Impact of biodiesel growth:
A strategic assessment

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The European Commission aims by 2010 to increase biodiesel markets dramatically. This paper profiles the market development, the process costs and the major associated impacts, which are: (1) By 2010, EU governments could offer €2.5 billion per year in tax breaks to biodiesel. (2) To satisfy demand in 2010, all current EU oilseed land (plus another 15% of acreage in addition) would need to be devoted to biodiesel. (3) Biodiesel is lower than petroleum diesel in greenhouse gas emissions and non-renewable energy consumption, but higher in NOx emissions. The verdict on particulate emissions is mixed. (4) Biodiesel will dominate global rapeseed markets, and glycerine markets will be swamped by byproduct output.

Keywords: biodiesel, alternative fuels, renewable fuels, energy policy, transport fuel policy

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[A] This page is for the reviewers' benefit. It can be deleted from the final manuscript.

1 Introduction: The rise of biodiesel in Europe

European policymakers want biodiesel to become something like bioethanol in the US, i.e. a significant road transport fuel. Their reasoning is similar: pushing biofuels is a way to subsidise farmers and reduce crude-oil dependence simultaneously. In addition, Europeans want to realise environmental benefits that biodiesel offers over petroleum diesel.

Biodiesel is not cost competitive with petroleum diesel, and European governments know this. Nonetheless, they have a very strong policy lever – fuel taxes. Fuel taxes in the European Union typically account for 80% of the retail price. In the US by contrast, taxes account for about 25-30% of the price at the pump [US DoE 2003].

In late 2001 the European Commission announced an 'action plan' to promote the usage of bio-fuels in road transport. Namely, the Commission said it aimed to increase biodiesel's market share from 0.5-1% in 2000, to 6% in 2010 and to 8% in 2020. Biodiesel production was about 775,000 kilotonnes in 2000; so this implies output of around 9 million tonnes in 2010 and 12 million tonnes in 2020.

Presuming this comes to pass, biodiesel's development will create significant economic and environmental impacts. The focus of this study is to identify and assess them. The main impacts fall into four areas:

- Land use – to grow the oilseeds that are biodiesel feedstock
- Emissions and energy – greenhouse gas and combustion emissions, plus consumption of non-renewable energy
- Rapeseed and glycerine markets – the former to provide oil that is transesterified to biodiesel, the latter is a byproduct of that transesterification
- Tax revenues – the amount of fuel taxes waived to promote biodiesel

The analysis is presented in four parts:

- What is biodiesel?
- European biodiesel outlook to 2010
- Process economics of biodiesel production
- Impact assessment of biodiesel growth

2 What is biodiesel?

Biodiesel is a mixture of fatty esters (Figure 2-1) that can fuel internal-combustion compression engines, better known as diesel engines. The fatty acid precursors are mostly oleic and linoleic (both C_{18}, oleic with one double bond, linoleic with two). The other side of the ester typically is a methyl group, sometimes an ethyl group.

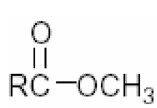

Figure 2-1: Fatty acid methyl ester, chemical formula

The *bio* prefix denotes that the fatty acids come from *natural* fats and oils. The most common commercial source is rapeseed (known in the US as canola). Other oils such as sunflower, soybean, palm and hemp also are used.

Ironically, when Rudolf Diesel (1858-1913) invented the compression engine, he intended for it to run on vegetable oil[B]. One of his showcase engines, presented at the Paris World's Fair of 1900, ran on peanut oil. However, petroleum diesel fuel from crude oil soon cornered the market. For one it was cheaper. For two it is less viscous, which is important in colder weather.

Biodiesel first reared its head as an alternative to mineral diesel in the mid 1970s, when shortages spurred public interest in diversifying fuel sources. Interest in biodiesel resurfaced in the 1990s, again for energy security reasons, but also for its potential benefits to the environment and the farming economy. Most of the interest has been in Europe (probably because diesels account for about 20% of the passenger car market, whereas in the US they are almost non-existent). The US is not at all opposed to biodiesel, but most of the biofuel development effort has been focused on bioethanol as a replacement for gasoline.

Today's diesel engines are designed to run either on mineral diesel or biodiesel fuel, which are very similar in terms of performance. Volkswagen, for instance, offers a standard warranty on the use of commercial biodiesel, which is sold at 100% purity in Germany and blended with mineral diesel elsewhere in Europe.

With minor technical barrie rs and strong tax incentives, biodiesel consumption in the EU went from a standing start in 1992 to 1 million tonnes in 2000. Robust growth is expected in this decade as well, which is covered in the next chapter.

3 European biodiesel market to 2010

In the past decade the market for biodiesel has seen extraordinary growth. Consumption has risen from about 35 kilotonnes in 1992 to almost 2,000 kilotonnes in 2003 (Table 3-1).

