COST/BENEFIT ANALYSIS OF PRODUCTION AND USE OF BIOETHANOL AS A GASOLINE ADDITIVE IN THE EUROPEAN COMMUNITY

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Cataloguing data can be found at the end of this publication.

Luxembourg: Office for Official Publications of the European Communities, 1987

ISBN 92-825-7581-0

Catalogue number: CB-50-87-170-EN-C

Printed in Belgium

Commission of the European Communities

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Document

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FOREWORD

The report was prepared by Agro Developpement (France), Parpinelli Tecnon (Italy), Institut für Landwirtschaftliche Technologie und Zuckerindustrie an der T.U. Braunschweig (West Germany), Laurence Gould Consultants Limited (United Kingdom).

Original language : English

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EXECUTIVE SUMMARY

The principal purposes of the study are :

- To carry out a cost/benefit analysis of the production and the use of bioethanol as a gasoline additive in the European Community (12) during the period 1986-2000,
- To study and quantify the implications of such a programme in terms of agriculture, technical know-how, costs, energy supplies, competition, employment and industry.

1) PROBLEMS OF OXYGENATED FUELS AND LEAD-FREE PETROL

Gasoline Demand : Based on an extensive analysis of the expected trends in the EC car parc, fuel efficiency and the average distance driven, gasoline demand in the EC (12) is projected to increase from 94.5 million tonnes in 1986 to 95.8 million tonnes at the end of the century.

Penetration of Unleaded Petrol and the Quality of the EC Gasoline Pool : Under the stimulus of EC regulations, rapid penetration of lead free petrol is projected, reaching levels of 20 % of the total market by 1990 and 83 % by 2000. As a result, the average lead content of the pool should reduce from 0.26 g/l in 1986 to only 0.06 g/l in 2000. Consequently, clear RON requirements for the total pool should increase by 2.4 points, whilst clear MON requirements increase by 2.8 points.

The Refining Industry in the EC : The industry has resolved the major problems of surplus capacity it faced in the 1970's through an extensive rationalisation programme involving a painful process of plant closures and job losses, whilst simultaneously investing billions of dollars in new highly sophisticated gasoline conversion and octane capacity.

Oxygenated Fuels Use in the EC : Oxygenates are regarded as a convenient option to meet the octane requirements of the gasoline pool, but they are not the only option and price competitivity will continue to be the key element in determining their actual use. Most of the projected increase in the use of oxygenates centres on MTBE because it has established a dominant market preference over the competing oxygenates owing to its superior blending characteristics.

Octane Balances in the EC : Based on a number of conservative assumptions, it is calculated that no octane shortage will materialize in the Northern countries of the EC before the end of the century. In contrast, the calculations suggest that an octane deficiency could emerge in the EC-South during the mid 1990's unless there is further investment in local refineries. However, past experience indicates that refineries in the South are very likely to make these investments in order to avoid a potential exposure to octane deficiency. In conclusion, the analysis suggests that the refining industry in the EC will not be faced with an octane deficiency throughout the rest of the century. The use of oxygenated fuels should therefore always be viewed as being complementary to, and competing with the refinery's internal octane supplies, rather than as an essential requirement in the gasoline pool.

Blending Properties of the Oxygenates : Generally characterized by high RON relative to gasoline (though their contribution to the MON is less significant) the oxygenates have high sensitivity (RON - MON) and a high volatility. These characteristics imply respectively an economic premium and a penalty. The economic penalty is particularly pronounced for the alcohols which also suffer from low water tolerance. Of the oxygenates, MTBE has established a clear superiority amongst refiners because its characteristics are closest to gasoline specifications. Amongst the alcohols, GTBA is superior to ethanol in terms of its average blending properties, whilst Oxinol 50 is superior to the M3E3 blend.

Breakeven Values of Oxygenated Fuels : Taking both the positive (octane boosting effect) and negative (sensitivity, volatility) contributions into account, the economic evaluation of breakeven values for the oxygenates have been tested under a wide range of historical market conditions including crude oil prices as high as $ 35 a Bbl and as low as $ 10 a Bbl. These calculations confirm prevailing market indications : relative to premium gasoline, the breakeven value of MTBE falls around the level of 1.20, that of GTBA around 1.00 and that of Oxinol around 0.85. For ethanol the calculations suggest breakeven values close to those of Oxinol in the range 0.80 - 0.90. However in order to achieve a high penetration of the available market,it is highly probable that ethanol would have to be significantly discounted below its calculated breakeven value.

2) TECHNICO-ECONOMIC ANALYSIS OF A BIOETHANOL PRODUCTION SYSTEM

Current Alcohol Situation in the EC : The European Community finds itself with structural surpluses in alcohol, the sales of which appear to be difficult. The measures adopted in DUBLIN in this connection should make it possible to improve the situation noticeably. However, by the year 1992, the surplus of wine would still amount to 22 million hl, i.e. corresponding to an annual production of 2.2 million hl of alcohol. Community stocks have risen to 4.6 million hl of alcohol. The question of finding an outlet for this alcohol is raised. One possible use could be its incorporation into gasoline as part of the move towards the use of unleaded gasoline.

However, this alcohol has to be subsidized if its price is to be considered acceptable by the petroleum producers. An increase in the prospects for ethanol raises the question of market support and of guaranteed outlets.

Projected Potential Market for Bioethanol : Based on a projected gasoline demand of about 95 million tonnes in the 1990's, the Consultants estimate a potential target market for ethanol, after making allowance for sea-borne gasoline imports and remote market sectors, of up to 2.5 million tonnes ; this is equivalent to about 31.4 million hectolitres of ethanol.
In order to achieve a significant penetration into this potential market, however, it is highly probable that ethanol would have to be priced at levels below the 80 - 90 % valuation indicated above on the basis of blending properties alone. In this context, practical experience in the US market suggests that levels as low as 60 - 70 % (weight basis) of premium gasoline prices may be necessary in order to gain a substantial market share from the existing oxygenates and from captive sources of octane.
The maximum potential market for bioethanol based on a low price/high volume strategy corresponds to 1.1 million ha and a quantity of 8.5 million tonnes of wheat in the year 2000, for 100 % wheat plants. For combined plants (wheat and beet), the corresponding figures are 0.7 million ha - 5.7 million tonnes of wheat and 0.2 million ha - 10.5 million tonnes sugar beet.
Alternatively, however a strategy of high price/low volume could be adopted on the basis of small-scale bioethanol plants located near to refineries identified as having problems in meeting RON requirements. During the 1990 's, this strategy could aim at a market of up to 0.6 million tonnes or 7.5 million hl of bioethanol, at a pricing level of 100 to 120 % of premium gasoline.

Present Crops and Alternative Crops : Europe has gone beyond self-sufficiency in the agricultural raw materials under consideration except for potatoes which are at 100 %. Taking into account the continued increases in yields and the state of internal and external markets, secure supplies are available to the Community for a possible bioethanol programme. The computations were based on the intervention price for wheat and on the B quota for sugar beet. They should decrease respectively by 1% and 0.5 % per annum assuming that agricultural revenues are maintained, as forecast.
In the future, yields should continue to increase ; new possibilities could arise through the increased use of biotechnologies. Average yields obtained by the member countries do not reflect regional disparities ; as might be expected the traditional regions of industrial crops have the highest productivity.
New energy crops such as Jerusalem artichoke, sweet sorghum and short rotation forestry offer interesting possibilities. Research must nevertheless continue in order to optimise the nature and the cultivation conditions of these raw materials, as well as their processing.

TABLE I - PROJECTED LEVEL OF SUPPORT NEEDED IN VIEW OF NET PRODUCTION COSTS AND SELLING PRICE OF BIOETHANOL
Case of 100 % unit. Capacity 5000 hl per day
oil price : recovery scenario

	1986		1990		1995		2000	
	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B
1- Raw material price (intervention) ECU/Tonne	170.47	170.47	163.75	157.24	155.73	142.13	148.10	128.47
2- Net production cost ETOH ECU/hl	49	49	47.4	45.6	46.3	42.5	45.3	39.8
3- Selling price ETOH ECU/hl								
Ratio ETOH/ gasoline 1.1	15.03	15.03	16.87	16.87	17.78	17.78	20.9	20.9
Ratio ETOH/ gasoline 0.85	11.61	11.61	13.04	13.04	13.74	13.74	16.15	16.15
Ratio ETOH/ gasoline 0.7	9.56	9.56	10.74	10.74	11.31	13.31	13.30	13.30
Difference 2 - 3 ECU/hl								
Ratio ETOH/ gasoline 1.1	33.97	33.97	30.53	28.73	28.73	24.74	24.74	18.9
Ratio ETOH/ gasoline 0.85	37.39	37.39	34.36	32.56	32.56	28.76	29.15	23.65
Ratio ETOH/ gasoline 0.7	39.44	39.44	36.66	34.86	34.88	31.19	32	26.50
Difference 2 - 3 with EC Restitution 70 ECU/Tonne (18.92 ECU/hl)								
Ratio ETOH/ gasoline 1.1	15.05	15.05	11.61	9.81	9.6	5.8	5.48	- 0.02
Ratio ETOH/ gasoline 0.85	18.47	18.47	15.44	13.64	13.64	9.84	10.23	4.73
Ratio ETOH/ gasoline 0.7	20.52	20.52	17.74	15.84	16.07	12.27	13.08	7.56

Source : Consultant's estimates

ETOH = Bioethanol

Scenario A : 1 % decrease in price
Scenario B : 2 % decrease in price

<u>Production Costs</u> : The net production costs of bioethanol are estimated in a range from 46 to 53 ECU/hl, depending on the size of the units and raw materials used.
Economies of scale remain significant between 1000 hl and 5000 hl per day capacities.

70 % of total outflows come from agricultural raw material and receipts from co-products represent 20 % to 25 % of the total inflows. The production costs of bioethanol in existing plants will remain, at best, at a level similar to those of new units. But modernisation investment will be needed in existing units to produce bioethanol on a large scale.

It is possible to foresee an overall reduction in the net production cost of bioethanol by 10 to 20 % in constant values by the year 2000, mainly as a result of :

- reductions in the price of agricultural feedstocks
- reduction in conversion costs
- co-products price changes

The fact that the cost of transporting and storing raw materials is greater than that for bioethanol and its co-products should be taken into account when choosing a location for a bioethanol unit.
Finally, the largest existing bioethanol plants in the EC are located in France, Spain and Italy. These plants work mostly from sugar beet and wine substrates. Some projected production costs and support levels, taking into account the forecast selling price for bioethanol, are summarised in table I.

<u>Other Possible Uses of Bioethanol</u> : It is technically feasible to convert ethanol to ethylene for use as a base material for the chemicals industry. A preliminary analysis suggests that, in the absence of additional financial incentives, bioethanol production directed at the chemicals industry is likely to be even less viable than its production as an oxygenate.

<u>Alternative Options for Agriculture</u> : Projections of agricultural production and demand for produce suggest that the continuation of the current pattern of agricultural land uses will lead to increasing stockpiles of farm produce, particularly cereals. The most feasible alternative land uses include the production of protein and oilseed crops, in addition to the production of feedstock for bioethanol. All of these alternatives would represent a higher cost to the Community and/or Member States than the current cost of cereals support for export. The total support required for a bioethanol programme would represent the highest financial cost per hectare of any of these alternatives by a considerable margin. Community support for a bioethanol programme could be no more costly to the Community Budget than support for export wheat if the Member States agreed to provide the additional support which would be necessary.

3) ANALYSIS OF THE IMPLICATIONS OF A BIOETHANOL PRODUCTION PROGRAMME FOR THE BUDGET, EMPLOYMENT, ENVIRONMENT, ENERGY BALANCE AND COMPETITION

Co-products Markets and implications : The maximum European bioethanol production forecast at 31.4 million hl produced from 1/3 EP2, and from 2/3 wheat would generate 0.9 million tonne of EP2 vinasses and 2.1 million tonnes of DDGS, co-products which, because of their composition and especially their high protein nitrogen content, are particularly well suited for cattle feed, and secondary feed for porcines and poultry, as partial substitutes for soya oilcake, corn gluten feed and various protein-rich seeds which today represent for Europe imports of 25 million tonnes.

This partial substitution in animal feed ingredients would make it possible to save the equivalent of 2.2 million tonnes of oilcake, i.e. almost 385 million ECU per year in import savings. Production of protein-rich co-products from the bioethanol process would have no effect on the sales of corn gluten feed resulting from the starch producing operations in France and Italy since the production of corn gluten feed in Europe as a whole continues to show a deficit.

Environmental Aspects :Environmental impacts potentially created by a bioethanol programme include the adverse effects of maintaining existing intensive arable land use, the creation of highly polluting waste streams by the fermentation process, direct local impact of storage and transport facilities for bioethanol plants and blending facilities and the change in combustion products compared to current fuels. Many of the potential effects may be minimised by using the stillage as feedstuff, sensitive design, appropriate location and investment in pollution control measures. The effects on the atmosphere of the replacement of lead by oxygenates are perceived to be environmentally beneficial but further research is justified.
The cost of environmental protection measures is included in the Consultants' financial and economic projections. These costs are likely to be higher for plants using sugar-based feedstock than for plants based exclusively on cereals.

Experiences in Countries outside the EC : Experiences in Brazil, USA, Sweden confirm that a high degree of government support, both legislative and financial, is required to establish and maintain a large scale bioethanol programme ; without this commitment, the projects become very vulnerable, particularly in an era of low oil prices.
The Brazilian experience is least applicable to the EC. In Sweden, ethanol blending ceased in October 1986 on economic grounds. Apart from the 10 % level of ethanol blending, the US experience is considered to be broadly applicable to the EC.
These experiences have encouraged investment and job saving/creation. In the US the saving in price support for corn slightly outweighs the loss of income from gasoline excise taxes.

On average in 1985, the tax exemptions in the US totalled 8.7 cents/gallon of gasoline (87 cents/gallon of ethanol), representing about 85 % of the equivalent raw material cost. Ethanol pricing in the US indicates that, before the drop in oil prices, ethanol sales prices adjusted for the available state and federal tax reliefs, averaged about 60 - 70 % of unleaded regular gasoline prices on a weight basis. In 1986, however, ethanol prices relative to gasoline declined throughout the year to reach an average of less than zero in the last quarter, giving blenders a feedstock of zero net cost, without generating any apparent increase in the volume of ethanol blended into gasoline. Ethanol prices began to recover in 1987.

Fiscal effect and implications : The net effect of a bioethanol programme on the balance of trade in hydrocarbons is likely to be small in comparison with the total volume of trade in the EC.
Given that the difference between production cost and selling price of bioethanol is unlikely to be funded from the Community Budget, a significant support would be required from Member States. So, if bioethanol is produced from wheat at world price market level (with the 70 ECU/tonne export restitution) the remaining support required would need to be covered by Member States. However, Member States would also benefit from increased tax revenues and any reduction in social welfare payments due to employment created. At best, as in the case of France, the net financial effect on Member States may be neutral ; however it is most likely that there will be some net cost to Member States. Projected requirement for support is highlighted in Tables II, III and IV.

Employment Impacts : A bioethanol programme throughout the EC would create a maximum of 23,600 to 39,300 jobs in rural areas if the maximum potential market of 1.5 to 2.5 million tonnes were fully achieved. Against this should be set possible job losses in the refining and petrochemical sectors. The potential impact on employment is small in relation to the actual contraction in employment in both the agricultural and refining-petrochemical industries.

