Cost-benefit analysis of biofuel of oil-seed origin in Greece

Diakoulaki D., Kavadakis G.

in

Rozakis S. (ed.), Sourie J.-C. (ed.).
Comprehensive economic and spatial bio-energy modelling

Chania : CIHEAM / INRA
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 48

2002
pages 77-84

Cost-benefit analysis of biofuel of oil-seed origin in Greece

Danae Diakoulaki*, George Kavadakis**
*Laboratory of Industrial and Energy Economics, NTUA, Dpt. of Chemical Engineering, Greece
**Centre for Renewable Energy Sources, Greece

Abstract: This paper presents a Cost-Benefit Analysis for the assessment of biodiesel in comparison with conventional diesel used in the transport sector in Greece. The analysis takes into account costs and benefits related with both marketed and non-marketed goods. The results show that based on purely financial criteria biodiesel is hardly competitive to oil products and that the overall economic performance of such an investment depends highly on the prices of both, raw materials and by-products. However, from a social point of view the introduction of this alternative energy source in the transport sector is extremely desirable and this calls for promoting economic incentives and other policy measures aimed at encouraging producers to be involved in such kind of activities.

Keywords: Bio-diesel, cost-benefit analysis, externalities.

1. Introduction

The oil crisis of the 70's revealed the dependence of the industrial world on non-renewable and finite fossil energy sources. This crisis stimulated increased efforts in research and development of renewable forms of energy. In recent years another reason for the promotion of renewable energy sources was the public awareness for environmental protection. Concerning environmental damage the transport sector has a clear responsibility. Emissions of CO_2 from transport in the EU increased from 0.6 to 0.8 bn tons in the period 1985-1996 (an increase from 20 to 26% of total anthropogenic emissions), with road transport accounting for 85% of all transport CO_2 emissions (E.E.A, 2000). In addition to environmental considerations, another motivational factor for using biodiesel was the increasing concern about key-aspects of the agricultural sector (surpluses, employment etc). Levy (1993) has shown that the annual production of 100,000 tons of biodiesel results in the creation of about 1,800 additional jobs in the agricultural and industrial sector, while in another study socio-economic benefits (job creation, reduction of mineral diesel fuels import) were estimated to 0.07 € per liter produced (Sourie, 1996).

During the previous decade emphasis was given on tightening vehicle emissions and fuel quality standards. The achieved reduction in the associated atmospheric emissions was, nevertheless, offset by the huge increase in transport activities. Hence, relevant measures, although necessary, are not sufficient to meet international and national targets. For that reason, today significant efforts are directed towards the development of alternative fuels, among which biofuels. With the term "biofuels" we refer principally to biodiesel and bioethanol. The main advantage of biodiesel compared to other alternative "clean" fuels is that it does not require high investment costs, as it can be used in existing diesel engines and does not require any further infrastructure for fuel storage and distribution.

The idea of using vegetable oils as fuel for diesel engines is not new. Rudolf Diesel used peanut oil to fuel one of his engines at the Paris Exposition of 1900 (Altin, 2001). However, a series of problems (e.g. engine knocking, carbon deposits, excessive engine wear) proved that the direct use of vegetable oil is not a satisfactory solution, as the engine must be modified according to the conditions of use and the type of oil (Ma, 1999; Srivastava, 2000). These problems can be alleviated by modifying the oil through transesterification, as the resulting product has very similar characteristics to diesel fuel and can be used in all types of diesel engines (E.C, 1994).

This is due to the transformation of the large, branched molecular structures of oils into smaller, straight chain molecules, similar in size to components of diesel fuel (IEA/AFIS, 1996).

Despite significant advances in the technology field, biofuels make still, at the international level, a very modest contribution to the total energy consumption in the transport sector. One of the major factors explaining this delay is that relevant investment decisions are based on market prices, which do not reflect positive environmental impacts and other benefits associated with the use of biofuels. The purpose of this paper is to assess the overall attractiveness of promoting the use of biodiesel in Greece by taking into account not only private cost considerations, but also external costs and benefits resulting from their use.

2. Biodiesel production and use

2.1. Production process and properties

Biodiesel is an ester that is produced from the transesterification of vegetable oils. This process involves reacting a vegetable oil with an alcohol (ethanol or methanol), in the presence of a catalyst to produce an ester (biodiesel) and glycerine. Biodiesel can be produced from various oilseeds by first extracting the oil (either by mechanical means or by solvent extraction) from the seeds, purifying it, adding methanol for the transesterification, and finally, separating and purifying the resulting methyl-ester.

