as low as 5% ethanol, lowers the flash point to just 11 °C, similar to that of petrol. To reduce the chances of an explosion, eDiesel must be treated like petrol, potentially requiring:

- Flame arrestors on fuel storage and vehicle tank vents and fill openings.
- Vapour recovery systems on fuel transfer processes, including vehicle fuelling.
- Electrical ground between vehicle and fuel pump.
- Intrinsically safe vehicle tank-level indicators.
- Education on proper fuel-handling methods for staff handling the fuel.[28]
- Consideration of the risks associated with the bulk storage and handling of the fuel, and where applicable installing items such as vacuum and pressure valves on central storage tanks.

It is worth noting that these provisions are standard for the storage, handling and use of petrol and therefore do not represent a significant barrier to the use of ethanol–diesel blends.

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[24] Department of the Environment and Heritage. *Setting National Fuel Quality Standards: Discussion Paper on Diesohol*. Clean Fuels and Vehicles Section, Department of the Environment and Heritage, Australia, 2004. p.16.

[25] Akzo Nobel Surface Chemistry AB. *Bio-Ethanol Vehicles: Cleaner Exhaust Gas – Cleaner Air*. p.4.

[26] He, B. Q., Wang, J. X., Yan, X.G., Tian, X. and Chen, H. *Study on Combustion and Emission Characteristics of Diesel Engines Using Ethanol Blended Diesel Fuels*. State Key Laboratory of Automobile Safety and Energy, Tsinghua University, 2006.

[27] http://findarticles.com/p/articles/mi_m0CYH/is_22_6/ai_94765905

[28] Waterland, L.R., Venkatesh, S. and Unnasch, S. *Safety and Performance Assessment of Ethanol/Diesel Blends (E-Diesel)*. NREL, 2003. p.ES-1.

4.8 Reliability, Maintenance and Warranties

The question over the effect of the use of ethanol–diesel blends on engine reliability and on engine warranties is a key factor that will determine the likely market and the extent of their use. This issue is not particular to ethanol–diesel blends, but affects the use of all non-standard biofuels, i.e. diesel that does not meet the EN 590 diesel standard.

A trial of Akzo Nobel's eDiesel product on Scania engines showed no adverse impacts on engine oil and no special maintenance was required.

In general, engine manufacturers do not provide warranties for engines operating on non-standard fuels. This will obviously affect the market for non-standard biofuels in new engines, but, in theory, should not affect their use in engines where the warranty has expired. The typical period for an engine warranty is three years. As the average age of a goods vehicle fleet is estimated at six years,[29] there should remain a significant market for the use of non-standard fuels in vehicles. It is estimated that some 195 000 of the 286 000 goods vehicles in Ireland in 2006 were more than three years old, emphasising the extent of the potential market.

The reluctance of engine manufacturers to provide warranties for engines operating on biofuels has a knock-on effect on the willingness of fleet operators to use those fuels and it creates an impression of the effect on reliability.

The attitude of engine manufacturers to the use of ethanol–diesel blends varies, with companies such as Scania engaging actively in trials, indeed to the extent where Scania have gone further to move towards the development of a diesel cycle engine to run on 95% bioethanol. Similarily, Volvo are part of the E4D (Ethanol for Diesel) Consortium headed by Innovation Energy Environment (IFP), which has started an ambitious research and development programme on ethanol–diesel.

In contrast with this, Cummins are stridently opposing the use of ethanol–diesel blends in their engines[30] based on concerns over flammability and engine performance.

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[29] *Energy in Transport – Trends and Influencing Factors*, SEI EPSSU, 2006.

[30] *E-Diesel Effects on Engine Component Temperature and Heat Balance in a Cummins C8.3 Engine*, Mendoza and Woon, SAE Technical Papers, 2002.

5 Emissions

5.1 General

Much research has been carried out worldwide into the use of ethanol–diesel blends, or eDiesel. In general the conclusion of the research to date indicates that blends of up to 15% can be used without significant modification to engines, and indeed in certain cases without any modifications to engines. Research has further concluded that increases in engine efficiency somewhat offset the lower calorific value of the ethanol content and that significant reductions in NO_x, particulate, CO and SO_2 emissions are achieved. In contrast with this, both pure plant oil and biodiesel produce higher levels of NO_x emissions than diesel.[31]

The use of eDiesel has fewer environmental impacts than the use of diesel due to the substitution of a percentage of fossil fuels by a renewable fuel, thereby reducing net greenhouse gas emissions. The ethanol also oxygenates the fuel and slightly alters the combustion characteristics of diesel, which results in significantly reduced particulate matter and hydrocarbon, NO_x and CO emissions.

5.2 Trials

eDiesel has been tested around the world; Table 5.1 contains details of known trials.

5.3 Emissions

A number of life-cycle assessments, trials and emission-testing studies have been carried out and have published results. That CO_2 and particulate matter (PM) emissions are reduced is a universal conclusion of the studies, although the extent of emission reductions reported varied. The findings of the various studies on NO_x, CO and other emissions, although generally reporting emission reductions, also varied.

The reference fuels are: low sulphur diesel (which is defined as having 500 ppm sulphur content) and ultra low sulphur diesel (15 ppm sulphur) in the USA; and Euro IV diesel (with 50 ppm sulphur and ultra low sulphur diesel with a maximum of 10 ppm sulphur) in the EU.

Table 5.1 eDiesel Trials

Country	Date	Additive	Details
Denmark	Oct. 2001–May 2002	Akzo Nobel, Beraid	2x Scania Trucks (1 diesel, 1 eDiesel)
Rotterdam, Netherlands	2007	O2Diesel	Multiple buses (Bioethanol for Sustainable Transport -BEST project)15
Ireland	2001	O2Diesel	Unknown
La Spezia, Italy and Biofuel Region, Sweden	2007	Sekab, Etamix D3	Multiple buses (BEST project)[32]
Decatur, Illinois, USA	November 1998	Pure Energy, Puranol	4x Mack Trucks
Chicago	Unknown	Pure Energy, Puranol	15 eDiesel, 15 diesel buses (Chicago transit authority)
Unknown	2003	Lubrizol	Benchtesting on a diesel engine. Improper blends can wear pumps.
Curitiba, Brazil	Feb. 1998–May 1999	Ecomat, AEP102	2x Mercedes buses (each bus covered 100k km)
Australia and overseas	Unknown	Apace additive	Engine test cell and field trial evaluations with industry organisations

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[31] *Liquid Biofuels Strategy Study for Ireland*, December 2004, Report by Ecofys for Sustainable Energy Ireland.

[32] Ericson, Jonas. Sv: Vd: *Results of e-Diesel trials*. Personal email. 9 May 2007.

5.3.1 Smoke

Smoke, in this instance, refers to the visible component of emissions from vehicles and is measured using the Bosch smoke index. Studies have shown reductions in smoke emissions when using eDiesel in vehicles.

Figure 5.1 shows the smoke emissions from a 22 kW 2 cylinder diesel engine running on diesel and eDiesel blends. Reductions in smoke emissions are proportional to the concentration of ethanol in the blend. Smoke emissions and savings are greatest at medium to high powers at around 30%. Negligible savings were realised at low-power outputs.

In another study, a test of two buses in Curitiba, Brazil over seven months also showed a reduction in smoke emissions.[34]

Tests on two diesel engines (one 1.65 litre, 2 cylinder, 22 kW engine; and one 2 litre, 4 cylinder, 68 kW engine) showed that smoke opacity is 'generally reduced' and the reduction in visible smoke was greatest with higher ethanol blends. This reduction is relative to using a baseline diesel fuel with a sulphur content of 34 ppm.[35]

Afonso[36] refers to tests by the Colorado School of Mines and the California Air Resources Board, which found that eDiesel reduces smoke emissions by 50–70%.

Figure 5.2 summarises the study conclusion on smoke emissions.

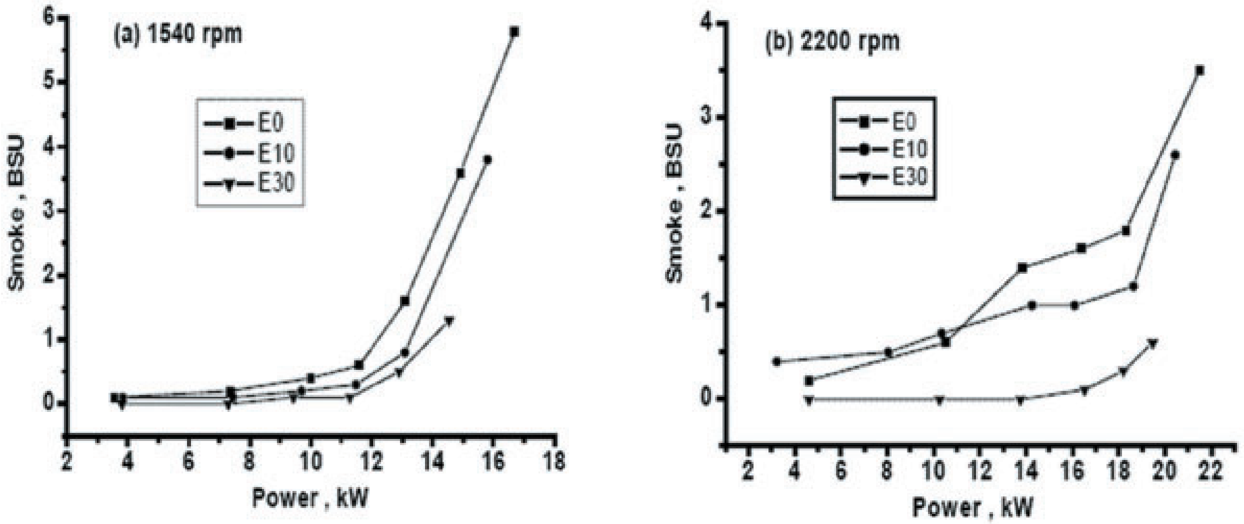

Figure 5.1 Bosch Smoke Index at Varying Blends, Power and Speed[33]

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[33] He, B. Q., Wang, J. X., Yan, X.G., Tian, X. and Chen, H. *Study on Combustion and Emission Characteristics of Diesel Engines Using Ethanol Blended Diesel Fuels*. State Key Laboratory of Automobile Safety and Energy, Tsinghua University, 2006.

[34] Laurindo, Jose Carlos. *Biodiesel and Diesohol Urban Buses Program Smoke Emissions and Performance*. 1998.

[35] Dominguez, J. I. and Miguel, E. 2004. *The Effects of Ethanol–Diesel Blended Fuels on the Performance and Emissions of Unmodified Diesel Engines*. 2004.

[36] Afonso, P. *Use of O2DieselTM Fuel in Sao Paulo City's Urban Fleet*. 2004.