This market has been driven by tax discounts or exemptions offered by European governments that chose to promote biodiesel[C]. Across Western Europe, taxes on road transport fuels typically amount to as much as 80% of the retail price – this gives a lot of room for incentives. Their main reasons for government support were and are to increase independence from crude oil imports, gain environmental advantages and to create new revenues for farmers.

Concerns in Europe about energy independence and environmental damage have increased over the past few years. Partly this has been fuelled by tensions in the Middle East, partly by an ever-increasing environmental consciousness. The result

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[B] Straight vegetable oil act ually can fuel current diesel vehicles. For instance in January 2003 there were numerous reports of motorists in Wales tanking up with bulk cooking oil bought at local supermarkets. The incentive is clear: according to the same reports, cooking oil was selling for £0.42 per litre, while diesel was retailing for at least £0.72. Still, in cold weather straight vegetable oil can clog, it tends to coke up the engine and the injectors, and problems it causes will not be covered by manufacturer warranties.

[C] It also has been has been pushed indirectly by 'set-aside' subsidies to farmers who grow rapeseed. These subsidies apply to a limited amount of land, and since 2001, the biodiesel market has grown so much that non-subsidised farmland is being used to supply rapeseed for biodiesel. Current demand for biodiesel consumes output from about 1.7 million hectares of cropland; only 700,000 hectares qualify for the 'set-aside' subsidy.

has been an even stronger, pan-European commitment to push the further development of biodiesel. In late 2001 the European Commission announced an 'action plan' to promote the usage of bio-fuels in road transport.

Namely, the Commission said it aimed to increase biodiesel's market share from 0.5-1% in 2000, to 6% in 2010 and to 8% in 2020. Biodiesel production was about 775,000 kilotonnes in 2000; so this implies output of around 9 million tonnes in 2010 and 12 million tonnes in 2020.

One likeable feature of subsidised markets is that they are easier to predict. The main variable is the will of the government to meet its own targets. Judging from statements made by the EU, our estimation is that consumption will rise to less than the target of 9 million tonnes in 2010, but nonetheless will grow considerably to 6-8 million tonnes (Table 3-1).

Table 3-1: European biodiesel production/consumption (kilotonnes)

	1992	1995	1998	1999	2000	2001	2003	2010
Austria	-	15	15	20	30	35	85	
Belgium	-	-	-	-	20	45	50	
France	-	170	220	210	300	350	380	
Germany	5	45	100	120	250	500	850	
Italy	30	100	100	125	175	250	300	
Other	-	-	NA	NA	NA	200	270	
EU Total	35	330	435	475	775	1,380	1,935	6,000-8,000

The main national markets for biodiesel are Germany, France and Italy. These will probably continue to lead the EU. Germany and France have particularly strong farming lobbies.

The UK market is largely untapped to date, but ready to take off, and EU's ten new members who join in 2004 also are likely to get well into biodiesel. Both the Czech Republic and Slovakia have production already. (Table 3-2)

Table 3-2: Biodiesel capacity, by country, 2003 (kilotonnes)

Austria	106
Belgium	50
Czech	30
France	380
Germany	1,480
Italy	440
Netherlands	100
Spain	40
Slovakia	60
Sweden	11
UK	27
Total	**2,724**

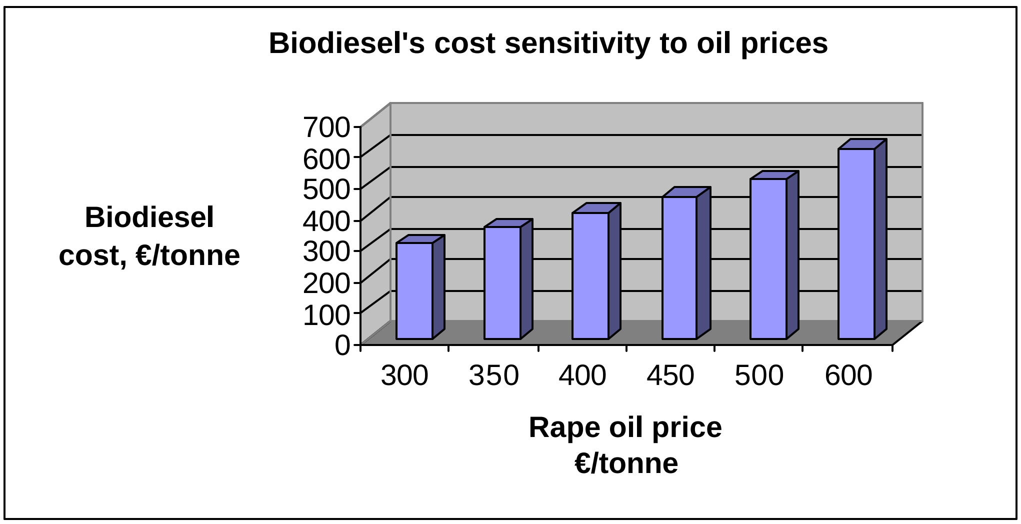
4 Process economics of biodiesel production

Using representative prices for the first half of 2003, the estimated cost of producing biodiesel from rape oil in Germany is just over €500 per tonne. This equates to about €0.45 per litre.