By-products from biodiesel production are the meal produced during the stage of oil extraction that is used as animal feed and the glycerol produced during the transesterification stage which is used for pharmaceutical purposes. Other possible feedstocks except from oilseeds are animal fats and used frying oils.

Besides the lower atmospheric emissions as compared to diesel, other properties of biodiesel which contribute to its positive environmental profile are:

- High biodegradability: It is proved that over 98% of biodiesel degrades biologically in three weeks in comparison to 50% of diesel during the same period (Williamson, 1998). When mixed, biodiesel can also promote and accelerate the biodegradation of diesel and therefore substantially reduce risks of pollution to ground and surface waters (Zhang).
- Low oral and dermal toxicity and low evaporation reducing inhalation risk (Korbitz, 1995)
- High flashpoint, reducing risk of fire (for biodiesel it ranges from 100-180 ^{0}C, compared to 55-60^{0}C for diesel)

2.2. World market penetration

There is a steady increase worldwide of biodiesel production and Europe is by far the world's largest producer. In 2000, the production of biodiesel in the EU has reached 500 thousand tons representing approximately two thirds of total world production. In a recent survey (ABI, 1997), 85 biodiesel plants were identified around the world, of which:

- 44 plants in Western Europe, with Italy being the leading country with 11 plants,
- 29 plants in Eastern Europe, with Czechia being the leading country with 16 plants,
- 8 plants in North America, and
- 4 in the rest of the world

The European dominance is largely due to EU's policy that allows farmers to grow oilseeds for non-food uses on set-aside lands. In the early nineties the EU required from big farmers to withdraw from food production 15% of their arable acreage, giving them a compensatory payment. In this acreage, farmers were allowed to grow non-food crops, such as rapeseed or sunflower for biodiesel production and still receive the subsidy. Oilseeds grown on set aside represent the main energy crop with nearly 400,000 ha in 1997/98 (E.C, 1998). With more than half of the total European biodiesel production, France is the leader. Italy follows with 20% of the total volume and has the particularity of consuming 90% of its production for heating purposes. Germany, Belgium and Austria with 14%, 5% and 3% of European production respectively, are the other most important producer countries (ADEME, 2000). In all those countries, biodiesel promotion is encouraged by tax exemption through the implementation of a EU Directive (92/81) that gives the opportunity to Member States to apply for total or partial detaxation or tax reduction in the field of pilot actions for fuels derived from renewable sources. It has been recognized by EU, that tax exemption is a key condition for the relative profitability of liquid biofuels, because its production cost is still quite higher than that of conventional fuels.

Each country follows a different strategy for biodiesel market penetration. In Germany and Austria it is used as pure biodiesel, while in France blended with diesel. The most common blend in the United States is 20% biodiesel and 80% diesel. In the USA, the main source of biodiesel is soybean oil, whereas in Europe rapeseed and sunflower oil are the usual sources. In France, biodiesel is sold blended (5%) with diesel because it is believed that this mix does not cause any damages to the engines while improving the fuel lubricity when mixed with a low sulphur content fuel (Poitrat, 1999). This blend is sold in gas stations with no special signs and the consumer does not know the exact composition of the fuel purchased (pure diesel or blend). This strategy allowed the easier penetration of biodiesel in the market, but on the other hand it did not help to clearly demonstrate the benefits from its use. In France, there also exists the "Club de Villes Diester", a network of 30 communities, founded in 1994, where biodiesel is used in a 30% blend by the public transport sector (Le Club de Villes). Austria is the only country that produces biodiesel from used frying oils, while in Germany the only raw material used is rapeseed oil. Many EU car manufacturers (VW, Volvo, Audi, etc.) have manufactured cars, which burn pure biodiesel that meets German biodiesel standards (ADEME, 2000).

A key-point for the successful market introduction of biodiesel is its compatibility with diesel engines. The first standard was initiated in Austria, followed by other countries as Germany, France, etc.(Korbitz, 1998), whereas in 1997 the European Comission mandated the Eur. Organisation for Standardisation (CEN) to develop appropriate European standards (ADEME, 2000).