Energy Balances : Like most of the published results, the Consultants analysis shows a positive net output of energy for the production of ethanol from sugar beet or wheat if solar energy is omitted from the calculation. Based on the same processes as for the calculation of production costs, the energy balance for sugar beet is more favourable than for wheat. In the case of small-scale wheat based ethanol production, the utilisation of the straw as a fuel improves the energy efficiency substantially. However, this is not practical for a large scale operation in which the straw can only be used as a fertilizer which therefore generates a rather lower energy balance, albeit still a positive one.
For technical considerations, the Consultants conclude that it is inappropriate to compare the energy balances for the fossil-based oxygenates with those for ethanol derived from biomass.

TABLE II : ESTIMATE OF TOTAL MEMBER STATE SUPPORT REQUIRED TO ENCOURAGE INVESTMENT IN A BIOETHANOL PROGRAMME
(Assuming ethanol : premium gasoline price ratio of 0.7:1 Oil price recovery scenario)

SOURCE OF SUPPORT	SUPPORT REQUIRED PER YEAR					
	PER TONNE		PER HECTARE		TOTAL	
	ECU 1990	ECU 2000	ECU 1990	ECU 2000	MILLION ECU 1990	MILLION ECU 2000
Community Budget	70	70	449	545	360-600	360-600
Member States	66	48	423	375	336-561	248-413
TOTAL	136	118	872	920	696-1161	608-1013

Source : Consultants'estimates

TABLE III : INDIVIDUAL MEMBER STATE SUPPORT REQUIRED FOR BIOETHANOL
(Assuming ethanol : premium gasoline price ratio of 0.7:1. Oil price recovery scenario)

MEMBER STATE	SUPPORT REQUIRED PER YEAR	
	Million ECU 1990	Million ECU 2000
FRANCE	84-140	62-103
WEST GERMANY	126-210	93-155
ITALY	42-70	31-52
UK	70-117	52-86
Others	14-24	10-17
TOTAL	336-561	248-413

Source : Consultants' Estimates

TABLE IV - BUDGETARY IMPLICATIONS OF A BIOETHANOL PROGRAMME (oil price recovery scenario)

ETHANOL PRICE	ETHANOL MARKET SIZE	WHEAT PRODUCTION AREA	SUPPORT REQUIRED			TOTAL SUPPORT
Ethanol:premium Gasoline ratio	Million tonnes	Thousand hectares	ECU/Hl	ECU/t	ECU/Ha	million ECU
			2000	2000	2000	2000
1.0 - 1.2 : 1 mid point 1.1 : 1	0.1 - 0.6	43 - 261	24	90	700	31-185
0.8 - 0.9 : 1 mid point 0.85: 1	1.0 - 1.5	427 - 666	29	108	840	369-553
0.6 - 0.8 : 1 mid point 0.7 : 1	1.5 - 2.5	666-1 088	32	118	920	608-1013

Source : Consultants'Estimates.

Budgetary Aspects : The total financial support required to encourage a bioethanol programme capable of capturing all the potential market (1.5 to 2.5 million tonnes)is currently estimated at a total of 608 - 1013 million ECU in the year 2000. This sum can be divided into a support from the Community Budget and a support from the Member States. In the first case, a support of 70 ECU/tonne of wheat to provide access to the world market price level represents 360 to 600 million ECU. In the second case the remaining support is of 48 ECU/tonne of wheat, i.e. 248 to 413 million ECU, which may be totally (case of France) or partially covered by the fiscal effects of a bioethanol programme.
This represents a total level of support per tonne of wheat of 118 ECU and support per hectare of 920 ECU, both figures substantially in excess of current support for the cereal sector and proposed alternatives such as set aside. Nevertheless, it is very close to the present support of 110 ECU per tonne of wheat (from 1st July 1987) subject to industrial processing for non food utilisations. Although the required support would reduce if the oil price rises and/or the cost of feedstock falls, both of which are likely developments, the magnitude of the necessary change is much greater than any reasonable projections.

4) ECONOMIC COST/BENEFIT ANALYSIS

Economic Cost/Benefit Analysis : Economic cost/benefit analysis has been used to determine whether or not a bioethanol programme would be of net benefit to the EC as a whole, making allowance for fiscal effects, distortions of the market through government intervention and the true economic value of land, labour and capital in the EC, as these are influenced by current developments in the European agricultural and petrochemical industries.
This analysis has been conducted using average data for each Member State, without taking into account regional situations which may offer more favourable circumstances. The results of the analysis indicate that it would not be in the economic interests of the EC as a whole to embark upon a large scale bioethanol programme under any of a wide range of assumptions.
Although the models are relatively sensitive to the economic production cost of feedstock and to bioethanol value, the extent of the variation required for the model to show a net economic benefit is very large. A sustained real oil price in the range of $30 - 40/Bbl or a reduction of 35 % - 45 % in economic production cost of feedstock would be required to achieve economic viability, for average conditions in the Community. However for certain favourable regional situations (high yielding production areas), the required percentage reduction in economic cost of production could be lower. Finally, it should be noted that these results are valid if agriculture is considered to be managed with economic criteria. Taking into account the Common Agricultural Policy, the present situation is quite different.

PREFATORY NOTE

The Commission of the European Communities invited consultants to submit proposals for a study on bioethanol in March 1986. M. Guy Legras, the Director General of DG VI - the Directorate for Agriculture - wrote to the consultants and enclosed specifications for the study. The Terms of Reference for the study are included as Appendix II to this report.

Following detailed discussions and negotiations, the Commission of the European Communities awarded the study to a consortium of consultants comprising :

* AGRO DEVELOPPEMENT (Paris France)
* PARPINELLI TECNON (Milan Italy)
* LAURENCE GOULD CONSULTANTS (Warwick UK)
* INSTITUT FUR LANDWIRTSCHAFTLICHE TECHNOLOGIE UND ZUCKERINDUSTRIE AN DER T.U. BRAUNSCHWEIG (Braunschweig West Germany)

Specific responsibilities for the various aspects to be covered by each of the participating Consultants were identified and agreed, administrative responsibility was allocated and the contractual obligations of the Consultants outlined at a meeting at the Berlaymont, Brussels, on 4th July 1986. It was agreed that the Consultants should submit an Interim Report by the end of January 1987. The Interim Report was presented to the Commission on 30th November 1986 and reviewed on 4th December 1986 by the Steering Committee charged by the Commission of the European Communities with supervising the execution of the study. The Consultants now have pleasure in submitting their Final Report to the Steering Committee. The Final Report is designed to provide a brief introduction to the project, to give an overview of the agricultural and oil industries of Europe and to summarise the key findings of the study.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Considerable interest has developed within the EC over several years in the potential for producing ethanol from biomass. Interest has heightened since the adoption of Directive 85/210/EEC imposing reduced limitations upon the permissible levels of lead in gasoline and the mandatory requirement for Member States of the EC to offer lead-free gasoline by 1989. This Directive has and will require suppliers of gasoline to modify their procedures in order to meet the quality standards required for the efficient operation of motor vehicles in Europe. The suppliers of gasoline have a variety of options available to them to meet these quality standards. These include the addition of oxygenates to gasoline and, in this context, ethanol has been suggested as a possibility.

This study is specifically directed towards the consideration and comparison of ethanol produced from biomass (bioethanol) as a gasoline additive with other options available to suppliers of gasoline. It must be emphasised, however, that there is no chemical difference between ethanol derived from biomass and ethanol derived from fossil origins. The term bioethanol merely indicates that the ethanol is derived from biomass.

1.2 STUDY OBJECTIVES

The principal purposes of the study are defined in the guidelines, as follows :

(a) To carry out a cost /benefit analysis of the production and use of bioethanol as a gasoline additive in the European Community during the period 1986 - 2000.

(b) To study and quantify the implications of such a programme in terms of agriculture, technical know-how, costs, energy supplies, competition, employment and industry. The following countries were specified for detailed analysis :

Belgium, France, West Germany, Italy, Netherlands, Spain, United Kingdom.

An additional requirement was to provide an objective overview of the many diverse topics which have tended to obscure the widespread debate over the feasibility of a bioethanol project.

1.3 THE CONSULTANTS' APPROACH

1.3.1 Introduction

The Consultants' approach has been to examine critically but constructively as much research and as many studies as possible within the constraints imposed by the budget and time schedule for he Bioethanol Study. Much of the research and many of the studies are contradictory and the Consultants have needed to make professional judgements between conflicting viewpoints. Equally, discussion in much documentation appears to be assertive rather than based on a rigorous factual analysis and such assertions are frequently accepted and reproduced in subsequent documentation. The Consultants have also held extensive discussions with leading authorities on the different aspects of the study and with organisations having vested commercial interests either as protagonists or antagonists in the context of proposals for a bioethanol programme.

Finally, the Consultants have synthesised and developed their own modelling techniques, particularly with regard to the simulation of refining operations, the forecasting of future oil prices, the valuation of co-products of bioethanol production and the cost/benefit analysis technique.

Following the report given to the Commission on 5th February 1987, the Commission issued new guide lines (March 13th 1987), requesting modifications in the presentation of the report, including in particular giving more emphasis to the financial analysis at the expense of the economic analysis.

1.3.2 Principles of Analysis

Following detailed guidance by the EC Commission, chapters 3 to 5 of this report are concerned with analysis of the effects of a possible bioethanol programme in specific sectors of the economy of the EC and the Member States, using financial analysis techniques. In chapter 6 the Consultants have assessed the broad economic effect of the programme using economic cost/benefit analysis techniques accepted by the International Agencies. The principles of the economic methodologies are summarised in chapter 6.

1.3.3 Approach to the Evaluation of Bioethanol as a Component in the EC Gasoline Pool of the 1990's

In view of the multitude of factors which influence the potential role for bioethanol as a gasoline component, a number of separate but connected processes have been modelled/simulated. This involves evaluating the expected octane requirements (which will depend upon developments in the car parc, gasoline quality and in the overall level of gasoline demand) and octane availability both within the refinery and from external sources such as MTBE (Methyl Tertiary Butyl Ether), Methanol, TBA (Tertiary Butyl Alcohol) and, potentially, ethanol. Since there are many uncertainties associated with each of these processes, sensitivity cases have been developed to evaluate the potential impact of variations in the base case assumptions.

1.3.4 Technical annexes

The very long and substantial technical annexes prepared by the Consultants in the course of the study, are issued separately from the present report. References to these technical annexes are given in the report according to the following code :

- PT annex : prepared by PARPINELLI TECNON
- AD annex : prepared by AGRO DEVELOPPEMENT
- BU annex : prepared by BRUNSCHWEIG
- LG annex : prepared by LAURENCE GOULD.

CHAPTER 2

HYPOTHESES DEVELOPED FOR THE STUDY

2.1 CRUDE OIL PRICE SCENARIO

The unparalleled volatility which characterised world crude oil markets throughout 1986 clearly illustrates the difficulties attached to formulating any long term projections for crude oil prices. For the purpose of this analysis, however, two alternative price profiles have been developed. The central scenario assumes that OPEC manages to maintain discipline over its production at a level of around 17 million Bbl/day (mbd) in the short term, to the extent that the credibility of a long-term recovery in prices becomes accepted by the market. As summarised in Table 2.1 this is projected to lead to a recovery to about $20/Bbl, in then-current prices by 1990. By the middle of the 1990's, demand on OPEC should increase to the 25 mbd (million barrel/day) level which would probably provide the basis for renewed real price increases, initially at the rate of 1-2 % p.a., growing to 3-5 % p.a. by the end of the century, such that crude oil prices would reach about $38/Bbl in then current dollars, equivalent to about $22/Bbl in real terms, by 2000.

Although this recovery scenario may be described as offering the best prospects for both producers (higher revenues in the short term) and consumers (stability in oil markets), there is considerable doubt as to whether OPEC's internal discipline is sufficient to maintain production at the low levels necessary during the next few years. Accordingly, several oil companies prefer to base their evaluations on a scenario in which oil prices fluctuate around $15/Bbl, at least until 1990. Since this price level would tend to limit development of crude reserves in non-OPEC areas, the possibility of significant real increases in oil prices during the second half of the 1990's is much greater than in the recovery scenario. Under this scenario, crude oil prices would rise to the level of $48/Bbl in then current dollars, or about $28/Bbl in constant 1986 dollars, by 2000. The inherent instability in this latter scenario offers the prospect that producers and consumers would both suffer from the continuation of uncertainty.

Figure 2.1 illustrates the projected price developments for both the recovery and the unstable scenarios. Prices are presented in both nominal (then-current $) and real (constant 1986 $) terms.

TABLE 2.1 CRUDE OIL SUPPLY/DEMAND SCENARIOS 1985-2000 (IEA BASIS)

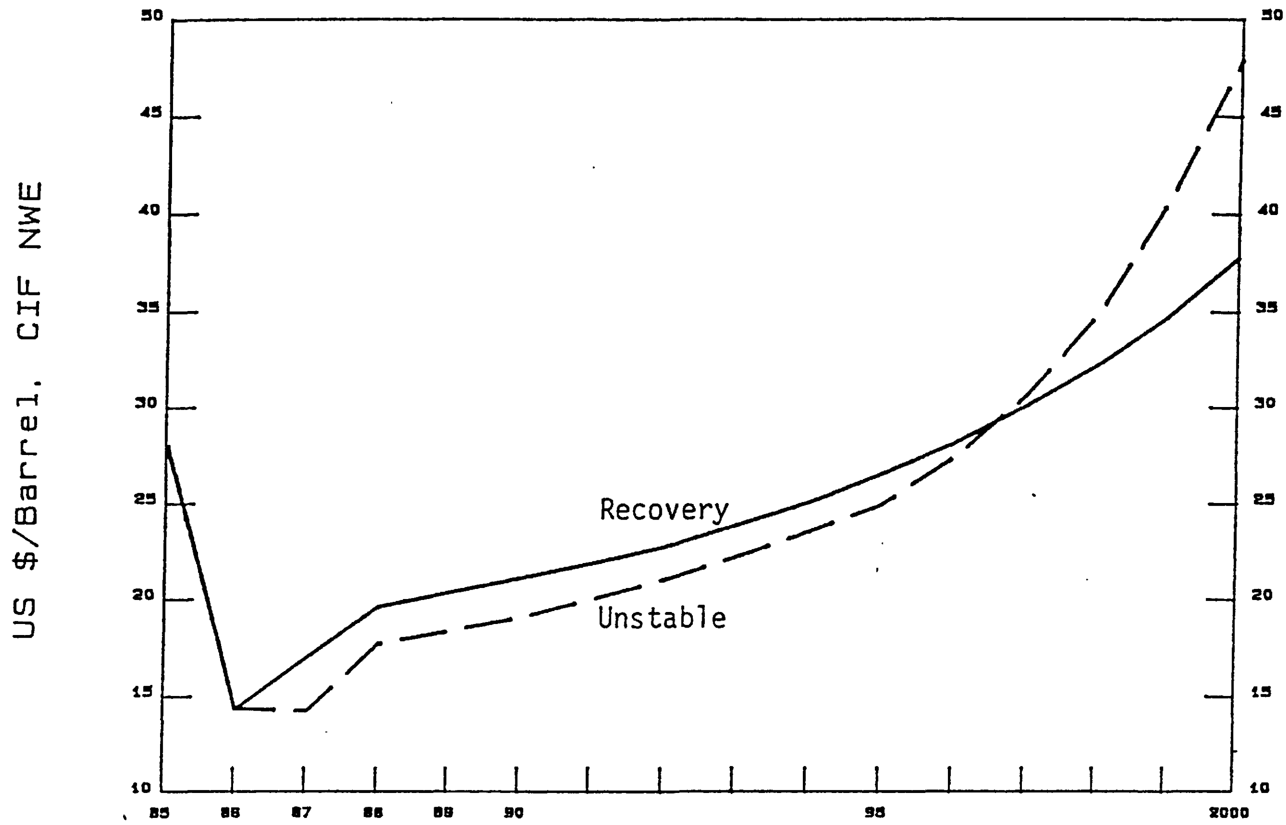
Million BBls/day	1985	1986	1987	1990	1995	2000
Oil Demand	45.6	46.6	46.6-47.1	49.0	52.0-53.0	52.0-55.0
Supply						
Free World Non-OPEC	25.1	25.5	25.5	25.0-26.0	25.0-26.0	22.0-23.0
Net CPE	1.6	1.7	1.7	1.0	1.2	1.0
Non-Conventional) Processing Gains)	1.5	1.5	1.5	1.5	1.5	1.5
	28.2	28.7	28.7	27.5-28.5	27.7-28.7	24.5-25.5
OPEC						
NGL	1.3	1.4	1.4-1.3	1.5	1.8	2.0
Crude	15.9	17.8	17.0-15.3	20.0-19.0	23.5-21.5	28.5-24.5
	17.2	19.2	18.4-16.6	21.5-20.5	25.3-23.3	30.5-26.5
Total Supply before Stock Change	45.4	47.9	45.3-47.1	49.0	52.0-53.0	52.0-55.0
Stock Change	(0.2)	1.3	(1.3)-0	-	-	-
Crude Oil Price $/Bbl*						
Nominal - FOB	27.1	13.5	16.3-13.5	20.3-18.3	25.5-24.0	36.5-46.5
Nominal - CIF NWE	27.9	14.3	17.0-14.2	21.1-19.1	26.5-25.0	38.0-48.0
Real (1986 $) - CIF NWE	28.7	14.3	16.5-13.8	18.5-16.5	19.0-18.0	22.5-28.5

* First value in the range represents the base case projection ("recovery" scenario); the second value represents the alternative crude oil price sensitivity case (low prices through to 1990, then rapid increases towards the end of the century).

