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IMPLEMENTATION AND EVALUATION OF THE FIRST BIODIESEL CHAIN IN GREECE

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ABSTRACT: The EU White Paper: Energy for the future: Renewable Sources of Energy, *COM (97)599*, recognises that there is a need for actions to promote the uptake of liquid biofuels for transport applications. Also, according to the "Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport, a minimum proportion 2% of biofuels of all petrol and diesel for transport purposes is encouraged to be achieved by 31 December 2005. This proportion is expected to increase to 5.75% by 31 December 2010.
Integrated biofuel chains for local transport applications offer the possibility to combine several sectors of the society such as the farming community, the conversion-to-fuel industry, the fuel distribution companies and the consumers into a sustainable business community dedicated to the transport sector. The main purpose of this work is to present all steps for the design, evaluation and implementation of the first biodiesel plant in Greece. Based on the general framework for biofuels in EU as well as on the current state of the country in terms of human resources, infrastructure and technology the first biodiesel plant is being implemented in Greece.
Keywords: bio-diesel, frying oil, liquid biofuels

1 INTRODUCTION

The EU White Paper: Energy for the future: Renewable Sources of Energy, *COM (97)599* [1], recognises that there is a need for actions to promote the uptake of liquid biofuels for transport applications. The rationale includes changing to alternative road transport fuels, which offer lower emissions of greenhouse gases and/or reduced emissions of local air pollutants. Also, according to the "Directive 2003/30/EC of the European Parliament and of the Council, of 8 May 2003, on the promotion of the use of biofuels or other renewable fuels for transport" [2], a minimum proportion 2% of biofuels of all petrol and diesel for transport purposes is encouraged to be achieved by 31 December 2005. This proportion is expected to increase to 5.75% by 31 December 2010.

Greece is still at an early stage in this field and does not have any commercial activities, as other EU member states (Austria, Germany, France etc). Up to now there is no biodiesel production in Greece. The first plant will be built by ELINOIL in the Industrial Area of Volos region (Central Greece). The annual capacity of the plant will be 2000-3000 tons of biodiesel.

The main faces prior to plant construction are thorougly analysed in this paper and refer to:

- resource assessment
- site selection and licensing of biodiesel plant
- biodiesel plant design
- product quality assurance management
- biodiesel distribution networks – end-users
- economic, social and environmental analysis

2 RESOURCE ASSESMENT

A critical requirement for any investment on bioenergy and biofuels is biomass feedstock availability. In this section, "complete biomass production chains" will be addressed in terms of technical quality assurance and economic assessment.

2.1 Waste oils

This task will assess the available quantities of waste oils, suitable for the production of biodiesel and in particular Used Frying Oils (UFOs) and will perform economic evaluation of setting up a collection system of waste oils from restaurants. In addition, their collections/handling systems aspects specifications for collection bins, inliner and trucks and concerning the contact studies about engineering of cleaning facility for UFOs will be covered.

Up to now, the total quantities of UFO's have been recorded for the largest fast-food service chains in Greece. The recorded quantities of palm oil used for frying, for year 2003, where about 1,000 thousand tons for a number of about 170 restaurants, distributed over Greece. From those quantities, the resulted UFO's where about 650 thousand tons (65-70% of palm oil).

2.2 Agricultural raw materials

This task will assess the potential of agricultural raw materials and will deal with the production of energy crops.

The availability of agricultural raw materials depends primarily on the current land-use systems. More specifically, the assessment will address the following aspects:

- Agricultural area
- Set-aside land
- Existing agricultural crops suitable as raw material for biodiesel production (e.g. sunflower)
- Yields
- Introduction of energy crops in set aside land through the establishment of demonstration fields (e.g. rapeseed)
- Agricultural industry by-products (e.g. cotton seed)

This data will be used for the estimation of the theoretically available quantities of raw materials for

biodiesel. Further to, the estimation of economically available quantities will be performed.

Till now, the cultivated areas and respective production for all Greek regions and departments, have been recorded for sunflower, cotonseed and soya been along with agricultural area, arable and set aside land. Industrial production, imports and exports of seed oils (cotton seed oil, sunflower oil, soya been oil, palm oil and rapeseed oil) and imports and exports of oilseeds (cotton seed, rapeseed, soya been and sunflower seed) have also been recorded at national level. In order to collect reliable and comparable data, the source used is the National Statistical Service of Greece [3].