2.3. Biodiesel in Greece

In Greece the agricultural sector contributes to the Gross Domestic Product five times more than in the other European countries (OECD, 1996). Although many research efforts have been undertaken in the field of liquid biofuels, there is no commercial production of biodiesel up to now in Greece. In brief, besides the high production cost, the main non-technical barriers identified for the promotion of liquid biofuels in Greece are the following (CRES, 1996):

- Project and financial risk for non-proven technologies and emerging markets
- Lack of proper legislation
- Organizational barriers (e.g. small size of agricultural enterprises)

Financial barriers could be minimised through a total or partial detaxation of biodiesel, in accordance with the Directive 92/81/EEC. However, no such measure exists in Greek legislation up to now. Another possible barrier is that diesel in Greece has the lower excise duty after Portugal (252.55 €/1000 lt) among EU Member States (Ministry of Development, 2000). It must be noticed that during the last two years, a private oil company has started to distribute (at the same price with diesel) small quantities of biodiesel imported from Austria through its gas-stations in northern Greece, with the blend being very well accepted from the consumers.

3. Cost-benefit analysis

3.1. Private costs and benefits

It is well known that the main cost component of biodiesel production is the cost of raw material. According to different studies this cost varies widely depending on the type of feedstock used (Bender, 1999). In Greece, the possible raw materials for producing biodiesel are sunflower, cotton, used frying oils (UFO) and rape. The use of animal fats as raw material must be excluded due to its high price and the small quantities available. Among the available alternatives sunflower seems to be the most attractive solution for the near future, as it is already cultivated in Greece and the produced biodiesel is of high quality. On the other hand, rape is not yet cultivated in the country, cotton has not yet been tested in commercial applications, while the quantities of UFO are insufficient for supplying a medium-scale biodiesel plant.

Table 1 shows the cost of producing biodiesel from sunflower and its breakdown in distinct cost components that has been estimated in a recent study of the Agricultural University of Athens (2000).

Table 1. Costs and revenues from biodiesel production

Raw material cost	0.62
Labor cost	0.05
Variable cost (consumables)	0.05
Depreciation	0.05
Revenues from meal	-0.18
Revenues from glycerine	-0.06
Total net cost (€/lt)	0.53

Source: AUA, 2000.

It is clear from the above composition that the greater sensitivity of the net production cost is due to changes in the cost of raw material and in the price of the produced meal in the animal feed market. Table 2 shows the variation of net production cost in a number of scenarios established on the basis of different assumptions regarding extreme values of these two key-parameters and the existence of subsidy of the investment cost. Hence, if we consider the most optimistic scenario (40% subsidy, full sale of byproduct and raw material cost equal to 0.16 €/kg), the production cost of biodiesel is estimated to be equal to 0.28 €/kg, cost quite lower compared to that of diesel.

Table 2. Scenarios of sensitivity analysis.

	Raw material cost	By-product sales	Subsidy	Production cost (€/lt)
Scenario 1	0.16	YES	40%	0.28
Scenario 2	0.16	YES	0%	0.31
Scenario 3	0.16	NO	40%	0.52
Scenario 4	0.25	YES	0%	0.53
Scenario 5	0.16	NO	0%	0.55
Scenario 6	0.25	NO	40%	0.74
Scenario 7	0.25	NO	0%	0.77

Another component that may significantly increase the final production cost is the transportation cost of seeds from the fields to the oil plant. For distances up to 70 km this cost is 0.01 €/kg of seed (Kolioglou, 2000) that results in an increment of biodiesel cost equal to 0.015 €/lt. To this purpose, great attention should be paid to the siting of the plant in order to minimise this cost component. Thrace is very advantageous from this point of view since 88% of the total national sunflower production is already produced in that area, while the acreage in the county that is not cultivated (set-aside scheme) is more than 10,000 ha (National Statistic Service, 2000).

3.2. Environmental costs and benefits

In recent years the rising concern about environmental protection revealed the need for calculating and incorporating environmental externalities into the decision-making process. Externalities are costs or benefits imposed on society due to actions of firms and individuals, which are not reflected in market prices. External costs of energy have gained increasing interest in recent years, since it has become obvious that a variety of environmental and social damages are caused by energy production and use. The translation of these damages into monetary units allows for externalities to be treated as any other cost component and offers planners a simple and flexible method for achieving a socially least-cost provision of energy services.

For an accurate estimation of the externalities associated with biodiesel, it is essential to perform a Life Cycle Analysis (LCA), in order to take into account the positive externalities of carbon sequestration during the photosynthesis, as well as the external costs associated with the use of fossil fuels in the production of energy crops (Vollebergh, 1997). A detailed comparative study between biodiesel and diesel concerning their emissions through the whole fuel cycle was carried out in USA (Sheeman, 1998) and its main results are shown in Table 3. The production stage includes all upstream activities before the fuel (diesel or biodiesel) is consumed in a diesel engine. In the specific case of biodiesel production, the reported emissions are produced during the cultivation of energy crops, as well as in the processes of oil extraction and transesterification.