FIGURE 2.1

PROJECTED OIL PRICE DEVELOPMENT

NOMINAL (THEN CURRENT $)



REAL (CONSTANT 1986 $)

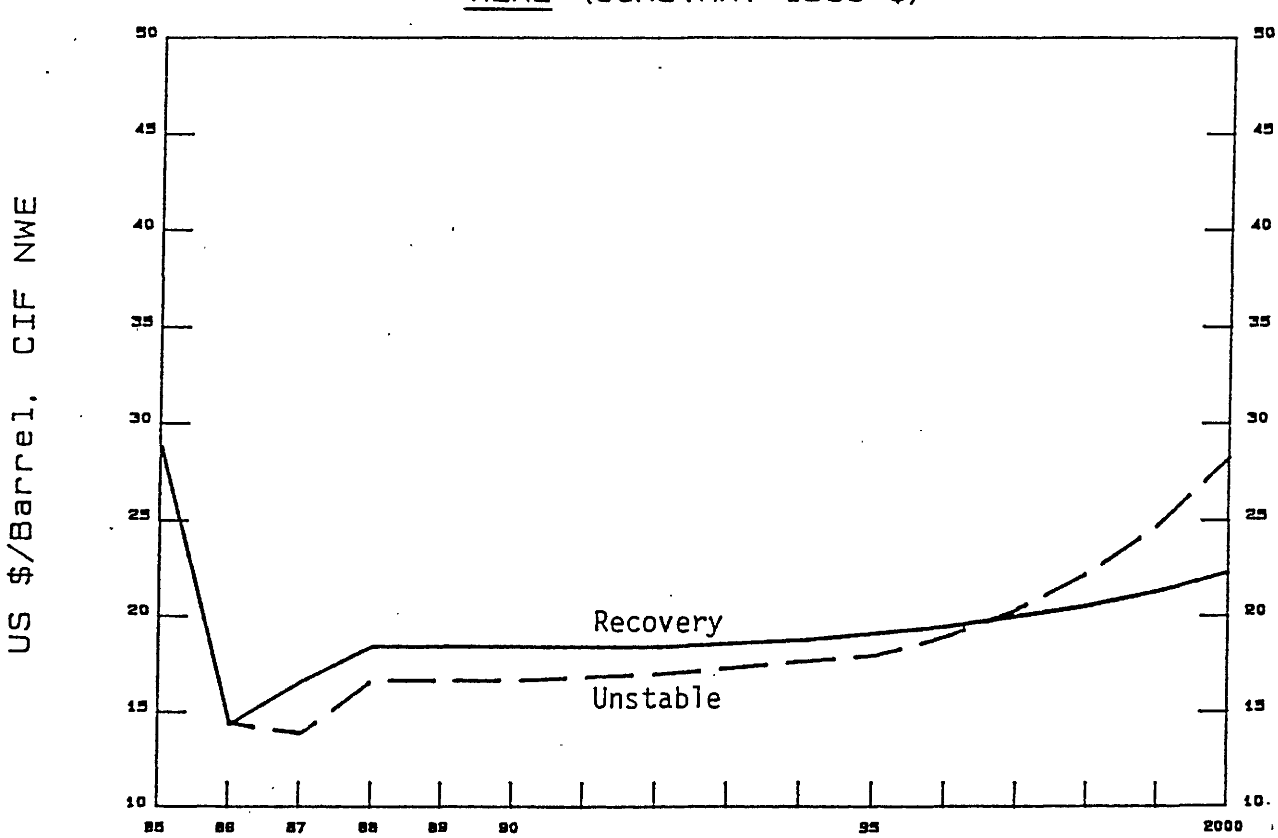


TABLE 2.2
PROJECTED PRICES : BASE CASE
BASIS : ASSUMING A STABLE RECOVERY IN CRUDE OIL PRICES

REAL (1986 $)

Year	Avge. Crude CIF NWE $/Bbl	Avge. Crude CIF NWE $/Ton	Ratio of Premium to Landed Crude Cost	Premium Gasoline Price $/Ton	Ethanol Values * $/Ton Low (0.6)	Ethanol Values * $/Ton Base (0.8-0.9)
1985	28.7	213	1.32	281	169	225-253
1986	14.3	106	1.63	172	103	138-155
1987	16.5	122	1.50	184	110	147-165
1988	18.4	136	1.42	194	116	155-175
1989	18.4	136	1.42	194	116	155-175
1990	18.4	136	1.42	194	116	155-174
1995	19.1	141	1.44	203	122	163-183
2000	22.3	165	1.45	239	144	192-216

NOMINAL (Then - Current $)

Year	Avge. Crude CIF NWE $/Bbl	Avge. Crude CIF NWE $/Ton	Ratio of Premium to Landed Crude Cost	Premium Gasoline Price $/Ton	Ethanol Values * $/Ton Low (0.6)	Ethanol Values * $/Ton Base (0.8-0.9)
1985	27.9	207	1.32	273	164	218-246
1986	14.3	106	1.63	172	130	133-155
1987	17.0	126	1.46	184	110	147-165
1988	19.6	145	1.42	207	124	166-186
1989	20.4	151	1.42	215	129	172-193
1990	21.1	156	1.42	222	133	178-200
1995	26.6	197	1.44	284	170	227-255
2000	37.8	280	1.45	406	244	325-365

* Ethanol Values have been calculated on the basis of the ratio to premium gasoline prices, estimated as follows:

Base: Range of valuations based on blend characteristics for the pool of the 1990's.
Low : Minimum valuation considered necessary to achieve a significant penetration of the available market, suggested on the basis of actual realisations in the U.S. market.

The agreement reached by OPEC at the end of 1986 is consistent with the recovery scenario. In fact, the positive market reaction to this agreement, together with the sudden onset of very cold weather throughout the European continent, helped prices to recover by about $4/Bbl from early December 1986 levels. Whether this recovery can be maintained over the next two years will, however, critically depend upon OPEC's ability to limit production to the 16-17 mbd range throughout 1987.

Developments in the first half of 1987 have confirmed that the vast majority of participants in crude oil markets much prefer stable prices oriented around the $ 18/Bbl level to the volatile swings which characterized markets in 1986. Although the Base Case recovery scenario assumed that prices would reach this level over the period 1987-88, the stable $ 18/Bbl level is perfectly consistent with the price profile projected for the 4 years following 1988. Moreover, prices could easily revert to the Base Case profile for 1987-88 if OPEC discipline shows signs of temporary weakness during the summer when demand for OPEC crude drops to its seasonal low point.

As a corollary, the latest developments tend to weaken the case for the alternative scenario associated with a lack of discipline by OPEC. Nevertheless, this remains a valid scenario, since any firm evidence of sustained cheating by individual OPEC members and/or of a significant stock-draw by the major oil companies could quickly restore prices to the $15/Bbl level, or even lower.

On the basis of these projections of crude oil prices, the equivalent gasoline and ethanol prices have been calculated by the Consultants and are detailed in Table 2.2 for the recovery scenario.

It should be noted that the increase in the ratio between gasoline prices (Basis $/tonne, Barges FOB Rotterdam) and crude oil prices (Basis $/ton, delivered NWE) during the 1990's reflects the switch from a predominantly leaded pool (0.15 g/l) to a predominantly lead-free pool.

2.2 FEEDSTOCK PRICE SCENARIO

The feedstock prices used in the financial analysis are those proposed by the Commission of the European Communities (CEC), namely :

- feed wheat, the intervention price, 170.47 ECU/tonne (campaign 1986/1987)

- sugar beet, the B quota price, 24.74 ECU/tonne (plus 4 ECU/tonne transport cost) (campaign 1986/1987)

The central assumptions about price changes during the life of the project (1986/2000) are :

- feed wheat : 1 per cent per annum reduction in price
- sugar beet : 0.5 per cent per annum reduction in price

These changes reflect the more basic assumption that feedstock producers' incomes remain at a level which is similar to current margins, taking into account projected changes in input and output prices.

Sensitivity analyses using different price changes have been carried out where this is considered appropriate.

2.3 NOTES ON DEVELOPMENTS SINCE THE ABOVE HYPOTHESES WERE ADOPTED

At the request of the Steering Committee, the major assumptions underlying the above hypotheses were essentially frozen at the time of the presentation of the interim report (presented on December 5th 1986).

It has been assumed that the exchange rate between the ECU and the US dollar would remain at an average of 1 to 1 during the period under consideration. This was the rate prevailing at the beginning of the study. Although the models which have been constructed to enable the Consultants to carry out the cost/benefit analysis incorporate the facility to vary exchange rate and pricing assumptions, no such sensitivity cases are presented in the study.

It should be mentioned however, that variation in the exchange rate between the ECU and the US dollar may have an influence on the markets for petroleum and agricultural products and also upon the costs of production.

At the time of going to press (end of July 1987), the values used for the study have evolved as follows :

- Purchase price of wheat submitted to intervention (30th June 1987) : - 6 %,
- Sugar beet B quota price : unchanged,
- Ratio ECU/US dollar : 1 $ US ≈ 0.9 ECU,
- Crude oil prices : as forecast in the base case scenario, crude oil prices recovered from the average of $ 14.3/Bbl in 1986 to reach $ 18.1/Bbl in the first half of 1987. This compares with the forecast of $ 17.0/Bbl for 1987 and $ 19.6/Bbl for 1988 in the base case scenario.

CHAPTER 3

PROBLEMS OF OXYGENATED FUELS AND LEAD-FREE PETROL

CONTENTS

1 Evaluation of the overall market (existing and potential) for lead-free petrol and, consequently, the market for octane boosters

2 Evaluation of production capacities and costs, prices and availabilities of oxygenated fuels of fossil origin (existing and potential) in competition with bioethanol (TBA, methanol, MTBE, synthetic ethanol).

3 Analysis of present level of use of all oxygenated fuels as lead replacers in gasoline, taking account of their cost and physico-chemical properties. Calculation of incremental octane improvement cost.

4 Economic analysis of production of lead-free petrol in refineries.

In order to avoid overlapping and duplication of various points covered in the terms of reference (repeated above), these topics are discussed in the following sub-sections :

3.1 Evaluation of the overall market (existing and potential) for lead-free petrol and, consequently, the market for octane boosters.

3.2 The Refining Industry in the EC.

3.3 Evaluation of production capacities and costs, prices and availabilities of oxygenated fuels of fossil origin (existing and potential) in competition with bioethanol (TBA, methanol, MTBE, synthetic ethanol).

3.4 Actual and Projected Octane Supply/Demand Balances in the EC.

3.5 Physico-chemical properties of oxygenated fuels.

3.6 Evaluation of incremental octane improvement cost of Oxygenated Fuels.

SUMMARY

Gasoline demand in the EC (12) is projected to increase from 94.5 million tonnes in 1986 to 95.8 million tonnes at the end of the century. Under the stimulus of EC regulations, rapid penetration of lead-free petrol is projected, reaching levels of 20 % of the total market by 1990 and 83 % by 2000. The average lead content of the pool should reduce from 0.26 g/l in 1986 to only 0.06 g/l in 2000. Consequently, clear RON requirements for the total pool should increase by 2.4 points, whilst clear MON requirements increase by 2.8 points.
The refining industry in the EC has resolved the major problems of surplus capacity it faced in the 1970's through an extensive rationalisation programme involving a painful process of plant closures and job losses, whilst simultaneously investing billions of dollars in new highly sophisticated conversion and reforming capacity.

Oxygenates are regarded as a convenient option to meet the octane requirements of the gasoline pool, but they are not the only option and price competitivity will continue to be the key element in determining their actual use. Most of this projected increase in the use of oxygenates centres on MTBE because it has established a dominant market preference over the competing oxygenates due to its superior blending characteristics.

Based on a number of conservative assumptions it is calculated that no octane shortage will materialize in the Northern countries of the EC before the end of the century. In contrast, the calculations suggest that an octane shortage could emerge in the EC-South during the mid 1990's unless there is further investment in local refineries. However, past experience indicates that refineries in the South are very likely to make these investments in order to avoid a potential exposure to octane deficiency. In conclusion, the analysis suggests that the refining industry in the EC will not be faced with an octane shortage before 2000. The use of oxygenated fuels shoud therefore always be viewed as complementary to, and competing with the refinery's internal octane supplies, rather than as an essential requirement in the gasoline pool.

Generally characterized by high RON relative to gasoline (though their contribution to MON is less significant), the oxygenates have high sensitivity (RON - MON) and a high volatility. These characteristics imply respectively an economic premium and a penalty. This economic penalty is particularly pronounced for the alcohols, which also suffer from low water tolerance. Of the oxygenates, MTBE has established a clear superiority amongst refiners because its characteristics are closest to gasoline specifications. Amongst the alcohols, GTBA is superior to ethanol in terms of its average blending properties, whilst Oxinol-50 is superior to the M3E3 blend. Taking both the positive (octane-boosting effect) and negative (sensitivity, volatility) contributions into account, the economic evaluation of breakeven values for the oxygenates have been tested under a wide range of historical market conditions.

These calculations confirm prevailing market indications : relative to premium gasoline, the breakeven value of MTBE falls around the level of 1.20 %, that of GTBA around 1.00 % and that of Oxinol-50 around 0.85 %.

For ethanol the calculations suggest breakeven values close to those of Oxinol in the range 0.80-0.90. However, in order to achieve a high penetration of the available market, it is highly probable that ethanol would have to be significantly discounted below its calculated breakeven value.