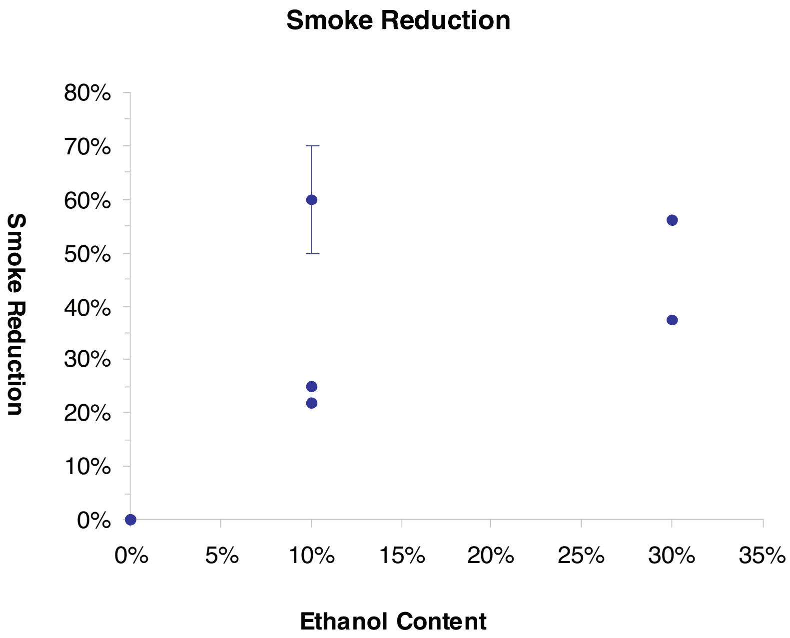

Figure 5.2 Smoke Reduction Study Review Results

5.3.2 *Particulates (PM_{10})*

Particulates are measured using the PM_{10} standard. This variable measures the mass fraction of particles with an aerodynamic diameter less than or equal to 10 μm, which are considered to be most likely to reach the lung and the most hazardous to human health.

Tests of the AAE, PEC and Betz Dearborn additives show a drop in PM emissions proportional to the concentration of ethanol, the blended fuel, as shown in Figure 5.3.

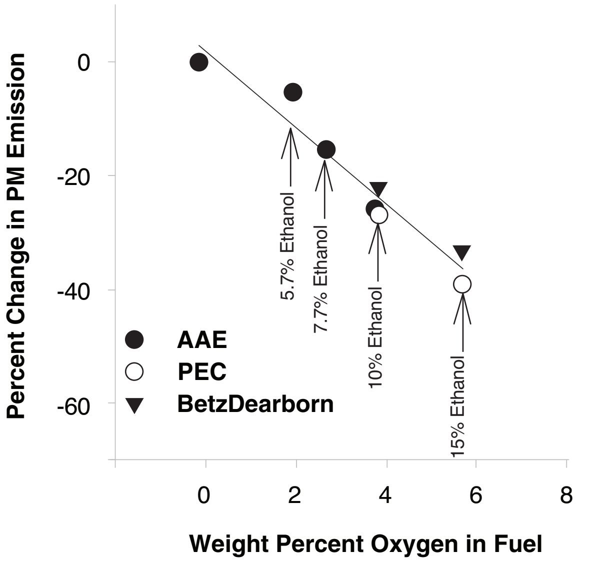

Figure 5.3 PM Reduction versus Oxygen[37]

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[37] McCormick, R. L. and Parish, R. *Technical Barriers to the Use of Ethanol in Diesel Fuel*. NREL, 2001.

A number of eDiesel studies have found a reduction in particulate emissions from the use of eDiesel. Beer[38] found that using 15% ethanol eDiesel reduced PM_{10} emissions from around 40 mg/MJ on Diesel to 30 mg/MJ. Other tests on a 160 kW, 5.9 litre Cummins engine[39] found a reduction in particulates of 20% and 30%, using 10% and 15% ethanol blends respectively, and a Betz Dearborn additive.

A study by Afonso on the emission reduction potential of eDiesel on Sao Paulo buses[40] noted a drop in PM (assumed to be equivalent to PM_{10} in the study) of 20–31% using the O2Diesel additive with ethanol and diesel. Löfvenberg[41] also found that using 10% ethanol with Akzo Nobel's Beraid additive reduced PM_{10} emissions by 31% from 0.13 g/kWh to 0.09 g/kWh.

In contrast, Wang et al.[42] showed that using eDiesel can increase total PM_{10} emissions, even if local PM_{10} emissions are reduced. This is particularly relevant where coal is used to make ethanol and additives. They found that using 10% and 15% ethanol eDiesel reduced local PM_{10} emissions from 0.23 g PM_{10}/mile (baseline diesel) to 0.19 (17% reduction) and 0.2 (13% reduction) respectively. However, total PM_{10} emissions increased from 0.45 g PM_{10}/mile (using baseline diesel) to 0.5 and 0.58 g PM_{10}/mile on 10% and 15% ethanol blends respectively. The rise in PM_{10} emission for 15% eDiesel shows there may be an optimum maximum blend.

The report noted that local PM_{10} emission reductions, combined with the rise in total emissions may not be sufficient to drive policy decisions. With the increasing focus on energy efficient biofuel production, an increasing use of natural gas and with coal supplying just 28% of Ireland's electricity in 2005, this study's conclusions may not apply to future use in Ireland. Additionally, PM_{10} emissions from remotely located power stations may impact less on human health than PM_{10} emissions emitted by vehicles on city streets.

Figure 5.4 summarises the local drops in PM_{10} emissions from eDiesel use.

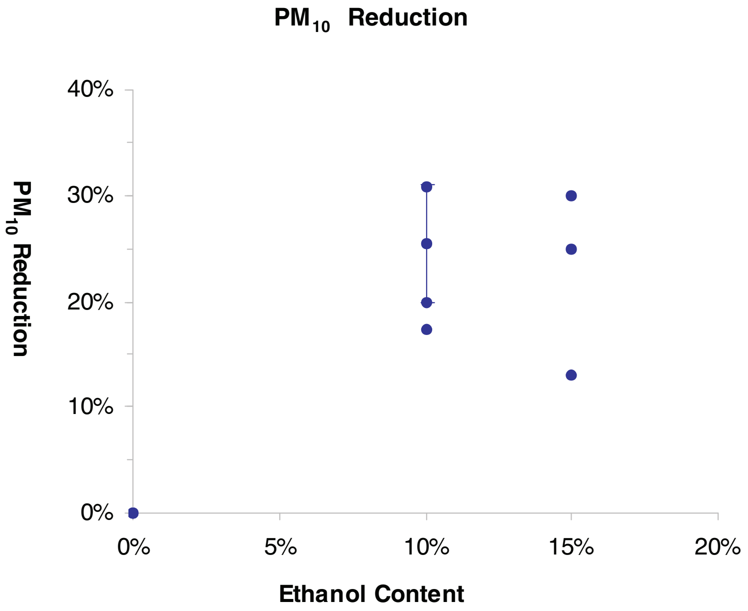

Figure 5.4 Local PM10 Reduction – Study Review Results

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[38] Beer, T. *Lifecycle Emissions Analysis of Alternative Fuels for Heavy Vehicles*. CSIRO.

[39] Kass, M. D., Thomas, F. T., Storey, J. M., Domingo, N., Wade, J. and Kenreck, G. *Emissions from a 5.9 liter Diesel Engine Fueled with Ethanol Diesel Blends.*

[40] Afonso, P. *Use of O2DieselTM Fuel in Sao Paulo City's Urban Fleet*. 2004.

[41] Löfvenberg, U. *E-diesel Demonstration Test in Denmark*. Akzo Nobel Surface Chemistry AB, 2002.

[42] Wang, M., Saricks, C. and Lee, H. *Fuel-Cycle Energy and Emission Impacts of Ethanol–Diesel Blends in Urban Buses and Farming Tractors*. 2003.

5.3.3 Carbon Dioxide (CO_2)

The method of producing ethanol can have a large affect on the entrained carbon dioxide. If ethanol is sourced from a renewable biomass source, eDiesel use reduces CO_2 emissions compared to pure diesel. However, a variety of crops may be used to create ethanol, and the amount of fossil fuels and fertilisers required to grow, harvest and convert these crops can vary by orders of magnitude.

The first generation biofuels that are currently in production have a relatively high energy and carbon intensity. For example, some processes using grains to produce bioethanol in the USA can consume more energy than is present in the final fuel. However improved energy efficiency in production processes is improving the energy payback. A study conducted by the EC Joint Research Centre (JRC), Concawe and Eucar[43] calculated all energy inputs and carbon emissions for a comprehensive range of European fuel options. This type of study is called a well to wheels (point of extraction to point of use) study.

The study shows that growing wheat and burning lignite to distil ethanol can emit more carbon than diesel would, emitting 209 g of CO_2 per km driven (for current model vehicles). In contrast, growing sugar beet and burning the pulp by-product for heat emits 68 g/km, and making ethanol from wheat straw emits just 22 g/km. However, wheat straw and sugar beet (and the land used to make them) have other commercial uses, and low-cost, low-carbon resources may be limited.

Of the second generation fuels, using hydrolysis and distillation to convert farmed wood to ethanol emits 50 g/km and offers a large-scale, low-carbon fuel option. It is however not commercially viable at present.

A life-cycle, well to wheels assessment by Apace Research in Australia[44] showed a reduction in net greenhouse gas emissions by almost 10% using a 15% ethanol–diesel blend. In a life-cycle assessment carried out for the Department of Trade and Industry in the UK,[45] CO_2 emissions of 0.029 kg/MJ for bioethanol (produced from wheat) and 0.087 kg/MJ for diesel are derived. For a 15% ethanol–diesel blend this equates to a CO_2 emissions of 0.82 kg/MJ, a 6% reduction compared to diesel.

Ireland's liquid biofuels strategy[46] contains well to wheels CO_2 emission rates for diesel and ethanol. A well to wheels study considers the whole emissions chain from fuel extraction to vehicle efficiency. However, the biofuels strategy document did not contain details of upper and lower values. As a point of comparison, the JRC Eucar well to wheels study calculates the carbon emissions from a range of fuels and biofuels in detail. The current (and upper) emissions case for diesel is for 2002 vehicles and the lower case is estimated for vehicles in 2010.

For the purpose of assessing CO_2 emissions savings yielded through using eDiesel, we assume that the ethanol is produced from wheat stream. We have further assumed that natural gas is burnt for process heat in a conventional boiler and that dried distillers grains and solubles (DDGS), a by-product of ethanol manufacture, are sold for animal fodder. This is the likely outcome given the current economics. The well to wheels carbon emissions for this scenario are 125 g CO_2/km.

Figure 5.5 shows the range of CO_2 emissions reported in the JRC Eucar study, with the upper range representing 195 g CO_2/km and the lower range 36 g CO_2/km. The well to wheels CO_2 emissions reported in *Liquid Biofuels Strategy Study for Ireland* (Hamelinck , 2004) are also shown in Figure 5.5. The upper range represents 180 g CO_2/km, the lower range 55 g CO_2/km and the emission rate shown in the graph of Figure 5.5 represents 75 g CO_2/km.