Table 3. Emissions (gr/kg) of biodiesel and diesel.

	Biodiesel			Diesel			% increase
	Production	Combustion	Total	Production	Combustion	Total	
CO	0.92	3.18	4.10	0.40	6.98	7.38	80%
CH_4	0.98	0	0.97	1.18	0	1.18	22%
NO_X	2.22	25.75	27.97	1.21	27.91	29.12	4%
N_2O	0.01	0	0.01	0.04	0	0.04	264%
PM10	0.10	0.13	0.23	0.02	0.47	0.49	113%
$PM_{unsp.}$	0.49	0	0.49	0.76	0	0.76	55%
SO_x	4.20	0	4.20	4.39	1	5.39	28%
CO_2	-2,155	2,827	672	495	3,186	3,681	448%

Source: Sheeman, 1998

It can be seen that the use of diesel is characterised by a significant increase of all types of emissions, in comparison with those associated with biodiesel. As expected the bigger increase is observed in the case of CO_2 emissions, while important increases are also reported for N_2O (also responsible for the greenhouse effect) and for suspended particulates. On the contrary, NOx emissions from the two fuels are almost equivalent.

The corresponding external costs have recently been calculated by the National Technical University of Athens in the framework of the EC's ExternE project (IER, 2000). The accounting framework used to assess the external costs is based on the Damage Function Approach (DFA), which is a step-by-step analytical procedure examining the sequence of processes through which emissions or other burdens associated with a particular polluting source result into environmental damages (EC, 1999). In the specific case of atmospheric emissions, relevant damage costs are due to the impacts of atmospheric pollution on human health, agriculture, forests and materials in the reference environment, as well as to the estimated future impacts of climate change at the global scale. It is clear that the most controversial stage of the DFA is the translation of physical impacts on non-traded goods in monetary terms. The values used in the ExternE project are derived from different valuation techniques (e.g. Contingent Valuation) based on welfare economics and consisting in uncovering the Willingness To Pay of individuals in order to avoid reductions in health risks and environmental effects. However, despite the high degree of uncertainty characterising the calculated external costs, their consideration in addition to private costs leads much closer to the real social costs of a given energy source, than if they were totally neglected.

As shown in Table 4, damage costs per ton of pollutant emitted, differ significantly among rural and urban areas mainly because of the different population densities.

Table 4. Damage costs of atmospheric emissions (Euro/tn)

	Rural area	Urban area
CO	0.20	6.86
CH_4	44.90	44.90
NO_X	7,453	4,471
N_2O	748.30	748.30
Particles	19,637	926,778
SO_X	4,519	26,593
CO_2	2.40	2.40

Source: IER, 2000.

Combining the data from the two previous tables and considering that both fuels are produced in a rural (not densely populated) area, we obtain the results shown in Table 5. Although in both rural and urban areas, external costs of biodiesel are lower compared to diesel, relevant benefits become very high (0.3 €/lt) if biodiesel is used in urban areas, principally because of the different damage cost associated with the emitted particles. Taking into account that in Greece, diesel is charged with an excise duty equal to 0.24 €/lt, it results that the detaxation of biodiesel is advisable from a social point of view if it is to be substituted for diesel in urban areas.

Table 5. External costs of biodiesel and diesel (€/lt)

	Transport in urban areas			Transport in rural areas		
	Production	Combustion	Total	Production	Combustion	Total
Diesel	0.02	0.50	0.52	0.02	0.2	0.22
Biodiesel	0.02	0.20	0.22	0.02	0.17	0.19

The same conclusion can be drawn from Table 6 which shows the total social cost of diesel and biodiesel used in both urban and rural areas, calculated as the sum of private and external costs.

Table 6. Social costs of biodiesel and diesel (€/lt).