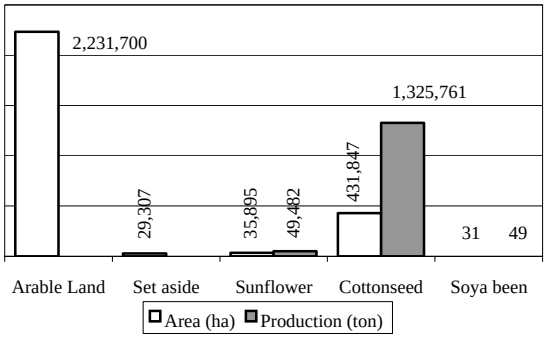

Figure 1: Agricultural area and respective production of sunflower, cottonseed and soya been in relation to arable land and set aside (Greece 1999)

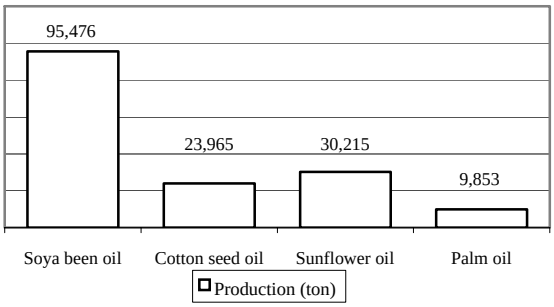

Figure 2: Vegitable oil production (Greece 2001)

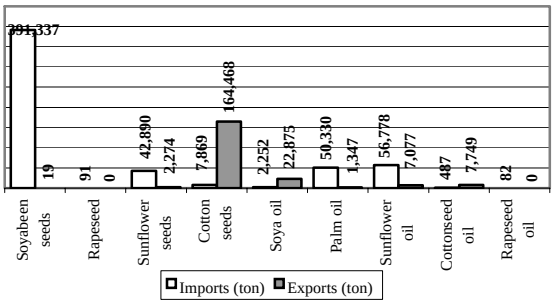

Figure 3: Imports and exports of seeds and oils (Greece 2003)

3 SITE SELECTIONS AND LICENSING OF BIODIESEL PLANT

ELINOIL decided to build the plant in the Industrial Site of Volos (Central Greece). The main reasons for this decision are:

- The distance from the harbor of Volos is quiet short.
- The respective industrial site is at the middle of Greece and it is convenient to manage the distribution throughout the country.
- It is close to the large agricultural plain of Thessaly, which is the largest in Greece (about 500,000 ha of agricultural land [4]).

4 BIODIESEL PLANT DESIGN

4.1 Production plant

Up to now there is no commercial biodiesel production in Greece. The first plant will be built in Volos region, in the Industrial Area. The annual capacity of the plant will be 2000-3000 tons of biodiesel. The main process sections of the plant are:

- Transesterification
- Methanol Recovery
- Process Control System

4.2 Use of various feedstocks

Various feedstocks will be used for biodiesel production, including cottonseed oil, sunflower oil, rapeseed oil and Used Frying Oils.

5 PRODUCT QUALITY ASSURANCE MANAGEMENT

Quality tests to assure the final product's suitability and to identify the most appropriate feedstock will be performed.

Based on past experience it can be stated that the crucial basis for obtaining warranties from Diesel vehicle producers is reliable high Biodiesel quality in order to assure required security in mobility. In order to assure this required high quality at all levels in production and distribution in the chain to the end user a quality assurance management system will be installed. This starts in the production plant with proper and regular analytical work and documentation and is continued during the distribution chain till the end user at the pump by independent analytical laboratories. This system is seen also as a self-protection against low quality methyl-esters entering the markets, which can disturb customers' confidence and damage the positive image as observed in Germany in 2001. It is intended to develop a quality seal as a sign for proven quality, which is promoted at pumps and through the press e.g. the automobile clubs. This action should contribute to give the Biodiesel producers a safe and trustworthy stand in the market place. Cooperation with Diesel vehicle producers will be actively established with the intention to expand the present list of vehicles with existing biodiesel warranties. Fuel quality tests will be performed in line with the imminent CEN biodiesel standard (EN 14214) [5]. All required parameters would be measured and tested for each batch of biodiesel produced for conformity with the relevant standard.