3.1 EVALUATION OF THE OVERALL MARKET FOR LEAD-FREE PETROL

Based on assumptions of a relatively modest but sustained economic growth, the total car parc is projected to grow at an average rate of 1.7 % p.a., over the period 1985-2000, compared with an average of 2.5 % p.a., in the first half of the current decade. Within this overall trend, the growth profile is expected to slow from 2.1 % p.a. in the second half of the current decade to 1.7 % p.a. in the first half of the next decade and to 1.3 % p.a in the second half. (more details are given in PT Annex, section 3).

Figure 3.1 summarises expected developments in the three major parameters influencing demand for gasoline over the forecast period : the size of the petrol-engined car parc, trends in average distance driven, and the average fuel efficiency of the parc. The Combined Index, which is also detailed in this chart, reflects the net effect of the trends in these three key factors. As indicated, the relatively complex analysis results in a profile of projected gasoline demand which essentially maintains the higher level of consumption experienced during 1986, stimulated by lower oil prices and higher disposable income, through the early 1990's. Compared with an estimated consumption of 94.5 million tonnes in 1986, gasoline consumption in the EC (12) is projected to increase to 95.1 million tons in 1990 and to 95.8 million tonnes by 2000. During this period, it emerges that continued improvements in the fuel efficiency tend to offset the growth in the parc, whilst average distance travelled increases relatively slowly. This latter development reflects the growing trend towards multi-car ownership within individual households in EC countries. Towards the end of this forecast period, however, it is anticipated that the efficiency penalties associated with the introduction of lead-free petrol catalytic converters on a significant proportion of the new generation of the so-called environmental cars will tend to slow the rate of improvement in the fuel efficiency of new cars entering the market, with a consequent boost for gasoline demand.

FIGURE 3.1

DETERMINANTS OF GASOLINE DEMAND

1980 - 2000

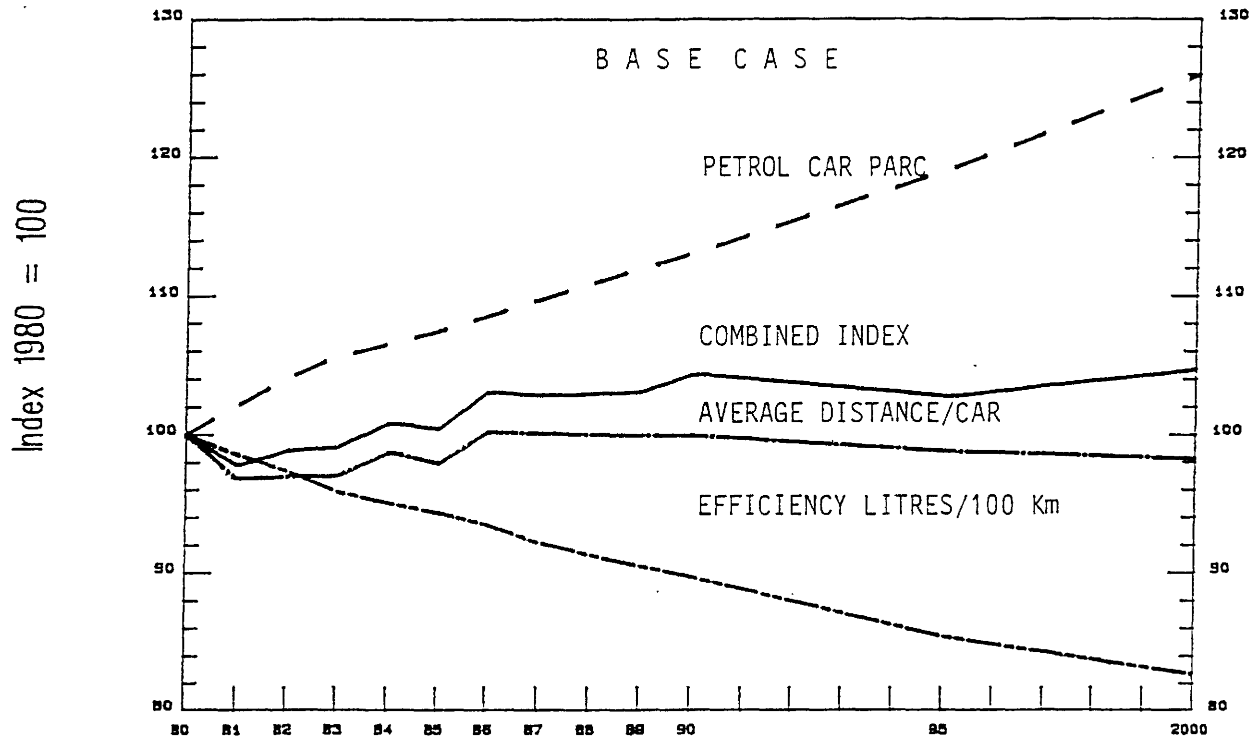
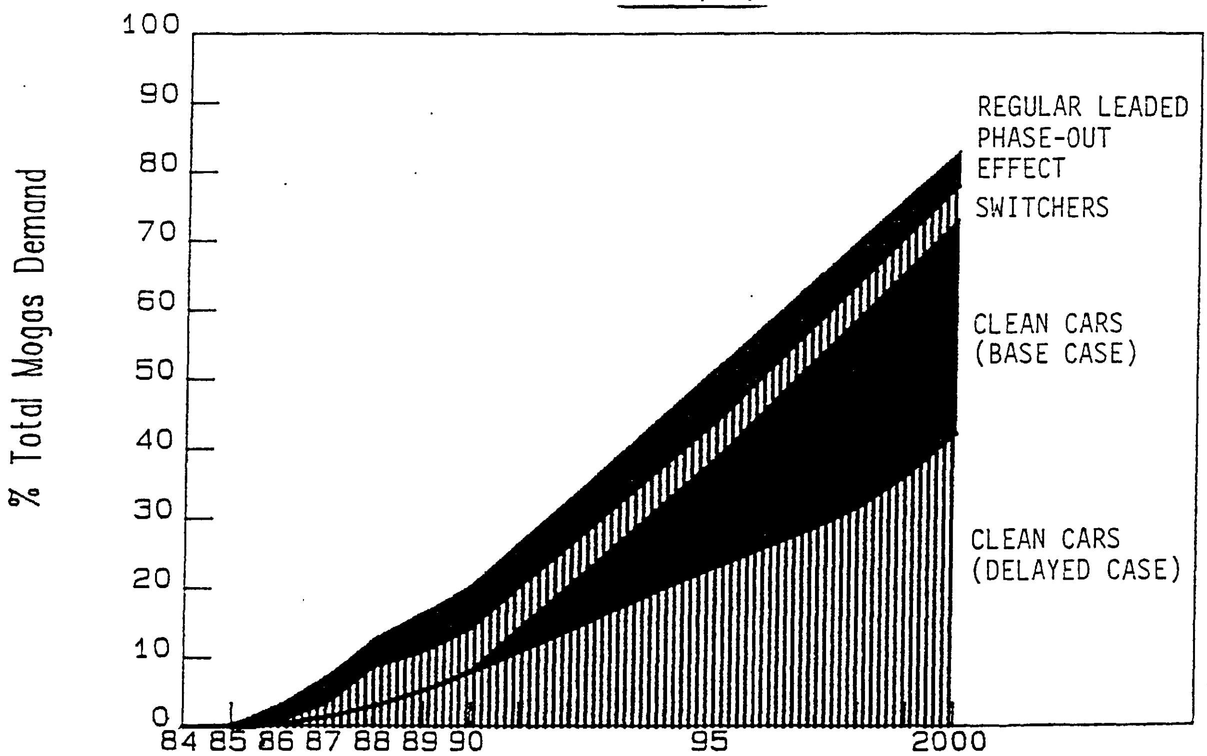


FIGURE 3.2

PENETRATION OF UNLEADED GASOLINE 1984-2000

EC (12)



In recent years, there has been considerable progress in the campaign to reduce the average lead content in petrol. The major measures initiated through the Directive 85/210/EEC may be summarised as follows :

a) all Member States must have lead-free petrol available in their territories by October 1989,

b) all Member States are encouraged to reduce the maximum permitted lead content of petrol sold in their territory to 0.15 g/l "as soon as they consider it appropriate".

In fact, West Germany had already introduced unleaded petrol during 1984. Several Member States, notably the Netherlands and Denmark, followed in 1985. In addition, most of the remaining countries have now introduced unleaded gasoline on a limited scale.

For the future, the penetration of lead-free gasoline will depend crucially upon the extent to which Member States comply with the Commission's proposals concerning vehicle emissions. In addition, switching by environmentally-conscious motorists in the existing car parc and the possibility of the accelerated phase-out of leaded regular grades, will both contribute to the development of the lead-free grades share of total demand, as shown in figure 3.2 and Table 3.1.

For the purpose of this analysis, the base case scenario assumes that all the individual governments do follow the timetable proposed by the Commission (more details are given in PT Annex, section 4.3), with the more enthusiastic countries (West Germany, the Netherlands, Denmark) acting in anticipation of the general arrangements with attractive fiscal incentives for the environmentally-conscious car buyers. In order to assess the impact of a potential delay in the introduction of the Commission's regulations in the less enthusiastic countries (essentially the Southern countries, Belgium, Ireland and the U.K.), a sensitivity case has been developed under which these latter countries do not implement the regulations for the small and medium categories of new cars until 5 years after the proposed timetable. (see Table 3.1,(b)).

TABLE 3.1 : PENETRATION OF LEAD-FREE GASOLINE IN THE EC (12)
% of total gasoline demand

	1986	1987	1990	1995	2000
(a) Base case					
Consumption by "Clean" cars	0.1	1.5	8.2	38.8	73.0
Switching by the existing parc	0.1	3.7	6.0	7.6	5.1
Effect of the phase-out of leaded regular grades	0.3	1.6	7.5	6.4	5.3
Total share for lead-free grades	0.3	6.8	21.6	52.8	83.5
(b) Minimum penetration of clean cars, assuming 5 years delay of the regulations in EC-South, Belgium, U.K. and Ireland	0.1	1.5	8.0	23.2	42.4
Switching/leaded regular effect	0.2	5.3	13.5	13.6	10.2
Total share for lead-free grades	0.3	6.8	21.5	36.8	52.5

Source : Consultants' estimates

Even under the pessimistic assumptions of the sensitivity case, therefore, the penetration of unleaded grades is expected to exceed 50 % by the end of the century, compared with a share of 83 % for the base case. Moreover, in the minimum case, the penetration of the lead-free grades should rapidly accelerate in the early years of the next century, due to the fact that very few of the new cars entering into service at that time would consume leaded petrol.

Within this overall result for the total EC, there are significant variations between the individual Member States, with West Germany at the forefront of the move to replace leaded petrol with unleaded grades, whilst the countries in the South are expected to follow a much slower penetration profile (more details are given in PT annex section 4.7 about the projected penetration profiles for the individual countries).

3.1.1 The impact on the quality of the gasoline pool of the 1990's

In order to evaluate the potential impact of these developments on the gasoline pool of the 1990's, a series of sensitivity cases have been developed in an attempt to incorporate most of the uncertainties which characterise the timing, quality and grade structure associated with the introduction of unleaded gasoline in the various EC markets.

The results for the base case and the major sensitivity case are illustrated (for the total EC pool) in Figures 3.3 and 3.4 with the full detail summarised in Table 3.2. The most striking feature is the rapid growth of the unleaded market from a negligible share of the total pool in 1985 to over 83 % by 2000 in the base case. As a result of this development, the pool's clear octane requirement is projected to increase from 91.1 RON/80.6 MON in 1985 to 93.5 RON/83.2 MON in 1995 and to 94.4 RON/84.4 MON in 2000, in the base case. Consequently, the average lead content of the total pool is projected to fall from 0.34 g/l in 1985 to 0.15 g/l in 1995 and 0.06 g/l by 2000.

As noted previously, the delayed introduction sensivity case generates a much slower profile for the penetration of unleaded grades, reaching only 52 % in the year 2000 versus 83 % in the base case. This results in higher average lead content (+ 0.04 g/l in 1995 and + 0.09 g/l in 2000 compared with the base case), and higher pump octane levels (+ 0.08 points RON and + 0.03 points MON in 2000). However, because of the higher lead content in the pool, the clear octane requirements would be significantly lower (0.6 points RON and 0.4 points MON in 2000, compared with the base case).

FIGURE 3.3

EC GASOLINE POOL 1981-2000

GRADE STRUCTURE

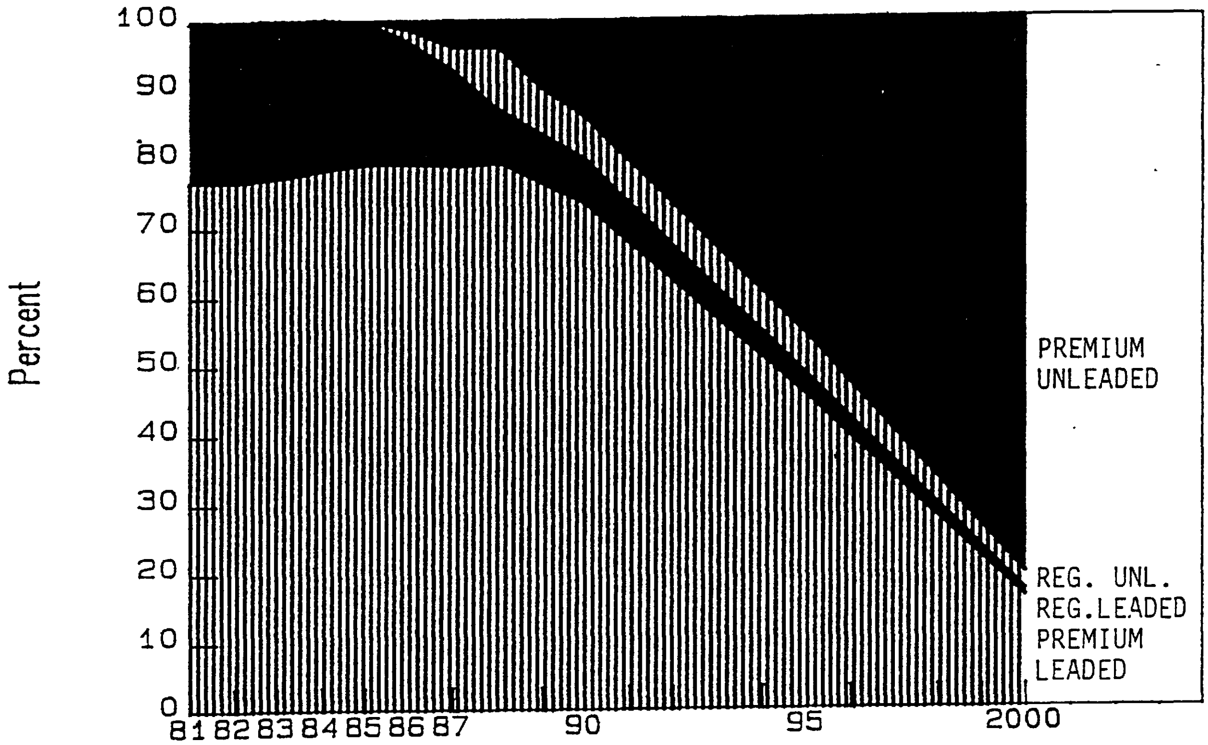


FIGURE 3.4

EVOLUTION OF THE GASOLINE POOL IN THE EC (12):