The overwhelming determinant of cost is the price of rape oil (Table 4-1), which moves in a wide range. Since 1990, when it was just over $400/tonne, it climbed to $550-650 from 1994-8, then plunged back to $350-400 until early 2002 when it began to rise again. Current prices are around $500/tonne [Statcom 2003, Oil World Monthly 2003].

The cost of biodiesel is higher than that of petroleum diesel, which has been priced in the €0.15-0.25 range over the past two years. Indeed, as Figure 4-1 suggests, biodiesel becomes cost-competitive with petroleum diesel only of rape oil prices are around $300-350/tonne and crude oil prices are around $25-30/bbl.

Figure 4-1: Cost of biodiesel vs. rape oil price



Biodiesel also sells at about a €0.10/litre discount to petroleum diesel in Europe. This discount is partly self-imposed to generate sales volume, but it also is in response to biodiesel's lower energy content, i.e. a vehicle will go 5-10% less distance on biodiesel than petroleum diesel.

Clearly, the commercial basis for biodiesel production is provided by tax exemptions. In Germany, for instance, the government recently decided to waive its fuel excise tax of €0.47 per litre on biodiesel until 2008[D]. The European Union is calling on all of its other member states to take similar fiscal actions, although the EU's recommended target is only a 50% waiver for biodiesel (and tax rates vary). In any event, the tax waiver makes the difference between a viable and unviable biodiesel business.

[D] Value added tax at 16% has not been waived, however.

Table 4-1: Cost of Production, biodiesel from rapeseed oil

Time	2003				
Location	Germany				
Plant type	Oil refining and transesterification				
Capacity	100,000	tonne/year			
Capital Cost	25,000,000	€			
Cost item	**Input/tonne of product**	**Unit**	**Unit cost, €**	**€/tonne**	**€/year**
Variable					
Raw Materials					
Rapeseed oil	1.03	t	500	515.00	51,500,000
Methanol	0.096	t	230	22.08	2,208,000
Hydrochloric acid	0.01	t	100	1.00	100,000
Sodium hydroxide	0.0015	t	200	0.30	30,000
Sodium methoxide (catalyst)	0.005	t	1,000	5.00	500,000
Byproduct credits					
Crude glycerine	0.128	t	-720	-92.16	-9,216,000
Utilities					
Cooling water	25	t	0.02	0.50	50,000
Electricity	12	kWh	0.04	0.48	48,000
Process water	20	t	0.2	4.00	400,000
Steam	0.415	t	15	6.23	622,500
Solid waste disposal	0.012	t	100	1.20	120,000
Sum, variable cost				463.63	46,362,500
Direct fixed					
Operators	12	Year	62,400	7.49	748,800
Office manager	1	Year	50,000	0.50	50,000
Loading/storage	1	Year	43,680	0.44	43,680
Foreman	1	Year	93,600	0.94	93,600
General manager	1	Year	130,000	1.30	130,000
Supplies					
Allocated fixed					
Plant overheads	35% direct fixed			3.73	373,128
Taxes & insurance	1.5% capital			3.75	375,000
Sum, Cash costs				481.77	48,176,708
Depreciation	10% of capital			25.00	2,500,000
Full cost of production				506.77	50,676,708
			€/litre	0.446	

5 Impact assessment of biodiesel growth

According to the European Commission's 'action plan' to promote biodiesel, the market will increase from its current size of around 2 million tonnes to 6-8 million tonnes by 2010. This would cause significant impacts in four areas:

- Land use – to grow the oilseeds that are biodiesel feedstock
- Emissions and energy – the pollution profile of biodiesel is significantly different to that of petroleum diesel, total energy consumption is also different.
- Rapeseed and glycerine markets – both would change dramatically
- Tax revenues – governments would forfeit substantial income from fuel excise taxes

These impacts are examined in more detail in the following subsections.

5.1 Land use

To grow enough rapeseed for 6-8 million tonnes of biodiesel requires about 6-7 million hectares of agricultural land. Currently and dating back to 1996, EU-15[E] farmers devote about 5.5 million hectares to oilseed crops, so this implies a significant change in agricultural land use.

There are other major producers of rapeseed, namely China, Canada and India, and to a lesser extent Central Europe and Australia. Any of these could supply the European biodiesel market, but with the exception of Central Europe, this would run counter to one primary objective of the EU action plan – namely to increase energy independence. Also, presumably this would not be preferred way to subsidise EU farmers, because in effect much of the subsidy would flow outside the EU.