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[43] Edwards, R., *Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context*. Concawe, Eucar, JRC, 2007. p.2.

[44] Personal Communication, Dr Russell Reeves, Apace Research.

[45] *Carbon and Energy Balances for a Range of Biofuels Options*, Sheffield Hallam University, 2003.

[46] Hamelinck, C. *Liquid Biofuels Strategy Study for Ireland*. Sustainable Energy Ireland, 2004. p.31.

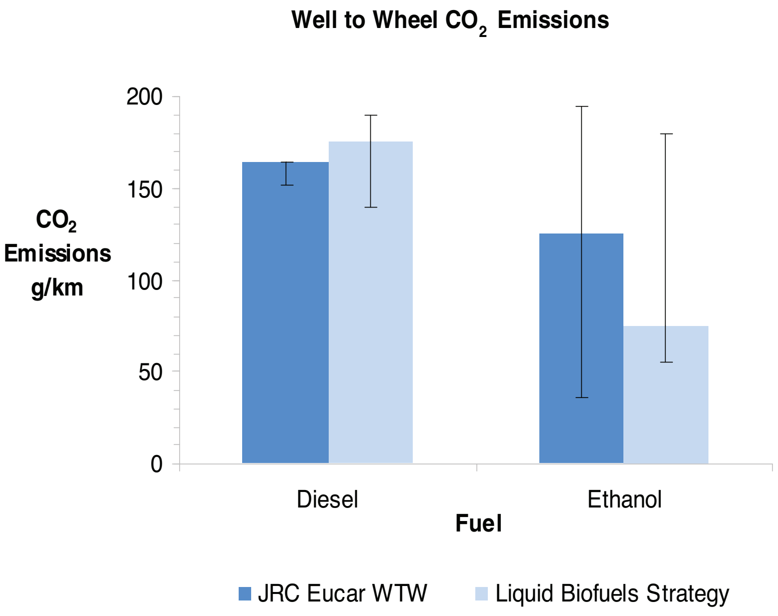

Figure 5.5 Well to Wheels CO_2 Emissions

Figure 5.6 shows CO_2 emissions reduction estimates with increasing ethanol concentration, assuming that the fuel additive has the same CO_2 intensity as diesel, based on the diesel and ethanol emission rates shown in Figure 5.5 and described previously.

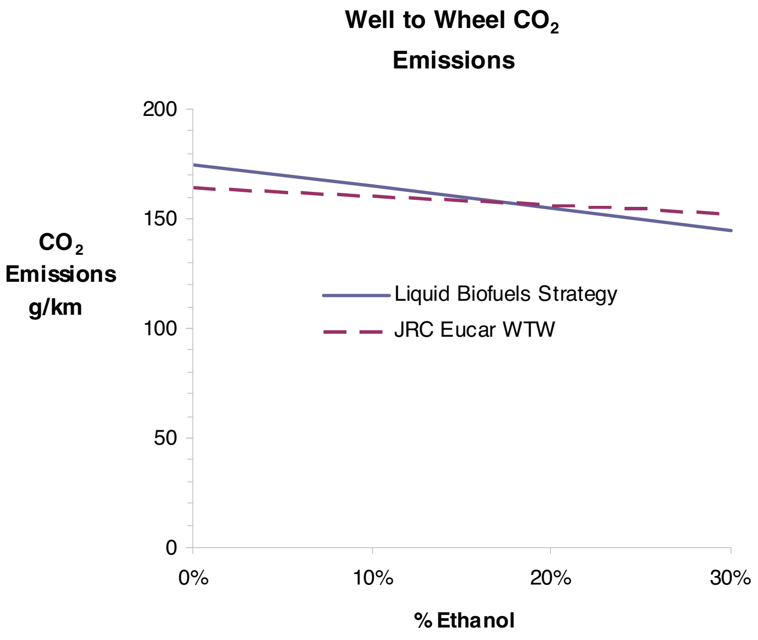

Figure 5.6 CO_2 Emissions versus Ethanol Concentration

Therefore, given the large possible range of energy and carbon balances, and the differing quality and environmental standards around the world, it is important to consider the energy and carbon balances of the production and use of ethanol, both within Ireland and overseas, when considering the environmental benefits of the use of bioethanol. However, it is worth noting that this is true of biofuels in general and is not restricted to bioethanol.

Ethanol produced from sugar cane has a low carbon intensity, but is obviously not suited to the Irish climate. Sugar beet is also a carbon effective feedstock although the carbon intensity of ethanol produced from sugar beet is higher than that from sugar cane.

5.3.4 Carbon Monoxide (CO)

A literature review shows conflicting conclusions on the effect of ethanol on CO emissions, with sources reporting large (50%) increases, large (15–35%) decreases and others showing little effect.

Cole[47] showed that CO emissions from a 10% ethanol blend (4 g CO/kWh) were 35% less than for diesel (6.2 g/kWh). Emissions from 15% ethanol blends (5.7 g CO/kWh) were 8% less. The tests also showed that CO is emitted at low engine torques, and emissions were at or below 1 g CO/kWh when the torque was above 100 Nm.

Similarly, Pantar and Corkwell[48] reported a 9% reduction in CO emissions (if the cetane number is kept equivalent), using the Lubrizol additive with 10% ethanol.

Rodríguez[49] reports a slight drop (2.5%) in CO emissions from 0.8 g CO/km on the baseline diesel to 0.78 g CO/km using a 10% ethanol blend.

McCormick and Parish's 2001[50] study of three additives with 10% ethanol showed a 15–20% drop in CO emissions for AAE (now O2Diesel) and PEC additives. The Betz Dearborn eDiesel blend produced a small rise in CO, but this is still an order of magnitude below US emission standards for heavy duty engines.

A study by Löfvenberg[51] using 10% eDiesel reported CO emissions of 0.47 g/kWh, a 28% reduction compared to 100% ultra low sulphur diesel (0.65 g/kWh).

Wang[52] reported a 20–25% reduction in CO emissions using a 10% ethanol blend.

Tests by Kass[53] on a 160 kW 5.9 litre Cummins engine showed a significant increase in CO emissions. Where CO emissions from baseline diesel were 1.0 g/hp-h the emissions using 10% ethanol rose to 1.5–1.6 and 1.4–1.5 with 15% ethanol. The report also noted that these were still below the US Environmental Protection Agency's requirements and could be mitigated with oxidation catalysts.

In evaluating emissions in Sao Paulo, Afonso (2004) assumed a drop in CO from 12% to 23%; these figures were supplied by the makers of the O2Diesel additive.

Figure 5.7 summarises the findings of the literature study in relation to the effect of ethanol blends on carbon monoxide emissions.

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[47] Cole, R.L., Poola, R.B. Sekar, R., Schaus, J.E. and McPartlin, P. *Effect of Ethanol Fuel Additive on Diesel Emissions*. Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2000. p.23.

[48] Pantar, A.V. and Corkwell, K.C. *E Diesel: A Viable Alternative Fuel*. 2003.

[49] Rodríguez, Jose C. *Life-cycle Assessment of Wood-Based Ethanol–Diesel Blends (E-Diesel)*. 2003.

[50] McCormick, R.L. and Parish, R. *Technical Barriers to the Use of Ethanol in Diesel Fuel*. NREL, 2001.

[51] Löfvenberg, U. *E-diesel Demonstration Test in Denmark*. Akzo Nobel Surface Chemistry AB, 2002.

[52] Wang, M., Saricks, C. and Lee, H. *Fuel-Cycle Energy and Emission Impacts of Ethanol–Diesel Blends in Urban Buses and Farming Tractors*. 2003. p.20.

[53] Kass, M.D., Thomas, F.T., Storey, J.M., Domingo, N., Wade, J. and Kenreck, G. *Emissions from a 5.9 liter Diesel Engine Fueled with Ethanol Diesel Blends.*

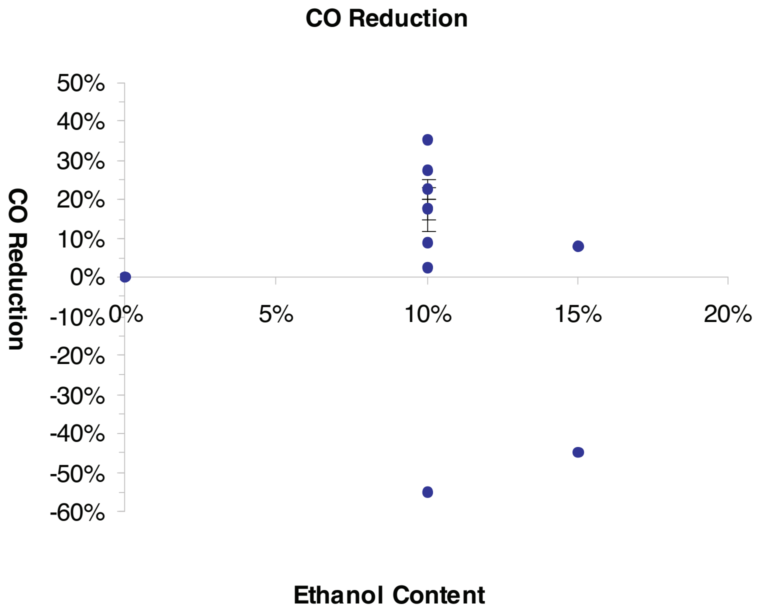

Figure 5.7 CO Reduction Study Review Results

5.3.5 Total Hydrocarbons (THC)

Results for the effect of eDiesel tend to increase total hydrocarbon (THC) emissions range from no increase to a doubling in THC emissions.

Kass[54] reports an increase in THC emissions of 50–100% from 0.2 g/h.p.h in the baseline diesel to 0.40–0.42 with 10% ethanol, and 0.34–0.36 with 15% ethanol.

Cole (2000)[55] shows 33% (7.2 g/h) and 4% (5.6 g/h) rise in THC emissions for 10% and 15% eDiesel blends respectively compared with 5.4 g/h for diesel during engine idle.

Löfvenberg (2002)[56] noted a 13% rise in THC from 0.35 g/kWh for ultra low sulphur diesel, to 0.39 g/kWh for 10% eDiesel.

Dominguez and Miguel (2004)[57] state a 'slight to moderate' rise in THC emissions compared with baseline diesel.

Pantar and Corkwell (2003)[58] noted a 6% increase in THC from diesel to 10% eDiesel if the cetane number is kept equivalent. THC emissions are higher if the cetane number is lower.

Beer[59] reported no change in emissions, with THC emissions from the low sulphur diesel and 15% eDiesel both around 0.15 g /MJ.

Figure 5.8 summarises the effect of eDiesel use on THC emissions.

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[54] Afonso, P. *Use of O2Diesel™ Fuel in Sao Paulo City's Urban Fleet*. 2004.

[55] Cole, R.L., Poola, R.B. Sekar, R., Schaus, J.E. and McPartlin, P. *Effect of Ethanol Fuel Additive on Diesel Emissions*. Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2000.