NORTH/SOUTH COMPARISON FOR 2000

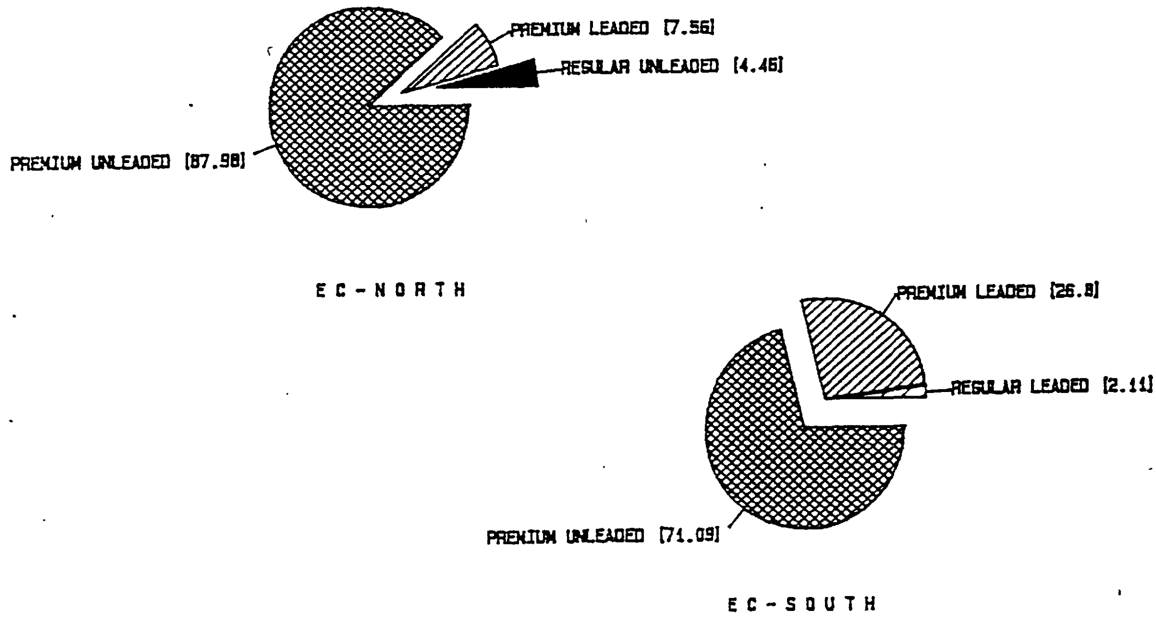


TABLE 3.2 : GASOLINE POOL 1981-2000 : EC (12)

Summary of base case and the major sensitivity case

	Lead Content g/l	Pump RON*	Clear RON*	Pump MON*	Clear MON*	% Unleaded in pool
1981	0.35	95.85	90.67	85.50	80.26	-
1982	0.35	95.73	90.67	85.50	80.28	-
1983	0.34	95.79	90.76	85.53	80.34	-
1984	0.34	95.87	90.92	85.59	80.50	0.01
1985	0.34	95.98	91.08	85.64	80.58	0.29
1986	0.26	96.03	91.98	85.68	81.52	3.15
1987	0.24	96.03	92.25	85.70	81.80	6.81
1988	0.24	96.08	92.48	85.78	82.05	11.08
Base case						
1990	0.22	95.96	92.72	85.74	82.36	21.65
1995	0.15	95.54	93.47	85.42	83.25	52.84
2000	0.06	95.18	94.40	85.22	84.40	83.49
Delayed introduction						
1990	0.22	95.96	92.72	85.74	82.36	21.50
1995	0.19	95.82	93.07	85.58	82.70	36.77
2000	0.15	95.78	93.69	85.60	83.40	52.55

Source : Consultants' estimates

* For consistency with the scenarios projected for the 1990's minimum RON/MON ratings have been used for the evaluation of Pool Octane characteristics in the period 1981-1985.

3.1.2 Limitations on the use of oxygenates in gasoline

General concern over the technical problems resulting from the use of high proportions of oxygenates, particularly methanol, in gasoline has encouraged the Commission to implement proposals aimed at harmonising regulations throughout the EC. As with unleaded gasoline, however, it proved difficult to establish a common consensus on the issue. Since not all Member States were prepared to accept the maximum limits initially proposed by the Commission, the final regulations retain two sets of limits, as detailed in Table 3.3 below. The lower limits represent the minimum ratios which all Member States are obliged to authorise as the maximum level permitted for oxygenated blending in their territories. The higher ratio represents the limits beyond which all governments must insist that oil companies label the blended product which could not then be distributed or sold as ordinary gasoline.

The Commission has stressed that it wishes to retain as flexible an approach as possible in order to facilitate future amendments of the regulations, if and as necessary. In fact, the Directive provides for the establishment of a Permanent Committee to allow for the modification of the Directive in the light of future technical developments.

TABLE 3.3 : EC LIMITATIONS ON THE USE OF OXYGENATES

	A Lower obligatory limit vol %	B Upper limit without labelling vol %
Methanol, stabilising agents must be added	3	3
Ethanol, stabilising agents may be necessary	5	5
Iso-Propyl Alcohol (IPA)	5	10
Tertiary Butyl Alcohol (TBA)	7	7
Iso-Butyl Alcohol (IPA)	7	10
Ethers containing 5+ carbon atoms per molecule	10	15
Other organic oxygenates	7	10
Mixture of any organic oxygenates oxygen weight %	2.5	3.7

Source : Consultants' estimates

3.2 THE REFINING INDUSTRY IN THE EUROPEAN COMMUNITY

In the wake of the economic recession and the associated decline in demand for oil products which followed the 1979 oil price rise, the refining industry in the Community has undertaken an extensive programme of capacity rationalisation, cost reductions and increased efficiency. The large surplus which existed between crude processing capacity and oil demand at the beginning of the current decade, more than 300 million tonnes, has been largely corrected through the permanent closure of older and less efficient refineries : in total, 35 refineries were shut down between 1980 and 1985, or slightly less than 30 % of the total existing in 1980.

At the same time, the industry has undertaken investment programmes costing billions of dollars in order to upgrade its conversion capacity. This has been necessitated by the significant shift in the types of oil products required. Whilst demand for the light products such as gasoline, diesel oil and jet fuel have been increasing, consumption of the heavy products such as fuel oil has been dramatically reduced due to a combination of : displacement by natural gas, coal and electricity ; conservation and the relative decline of the industrial sector within the economic structure of the EC.

The impact of these major changes is clearly outlined in the EC document COM (88) 263, May 1986. In that document, it is estimated that direct job losses in the local refining industry, due to the rationalization process, amounted to almost 16,000 between 1977 and early 1986 (about 26 % of the 1977 total), with additional indirect losses (closure of depots, terminals, retail outlets, etc) amounting to between one and three times that total. During this period, the investment programme undertaken by the industry resulted in an 80 % increase in catcracking equivalent capacity between 1981 and 1985, with further expansion already underway and scheduled for completion within the next few years.

The need to increase the clear (unleaded) octane quality of gasoline has been widely anticipated by the EC refining industry. The effect of the development reviewed in section 3.1 on the EC gasoline pool's clear octane demand is evident from Table 3.4 which illustrates the various types of gasoline which are and will be marketed in the EC. It is important to note that for premium gasoline, the 0.15 g/l maximum lead content means that the required clear octane is already at parity or slightly above the specification of the unleaded product.

TABLE 3.4 : TYPICAL RATING OF EUROPEAN GASOLINES

		Octane rating			
	Lead content g/l	Pump RON	Pump MON	Clear RON	Clear MON
Premium	0.40	98.0	88.0	92.5	82.5
	0.15	98.0	88.0	95.5	85.5
	0.00	95.0	85.0	95.0	85.0
Regular	0.40	92.0	82.0	84.5	75.5
	0.15	92.0	82.0	88.0	78.0
	0.00	91.0	82.5	91.0	82.5

Source : Consultants' estimates

The gasoline pool generally consists of a large number of individual hydrocarbons, each with different blending characteristics in terms of octane rating, volatility, specific gravity, etc. However, to simplify this discussion, the pool can be represented by a few basic components, namely : reformate, catcracking gasoline, light naphtha, alkylates and butane.

From the above considerations, it is clear that, in order to meet the anticipated increase in clear octane requirements, the refinery has a number of options. These mainly concern the severity of both reforming and catcracking operations, the isomerisation of the low octane straight-run light naphtha, and the alkylation of light olefinic streams. All of these options have an associated cost, the extent of which is variable depending upon the investment required. In some cases, particularly when a new unit is involved, the associated investment can be substantial.

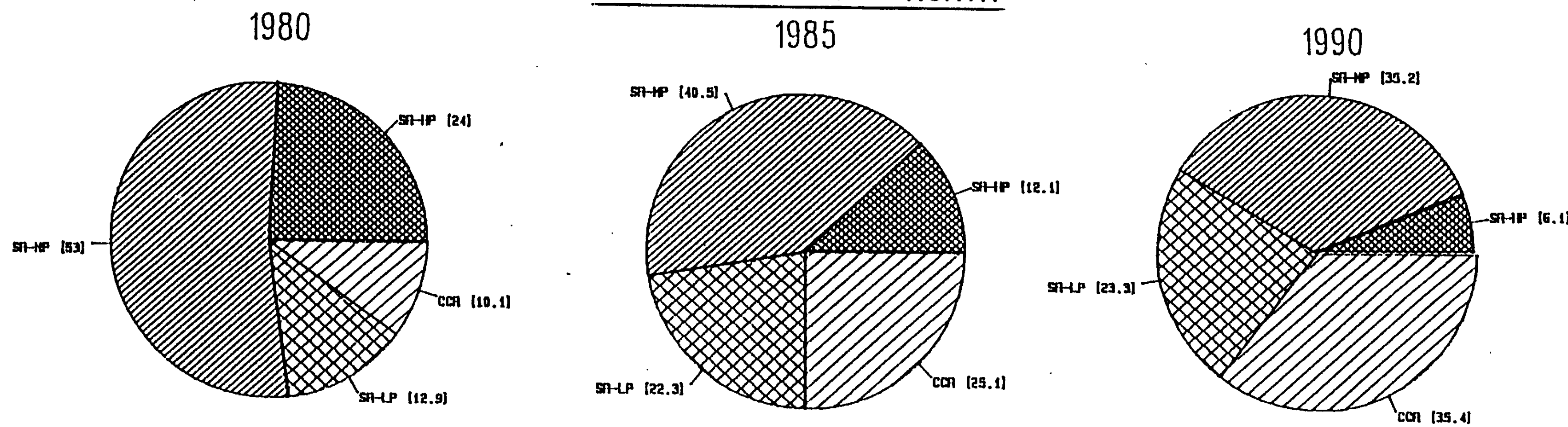
By the very nature of its extensive commitment to the gasoline market, there seems little doubt that the refining industry will undertake all reasonable steps to minimize the potential exposure to problems of octane deficiency. This statement becomes factual when considering the substantial investments in both gasoline production and octane upgrading capacity which the EC refining industry has already made during the past few years.

In particular, as implied above, reforming operations are of paramount importance in the octane balance of the refinery. Figure 3.5 illustrates recent and projected developments in the evolution of reforming capacity in the EC by type of operating severity (Note : the higher the operating severity of the reformate, the higher the octane rating of the reformate produced). In 1980, low/medium severity units accounted for almost 80 % of the total reforming parc. By 1985, however, the share of high severity units had increased to more than 45 % of the total. This phenomenon which, as could be expected, is more pronounced for the Northern than for the Southern countries of the EC, is indicative of the firm commitment by the local refining industry to retain control of its octane production capability. The effects of these developments on the octane balance of the EC are discussed later in this report.

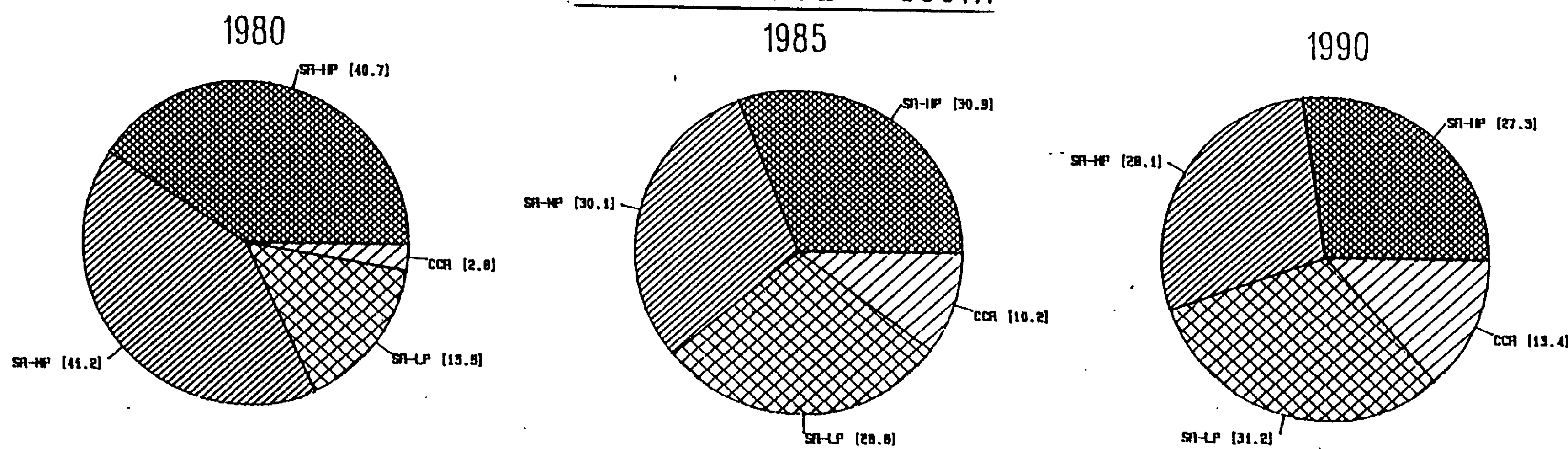
FIGURE 3.5

ESTIMATED BREAKDOWN OF REFORMING CAPACITY

WESTERN EUROPE – NORTH



WESTERN EUROPE – SOUTH



3.2.1 Refiners' attitudes towards oxygenates

In conjunction with the internal options discussed above, refiners may use oxygenates such as MTBE, TBA, methanol blends and ethanol. However, the use of oxygenates will generally remain complementary to traditional refinery processes. Apart from the aspect of security of supply, refiners express no major objections to the use of oxygenates, provided that the price is competitive with the alternative internal options available to them.

These considerations are confirmed by an analysis of the calculated octane balances discussed later in this report, which shows that the volume of oxygenates sold into the market in 1985 comfortably exceeded the volume necessary to meet the octane demand, after full utilisation of internal refinery operations. The inference is that the oxygenates were sold on a competitive basis as an alternative to the refiner's captive octane.

The situation is typical of the industry's reaction to any product or component available in the open market. The highly competitive nature of oil markets will not permit refiners to ignore a potentially profitable product if it is priced at the appropriate level. Whilst an individual refiner would obviously attempt to obtain the product at the lowest possible price, he could not afford to avoid a particular product simply because it originated from biomass rather than fossil fuels.