This is examined in the following two subsections: the first covers land requirements for biodiesel in general, the second land requirements for EU biodiesel in particular.

5.1.1 Land requirements for biodiesel production

In Western Europe, one hectare of land can grow enough 00-rapeseed[F] to produce just over a tonne of biodiesel (Table 5-1).

Table 5-1: The EU biodiesel yield chain, from land to biodiesel via rapeseed

Rapeseed/land *(t/hectare)*	**Rape oil/rapeseed** *(t/t)*	**Biodiesel/rape oil** *(t/t)*	**Biodiesel/land** **(***t/hectare)*
2.9	0.39	0.971	1.10

Rapeseed yields do vary. The EU's highest yields are reported in Germany, on average around 3.1 t/ha. Thanks to improved farming methods, they have increased steadily from 1-2 t/ha back in the 1970s. The record yield – achieved by a farmer in Schleswig-Holstein – is 2.9 t rape oil per hectare, which is equivalent to about 7.4 t rapeseed per hectare [Austrian Biofuels Institute 2002].

[E] EU-15 is the European Union of 15 member states, i.e. the EU as it stands in 2003. In 2004 the EU will expand to 25 member states, i.e. the EU-25.

[F] The preferred variety for biodiesel production.

Oil/seed ratios for rape are reported as low as 37% [ETSU 1992] and as high as 42% [British Assoc. of Biofuels and Oils 2003]. We have used the 39% ratio as reported in a recent German study [Schöpe and Britschkat 2002]. The biodiesel/rape oil ratio of 97.1% comes from the economics presented in the previous chapter.

5.1.2 Land requirements to supply the EU biodiesel market

In the EU-15, about 5.5 million hectares of cropland are devoted to oilseeds, and of this about 60% is devoted to rapeseed. The most recent available data are presented here (Table 5-2); figures for previous years dating back to 1996 are similar.

Table 5-2: Oilseed production and land use, 2001, EU-15

	Production	**Land factor**	**Land use**
Crop	*million tonnes*	*hectares/tonne*	*million hectares*
Rapeseed	8.87	0.34	3.06
Soybean	1.15	0.53	0.61
Sunflower	3.33	0.56	1.85
Total	13.35		5.51

Source: [UOP 2003]

Of this 5.5 million hectares devoted to oilseeds, about 700,000 hectares are designated as 'set-aside' land by national governments. Farmers of such land receive subsidies under the EU's Common Agricultural Policy (CAP) scheme as long as they set it aside, i.e. do not grow food or feed crops on it. Farmers can and do double-dip with such land by using it to grow *non-food* crops – namely rapeseed for biodiesel – and receiving the subsidy at the same time.

As of 2001, biodiesel demand for rapeseed has outstripped production from 'set-aside' land (Table 5-3). To satisfy consumption in coming years, land use will expand to 6.3 million hectares by 2010[G] - this is more than the entire land area currently devoted to oilseed crops in the EU-15.

Table 5-3: Land use required to supply biodiesel market, 2000-2010

	2000	**2001**	**2003**	**2010**
EU Biodiesel consumption *million tonnes*	0.775	1.38	1.935	7.0
Land use[H] *million hectares*	0.705	1.256	1.761	6.374

In total, EU-15 farmland is 140 million hectares (divided into just over 8 million farms). Requirements of crop rotation and 'other agricultural regulations' [Scharmer 2001, Tornevall 1998] restrict the maximum rapeseed planting to about15% of all farmland in a given year. Thus in theory, some 21 million hectares maximum could be devoted to rapeseed, which could yield 23 million tonnes of biodiesel[I].

[G] Assuming that yields stay constant at around 2.9 tonnes rapeseed/hectare. Yields have not moved upwards significantly since 1996, so a substantial increase in the short term seems unlikely.
[H] To grow rapeseed.
[I] Equal to about 15% of the current EU-15 diesel market for road transport.

5.2 Emissions and energy

Studies in the US, Europe and Australia [Scharmer 2001, ETSU 1996, Reinhardt and Jungk 2002, Spirinckx and Ceuterick 1996, NREL 1998, OTAQ 2002, Wang 1999, Beer et al 2000] show that over the 'life-cycle' of production, use and disposal, biodiesel emits less pollutants and consumes less non-renewable energy than petroleum diesel. These studies compare the life cycle of petroleum diesel against that of biodiesel (Figure 5-1).