[56] Löfvenberg, U. *E-diesel Demonstration Test in Denmark*. Akzo Nobel Surface Chemistry AB, 2002.

[57] Dominguez, J. I. and Miguel, E. *The Effects of Ethanol–Diesel Blended Fuels on the Performance and Emissions of Unmodified Diesel Engines*. 2004.

[58] Pantar, A.V. and Corkwell, K.C. *E Diesel: A Viable Alternative Fuel*. 2003.

[59] Beer, T. *Lifecycle Emissions Analysis of Alternative Fuels for Heavy Vehicles*. CSIRO.

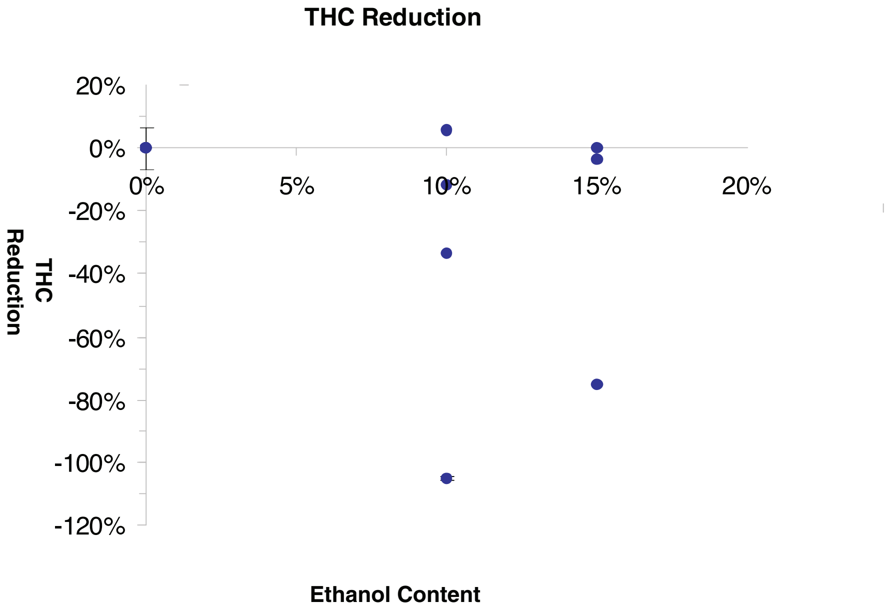

Figure 5.8 THC Reduction Study Review Results

5.3.6 Nitrogen Compounds (NO_x)

Most studies found that using eDiesel led to a reduction in NO_x emissions, of 1–10%. Rodríguez (2003)[60] noted a 1% reduction in NO_x using 10% ethanol. Afonso (2004) noted a drop in NO_x of 1.6–3% using 10% ethanol.[61]

Beer[62] reported NO_x emissions of 1.02 g NO_x/MJ from low sulphur diesel compared to 0.98 g NO_x/MJ with a 15% ethanol blend, equivalent to a 4% reduction.

Löfvenberg (2002) noted a 5% reduction in NO_x from 6.53 g/kWh on ultra low sulphur diesel to 6.19 g/kWh with 10% eDiesel.

Cole (2000)[63] had mixed results, with 10% ethanol reducing emissions by around 10%. However, with 15% ethanol, NO_x emissions rose at low torques, with significant reductions at high torques, as shown in Figure 5.9.

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[60] Rodríguez, Jose C. *Life-cycle Assessment of Wood-Based Ethanol–Diesel Blends (E-Diesel)*. 2003.

[61] Afonso, P. *Use of O2Diesel™ Fuel in Sao Paulo City's Urban Fleet*. 2004.

[62] Beer, T. *Lifecycle Emissions Analysis of Alternative Fuels for Heavy Vehicles*. CSIRO.

[63] Cole, R.L., Poola, R.B. Sekar, R., Schaus, J.E. and McPartlin, P. *Effect of Ethanol Fuel Additive on Diesel Emissions*. Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2000.

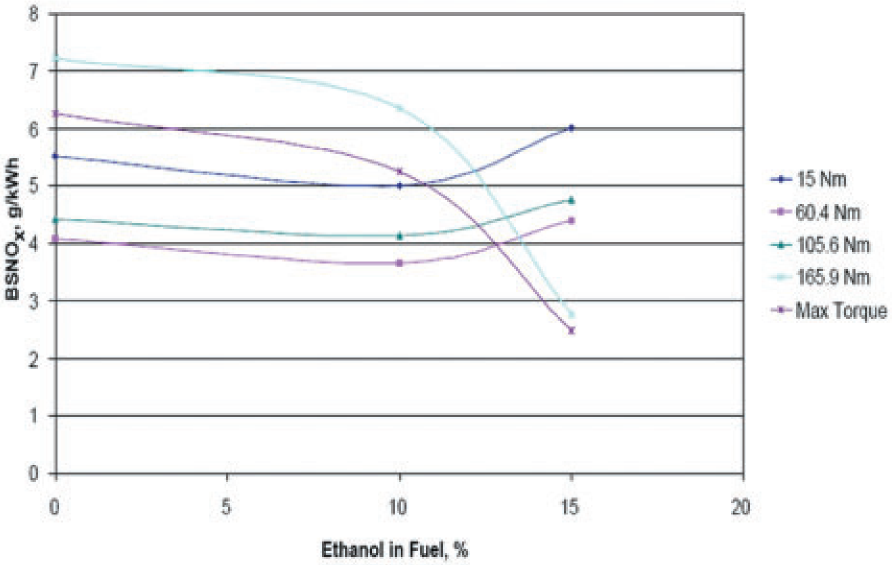

Figure 5.9 Effect of Ethanol Content on NO$_x$ at 1500 rpm[64]

Pantar and Corkwell (2003)[65] found NO$_x$ emissions increased by 12–25% with 10% ethanol, when the cetane number was kept as standard, or by 20% when the cetane number was lowered.

However, there are some exceptions worth noting. McCormick and Parish (2001)[66] in their literature review stated that studies of NO$_x$ are not conclusive, with developers claiming large reductions in NO$_x$ and other studies showing there is little effect.

Figure 5.10 summarises the effect of eDiesel blends on NO$_x$ emissions.

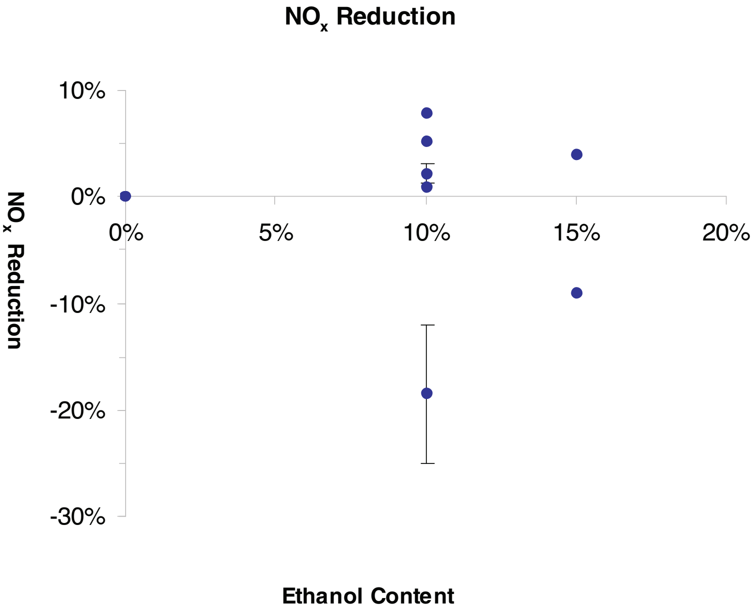

Figure 5.10 NOx Reduction Study Review Results

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[64] Cole, R.L., Poola, R.B. Sekar, R., Schaus, J.E. and McPartlin, P. *Effect of Ethanol Fuel Additive on Diesel Emissions*. Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, 2000.

[65] Pantar, A.V. and Corkwell, K.C. *E Diesel: A Viable Alternative Fuel*. 2003.

[66] McCormick, R.L. and Parish, R. *Technical Barriers to the use of Ethanol in Diesel Fuel*. NREL, 2001.

5.3.7 Ethanol, Acetaldehyde and Formaldehyde

Acetaldehyde and formaldehyde, products of incomplete burning in both petrol and diesel engines, are carcinogens and a contributor to smog. They are also a possible emission with eDiesel fuel.

Tests[67] show an increase in acetaldehyde emissions of 75–175% with 10% and 30% ethanol respectively, reporting emissions of 20 ppm from the baseline diesel, 35 ppm from 10% ethanol and 55 ppm from 30% ethanol.

Tests on formaldehyde emissions show no difference between baseline diesel and 10–30% ethanol blends, with both reporting emissions of 120 ppm.

In the same study ethanol emissions are reported as 0 ppm in the baseline fuel, 40 ppm with 10% ethanol and 110 ppm with 30% ethanol.

Other tests[68] using 10% and 15% ethanol blends found that acetaldehyde and formaldehyde emissions were below 10 ppm and raw ethanol emissions were below 20 ppm for all the fuels trialled.

Under current EU Euro IV vehicle air pollution regulations, the hydrocarbon emission limit from heavy duty diesel engines is 0.46 g/kWh. The effect of ethanol blending on these emissions is therefore significant but can be controlled by using oxidation catalysts. The use of catalytic converters on large diesel vehicles has been standard since the implementation of the Euro IV emission standards in 2005 and is now virtually standard in new vehicles.

5.4 Emissions Standards

EU directives set emission standards and test procedures for diesel engines. They are commonly referred to as the Euro I, Euro II, Euro III, Euro IV and Euro V standards, and increasingly stringent standards have been applied to new vehicles.

Directive 70/220/EEC was the first directive regulating light duty (<3.5 tonne 'technically permissible maximum laden mass') vehicles. This directive was amended a number of times, some of the most important amendments including Directive 91/441/EEC (Euro 1), Directives 94/12/EC (Euro 2) and Directive 98/69/EC (Euro 3 and 4). COM (2005) 683 contains proposed emission standards (Euro 5).

In 2005, the regulations were recast and consolidated by Directive 05/55/EC. The emission standards apply to all motor vehicles with a 'technically permissible maximum laden mass' over 3500 kg, equipped with compression ignition engines or positive ignition natural gas or LPG engines.

The first EU directive to regulate emissions from heavy vehicles (road vehicles heavier than 3.5 tonnes), came in 1988 (88/77/EEC). The Euro I and Euro II standards for medium and heavy engines were introduced by Directive (91/542/EC). Directive 1999/96/EC was adopted in 1999 giving standards for Euro III, Euro IV and Euro V which were scheduled to take effect in 2000, 2005 and 2008 respectively.

These directives apply to new vehicles, and compliance is demonstrated in accordance with the directives by type testing of the engines by manufacturers.

For vehicles in use, there is legislation on periodic inspections at which the state of maintenance of the vehicle is checked (Directive 96/96/EC as adapted by Directive 2003/27/EC). These directives are transposed into national legislation by S.I. 771/2004 European Communities (Vehicle Testing) Regulations.