Concentrating on the octane aspect, Table 3.5 illustrates the octane contribution of the individual components normally available in a refinery. Reformate is virtually the only individual component produced in the refinery whose octane rating can largely exceed the level of 95 RON/85 MON clear (unleaded) which represents the limit towards which the average EC gasoline pool will move in future years. Alkylates and butanes fall around the 95 RONC (RON clear) level but largely exceed the 85 MONC (MON Clear) level. However, catcracking gasoline, a major component of the pool in volume terms, is below those levels. At the bottom of the scale, there is the light straight-run naphtha, although isomerisation can significantly upgrade the octane rating of this material. In terms of sensitivity, which is one of the most important characteristics of gasoline, both reformate and catcracking gasoline tend to exceed the standard specification of gasoline which requires a sensitivity of 10 points. However, the remaining components fall below that level.

TABLE 3.5 : BLENDING OCTANE RATING OF INDIVIDUAL GASOLINE COMPONENTS

	RON (unleaded)	MON (unleaded)	Sensitivity (RON)-(MON)
Premium unleaded gasoline	95	85	10
Reformate	91-105	83-89	12
Catcracking gasoline	89-93	78-82	11
Light naphtha	67-71	66-70	1
Isomerate	82-90	81-88	2
Alkylate	93-97	91-95	2
Butanes	94-97	90-93	4

Source : Consultants' estimates

3.3 EVALUATION OF PRODUCTION CAPACITIES AND AVAILABILITIES OF OXYGENATED FUELS IN COMPETITION WITH BIOETHANOL

Detail on the present and projected use in the EC of the main oxygenated fuels in competition with bioethanol is reported in Tables 3.6 and 3.7.(Note that since synthetic ethanol is not used as a component in the gasoline pool, it is not considered in the section. Details of production capacities and consumption are provided in AD Annex, section 1). In terms of future availabilities, the study period has been subdivided into two different time intervals. The estimate of incremental oxygenated fuels availability over the period 1985-1990 is essentially based on consideration of new projects already under construction or firmly announced. Table 3.7 provides detail of the incremental MTBE and GTBA capacity projected to be on stream by 1990 on a country by country basis. For MTBE, the availabilities also include imports from the new large plant currently under construction in Saudi Arabia (500 thousand tonnes per year capacity), the output of which will be almost totally devoted to supplying the European market.

TABLE 3.6 : OXYGENATE PRODUCTION CAPACITY IN THE EC (12)
(Thousand tons)

Installed Capacity at 1985	MTBE	GTBA	METHANOL
Benelux	385	460-550	750
France	-	-	125
West Germany	165	-	820
Italy	100	-	120
U.K.	-	-	750
Total	650	460-550	2565
Additions 1985-1990			
France	40	380	-
West Germany	20*	-	-
Greece	100	-	-
Italy	170	-	-
Spain	180	-	-
U.K.	100	-	-
Total	610	380	-
Capacity at 1990	1260	840-930**	2565

Source : Consultants' estimates

* estimated share of total etherification plant capacity
** some of the TBA production may be converted to MTBE

TABLE 3.7 : ESTIMATED OXYGENATE SUPPLY/DEMAND BALANCE IN THE EC 1985-1990
(Thousand tonnes)

	MTBE		GTBA		METHANOL*		OTHERS**	
	1985	1990	1985	1990	1985	1990	1985	1990
Production	535	1000	435	930	) 580#))	250	85	200-250
Imports	19	450-500	15	-		1250	-	-
Exports	163	150	25	30	-	-	-	-
Apparent consumption	391	1300-1350	425	900	580	1500	85	200-250

Source : Consultants' estimates

* Excluding production, consumption and trade in chemical sectors (3 million tons in 1985) and in MTBE production (290,000 tonnes in 1985)

** Includes TAME and the higher alcohols

It is not possible to separate the elements of production and trade of methanol specifically directed towards gasoline blending rather than chemical uses.

Beyond 1990, the projections must necessarily rely on speculative new capacity, so that the estimate of longer term oxygenate availability becomes more questionable. Within this framework, there are several large export-oriented MTBE projects currently under consideration in both Western Europe and abroad. The main rationale for these projects, particularly in crude producing countries, is to find an alternative outlet for butane which is anticipated to remain in surplus, relative to world demand, throughout the period considered.

With the exception of a possible project located in the EC or in a non EC Western European country (mainly dedicated to supplying the EC market), most of the remaining speculative large scale MTBE projects based on field butane are located in the Western Hemisphere. Presumably, this should imply that most of this potential volume would be addressed to the US market. Nevertheless, it is reasonable to assume that part of the incremental production would also flow to the EC. By contrast, if plans for new MTBE capacity in the USSR were to be implemented, it is likely that this latter material would be almost entirely exported to the EC. In addition to these speculative large projects, there is the possibility of new small units built within the EC, based on iso-butylene feedstock co-produced in steamcracking and catcracking operations. Within this context, the estimate presented in this report for an incremental MTBE availability post-1990 of between 0.7 and 1.0 million tonnes in the EC could be optimistic but, also, very conservative. In contrast to MTBE, at this time, there has been no announcement of new capacity for the other oxygenates post-1990.

Two considerations are noteworthy here. On the one hand, the question of oxygenates availability beyond 1990 is of relatively little importance. As explained in the next sub-section, the octane balances developed in this study do not take account of any incremental oxygenates availability post-1990. On the other hand, it is worth noting that almost all of the new oxygenates projects currently under consideration worldwide centres on MTBE. As illustrated later in this report, this supports the fact that, among the oxygenates, MTBE has achieved a clear and significant superiority over the alcohols.

3.4 ACTUAL AND PROJECTED OCTANE SUPPLY/DEMAND BALANCES IN THE EC

The calculated octane balances for the Member States of the EC have been analysed and are illustrated in figure 3.6 for, respectively, the Northern and Southern countries. The octane supply is alternatively expressed in terms of RON (in the upper graphs) and MON (lower graphs). Five separate lines are reported in each graph. Lines 1 to 4 report the calculated octane supply depending upon whether reforming units in the refinery are operated at maximum or minimum severity, and whether the available oxygenates are, or are not, blended into the pool. Finally, line 5 reports anticipated developments in the clear octane requirements. It is clear that if line 5 falls above line 1, which is the case of maximum octane supply, there is a shortage of octane in the system and vice versa.

It is important to emphasize that a number of conservative assumptions have been made in developing the calculations. Firstly, no additional octane producing capacity in refineries has been considered over and above that already under construction. This is very unlikely, particularly as far as the upgrading of the existing reforming capacity is concerned. Similarly, no incremental availability of oxygenated fuels in competition with bioethanol over and above the previously discussed 1990 projected level has been considered. As already noted, this is an extreme position, since all indications suggest substantial increases in the availability of MTBE.

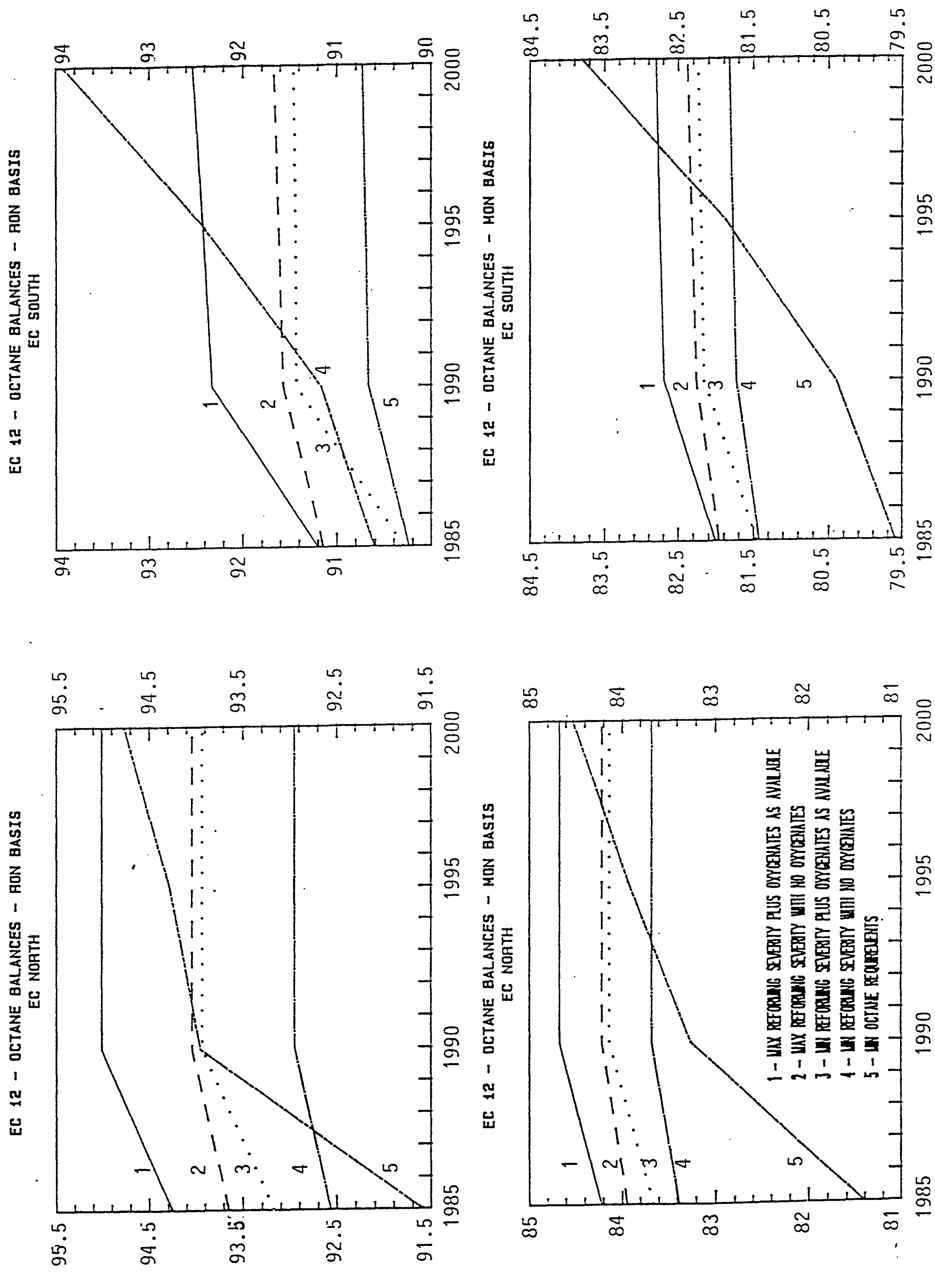
Nevertheless, even within this conservative scenario, the results of the calculations suggest the following considerations :

a) The volume of oxygenates sold into the market in 1985 comfortably exceeded the volume necessary to meet the octane demand. The implication is that, on average, oxygenated fuels were sold on a competitive basis as an alternative to the refiners' captive octane.

b) A similar situation will prevail for the Northern countries well into the 1990's. In fact, even disregarding further investment in refineries, the projected 1990 oxygenates availability is sufficient to meet the octane demand until the end of the century.

c) A different situation exists in the Southern countries. Unless there is further investment in reformers, not even the projected 1990 oxygenate availability would be sufficient to meet the anticipated octane demand and an increasing octane shortage would develop in the post-1990 period. However, the following two comments should be noted here. Firstly, investment in refineries in octane producing capacity has, so far, lagged because of the apparent intention to retain 0.40 g/l maximum permitted lead content in the leaded part of the gasoline pool. Secondly, there remains enough flexibility within the refining industry to minimise the octane problem.

FIGURE 3.6 : OCTANE BALANCES FOR EC 12



In conclusion, this analysis suggests that it is doubtful whether the refining industry in the EC will need outside supplies to meet the higher octane demand anticipated for the 1990's. Consequently, all oxygenates must be seen as competing with captive sources of octane, with obvious implications for pricing ambitions.

The bases for the calculation of the octane balances are reported in PT annex, section 7.

3.5 PHYSICO-CHEMICAL PROPERTIES OF OXYGENATED FUELS

It is important to note that the blending properties of the oxygenated fuels are quite different from the equivalent values measured for the products in their pure form. Similarly the blending properties of the oxygenates may vary considerably between individual refineries, since they are largely influenced by the characteristics of the gasoline base stock and by the oxygenate's concentration in the blend. For these reasons, a wide range of blending properties are reported in the technical literature for each of the major oxygenates. In general, the refiners' consensus seems to be that, on the basis of practical experience, the reported characteristics of oxygenated fuels tend to be inflated vis-à-vis actual performance.

In general, the oxygenates have a blending octane rating which is considerably higher than gasoline specifications (hence, they are also commonly defined as octane boosters). By contrast, they have two distinct disadvantages : both their sensitivity (the delta between the Research Octane Number and the Motor Octane Number) and their blending volatility (their ability to evaporate) fall far above the gasoline specifications. Table 3.8 illustrates the situation.

These contrasting characteristics of the oxygenates imply both an economic premium and a penalty. The premium is related to their octane boosting effect, although the latter is reduced when motor octane becomes the predominant specification. The economic penalty is related to the effect that the addition of an oxygenate has on the volatility of the gasoline. This latter phenomenon is particularly pronounced for the alcohols (ethanol, methanol). To compensate for the presence of the alcohol and its disproportionate "volatility" effect, some volatile gasoline component (usually butane) must be removed or "backed out" of the gasoline pool. The volume of butane backed-out which is generally associated with the use of a given oxygenated blending component can be a significant factor in the economic analysis of octane blending. Butane must be sold in another market if it is withdrawn from the gasoline pool. This usually represents a revenue loss to the refinery, since the price commanded by butane in virtually any other market is lower than the price of gasoline.

TABLE 3.8 : AVERAGE BLENDING PROPERTIES OF THE OXYGENATED FUELS

	RON (unleaded)	MON (unleaded)	SENSITIVITY (RON)-(MON)	VOLATILITY (bars)
Premium Gasoline	95	85	10	0.70-0.80
MTBE	118	101	17	0.55
GTBA	105	95	10	1.03
Oxinol -50*	118	97	21	2.00
Methanol (3% blend)	130	95	35	5.24
Ethanol (5% blend)	120	99	21	1.54
M3E3 **	120	98	22	2.59

Source : Consultants' estimates

* Registered trade mark of Atlantic Richfield Co for oxygenated gasoline blending components containing methanol and gasoline grade tertiary butyl alcohol (GTBA). The suffix indicates the concentration of methanol in the blend.

** Blend of methanol/ethanol in equal parts. The suffixes indicate the concentration of methanol and ethanol in the finished gasoline.

These characteristics help to explain why, among the oxygenates, MTBE has achieved a clear superiority over the alcohols. In addition to its high octane boosting features, MTBE has achieved prominence amongst the options open to refiners because : it has no utilisation/handling problems ; it has no associated water problems ; it has a low blending RVP ; its sensitivity is narrower than for the alcohols ; and finally, it is easily transportable, easy to blend, and does not inhibit gasoline exchanges between refiners.

In contrast, the alcohols are viewed as being less convenient to use for octane boosting purposes. Rather, they are frequently used purely on economic grounds predominantly as co-solvents permitting the utilisation of low cost methanol in the pool. Disadvantages of using alcohols focus on the need to restrict contact with the water which is normally to be found throughout the refining and distributing systems. This necessitates additional investment in storage facilities and in "drying out" the transportation/distribution system. Moreover, these problems tend to restrict the scope for product exchanges between refiners because of opposition from some companies to the use of alcohols. Ethanol is viewed by refiners as suffering from all of the general disadvantages described above for the alcohols, exacerbated by the lack of familiarity associated with any new product attempting to penetrate a very competitive market.