6 BIODIESEL DISTRIBUTION NETWORKS – END-

USERS

In the framework of this phase the availability of current distribution networks in selected regions will be assessed. Additionally, fuel performance will be tested in Elinoil's tank truck fleet, involving both actual end-users and industrial partners who have relevant activities and interest either in biofuels only or in alternative fuels for transport in general.

6.1 Biodiesel distribution networks

The following aspects will be considered:

- Logistics architecture including existing infrastructure (such as storage tanks)
- Reaction of stakeholders to the fuel (including drivers, distributors, managers, etc.)
- Biodiesel use in Elinoil's fleet, after modification. Elinoil owns 35 diesel engine tank trucks, which will be using biodiesel blends and will be subject to performance, emissions and wear research.

6.2 End-users

The aim of this task is to analyse the end-users' perception. Part of the produced biodiesel will be distributed through Elinoil's petrol station network (400 petrol stations all over Greece). Following the European Norm EN 590:2004 [6], a concentration of 5% biodiesel in the diesel fuel will be used in the beginning.

According to the "Directive 2003/30/EC of the European Parliament and of the Council, of 8 May 2003, on the promotion of the use of biofuels or other renewable fuels for transport" [2], a concentration higher than 5% biodiesel up to pure (100%) in the traditional diesel fuel is encouraged for use in the public transportation and in private fleets. Different mixtures of biodiesel (5% up to 100%) are going to be used. ELINOIL's fleet of around 100 trucks is going to have the required modifications for consuming up to 100% percent biodiesel from various feedstocks in order to evaluate the actual performance of the fuel.

6.3 Glycerin

Glycerin is the by-product of biodiesel production. By selling glycerin, the biodiesel unit can increase its revenues. The aim of this task will be to identify the possibility of glycerin purification by evaluating Glycerine Evaporation and Glycerine Distillation and Bleaching Unit. Commercialization aspects (potential customers, prices etc.) will also be examined.

7 ECONOMIC, SOCIAL AND ENVIRONMENTAL PERFORMANCE

Economic analysis of the selected biofuel chains along with fiscal measures, taxation systems and financial incentives will be performed. Also, quantification of the benefits from the development of regional biodiesel schemes in terms of social criteria, and identification of whom and how they accrue, will be done. An assessment of the environmental impacts for the production and use of biodiesel will complement the ones of economic performance and social impacts.

7.1 Cost analysis of biodiesel chains

Past experience shows that approximately 75% of final biodiesel product cost is due to the cost of the raw material [7].

All tested biodiesel chains will be analysed in order to identify and measure all related costs, first in physical quantities (e.g. land area, man and machine hours, fuel needs, raw material volumes, etc.). This will provide a cost measurement system independent of resources prices and therefore stable through time in the short and medium term. The required quantities of factors of production and raw materials will then be multiplied by their corresponding prices to calculate total cost in value terms.

All cost items will be classified into four distinctive cost phases: (a) biomass production/collection, (b) transport of raw material, (c) transformation, (d) transport and distribution of biodiesel.

The cost figures will be measured on site at the experimental fields that will be used by the project. Also, bibliographical information will be used, mainly for comparisons.

By using marketing information, biodiesel selling prices will be estimated and will be used for profitability forecasting. In effect, it is already known that biodiesel is two to three times more expensive than fossil fuels [7], thus cost/profitability analysis will (a) select the least cost chains, (b) identify opportunities of cost reduction and (c) indicate the cost categories where cost can be avoided, reduced or negotiated.

7.2 Investment appraisal of biodiesel chains

Initially an economic, additionally to the technical, comparison among the existing raw materials and the energy crop production will be made to define the most viable raw material for biodiesel production.

Full investment appraisal will be conducted for all stages of biodiesel chains and for each raw material. This will compare the future benefits of biodiesel investments with the initial investment cost.

In the investment appraisal all costs identified will be used as well as the incomes from sales according to estimated competitive market prices for biodiesel. All possible alternative markets for the feedstock will be defined, so that their opportunity cost can be estimated as base feedstock price for the biodiesel production. Furthermore, possible markets of agricultural by-products will be defined, because the selling of those by-products increases farm income and contributes to energy crop production economic viability.

With the necessary modifications, cost/profitability analysis will be re-formed into statements of cash flow. This will allow the calculation of common investment appraisal indicies, including Payback Period, NPV, IRR, etc. Project evaluation will show if the inflows generated from biodiesel production are sufficient to pay back the necessary investment capital.