	Transport in urban areas			Transport in rural areas		
	External costs	Private costs	Total costs	External costs	Private costs	Total costs
Diesel	0.52	0.35	0.87	0.22	0.35	0.57
Biodiesel	0.22	0.53	0.75	0.19	0.53	0.72

Conclusions

The main conclusions drawn from the comparative cost-benefit analysis presented in the previous paragraphs are the following:

1. The main factors determining net production cost are a) the cost of raw material (80% of the total cost) and b) the possibility of selling the by-products and especially the meal as animal feed. For that reason, efforts for ensuring the competitiveness of biodiesel with respect to diesel should primarily focus on these two parameters.
2. The implementation of 92/81 EC Directive in Greece is socially advantageous, as losses from tax credits will be overbalanced from the environmental benefits associated with the substitution of diesel by biodiesel.
3. From an environmental point of view, biodiesel is preferable to be used in urban instead of rural areas. This means that efforts for market penetration should be addressed to the taxi and bus fleets within urban areas. In addition, the penetration of biodiesel in rural areas would be more difficult since farmers are already beneficiaries of tax exemption for diesel.

References

[1] ADEME (2000), Final Report of NTB-Phase IV.

[2] Altin, R., Cetinkaya, S., Yucesu, H. S. (2001), The potential of using vegetable oil fuels as fuel for diesel engines, *Energy Conversion and Management* **42**, 529-538.

[3] A.U.A. (2000), Techno-economic feasibility study of biofuels in Greece (prepared for the *Ministry of Transport*, (in Greek).

[4] Austrian Biofuels Institute (1997), Biodiesel Documentation of the World-Wide Status, Report prepared for the *International Biofuels Institute*.

[5] Bender, M. (1999), Economic feasibility review for community-scale farmer cooperatives for biodiesel, *Bioresource Technology* **70**, 81-87.

[6] C.R.E.S. (1996), National Report of NTB-Phase I.

[7] E.E.A. (2000), Are we moving to the right direction? Indicators on transport and environment integration in the EU, *European Environment Agency*, Copenhagen.

[8] EC (1994), Biofuels – Application of Biologically Derived products as Fuels or Additives in Combustion Engines, *European Commission*, DG XII.

[9] EC (1998), Working Document on non-food crops in the context of Agenda 2000.

[10] EC (1999), ExternE: Externalities of Energy, Vol. 7 Methodology, Publ. by theEur. Commission

[11] IEA/AFIS (1996), Automotive fuels survey, Part 2: Distribution and use.

[12] IER (2000), The ExternE project: External costs in the transport sector, Final Report of JOS3-CT97-0015, European Commission, DG XII.

[13] Kolioglou, Transport Co., (2000), Personal communication.

[14] Korbitz W. (1995), Utilization of oil as a biodiesel fuel. In: Kimber, D., McGregor, D.I. (Eds.), *Brassica Oilseeds: Production and Utilization.* CAB International, Wallingford, UK, pp. 253-371.

[15] Korbitz, W. (1999), Biodiesel production in Europe and North America, an encouraging prospect, *Renewable Energy* **16**, 1078-1083.

[16] Le Club des Villes Diester, in www.villesdiester.asso.fr

[17] Levy (1993): Le biocarburants.(Translation N. Dercas). C.R.E.S

[18] Ma F., Milford A. Hanna (1999), Biodiesel production: a review, *Bioresource Technology* **70**, 1-15.

[19] National Statistic Service (2000), Production of agricultural and animal products in year 1999, Athens.

[20] Ministry of Development (2000), Oil crisis and fuel market in Greece (in Greek). Athens.

[21] Ministry of Development, Inf. Division (2000). Higher indicative retail prices of oil.

[22] OECD (1996), The OECD Observer, OECD in Figures – Statistics on the Member Countries, Paris.

[23] Poitrat, E. (1999), The potential of liquid biofuels in France, *Renewable Energy* **16**, 1084-1089.

[24] Sheeman J. et al (1998), Life cycle inventory of biodiesel and petroleum diesel for use in an urban bus, N.R.E.L Final report.

[25] Sourie J. et al., (1996), The costs of liquid biofuels in the French context. Proceedings of 2st European Forum on motor biofuels.

[26] Srivastava, A., Prasad, R. (2000), Triglycerides-based diesel fuels. *Renewable and Sustainable Energy Reviews* **4**, 111-133.

[27] Vollebergh, H. (1997), Environmental externalities and social optimality in biomass markets: waste-to-energy in The Netherlands and biofuels in France. *Energy Policy*, **25/6**, 605-621.

[28] Williamson, A. and Badr, O. (1998), Assessing the viability of using Rape Methyl Ester (RME) as an Alternative to Mineral Diesel fuel for Powering road Vehicles in the UK, Applied Energy, Vol. 59, No. 2-3, pp.187-214, 1998.

[29] Zhang, X., Peterson, C. L., Moller, G., Haws, R., Biodegradability of biodiesel in the aquatic environment, in www.biodiesel.org.