3.6 EVALUATION OF THE INCREMENTAL OCTANE IMPROVEMENT COST OF OXYGENATED FUELS

In order to make the interpretation of the results presented in this section easier to understand, the economic evaluation of the incremental octane improvement cost of the oxygenated fuels has been carried out through a simplified technique which considers the effects of adding the oxygenate to a gasoline base stock. This simplified approach, whilst ensuring reliable results, has the merit of providing a straightforward assessment of the most important effects deriving from blending an oxygenate with gasoline. Essentially, these simplified economics determine the relative value in the gasoline pool for each oxygenate on the basis of the following parameters :

a) Butane back-out : The volatility of the gasoline has to be maintained constant, and this implies that the addition of the oxygenate, which normally has a higher volatility than gasoline, displaces highly volatile components already existing in the pool, typically butane. Because the market price of butane generally falls below that of gasoline, this effect generally implies an economic penalty for the oxygenate.

b) Volume change : Because of differences in the relative volatility, the volume of butane backed out from the pool is generally different from the volume of oxygenate added to it, and this causes a change in the total volume of gasoline produced, with a resulting impact on total revenues.

c) Specific gravity change : Similarly to the volume change, the difference which exists in the specific gravity of butane and the oxygenate causes a change in the weight of the gasoline produced, with a resulting impact on total revenues.

d) Octane boosting effect : The difference in the blending octane rating between the oxygenate and octane boosting effect in the finished gasoline produced. This economic premium is evaluated on both a RON and a MON basis.

The calculations have been performed on the basis of actual market data over an extended period of time (quarterly, from 1983 through to 1986). This ensures that the results are not limited to one specific situation, but cover a wide range of different conditions. In terms of crude prices, for instance, the calculations cover prices as high as $ 30-35/Bbl in 1983 and as low as $ 10-15/Bbl during 1986. It should also be noted that the calculations are all made on a clear octane basis. Considering that a premium gasoline with a 98 RON/88 MON rating and with a 0.15 g/l lead content is approximately equivalent to a 95.5 RON/85.5 MON unleaded material, the results also apply to the future EC specification for unleaded premium gasoline.

Two sets of blending characteristics for the oxygenated fuels have been considered. The first set assumes the average characteristics previously reported. The second set considers characteristics towards the lower end of the range indicated in the technical literature. As already mentioned, practical experience in actual blending would seem to suggest that the latter characteristics are more in line with actual performance of the oxygenates.

The results of the calculations are graphically illustrated for ethanol and MTBE in figure 3.7 with the equivalent charts provided for the other oxygenated fuels in PT Annex section 8. The results are quantified in summary form in Table 3.9. Each of the graphs reports four different sets of calculated values : on a RON and a MON basis, with butane alternatively considered at market prices or fuel value. The latter case is important and with butane generally expected to be in surplus, it is a realistic case. Furthermore, the butane backout effect is particularly pronounced during the summer period, when the vapour pressure of gasoline is lower, and butane demand as premium fuel is at its seasonal low.

FIGURE 3.7

CALCULATED BLENDING VALUES

ROTTERDAM BASIS - RATIO TO PREMIUM GASOLINE

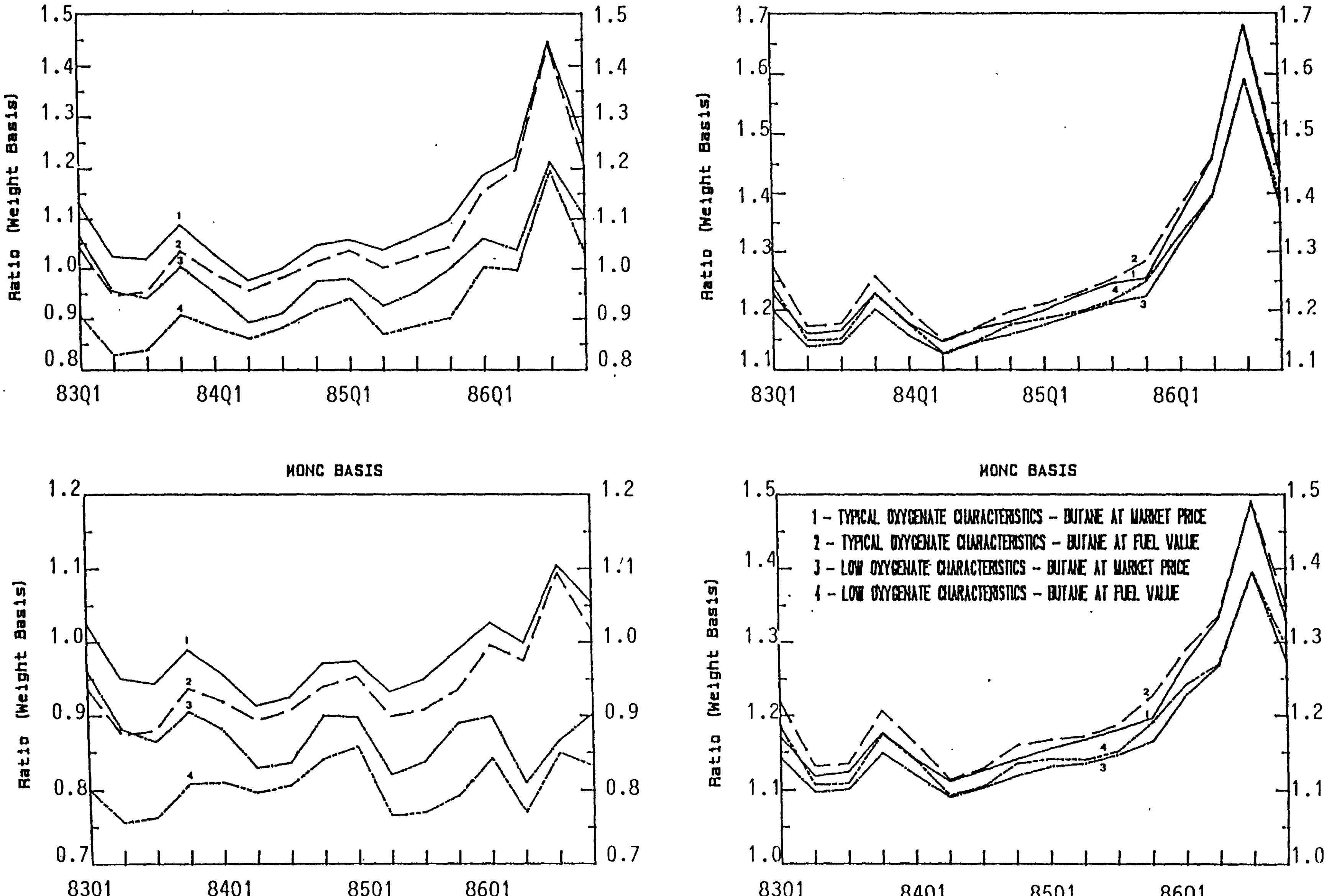


TABLE 3.9 SUMMARY OF ECONOMIC CALCULATIONS OF OXYGENATED FUELS BLENDING VALUES
(Ratio to premium gasoline)

	1983	1984	1985	1986
MTBE				
Minimum	1.10	1.09	1.13	1.23
Average *	1.17	1.14	1.19	1.39
Maximum	1.27	1.20	1.28	1.68
Delta Min/Max	0.17	0.11	0.15	0.46
% of average	15.0	9.4	12.8	32.7
GTBA				
Minimum	0.88	0.90	0.89	0.92
Average *	0.97	0.96	0.97	1.03
Maximum	1.04	1.01	1.03	1.14
Delta Min/Max	0.16	0.11	0.14	0.22
% of average	16.3	11.5	14.4	21.8
OXINOL 50				
Minimum	0.63	0.70	0.64	0.60
Average *	0.86	0.85	0.85	0.93
Maximum	1.10	1.00	1.04	1.30
Delta Min/Max	0.46	0.30	0.40	0.70
% of average	53.6	35.7	46.8	75.7
ETHANOL				
Minimum	0.76	0.80	0.76	0.77
Average *	0.94	0.92	0.94	1.05
Maximum	1.13	1.05	1.10	1.45
Delta Min/Max	0.37	0.25	0.33	0.68
% of average	39.7	27.2	35.4	64.3
M3E3				
Minimum	0.57	0.64	0.57	0.51
Average*	0.80	0.79	0.78	0.85
Maximum	1.08	0.96	0.99	1.25
Delta Min/Max	0.52	0.32	0.42	0.74
% of average	64.5	40.9	53.6	87.4
METHANOL				
Minimum	-0.05	0.11	-0.09	-0.36
Average	0.44	0.44	0.38	0.32
Maximum	1.06	0.82	0.81	1.01
Delta Min/Max	1.11	0.71	0.90	1.37
% of average	252.2	161.4	236.8	428.1

Source : Consultants' estimates

* Average of all calculated values

The charts clearly outline two effects deriving from the addition of oxygenated fuels to the gasoline base stock. On the one hand, the value on a MON basis is generally considerably lower than on a RON basis. Considering that, as previously seen, the average sensitivity of the gasoline pool tends to increase as lead is progressively removed from it, the MON specification will become increasingly important in determining the value of the oxygenate.

On the other hand, the charts also clearly outline what is considered to be the major drawback of the alcohols. The variability existing in their blending characteristics depending upon the type of the base gasoline, has a large effect on their values, with the minimum/maximum of the range varying within very wide limits. In the case of both MTBE and GTBA, however, this phenomenon is considerably less pronounced. By contrast, the large butane backout effect generated by methanol implies that the straight addition of this latter component into the pool may generate a negative value under unfavourable butane pricing conditions.

The results in general confirm the previously mentioned preference given to MTBE by refiners. They also help explain the considerably different values reported in the technical literature. Discussions with refiners confirm that their valuations of the alternative oxygenates are in line with the calculated breakeven values. The majority of oil companies would consider a value of MTBE, relative to premium gasoline to fall in the range of 1.20-1.25, with a maximum sustainable value of about 1.30 indicated for some refineries with a marked octane deficiency. Equally, refineries which have already invested in new reforming facilities indicate a valuation in the range 1.10-1.15 or even lower. In the case of GTBA, a value in the range 1.0 to 1.1 is generally indicated whilst Oxinol 50 (a 50/50 blend of GTBA and methanol) would fall in the range of 0.8-0.9. Virtually all companies contacted valued ethanol in this latter range on the basis of blending properties, with a further penalty for the additional costs associated with the handling, storage and distribution problems described earlier.

It is interesting to note that the much higher volatility of ethanol and ethanol/methanol blends implies a more pronounced butane backout effect than for the alcohols which are currently used in blending operations (GTBA and Oxinol, respectively). The result is an economic penalty in their blending values relative to the latter alcohols.

Finally, Tables A1 and A2 in appendix I, detail respectively the blending characteristics of oxygenated fuels and the market prices for gasoline, butane and octane, which have been used in the economic evaluation presented in this report.

CHAPTER 4

TECHNICO-ECONOMIC ANALYSIS OF A BIOETHANOL PRODUCTION SYSTEM

CONTENTS

4.1 Analysis of overall market for ethanol of fossil or agricultural origin (production, origin, destination).

4.2 Estimation of potential market for bioethanol according to different offer prices in the motor fuels industry. Evaluation of quantities of agricultural feedstocks and land resources involved.

4.3 Forward analysis of availability, quantity and cost of agricultural feedstocks in the Community (present crops and alternative crops).

Present crops : wheat, sugar beet, wine, potatoes ;
Alternative crops : Jerusalem artichoke, sweet sorghum, lignocellulosic materials (short rotation forestry).

4.4 Evaluation of bioethanol production costs (process, investment, yields, economies of scale, storage and transport of agricultural raw materials, etc) and prospects for technological progress in this field. Situation outlook as regards imports of bioethanol from third countries. Inventory of production units in the Community, capacities and location.

4.5 Economic analysis of other possible uses of bioethanol (chemicals industry).

4.6 Economic analysis of other options in competition with the conversion of agricultural raw materials to bioethanol. Evaluation of opportunity costs, taking into account other possible uses of land resources.

SUMMARY

The EC currently has surpluses in alcohol, and by the year 1992, these will probably amount to 2.2 million hl, mainly caused by wine production in excess. The possible use of this alcohol in the gasoline pool would need to be subsidized to meet the financial requirements of the petroleum industry.

A potential market of 29 to 31 million hl could be achieved for bioethanol, on the basis of the projected gasoline demand, within the context of unleaded gasoline. Such a market would represent about 1.1 million ha of wheat by the year 2000.

In order to achieve a significant share of this potential market, bioethanol would probably have to be sold at levels as low as 60 to 70 % of premium gasoline price, on a weight basis. However, a strategy of low volume and high price could be envisaged on the basis of small scale bioethanol plants located near to refineries identified as having problems in meeting RON requirements. This would represent a market up to 7.5 million hl of bioethanol in the 1990's at a pricing level of 100 to 120 % of premium gasoline.

The EC has gone beyond self-sufficiency in agricultural production. The continued increases in yields imply that secure supplies would be available for a possible bioethanol programme. At the same time, the improvement of productivity will probably allow reductions of agricultural feedstocks prices at a rate of 1 to 2 % per annum, while assuming that agricultural revenues will be preserved in constant value.

The net production costs of bioethanol appear to range from 46 to 53 ECU per hl. An overall reduction of these net production costs by 10 to 20 % in constant value may be possible by the year 2000.

In choosing locations for bioethanol units, account must be taken of the fact that the costs of the related agricultural activities (production, transportation and storage of the feedstocks) constitute a major part of the total production costs of bioethanol.

The production costs of bioethanol in existing plants would be, in the best conditions, similar to costs in new units. The largest existing bioethanol plants in the EC are located in France, Spain and Italy. But these plants work mostly from beet and wine substrates, and modernisation investments would be needed to produce bioethanol in a large scale programme.

Although it is technically feasible to convert bioethanol to ethylene for chemical uses, such a conversion would be more expensive than its production as an oxygenate.

Finally, continuation of the current pattern of agricultural land use will lead to increasing stockpiles, particularly of cereals. The production of feedstocks for bioethanol would represent a higher cost to the EC and Member States than the current cost of cereals support and alternative land uses.

4.1 : PRODUCTION OF AND MARKET FOR ALCOHOL OF FOSSIL AND AGRICULTURAL ORIGIN

The European Community of 10 produced nearly 15 million hectolitres of alcohol in 1984, broken down as follows :

- alcohol of agricultural origin : approximately 9.5 million hl
- alcohol of synthetic origin : approximately 5.2 million hl

With the Community's broadening to 12 countries, the production of alcohol of agricultural origin rose to 12 million hl, i.e. a total of 17.2 million hl.

In the Europe of 10, the production of alcohol of agricultural origin increased by nearly 5 million hl during the last 12 years. This production comes for the most part from wine, molasses and sugar beet. Taking the growth of production into account, the share of the respective raw materials changed as well. This is especially true for wine, which accounted for 10 % of the production initially, and now represents 40 %. The level of change has otherwise varied from country to country, the most noteworthy feature being the doubling of the share of alcohol made from wine in France and Italy, the major producers. Spain's production is mostly intended for internal uses. All of its surplus production of wine was exported before it joined the Community. However, Spain is in a situation of overproduction of wine, and a question remains posed regarding the evolution of its yields.

Control of the markets for alcohol of agricultural origin is being relaxed ; however, market support systems remain (West Germany - France for sugar beet and wine), as well as tax structures that play a similar role (Italy).