Measuring exhaust gas opacity is part of the required inspections. Directive 72/306/EEC sets a requirement for type testing and labelling, and stipulates measures to be taken against emissions from motor vehicle diesel engines. Compliance with Directive 96/96/EC is

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[67] He, B. Q., Wang, J. X., Yan, X.G., Tian, X. and Chen, H. *Study on Combustion and Emission Characteristics of Diesel Engines Using Ethanol Blended Diesel Fuels*. State Key Laboratory of Automobile Safety and Energy, Tsinghua University, 2006.

[68] Kass, M. D., Thomas, F. T., Storey, J. M., Domingo, N., Wade, J. and Kenreck, G. *Emissions from a 5.9 liter Diesel Engine Fueled with Ethanol Diesel Blends.*

demonstrated if the coefficient of absorption does not exceed the level recorded on the plate pursuant to Directive 72/306/EC, or:

- 2.5 m^{-1} for naturally aspirated engines.
- 3.0 m^{-1} for turbo charged diesel engines.
- 1.5 m^{-1} for engines that have been type approved according to Euro IV or Euro V.

The *Vehicle Testers Manual for Heavy Commercial Vehicles* (Department of Transport, 2004) defines limits of 2.5 m^{-1} in the case of naturally aspirated diesel engines, 3.0 m^{-1} in the case of turbo charged diesel engines registered before July 2008, and an average smoke reading of 1.5 m^{-1} for engines registered after July 2008.

6 Market Analysis

6.1 Introduction

An eDiesel information sheet and a questionnaire were sent to 81 companies to determine the extent of centrally fuelled captive fleets and the potential market for eDiesel. A copy of the information sheet is contained in Appendix A and a copy of the questionnaire is contained in Appendix B. The 81 companies contacted represented 71 separate organisations as a result of consolidation and acquisition.

The organisations are broken down in Table 6.1 by category and by the criteria used to select the organisations.

6.2 Responses

Initial contact made at CEO/MD level provided a poor response rate. Follow-up phone calls and emails improved the overall response rate to 33 organisations, or 45% of the organisations surveyed. The response rate from local authorities was highest, followed by transport, waste and logistics, with a poor response rate from the concrete/cement sector and a zero response rate from general fleet operators. Table 6.2 summarises these responses.

Table 6.1 Organisations Surveyed

Sector	Criterion	Number of Organisations
Building materials	>100 employees	7
General fleet	Selected companies	4
Local authority	All local authorities	34
Logistics	>200 employees	6
Transport	>100 employees	7
Waste	>100 employees	13
Total		**71**

Table 6.2 Responses from Organisations Surveyed

Sector	Number of Responses	Operate Own Fleet	Central Fuel Storage	Total Fuel Consumption (000 litres)
Building materials	2	2	2	27 600
General fleet	0	-	-	-
Local authority	20	20	15	10 800
Logistics	4	2	1	12 000*
Public passenger services	3	3	3	69 600
Waste	4	3	3	3 220
Total	**32**	**29**	**23**	**103 220**

* Companies that did not operate their own fleets did not provide estimated fuel consumption.

6.3 Fuel Consumption

There is a significant variation in fuel use in local authorities (see Figure 6.1), who responded to the survey as would be expected given the variation in size of local authorities. In an attempt to determine a basis for the variation, the fuel consumption per employee for each local authority is graphed against the number of employees in Figure 6.2. There remains a significant, albeit lesser, variation in the fuel consumption per employee in each local authority. Although not evaluated quantitatively, there is a noticeable trend that the fuel consumption per employee is higher in the more geographically dispersed counties.

The average fuel consumption per employee in local authorities is 517 litres per employee per annum. Using this average to estimate the fuel consumption in the 13 local authorities that did not respond to the questionnaire gives a total estimated fuel consumption in local authorities of 15.3 million litres per annum.

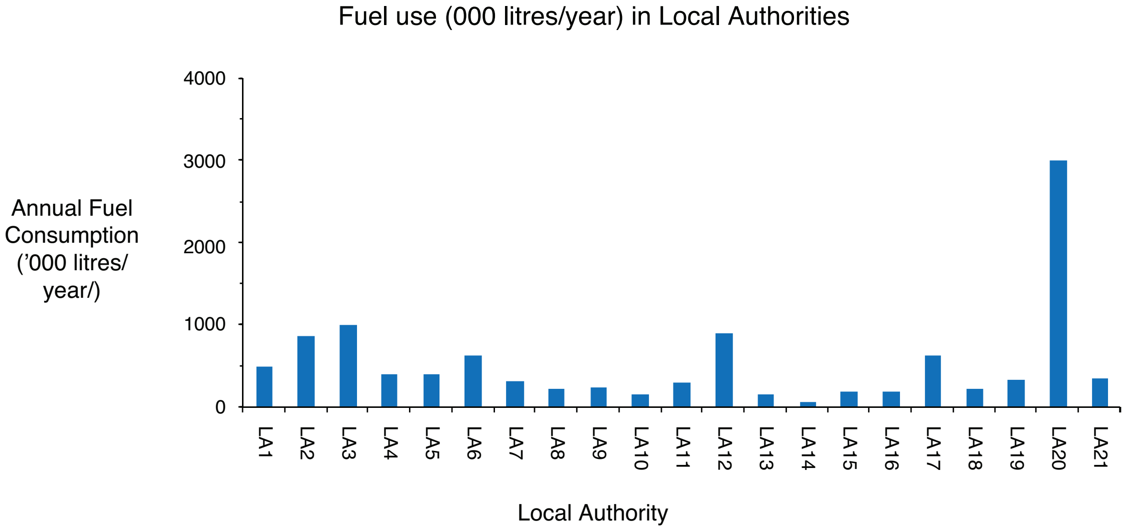

Figure 6.1 Local Authority Fuel Consumption

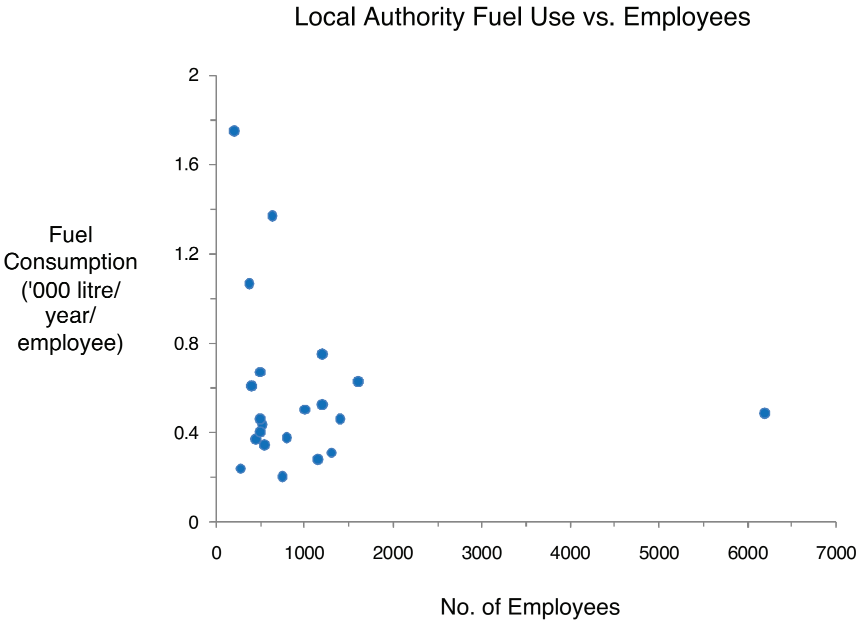

Figure 6.2 Local Authority Fuel Use versus Number of Employees

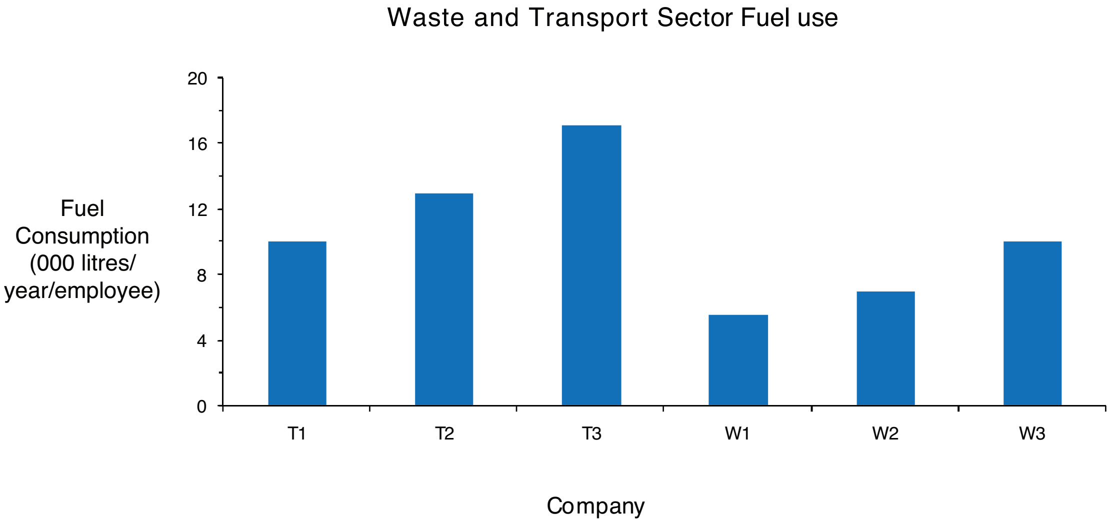

Figure 6.3 Waste and Transport Sector Fuel Use

Although representing a smaller sample, a similar analysis of fuel consumption per employee in the waste and transport sectors indicates that the fuel consumption per employee in each sector is generally of a similar magnitude, as Figure 6.3 illustrates. Using the average fuel consumption per employee in each sector yields an estimated consumption of 20.2 million litres per annum in the waste sector and 74.4 million litres per annum in the transport sector.

The response rates from other sectors were not sufficient to allow estimates of overall fuel consumption to be made.

However, the reported fuel usage in the concrete/cement/aggregates (CCA) sector was very high.

A total (estimated) 110 million litres of diesel transport fuel is used in the transport and waste sectors and in local authorities each year. The breakdown by sector is shown in Figure 6.4. It should be noted that the fuel consumption is an estimated total based on extrapolating the use in the companies that responded. Due to the low response rate in the building materials sector, it was not possible to extrapolate the survey results for this sector. The fuel consumption in this sector may be as high as 800 million litres per annum as discussed below.