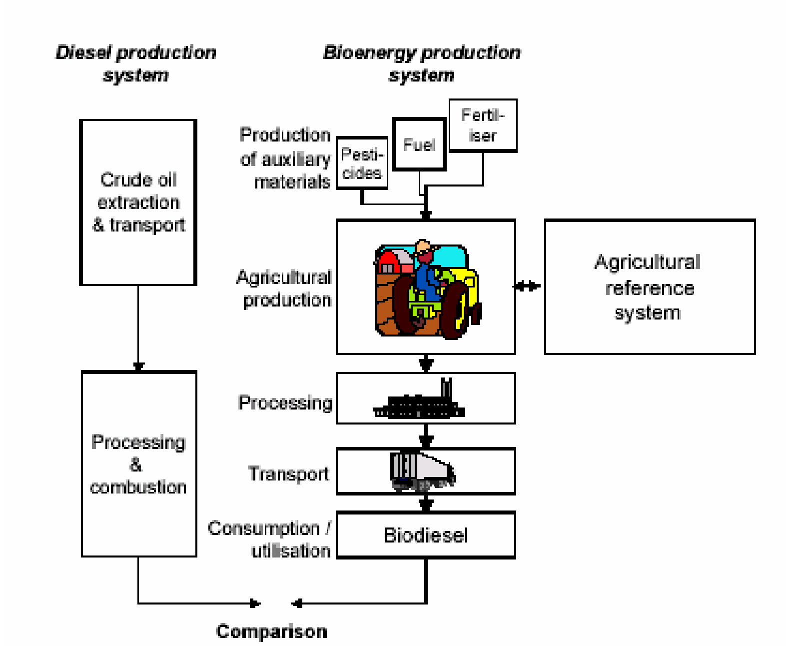


Figure 5-1: The life-cycles of petroleum diesel and biodiesel

Most of the studies compare 100% petroleum diesel against 100% biodiesel. Indeed biodiesel is sold at 100% strength in Germany, but elsewhere it is sold as a blend with petroleum diesel[J]. Biodiesel's emission and energy benefits are linearly proportional to its composition of the blend, e.g. a 30% blend will provide 30% of the benefits of pure biodiesel.

We review these results in three subsections below: first a look at greenhouse gases, second a review of other air pollutants and third the energy balance.

5.2.1 Greenhouse gases

Studies consistently show lower greenhouse emissions from biodiesel (Table 5-4).

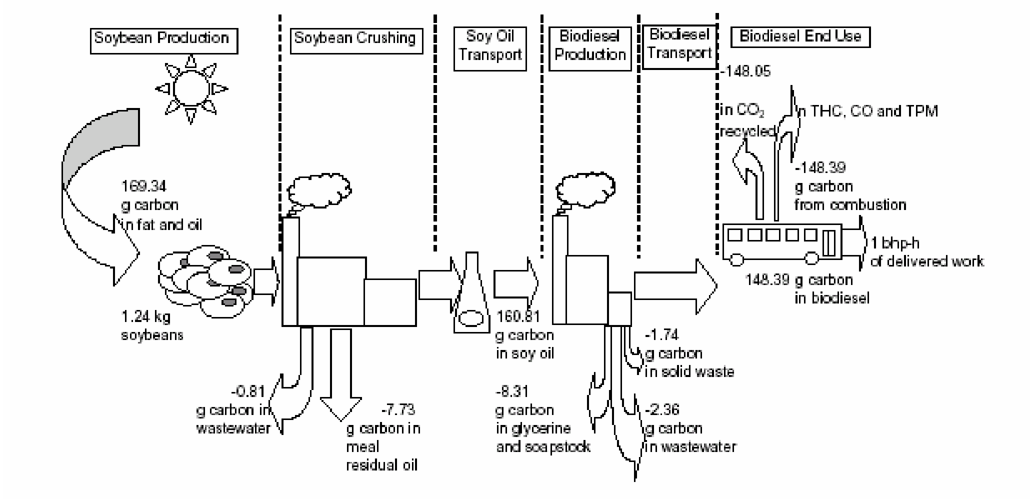
Table 5-4: Greenhouse gas reduction, biodiesel versus petroleum diesel

Source	**Reduction in greenhouse gases** (CO_2 equivalents)	**Comment**
CSIRO [Beer et al 2000]	Diesel scored 20-30 points, biodiesel 5 points	Rapeseed methyl ester
ETSU [ETSU 1996]	-180 g/km	Rapeseed methyl ester
GREET [Wang 1999]	-100 g/mile	Probably soybean based
IFEU, Bochum [Reinhardt and Jungk 2002]	-2.303 kg/kg fuel	Rapeseed methyl ester

[J] It is reported that blends up 30/70 biodiesel/petroleum diesel behave no differently than 100% petroleum diesel. At biodiesel concentrations above 30%, some engine modifications may be required to maintain equal performance.