7.3 Social impact assessment

The aim of this task is to establish and quantify the impacts from the development of biodiesel schemes in terms of social criteria, and to identify to whom and how they accrue (including job creation, energy independence, improvement of the balance of trade as well as alleviation of acute problems in the agricultural sector, etc.).

7.4 Environmental assessment

In this task all environmental implications of the production and utilisation of biodiesel originating from different raw materials will be assessed. This will be done by comparing them to diesel oil and taking local conditions into account.

Especially *Life Cycle Assessment* (LCA) as an environmental assessment tool will be used. Important inputs will be collected from experimental measurements on the production of resources, on conversion of the different raw materials to biodiesel and on biodiesel use in representative vehicles. Data for alternative fossil fuels, fertiliser production etc., will be derived from literature. Output of the task will be a set of quantitative and qualitative results for all scenarios (local fleets, different agriculture practices to produce the crops etc.) for each comparison of a biodiesel chain versus ordinary diesel related to the different resources and technologies used.

7.5 Energy efficiency analysis

The energy efficiency analysis will examine the life-cycle energy inputs and outputs of each biodiesel chain in order to make comparisons with the reference fossil fuel (diesel). Energy inputs occur during the agricultural production, harvest, storage, transport and conversion routes for the fuel production and energy outputs occur when the fuels are combusted during in-vehicle use.

The energy balance is calculated as both, the ratio of the biofuel energy produced during combustion for vehicle propulsion to the total energy input to the fuel production process as well as the difference between the two. The energy balance calculations will be carried out in conjunction with the LCA analysis.

7.6 Land use aspects

Different land use impacts exist, when energy crops are cultivated for local and/or regional use. Especially the agricultural production of the crops under concern leads to different land use impacts. Also, alternative agricultural reference systems compared to energy cropping might lead to significant differences. Such environmental implications will be analysed by using EIA (Environmental Impact Assessment). With this tool, especially local and regional effects are considered compared to regional and global ones by LCA-technique.

The analysis will take into account different agricultural reference systems like set-aside and food production, different crops, and different countryside settings. A comparison will be made to existing results of other countries of the EU, with an already existing infrastructure for biodiesel.

The output will be a set of quantitative and qualitative results related to the issues and questions listed above.

7.7 Sensitivity analysis

Based on an interpretation of the sensitivity of the selected system boundaries, assumptions, used data and results, a set of sensitivity analyses will be carried out to demonstrate the validity of the final results.

A conclusive interpretation taking all aspects mentioned above into account will be carried out.

8 CONCLUSIONS

The main idea of this project is to present all steps for the design, evaluation and implementation of the first biodiesel plant in Greece. As mentioned before, Greece is at an early stage with regard to biodiesel production and up to now there is no biodiesel plant.

The establishment of a biodiesel plant will also utilise significant quantities of agricultural products that now have marginal use at the market, such as cotton seed oil or sunflower oil, or raw materials that are not merchandised today and are concerned as wastes, such as Used Frying Oils. It will also provide opportunities for utilisation of set aside or marginal land, by cultivating energy crops such as rapeseed.

Another important point is the investigation and use of current distribution networks of biodiesel. This will make the end-users familiar with the fuel and will record their perceptions.

Concluding, the investigation of the first integrated biodiesel chain in Greece will provide us with useful information and experience for the dissemination of the production and use of biodiesel in the country. Also, the first biodiesel plant will be a good example for others to follow.

9 REFERENCES

[1] European Commission, 1997. *Energy for the Future: Renewable Sources of Energy*, White Paper, COM(97)599 final.

[2] European Commission, 2003. *DIRECTIVE 20003/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE CONCIL, of May 8 2003, on the promotion of the use of biofuels or other renewable fuels for transport.*

[3] National Statistical Service of Greece (NSSG), 2004.

[4] Economics.gr, 2004. http://www.economics.gr.

[5] EN 14214, Automotive fuels-fatty Acids Methyl Esters (FAME)-Requirements and Test Methods, CEN-European Committee for Standardization, Rue de Stassart 36, B-1050 Brussels.

[6] EN 590:2004, CEN-European Committee for Standardization, Rue de Stassart 36, B-1050 Brussels.

[7] International Energy Agency, 1994. “Biofuels”, OECD/IEA.

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