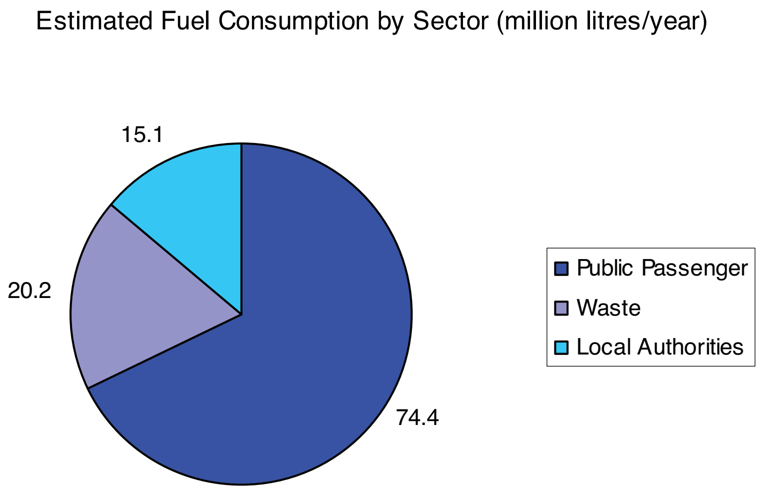

Figure 6.4 Fuel Consumption by Sector

This data accords reasonably well with data contained in *Liquid Biofuels Strategy Study for Ireland* (Hamelinck, 2004), which cites an estimated 2.04 PJ of fuel consumption in Bus Eireann and Dublin Bus. This equates to just over 55 million litres of diesel (assuming a calorific value of 43.3 MJ/litre and a density of 0.845 kg/litre). The estimated consumption in passenger transport of 74.4 million litres includes the consumption in the two large bus companies.

The energy used for public passenger services in Ireland in 2005 is estimated at 131 ktoe (*Energy in Transport: Trends and Influencing Factors – 2006 Report,* SEI EPSSU), which corresponds to 148 million litres per annum. The discrepancy between the estimated 74.4 million litres per annum in the companies surveyed and this larger figure is attributable to a number of smaller, public passenger operators and the inclusion of taxis and hackneys in this sector. This is not considered to be an underestimate of the potential market for ethanol–diesel blends in captive fleets as smaller companies are generally less receptive to biofuels and are less likely to operate a centrally fuelled fleet.

The 110 million litres per annum that comprises use in the sectors identified in the study as being those most likely to operate a captive fleet and hence the most suitable for biofuels is a small proportion of the overall diesel consumption for road freight, public services and other uses of 72 PJ or approximately 2 billion litres per annum.

The total fuel consumption for road freight is extremely large at 1218 ktoe (*Energy in Transport: Trends and Influencing Factors – 2006 Report*, SEI EPSSU) or 1.38 billion litres per annum. Very little of this was captured in our survey of the general fleet, waste, logistics and building materials sectors.

Response rates ranged from zero responses from general fleet operators to a small response from the logistics sector to low responses from the building materials sector. In addition, many logistics companies do not own their vehicles.

From discussions with general fleet operators and logistics companies we gained an impression that these sectors do not generally operate centrally fuelled fleets, and where companies do operate their own fleets, they primarily refuel at general forecourts.

A significant proportion of road freight in Ireland is accounted for by building materials. The group ‘crude and manufactured minerals, building materials’ accounted for 62% of the total weight of goods carried in 2005 (*Road Freight Transport Survey 2006*, Central Statistics Office). While this percentage cannot be directly translated into fuel consumption, it indicates that this sector may account for usage of about 800 million litres of diesel per annum. The nature of the companies engaged in the sector could not be quantified; and while there are large companies active, it is also reasonable to believe that there are many smaller operators servicing the building materials market.

Our survey responses reflect the significance of this potential market for ethanol–diesel blends, where the two respondents have a fuel usage of over 27 million litres per annum and have central fuelling facilities.

6.4 Attitude To and Use of Biofuels

The survey responses and subsequent phone conversations with the respondents demonstrated that there is, in general, a positive attitude towards the use of biofuels among the respondents. It is difficult to extrapolate this to the organisations that did not respond as it is considered more likely that those with a positive attitude to biofuels would have responded to the survey.

Table 6.3 summarises the responses by sector. A significant number (35%) of respondents are using, or trialling the use of, biofuels at present. While the quantities of biofuels were not recorded as part of the survey, follow-up phone conversations tend to indicate that companies who are using biofuels do so at a small scale, with trials of PPO, diesel–biodiesel blends and 100% biodiesel taking place on a selected number of vehicles rather than a full, wide scale deployment of biofuels.

Table 6.3 Responses from Organisations Surveyed

Sector	Number of Responses	Use or Have Used Biofuels	Would Consider Using Biofuels	Would Consider Trialling eDiesel
Building materials	2	2	2	2
General fleet	0	–	–	–
Local authority	20	8	19	12
Logistics/Hauliers	4	0	1	0
Public passenger	3	2	2	1
Waste	4	0	3	2
Total	**33**	**12**	**27**	**17**

Figure 6.5 shows the breakdown of biofuels used by companies that responded to the survey. The main fuel used is PPO, followed by biodiesel, and two organisations were running vehicles both with PPO and biodiesel.

The largest usage of biofuels was recorded in local authorities, with eight out of the 20 respondents using biofuels. A positive attitude to biofuels in the building materials and public passenger sectors is also evident, with the majority of organisations in these sectors using biofuels.

In the logistics and waste sectors there is a very low usage of biofuels which was largely attributed to cost and maintenance considerations. In particular, operators of general freight vehicles expressed concerns over engine warranties and the likelihood of breakdowns. A number of the operators spoken to said that their vehicles travelled long distances and are away from the depot for weeks at a time, and breakdowns are very costly. A widely held view was that they would use biofuels when widely available and mandated by the government and, possibly most importantly, when engine manufacturers provide warranties for engines using biofuels.

In general, most organisations that responded said that they would consider using biofuels in vehicles, with the exception of the logistics/haulier sector, where there is a reluctance to use biofuels for the reasons stated above.

Seventeen of the 27 (63%) companies who expressed a willingness to use biofuels said that they would consider using ethanol–diesel blends, with the remaining 10 saying that they would consider using eDiesel when more information was provided or when it is demonstrated in the Irish market.

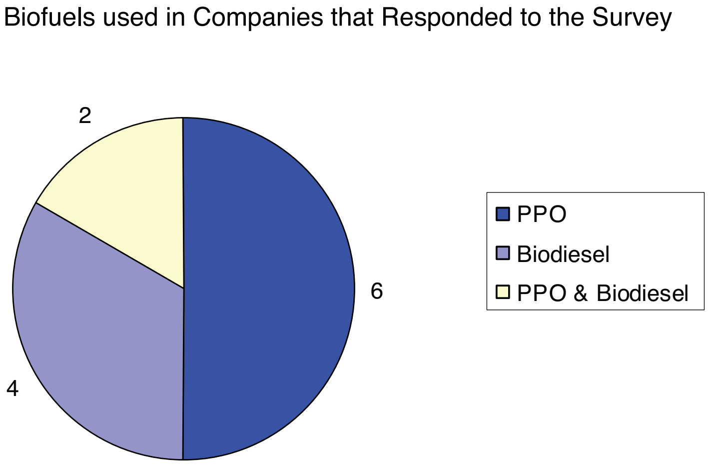

Figure 6.5 Biofuels Used by Survey Respondents

6.5 Emissions

A reduction in smoke, particulate and NO_x emissions from engines using eDiesel is a major benefit of the technology from the perspective of air quality and national emissions inventories. However, only one (a local authority) of the 33 respondents said that emissions from their vehicles are a consideration. This is due to the type testing regime for the Euro emission standards and the fact that the majority of newer vehicles easily pass the annual emissions test carried out on vehicles in Ireland.

7 Economics

7.1 General

The cost of ethanol–diesel blends will be determined by:

- The cost of diesel.
- The cost of bioethanol.
- The cost of the blending agent.
- The cost of blending facilities.

As blending facilities are inexpensive, typically consisting of a small skid with pumps and a dosing pump, this cost will be a minor factor in determining the cost of eDiesel. Accurate costs for the blending agent were not obtained from potential suppliers due to their caution in divulging commercial information, but typical costs in the order of €0.05–0.01/litre were cited.

The cost of eDiesel is therefore primarily determined by the cost of diesel fuel and the cost of bioethanol.

Figure 7.1 shows that the cost of Diesel Engine Road Vehicle (DERV) fuel has increased steadily in recent years, with interim fluctuations, from 83 c/litre in January 2003 to 117.5 c/litre in July 2007.[69] The cost of 117.5 c/litre comprises a diesel cost of 60.3 c/litre, excise at 36.8 c/litre and 20.4 c/litre VAT.

Bioethanol is an internationally traded commodity, with production being led in Brazil and the USA, where the bioethanol market has been led by the replacement of MTBE by bioethanol as an oxygenate. In the EU, bioethanol production has been steadily increasing as a substitute for fossil fuels: production increased ninefold from 60 million litres in 1993 to 526 million litres in 2004.[70]

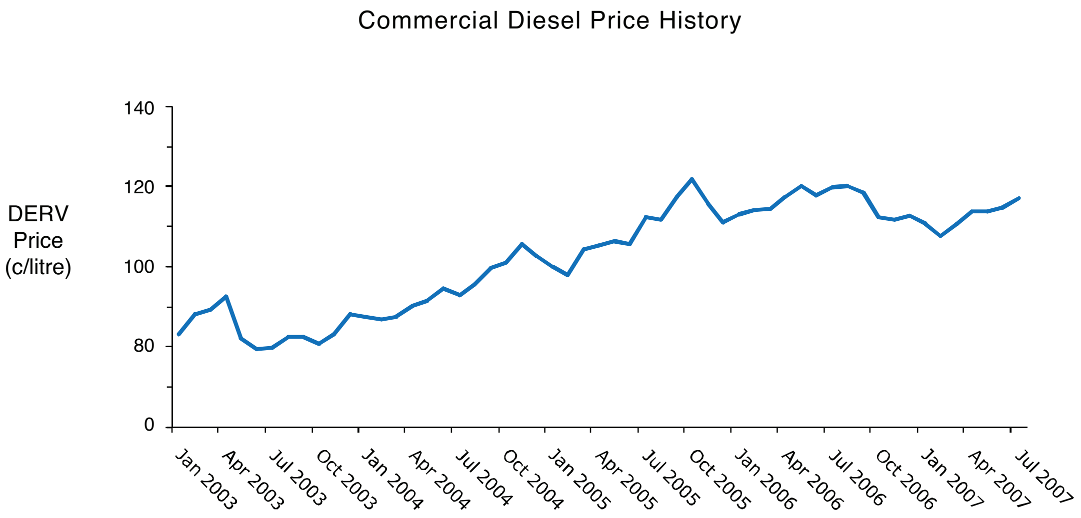

Figure 7.1. Commercial Diesel Price History

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[69] http://www.maxol.ie

[70] Robert Vierhout, European Bioethanol Fuel Association, World Ethanol 2005.