IFEU, Bochum, without glycerine credits [Reinhardt and Jungk 2002]	-0.898 kg/kg fuel	
NREL [NREL 1998]	-497 g CO2/bhp-h	Soybean methyl ester

The reason for this is fairly obvious. The carbon in biodiesel comes from the ambient atmosphere in the first place, to which it simply returns when combusted as a fuel (Figure 5-2).



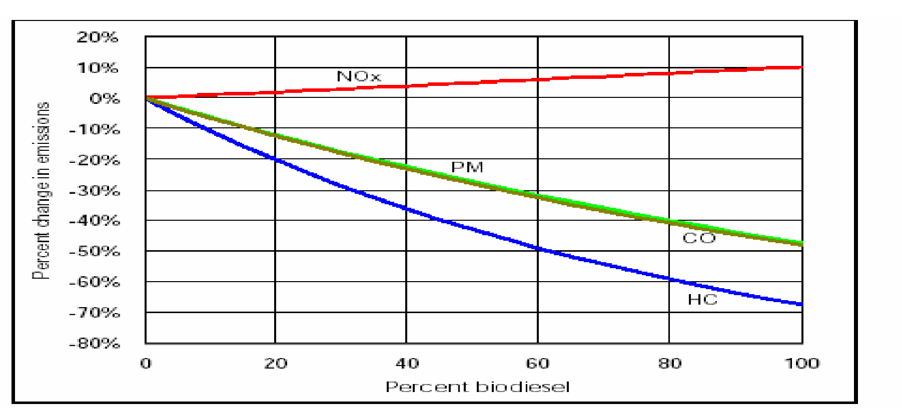
*Source [**Error! Bookmark not defined.**, p 20)]*

Figure 5-2: Carbon dioxide cycle in biodiesel (soybean based)

Nonetheless, biodiesel's 'carbon advantage' as reported in the IFEU/Bochum study [Reinhardt and Jungk 2002] is too high, in our opinion. IFEU/Bochum credit 1.4 kg carbon dioxide emissions per kg of biodiesel produced, on the presumed basis that byproduct *natural* glycerine will displace *synthetic* glycerine. Given that less than 10% of glycerine produced in Western Europe is synthetic, we believe this credit is unjustified. In the second line of Table 5-4, we have re-presented IFEU/Bochum's results minus this credit.

5.2.2 Other air pollutants

The simple summary of this category is presented in Figure 5-3.



Source [OTAQ 2002, p ii)]

Figure 5-3: Change in emissions of NOx, PM, CO and HC with shift to biodiesel

As it shows, biodiesel emits less particles, CO and hydrocarbons but more NOx than diesel. This is presented in more detail for PM and NOx in Table 5-5.

Table 5-5: Reduction in other air pollutants, biodiesel versus petroleum diesel

Study	PM	NOx	Toxics
CSIRO [Beer et al 2000]	Biodiesel higher		
ETSU [ETSU 1996]	0.3 g/km	0.8 g/km	
IFEU, Bochum [Reinhardt and Jungk 2002]	-0.44 kg/kg fuel	0.0002 kg/kg fuel	
IFEU, Bochum, without glycerine credits [Reinhardt and Jungk 2002]	0.0019 kg/kg fuel	0.01299 kg/kg fuel	
NREL [NREL 1998]	32% less		
OECD [Koo-Oshima et al 1998]	16-33% lower	11-25% less CO	
US EPA [OTAQ 2002]	45-50% lower	10% higher	
Volvo, Chalmers Institute of Technology [The Engineer 2001]			10 times more carcinogenic

NOx emissions clearly are higher in biodiesel[K]. Particle (PM) emissions are reported substantially lower for biodiesel in some of the studies, but three dissent, reporting PM from biodiesel to be higher across the life cycle: CSIRO, ETSU and IFEU/Bochum (minus glycerine credits).

We have included in Table 5-5 a comment from Volvo[L] that biodiesel exhaust is "ten times more carcinogenic" than exhaust from petroleum diesel. After a heated exchange with biodiesel proponents through the UK trade press, Volvo softened the statement, but never retracted it.

5.2.3 Energy balance

Studies consistently show that biodiesel consumes less 'non-renewable' energy, i.e. fossil fuels, than petroleum diesel (Table 5-6). The ETSU study appears to contradict this, because it reports total energy consumption without splitting out non-renewable and renewable.

Table 5-6: Energy use comparison, biodiesel versus petroleum diesel

Study	Biodiesel benefit (-) or deficit (+) over petroleum diesel	Comment
ETSU [ETSU 1996]	2.2 MJ/km	All energy (renewable and non-renewable).

[K] Presumably because biodiesel is oxygenated, which lends to the formation of NOx in combustion.
[L] Specifically from UK environmental manager John Pitts.

IFEU, Bochum [Reinhardt and Jungk 2002]	-54.37	Rapeseed methyl ester. Non renewable energy only.
IFEU, Bochum, without glycerine credits [Reinhardt and Jungk 2002]	-30.37	Rapeseed methyl ester Non renewable energy only.
NREL [NREL 1998]	-0.9 MJ/MJ fuel	Non-renewable energy only.
UK Energy Saving Trust [Foley 2002]	25-50% lower	Non renewable energy only.

5.3 Rapeseed and glycerine markets

Growth in biodiesel production would cause significant impacts on markets for two related products: rapeseed and glycerine.

5.3.1 Rapeseed

Our presumption is that rapeseed (i.e. rape oil) will continue to be the primary feedstock to the European biodiesel market, at least in the medium term to 2010. Rapeseed was not selected as the workhorse by accident; of the European oilseeds, it is most economic and technically feasible for biodiesel. Farmers, refiners, fuel retailers, additive suppliers and vehicle manufacturers have spent much time, effort and money on optimising around the rapeseed chain (rapeseed → rape oil → rape methyl ester, which is biodiesel).

There is some growth to be expected in making biodiesel from used cooking oils, but it will not be a serious contender to rape oil. Some of it, perhaps 20,000 tonnes per year, currently is fed into biodiesel plants. Nearly all the rest of the 450,000 tonnes per year of this generated in the EU-15 are blended into animal feed. If the European Commission were to proceed with proposals to ban used fats and oils from animal feed [APAG 2002], more of this material likely would go into biodiesel. Still, even so, supply would be limited by cooking requirements, and it would take time for technical issues (purity, composition and processing changes) to be resolved.

There are three key impacts to be expected in rapeseed markets from the growth in biodiesel (Table 5-7).

First, biodiesel will come to dominate global rapeseed markets. World output of rapeseed set a record in 2000 of 42.5 million tonnes. Otherwise over the past decade it has moved in the 32-40 million tonne per year range. Biodiesel requirements have moved from a market share of 5% in 2000 to 16% in 2003. By 2010, the 18.5 million tonnes of rapeseed for biodiesel will account for 40-60% of the market.

Second, by 2010 all rapeseed in the EU-15 will go to biodiesel, plus a substantial quantity of imports. The 18.5 million tonnes of rapeseed needed for biodiesel are twice as great as 2003 output in the EU-15 and considerable larger than the 2000 record production of 11.4 million tonnes. Over the long term, net imports are undesirable to EU governments, if for no other reason than they are a subsidy from European taxpayers to rapeseed farmers outside Europe [M].

[M] Of course there can be international trade in rapeseed and rape oil, as there is today. The point is that to avoid 'wasted' subsidies, governments will aim to match national production and consumption.

Third, rapeseed production in Germany will hit its maximum capacity sometime between 2003 and 2010. Assuming that Germany will try to match national consumption of biodiesel to national production to rapeseed, by 2010 the country would need to devote 2.6 million hectares to rapeseed (just for biodiesel). This is more than the 2.4 million hectares available [Scharmer 2001]. It is recognised that in bumper crop years, yields – thus capacities – are increased above the 3.1 tonnes rapeseed per hectare that has characterised the past 7-8 years of German production. If this happens towards the end of the decade, then undercapacity would not be reached until a few years later.

Table 5-7: Biodiesel growth impacts on rapeseed: World, EU-15 and Germany

	2000	2001	2003	2010	Maximum possible
EU Biodiesel consumption, tonnes	775,000	1,380,000	1,935,000	7,000,000	
EU land use for biodiesel rapeseed, hectares	705,700	1,256,601	1,761,973	6,374,061	21,000,000
Rape oil to biodiesel, tonnes	798,146	1,421,215	1,992,791	7,209,063	
Rapeseed for biodiesel, tonnes	2,046,529	3,644,142	5,109,720	18,484,776	
Actual rapeseed production, EU-15, tonnes [Oil World Monthly 2003]	11,400,000	8,950,000	9,370,000		
Actual rapeseed production, World, tonnes [Oil World Monthly 2003]	42,560,000	37,530,000	32,640,000		
German biodiesel consumption tonnes	250,000	500,000	850,000	3,074,935 [N]	
Rapeseed production, Germany, tonnes	3,590,000	4,160,000	4,000,000	8,119,928 [O]	7,440,000
Actual rapeseed land use, Germany, hectares [Oil World Monthly 2003]	1,080,000	1,140,000	1,300,000		
Rapeseed land use for biodiesel only, Germany, hectares	212,958	425,917	724,058	2,619,331 [P]	2,400,000

[N] Assumes that German market will grow in proportion with EU-15 market.
[O] Required to supply domestic demand for biodiesel. This exceeds national capacity, reported in the next column, thus in fact imports would be required.
[P] Required to supply domestic demand for biodiesel. This exceeds national capacity, reported in the next column.