The production cost of bioethanol depends on the particular feedstock used, transport costs for the feedstock and the production process used. There are a range of potential feedstocks for the production of bioethanol in Ireland including sugar beet, wheat and residues (such as the whey used to produce bioethanol by the Carbery Group). The typical cost of delivered bioethanol, excluding excise duty and VAT, is €0.74/litre which compares to typical biodiesel delivery costs of €0.80/litre.[71] An alternative estimated production cost of €0.685 for indigenously produced ethanol from sugar beet was calculated based on a beet cost of €52.50/t.[72]

Fuel ethanol costs from Rotterdam and from Brazil are recorded by ICIS and varied from 27 c/litre to 33 c/litre FOB Brazil and 53 c/litre to 60 c/litre FOB Rotterdam.

Ethanol production costs in Brazil are significantly lower than those in Ireland or the EU. However, when transport costs and import duty are accounted for, the cost rises significantly. When these costs, together with storage, handling and distribution costs are included the estimated cost of bioethanol from Brazil is €0.68/litre, which compares with estimated costs from Rotterdam of €0.82/litre.[73] The cost for ethanol produced from waste paper ranges from €0.20/litre to €0.31/litre, indicating the large potential for second generation bioethanol to provide a cost effective alternative to mineral oils.

The cost of bioethanol therefore exceeds the current diesel cost of €0.60/litre, and eDiesel using bioethanol from whatever source is more expensive than diesel before excise duty and VAT are included. Figure 7.1 shows the cost of diesel and the cost of eDiesel for different bioethanol cost and excise duty combinations. For a bioethanol cost of €0.74/litre, with no excise relief, eDiesel 15 is 2.3% more expensive than diesel, whereas with excise exemption with €0.68/litre bioethanol it is 4.5% cheaper. The relative cost of eDiesel is therefore most sensitive to the application of, or otherwise, excise duty on the bioethanol.

Therefore, in the absence of excise relief, eDiesel is more expensive than diesel fuel, but in a biofuel obligation scenario it is competitive with other biofuel alternatives.

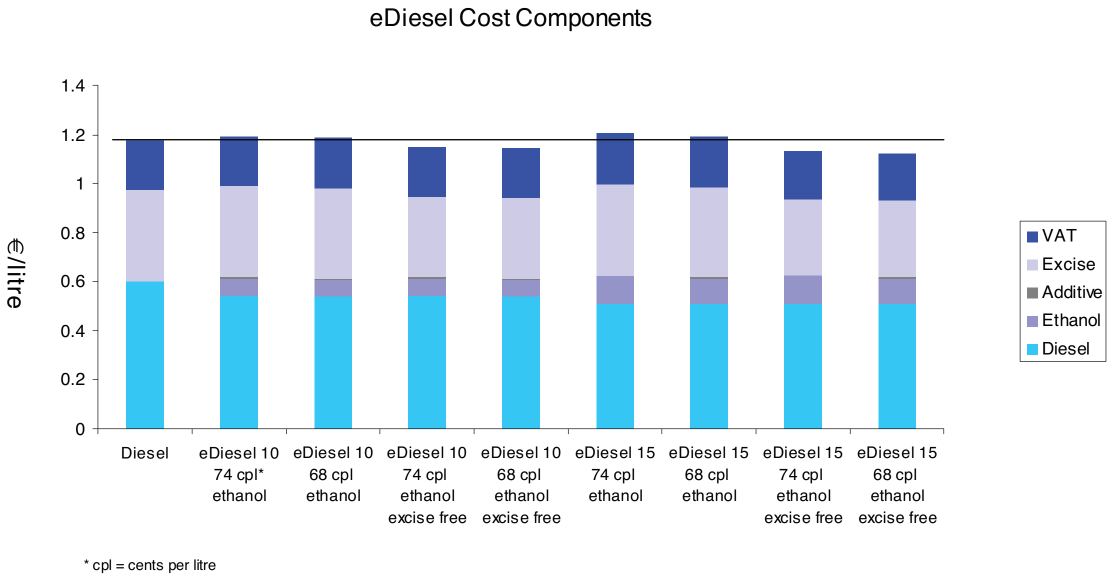

Figure 7.2 eDiesel Costs

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[71] Liquid Biofuels Strategy Study for Ireland, December 2004, report by Ecofys for Sustainable Energy Ireland.

[72] Murphy, J.D. and McCarthy, K. Ethanol production from energy crops and wastes for use as a transport fuel in Ireland, Applied Energy, October 2004.

[73] Mallow Sugar Factory Ethanol Production Evaluation Study, Cooley-Clearpower Research and Cork County Council, September 2006.

The government has signalled its intention to move to a biofuel obligation scheme to promote biofuels rather than introducing new excise exemption schemes.[74] In this case eDiesel will be competitive with other biofuels. In the meantime, the ethanol component of eDiesel would be eligible for excise relief if sourced from one of the projects successful in the Mineral Oil Tax Relief Scheme II.

7.2 Cost of Carbon Abatement

Energy Solutions have estimated the cost to the government of avoided CO_2 emissions by using eDiesel by comparing the CO_2 emissions of a litre of diesel and a litre of ethanol. The saving was then offset against the government subsidy (36.8 c/litre of excise tax not applied).

Although not captured in the abatement cost summary, the review estimates bioethanol costs at 29.5 p/litre and biodiesel at 45.1 p/litre. This indicates that abatement costs for biodiesel are significantly higher than for bioethanol, reinforcing the conclusion that bioethanol and eDiesel offer a cost effective carbon abatement technology for the transport sector.

Table 7.1 contains the result, comparing it with other carbon reduction alternatives. This table shows that while eDiesel is more costly than wind power, it is competitive with other biofuels.

The cost of CO_2 abatement for a particular technology or energy source is dependent on the cost of energy production and supply for the technology in question, the reference cost of production and supply (e.g. centralised power production or mineral oil) and the carbon saving. These factors obviously vary significantly with changing oil prices, technological developments and the availability of land for bioenergy or sites for wind and nuclear power.

In a review carried out for the Stern Report,[76] these factors were taken into account to estimate abatement costs for different carbon abatement technologies over varying time frames. The conclusions are presented in Table 7.2.

While not directly comparable with the abatement costs contained in Table 7.1, these indicate that the abatement costs are of the same order of magnitude in both studies, and that the abatement costs for alternative transport fuels are amongst the highest.

Although not captured in the abatement cost summary, the review estimates bioethanol costs at 29.5 p/litre and biodiesel at 45.1 p/litre. This indicates that abatement costs for biodiesel are significantly higher than for bioethanol, reinforcing the conclusion that bioethanol, and eDiesel, offer a cost effective carbon abetment technology for the transport sector.

Table 7.1 Carbon Abatement Cost Comparison

	CO_2 Abatement Cost (/tonne)[75]	
	Low (€)	**High (€)**
Onshore wind	74	236
Offshore wind	354	561
Energy crops	340	709
Biodiesel	531	1122
eDiesel (estimate) (€)	**284**	

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[74] Compliance with Directive 2003/30/EC, Department of Communications, Energy and Natural Resources (DCENR), July 2007.

[75] All data (except eDiesel) from UK Department for Transport, Towards a UK Strategy for Biofuels, public consultation, 2004. (Currency conversion valid on 4 September 2007.)

[76] Costs and Finance of Abating Carbon Emissions in the Energy Sector, Dennis Anderson, Imperial College London, October 2006.

Table 7.2 Carbon Abatement Costs

Market and Low-Carbon Technology	Period	Cost of Supply from Fossil Fuels	Cost of Supply from Low-Carbon Technologies	Weighted Average Incremental Cost of Carbon Abatement (£/tonne C)
Electricity: Central electricity from coal or gas with carbon capture and storage, nuclear power and renewable energy; decentralised generation from solar and small CHP generators.	2005–2015	6.0 p/kWh	7.5–10.5 p/kWh	105
	2015–2025	6.0 p/kWh	6.0–9.0 p/kWh	75
	2025–2050	5.5 p/kWh	4.0–9.0 p/kWh	25
Gas (heat for homes, industry and commerce): Biomass including wastes for CHP (large and small scale); hydrogen (longer term).	2005–2015	£5/GJ	£9/GJ to >£15/GJ	330
	2015–2025	£5/GJ	£7–14/GJ	300
	2025–2050	£5/GJ	£6.0–10/GJ	130
Transport: Biofuels; hydrogen (at fuel station).	2005–2015	30 p/litre	30–55 p/litre	375
	2015–2025	30 p/litre	30–50 p/litre	110
	2025–2050	30 p/litre	22–50 p/litre	230

8 Benefits and Barriers

The use of ethanol–diesel blends in the transport fleet would provide another alternative biofuel for use in centrally fuelled diesel engines which would complement the existing alternative fuels: PPO, biodiesel and EN 590 biodiesel blends. Like other biofuels, it offers the potential to reduce CO_2 emissions from transport and to reduce dependency on imported fossil fuels while fostering an indigenous biofuels industry.

eDiesel offers the benefit of easy use in existing engines without engine modification. The most common substitution rates vary from 7.7% to 15%, but substitution rates of up to 30% are possible. For substitution rates higher than this, engines would require modification. Higher substitution rates are being trialled, with 95% bioethanol being trialled in dedicated engines by Scania and Sekab.

eDiesel is fungible with diesel, allowing operators to fill eDiesel trucks with diesel from forecourts. This contrasts with PPO, which requires engine modification and has limited fungibility, but is similar to biodiesel in this regard.

An important differentiation factor between eDiesel and other biofuels is the reduction in smoke, particulate and NO_x emissions from engines that is achieved due to the oxygenation effect of the fuel. This is an important benefit in terms of air quality and national emission inventories, but very few of the fleet operators surveyed viewed this as a significant benefit. This is primarily due to the fact that emission limits compliance is demonstrated by type testing of engines by manufacturers and that the in-service testing requirements at present are not onerous.

A significant barrier to eDiesel is operators' concerns of effects on engine warranties, reliability and maintenance costs. Like other non-standard fuels (PPO, biodiesel), the use of eDiesel voids the engine manufacturer's warranty. This creates a perception among fleet operators that its use will have an adverse effect on reliability. While the numerous trials carried out to date have not shown any such impact on reliability, this concern can only be addressed through widespread demonstration, and ultimately by engine manufacturers taking a more positive attitude towards biofuels in general. It is encouraging that both Scania and Volvo are actively engaged in eDiesel trials.

The market survey carried out as part of this study demonstrated that there is a significant potential market for eDiesel in local authorities, public passenger services and building materials sectors. These sectors have a large fuel consumption and, in discussion with operators, show a positive attitude towards the use of biofuels.

In contrast, logistics companies, hauliers and operators of general fleets are less disposed to the use of biofuels. As vehicles may be away from the central depot for two weeks at a time, reliability is a high priority for these users. These operators are generally aware of the likelihood of a biofuels mandate being imposed on fuel suppliers and see this as the principal route to the use of biofuels rather than voluntary trials. As a result, we believe that even if eDiesel were commercially competitive, this sector would probably not use eDiesel due to perceived maintenance issues and the lack of eDiesel away from their central depot.