5.3.2 Glycerine

In the transesterification of oils to biodiesel, raw glycerine is inevitably produced as a byproduct. If this is converted to refined glycerine (which requires further processing), the mass yield is about 10%, i.e. one tonne of refined glycerine per 10 tonnes of biodiesel.

The increase in biodiesel production to around 7 million tonnes by 2010 would generate an equivalent of 700 kilotonnes of refined glycerine. This would swamp world glycerine markets as they exist today. Current Western European consumption of this product is 307 kilotonnes, global consumption is 547 kilotonnes. Conventional world demand[Q] for refined glycerine is expected to rise to 673 kilotonnes by 2010 (Table 5-8).

Table 5-8: Biodiesel growth impacts on glycerine, World and EU-15

	1983	1988	1993	1998	2000	2001	2003	2010
EU Biodiesel consumption tonnes					775,000	1,380,000	1,935,000	7,000,000
Byproduct glycerine from biodiesel, tonnes					77,500	138,000	193,500	700,000
Actual EU Glycerin production, tonnes [Camara-Greiner et al 2003]	205,000	188,000	198,000	219,000	233,000	247,000	307,000	
Actual world glycerine demand, tonnes [Camara-Greiner et al 2003]		282,595	357,716	452,804	494,328	516,000	547,424	673,263

European producers of glycerine have complained to the European Commission about this, arguing that the biodiesel subsidy is unfair [APAG 2002]. The Commission has not given an official response.

A massive increase in glycerine production presumably would lead to excess supply and significantly lower prices. An analyst at the Austrian Biofuels Institute, Werner Koerbitz, argues that this could open up a new range of competitive opportunities for glycerine. At much lower prices, it could compete with petrochemical-based products such as propylene glycol and pentaerythritol.

This would not be the first time the glycerine market has been stood on its head. In the 1960s and 1970s, a number of plants were built in Western Europe to make synthetic glycerine. With the rise of natural glycerine, these have steadily shut down. The only one still operating is a 36-kilotonne/year plant at Stade, Germany, owned by Dow Chemical.

[Q] For conventional, existing uses in personal care products, pharmaceuticals, foods & beverages and so on.

5.4 Tax revenues

The primary incentive to be used by the European Union to promote biodiesel is a waiver of excise tax levied on transport fuels. This is considerable leverage, as the representative figures in Table 5-9 suggest.

Table 5-9: Retail price buildup for road-transport diesel, EU mid 2002

Component	€urocents/liter	% of total
Diesel cost	17	20
Excise tax	50	58
Value added tax	19	22
Retail price	86	100

In mid 2002 on average in the EU-15, 58% of the retail price of diesel in the EU-15 consisted of excise tax. On top of the excise tax, a value-added tax (VAT) is levied as well, as it is on most products and services in Western Europe.

Table 5-10: Fuel excise and value-added taxes, EU 15, July 2002

	Fuel Excise *(Euro per 1000 litres)*			**Value added tax (%)**
	Unleaded gasoline	***Diesel***	***Light heating oil***	***Full rate***
A	414	290	77	20
B	507	305	13	21
D	624	440	61	16
DK	548	370	283	25
E	396	294	85	16
EL	296	245	245	18
F	574	376	43	19.6
FIN	560	305	68	22
I	542	403	403	20
IRL	401	302	52	20
L[R]	372	253	5	15
NL	627	345	198	19
P	479	272	34	17
S	504	341	274	25
UK	713	713	49	17.5
EU minimum	287	245	18	15

Source: [EU 2002]

The precise amount of the EU excise tax waiver is still unclear[S]. According to the European Commission's *Proposal for a Council directive amending Directive 92/81/EEC with regard to the possibility of applying a reduced rate of excise duty on certain mineral oils containing biofuels*, excise taxes would be reduced 50% 'on products made up of or containing biofuels.' The European Parliament has responded to this with a detailed debate. To them, this language could mean that petroleum diesel containing a drop of biodiesel would get the full waiver and that 100% biodiesel would get only a 50% cut in the tax.

[R] Luxembourg applies reduced VAT rateof 12 % to unleaded petrol

[S] Some waivers exist already at a national level. For instance Germany grants a 100% waiver. These must be harmonised at a EU level in a few years time, provisionally in 2008.

The way we (and most other analysts) interpret the proposal is that the tax waiver would be applied linearly on biodiesel content, with 100% biodiesel getting a maximum 50% waiver, 50% biodiesel a 25% waiver and so on.

Thus, we would calculate the maximum tax waiver in 2010 for 7 million tonnes of biodiesel to be:

7 million tonnes x 1000 litres/0.880 tonnes = 7.95 billion[T] liters
7.95 million liters x €0.25 excise waiver = €2 billion in excise taxes
€2 billion x 19% average VAT = €0.38 billion in value added tax

[T] 10 to the 9th or one thousand million

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