There are a number of technical issues around the use of eDiesel such as the effects on lubricity, cetane number, and potential vapour lock due to the lower vapour pressure of ethanol. These technical issues are addressed by the additive suppliers through the addition of cetane improvers and lubrication agents to the blending agents.

A key difference between eDiesel and diesel is the lower flash point of ethanol and the consequent classification of eDiesel as a flammable liquid rather than a combustible liquid. This is addressed through the use of flame arrestors on fuel tanks and taking appropriate measures in the storage and handling of eDiesel. The hazards posed by the storage and handling of eDiesel can be effectively neutralised by using in-line or splash blending technologies. While flammability is a barrier, it is worth noting that petrol, a flammable liquid, is widely used

Table 8.1 summarises the major benefits and costs of using eDiesel.

Table 8.1 eDiesel Cost/Benefit Summary

Cost	Benefit
Requires subsidy (excise exemption)	Smoke emissions reduced 20–60%
Requires central fuelling facilities	Local PM10 emissions reduced 10–30%
Requires vehicle and storage modifications	CO_2 emissions reduced up to 10%
Voids engine warranty (at present)	NO_x reduced 1–10%
Can increase total PM_{10} emissions Dependent on raw energy for production	Fungible with diesel
THC increase from 0–100% (mitigated by catalytic converter)	No major vehicle modifications required
Acetaldehyde emissions increased by 75–175% (mitigated by catalytic converter)	Limited maintenance issues (compared with PPO)
Ethanol emissions increase from 0 to around 110 ppm (mitigated by catalytic converter)	Easily mixed on-site or at point of delivery

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The following EU directives can be found by a search on either the European Commission website http://ec.europa.eu/ or by a search on the associated Eur-Lex website http://eur-lex.europa.eu/. A search on Google will also find these directives.

Directive 70/220/EEC of 20 March 1970 on measures to be taken against air pollution by gases from positive-ignition engines of motor vehicles.

Directive 98/69/EC of the European Parliament and of the Council of 13 October 1998 relating to measures to be taken against air pollution by emissions from motor vehicles and amending Directive 70/220/EEC.

Directive 88/77/EEC of 3 December 1987 on the approximation of the laws of the member states relating to the measures to be taken against the emission of gaseous pollutants from diesel engines for use in vehicles.

Directive 96/96/EC of 20 December 1996 on the approximation of the laws of the member states relating to roadworthiness tests for motor vehicles and their trailers.

Directive 2003/27/EC of 3 April 2003 on adapting to technical progress Directive 96/96/EC as regards the testing of exhaust emissions from motor vehicles.

Directive 72/306/EEC of 2 August 1972 on the approximation of the laws of the member states relating to the measures to be taken against the emission of pollutants from diesel engines for use in vehicles.

Acronyms

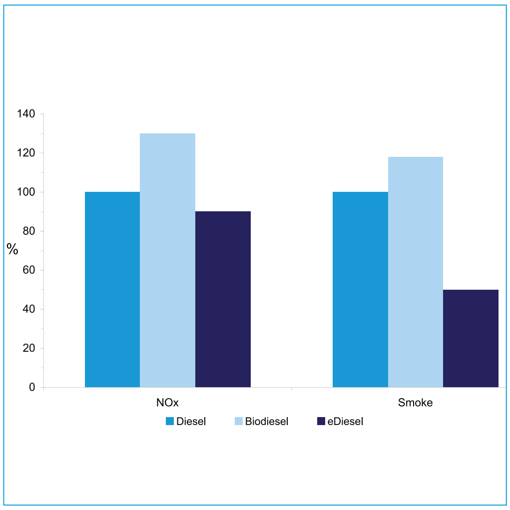
BEST	Bioethanol for Sustainable Transport
CCA	concrete/cement/aggregates
CO	carbon monoxide
DCENR	Department of Communications, Energy and Natural Resources
DERV	Diesel Engine Road Vehicle
IFP	Innovation Energy Environment
JRC	European Commission Joint Research Centre
MTBE	methyl tertiary butyl ester
NO_x	oxides of nitrogen
PJ	peta joule (1 x 1015 J)
PM_{10}	particulate matter with an aerodynamic diameter of less than 10 microns
PPO	pure plant oil
SO_2	sulphur dioxide
THC	total hydrocarbons
VRT	vehicle registration tax

Appendix A – eDiesel Information Sheet

energy solutions

eDiesel

The Sustainable Fleet Transport Fuel



What is eDiesel?

eDiesel is an alternative transport fuel that provides an economic and environmentally friendly means of using biofuels in existing vehicles.

Unlike petrol, diesel does not naturally form a stable blend with ethanol. eDiesel is a blend of ethanol and diesel using a patented emulsifier. Blends of 15% can be used with no modification to engines and blends of up to 30% can be operated in diesel engines with minor or no modification to the engine.

Using eDiesel replaces fossil fuels with environmentally sustainable biofuels and also reduces smoke, particulate and other emissions.

What are the benefits of eDiesel?

eDiesel allows fossil fuels to be substituted by clean, CO_2 neutral, bio-ethanol in existing engines with little or no modifications. It will help operators of fleets and individuals to reduce CO_2 emissions associated with their transport activities and meet targets set by Government.

The major effect of eDiesel on engine performance is a significant reduction in visible smoke and particulate emissions.

Smoke and particulate emissions are reduced by between 30% and 50% and NOx emissions are reduced by 10%.

Unlike eDiesel, both pure plant oil and biodiesel produce higher levels of NOx and particulate emissions than diesel. *(Liquid Biofuels Strategy Study for Ireland, December 2004, Report by Ecofys for Sustainable Energy Ireland.)*

As well as reducing these emissions further, eDiesel improves engine performance and increases engine efficiency by up to eight percent.

How does it work?

eDiesel uses a patented co-polymer blending agent that creates stable blends of ethanol and diesel.

As ethanol provides an oxygen component to the fuel, combustion characteristics are improved leading to increased efficiency and reduced smoke and NOx emissions.

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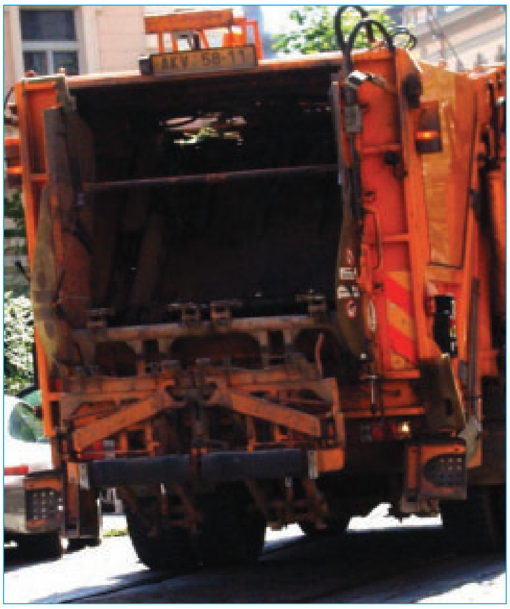
energy solutions

eDiesel

The Sustainable Fleet Transport Fuel



Where has it been used before?

eDiesel has been successfully trialled in Australia, Thailand, Chile, the USA, Malawi, Germany and Sweden. The trials prove that eDiesel reduces emissions, improves performance and that there are no barriers to its successful use.

eDiesel is currently being used in a number of captive fleets in Australia and there are plans to extend its use into the general fleet.

Does the engine need to be modified?

No, the majority of engines can use eDiesel directly. Minor modifications such as replacing some rubber seals may be necessary for certain engines. This is a small task and Energy Solutions can readily determine whether modifications are necessary depending on the engine type.

Where can it be used?

eDiesel can be used in any diesel engine. However, because of the logistics of fuel supply it is ideally suited to a centrally fuelled fleet.

Energy Solutions is currently seeking a suitable partner with a fleet to trial eDiesel in some of their vehicles.

What does it cost?

As with other biofuels and biofuel blends, the cost of eDiesel is related to the production cost of bioethanol and the excise duty rates applied. By using excise exempt bioethanol, eDiesel offers a simple and cheap way of substituting fossil fuels while reducing NOx, smoke and particulate emissions.

Further information

For further information, please contact Fergal Purcell of Energy Solutions on 01 521 9092 or email fergalpurcell@energysolutions.ie

Supported by

NDP NATIONAL DEVELOPMENT PLAN epa

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Appendix B – Questionnaire

1. Does your organisation have centrally fuelled vehicles? (please circle) Yes/No

2. Where are the fuelling depots/facilities located?
(Please list locations on Sheet 2 if there are more than one) ______________________________

3. What is the scale of your fuel storage facilities (e.g., tank sizes)? ______________________________

4. What is the estimated annual fleet fuel consumption (litres)? ______________________________

5. If there are a number of fuelling depots, what is the
estimated annual consumption at each facility? Please detail on sheet 2

6. a) Does your organisation have an environmental policy? a) Yes/No

   b) If yes, does the policy address the use of alternative fuels? b) Yes/No

7. Has your organisation used, considered using, or assessed the
feasibility of using alternative fuels or biofuels in the past? Yes/No

8. If so, can you provide brief details?

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9. Do you monitor your fleet’s aggregate vehicle emissions? Yes/No

10. Do you have any issues with compliance with emission standards? Yes/No

11. Would you consider using alternative transport fuels in your vehicles? Yes/No

12. Would you consider trialling eDiesel in some of your vehicles? Yes/No

13. Who is responsible for transport fuels/biofuels in your organisation?

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No	Fuelling Depot/Facility	Storage Capacity (litres)	Annual Fuel Consumption (litres/year)
1.			
2.			
3.			
4.			
5.			
6.			
7.			

National Development Plan 2007 - 2013

Science, Technology, Research and Innovation for the Environment (STRIVE) 2007-2013

The Science, Technology, Research and Innovation for the Environment (STRIVE) programme covers the period 2007 to 2013.

The programme comprises three key measures: Sustainable Development, Cleaner Production and Environmental Technologies, and A Healthy Environment; together with two supporting measures: EPA Environmental Research Centre (ERC) and Capacity & Capability Building. The seven principal thematic areas for the programme are Climate Change; Waste, Resource Management and Chemicals; Water Quality and the Aquatic Environment; Air Quality, Atmospheric Deposition and Noise; Impacts on Biodiversity; Soils and Land-use; and Socio-economic Considerations. In addition, other emerging issues will be addressed as the need arises.

The funding for the programme (approximately €100 million) comes from the Environmental Research Sub-Programme of the National Development Plan (NDP), the Inter-Departmental Committee for the Strategy for Science, Technology and Innovation (IDC-SSTI); and EPA core funding and co-funding by economic sectors.

The EPA has a statutory role to co-ordinate environmental research in Ireland and is organising and administering the STRIVE programme on behalf of the Department of the Environment, Heritage and Local Government.

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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SSTI
Strategy for Science, Technology and Innovation

Comhshaol, Oidhreacht agus Rialtas Áitiúil
Environment, Heritage and Local Government