Alcohol of synthetic origin is produced in 3 countries (UK, France, West Germany). Production increased by 1.5 million hl during the past few years, with the UK doubling its share from 1.5 to 3 million hl. This alcohol is sold on the open market.

These different alcohols are used for industrial purposes (as reagents and solvents), in which case the alcohol involved is mostly of synthetic origin, or for non-industrial purposes (oral consumption, perfumes, pharmaceuticals, vinegar-making). The latter mostly use alcohol of agricultural origin. However, for a given application the alcohol used varies from country to country.

The data relating to trade in ethanol are not always consistent. However it is possible to draw the following general conclusions. Trade in ethanol between Member States is substantial and is increasing. Exports to non Member States are decreasing. The net balance of exports less imports remains positive but is showing signs of decrease. It seems that it is becoming increasingly difficult to sell Community produced alcohol within the EC itself and in markets of non Member States. Consumption today stands in the order of 10 million hl, thus the Community finds itself in a situation of structural overproduction by approximately 5 million hl, attributable for the most part to alcohol made from wine.

The Community has taken measures aimed at reducing this surplus, through the DUBLIN accords, including especially :

- a distillation policy intended to reduce high yields ;
- a plan for reducing table wines acreage by 180,000 ha over the next 5 years, corresponding to a reduction in production in the order of 17 million hl.

Under these conditions, given the trend towards increases in production during recent years, a reduction in internal uses due to lower consumption, and the continuation of net exports at current levels, a structural surplus of 18 million hl of wine is forecast for 1992. With a Community broadened to 12 countries, this excess would amount to 22 million hl of wine by the same date. This corresponds to approximately 2.2 million hl of alcohol, of which almost 30 % represents an inevitable production made up of wine-based supplies.

Moreover, on May 14th, 1987, the Community's stock of mandatory distilled wine stood at 4.6 million hl of alcohol.

If the surplus of wine is to be eliminated, additional measures will be necessary, in the form of supplementary structural measures, and/or the possible use of grape sugar in order to make chaptalization possible.

Marketing of wine-based surpluses appears difficult. Italian exports for carburation purposes have been sold at a price lower than 10 ECU/hl. Recent auctions of wine-based alcohol by the Community on its internal market have not been successful. Also, the Community is subjected to pressures from the member countries intended to make it assume entire responsibility for distillation.

There are different possibilities for the utilisation of the current structural surplus of alcohol derived from wine. These are :

- exportation for blending into gasoline if opportunities to supply this market continue,
- combustion as an industrial fuel,
- internal use as an oxygenate in motor fuel.

In the event of a political decision to incorporate ethanol into gasoline, wine alcohol could be used in the short term, pending the development of ethanol production based upon other raw materials. This ethanol will compete with oxygenated compounds derived from petroleum. It must be subsidized if its price is to be deemed acceptable by petroleum producers.

In 1987, taking into account a gasoline price of $ 184/tonne, an ethanol to gasoline ratio of 0.7, a dehydration cost of 4 ECU/hl, and a market price of alcohol of 96 ECU/hl, the subsidy represents 90 ECU/hl.

However, if the market is to be exploited it must not have the effect of perpetuating wine surpluses in spite of the structural measures adopted. On a broader basis, an increase in the prospects for ethanol raises the question of market supports and of guaranteed outlets.

4.2 ASSESSMENT OF THE MARKET FOR BIOETHANOL AS A GASOLINE ADDITIVE

Under EC regulations concerning the use of oxygenates in petrol which are reviewed in section 3.1, the use of ethanol is limited to a maximum of 5 % of gasoline on a volume basis. Although blends of 10 % concentration are used in the US, representatives of the car manufacturers have stated that it would be unwise to move beyond the 5 % level in European conditions.

The low water tolerance associated with the alcohols provides an additional constraining factor on the potential use of ethanol in the gasoline pool. Contamination of gasoline blends containing ethanol by relatively small amounts of water (particularly salt water) can cause the blend to separate irreversibly into two different phases. Since this can result in poor vehicle performance and, possibly, engine damage, if the contaminated blends were to enter the distribution system, gasoline marketers would be very reluctant to use water-borne transportation for ethanol/gasoline blends. Whilst it is technically possible to minimise these problems, this would require purpose built vessels which are limited in number and which would imply significantly higher transportation costs than for conventional gasoline.

In the base case scenario developed by the Consultants, gasoline consumption in the EC is projected to increase to about 95.8 million tonnes by the end of the century. Assuming, for the purposes of this analysis, that imports from third countries and/or requiring transport by sea remain unchanged from the average import level during 1983-1986 (9.4 million tonnes) this total reduces to 86.4 million tonnes to be supplied from domestic refineries. Of this total, 81 % will be concentrated in the 4 major markets:France (18.4%) West Germany (24.0 %), Italy (14.0 %), and the U.K. (24.9 %), with the remaining 16.2 million tonnes distributed among 8 markets, including Denmark, Portugal, Spain and Ireland (all of which would require delivery of ethanol/gasoline by sea).

Although there are no reliable statistics on the modes of transportation for gasoline deliveries within each of these 4 major markets, oil company representatives estimate that a significant volume of gasoline is delivered by coastal tankers or internal waterways in the U.K, Italy and France. Similarly, it has been suggested that all 4 markets will contain market locations remote from the potential production areas of bioethanol. If guestimates of the volumes affected by these factors are deducted from the total, the residual target market available for ethanol in 2000 may be estimated as in Table 4.1.

Considering that the maximum oxygen content of gasoline should not exceed the 2.5 % weight limit (except for special exemptions by individual member countries), and assuming that the same gasoline market is also available for GTBA/methanol blends, the upper end of the range shown above for bioethanol would imply some displacement of the latter blends.

It must be emphasised, however, that ethanol could only hope to penetrate these markets at a price below the 80-90 % ratio to premium gasoline established as the range of valuations for ethanol on the basis of its blending characteristics. In addition to the margins necessary to compensate the refiner for tackling the transportation, storage and distribution problems associated with ethanol blends, the product would have to compete for the market both with existing oxygenates (particularly TBA) and with the internal octane producing options available to the refinery. Finally, the ethanol would have to be priced at a very low ratio to premium gasoline in order to find its way into the regular pool, which is not expected to be octane-deficient.

TABLE 4.1 MAXIMUM MARKET POTENTIAL AVAILABLE FOR ETHANOL AS A GASOLINE COMPONENT IN THE EC GASOLINE POOL OF 2000 (million tonnes)

	EC 12	FRANCE	W.GERMANY	ITALY	UK	OTHER
TOTAL DEMAND LESS IMPORTS	86.4	15.9	20.7	12.1	21.5	16.2
COASTAL DELIVERIES, REMOTE AREAS,ETC	35-40	3-4	3-4	6-7	10-11	14-15
TARGET MARKET FOR ETHANOL	46-51	12-13	17-18	5-6	10-12	1-4
MAX POTENTIAL FOR ETHANOL TO 5 %	2.3-2.5	0.6-0.7	0.8-0.9	0.2-0.3	0.5-0.6	0.1
MAX POTENTIAL FOR ETHANOL AS A CO-SOLVENT 3%	1.4-1.5	0.4	0.5-0.6	0.1-0.2	0.3	0.1

Sources : Consultants' estimates

NB : Components may not add exactly to totals, due to individual roundings

Given the strange behaviour of ethanol prices in the US in 1986, when prices net of tax relief declined to levels below zero compared with gasoline prices (refer section 5-3), it is very difficult to be precise about the likely price elasticity for ethanol blends in the European gasoline pool. However in an attempt to indicate the possible profile of the price/volume relationships, strategies which may be envisaged for the launch and operation of a bioethanol programme are shown in Table 4.2.

TABLE 4.2 POTENTIAL MARKET OF BIOETHANOL/PRICE RATIO TO UNLEADED GASOLINE

Strategies	Price ratio Ethanol to unleaded gasoline	Volume million tonnes
(a) High price/ low volume	1.0 to 1.2	0.1 to 0.6
(b) Medium price / average volume	0.8 to 0.9	1.0 to 1.5
(c) Low price / high volume	0.6 to 0.8	1.5 to 2.5

Source : Consultants' estimates

Strategy (a) would provide ethanol as an octane booster and would require a series of small scale ethanol plants located near to refineries identified as having problems in meeting clear RON requirements, particularly in the EC South, in the mid 1990's when a potential octane deficiency is projected. However this strategy would be vulnerable to investment in the target refineries which would send ethanol prices into category (c) without the corresponding volume benefits.

Strategy (b) would be targeted at a larger sector of the market aiming to achieve ethanol breakeven blending value in the gasoline pool in competition with existing oxygenates and internal refinery octane. The market as a cosolvent for the available methanol would form an important element of this strategy, especially if ARCO decided to convert most of their TBA production into MTBE. This latter market sector however would be very sensitive to prevailing methanol markets which could be pressurized by the chemical sector.

Strategy (c) would attempt to maximise the volume of ethanol sold as a gasoline extender, aiming to achieve up to the maximum 5 % potential wherever technically feasible without incurring major cost burdens in order to overcome water problems.

It is important to note that the foregoing assumes it would be possible to organise a multi-tier pricing structure. However, whereas strategies (a) and (b) could be adopted simultaneously, strategy (c) tends to exclude the other strategies.

These observations are supported by the CONCAWE Report Number 86/68 which concluded that ethanol could aim for a market of 2 million tonnes if it were priced at about 70 % of premium gasoline levels.

A more detailed description of the potential market available to ethanol in the EC gasoline pool is provided in PT Annex section 9.

In conclusion, it may be considered that ethanol would have to be sold at levels as low as those typically prevailing in the US (60-70 % of unleaded gasoline levels in pre-1986 conditions, on a weight basis) in order to achieve a significant share of this potentially available market. Quantities of agricultural feedstocks and land resources involved in a bioethanol programme are summarised in Table 4.3.

4.3 CURRENT AND POTENTIAL RAW MATERIALS FOR USE IN ALCOHOL PRODUCTION

As regards the 4 raw materials under consideration here (wheat, sugar beet, potatoes and wine), Europe has surpassed the self-sufficiency stage except for potatoes which are 100 %. Taking into account the production cost of ethanol for each of them, we will focus on wheat and sugar beet, which appear to have lower production costs.

TABLE 4.3 - QUANTITIES OF AGRICULTURAL FEEDSTOCKS AND LAND RESOURCES INVOLVED IN A BIOETHANOL PROGRAMME

ETHANOL/PREMIUM GASOLINE PRICE RATIO	TOTAL ETHANOL MARKET SIZE (Million Tonnes)	100 % WHEAT		2/3 WHEAT - 1/3 SUGAR BEET			
				WHEAT		SUGAR BEET	
		WHEAT CONSUMED (Million Tonnes) (year 2000)	AREA (000 ha)	WHEAT CONSUMED (Million Tonnes (year 2000)	AREA (000 ha)	SUGAR BEET CONSUMED (Million Tonnes) (year 2000)	AREA (000 ha)
1.0 - 1.2 : 1 mid point 1.1 : 1	0.1 to 0.6	0.34 - 2	43 - 261	0.2 - 1.36	29 - 174	0.4 - 2.5	7 - 44
0.8 - 0.9 : 1 mid point 0.85 : 1	1.0 to 1.5	3.4 - 5.26	427 - 666	2.3 - 3.5	295 - 441	4.2 - 6.4	72 - 110
0.6 - 0.8 : 1 mid point 0.7 : 1	1.5 to 2.5	5 - 8.5	666 - 1088	3.5 - 5.7	441 - 725	6.4 - 10.5	110 - 181

Sources : consultant's estimates

Changes in cultivation methods, the efficient use of fertilizers, the application of plant protection techniques, and genetic selection have made it possible to record sizeable increases in yield. These average 2 to 3 % per year for cereals and 1 % for sugar beet.

Assuming that current acreages are maintained, the production of cereals for the Europe of 10 would be 160 million tonnes in 1992. The broadening of the Community to 12 member countries should raise the total production to 180 million tonnes by the same date, with wheat representing 80 to 85 million tonnes. Should past trends continue, cereals production should rise to 190 million tonnes by the year 2000. The production of sugar has registered a considerable decrease over the past 5 years as a result of the difficulties on the world market. It is currently in the order of 12.5 million tonnes and should remain at the same level until 1992.

These production levels should be seen in the context of their respective markets. In the case of cereals, internal Community application has been characterized by great stability at 110/115 million tonnes for the past 15 years. Human consumption should remain stable, as should animal consumption as a result of restrictions in the dairy sector and the effect thereof on bovine meat. Industrial applications should rise, up to 10 million tonnes. Export levels will depend on the growth and solvency of the markets. At present, exports are taking place in a context of very intense competition, generating a very high restitution level (up to 140 ECU/tonne for wheat, recently). Assuming that export levels are maintained, the structural surplus will be in the order of 20 million tonnes in 1992.

Although governed by different mechanisms, the production of sugar exceeds human consumption, which is in the order of 11 million tonnes for the Community of 12. Despite the forecast increase of industrial applications (0.5 million tonnes), there will be an exportable surplus in the order of 1 million tonnes in quotas A and B. Because of the state of the world market for sugar, the areas under cultivation have been reduced considerably : between the 1981/82 and 1985/86 campaigns, they represented a potential of about 260 000 ha, which correspond to non-quota sugar but could be available for producing bioethanol.

At present, the average yields in the main European producing countries are 5.9 tonnes/ha for wheat and 49.9 tonnes/ha for sugar beet. These data do not take national and regional disparities into account. Thus, in intensive farming areas, average yields of 7 to 8 tonnes/ha for wheat, and of 10 to 11 tonnes/ha for sugar, are obtained.

In future, improvements are to be expected, thanks to the increasing use of biotechnological methods, especially genetic engineering, hybridization and seed conditioning. They should lead to an increase in productivity, to greater regularity in production, to an improvement in the quality of the products by making them more precisely suited to their final destinations, to greater resistance and less dependance on chemical fertilizers. The goal of ongoing research projects is to produce better at the best price. Progress expected in this field will cause profound changes in the form and nature of the input of a given crop. It is not easy to gauge the cost, as it depends on the increase in added value given to the seeds. Similarly, a certain caution must be exercised with regard to the dates on which this progress will be translated to industrial level. Certain problems still subsist, especially in the case of cereals.

By the year 2000, if the trends noted over the past few years continue, average yields will be of the order of 7.8 tonnes/ha for wheat and 57.8 tonnes/ha for sugar beet. If the application of biotechnologies results in a new quantitative and qualitative leap, these yields could reach 10 to 12 tonnes/ha for wheat and 75 to 87 tonnes/ha for sugar beet.

In certain regions production costs could be lower than average, however current market mechanisms and the surplus situation do not allow for a wheat offer lower than the intervention price. At present, this intervention price represents the minimum purchase price for the raw material wheat.

It is clear that the price of B quota sugar beet would be adequate to ensure a sufficient supply for a bioethanol programme. The decrease in the acreage of sugar beet during the last 5 years shows that the price which has been paid (C price) has been inadequate to encourage farmers to produce.

For the future, it has been assumed that farm revenue per hectare will remain constant over the period under consideration, assuming :

- changes in yields,
- changes in the real price and quantities of input.

That means a 1 % per annum decrease for wheat, potatoes and wine and 0.5% for sugar beet. This decrease in price also reflects the objective of the Commission to reduce the differential between Community prices and world prices.

As regards new energy crops such as Jerusalem artichoke, sweet sorghum and short rotation woody biomass, these have been the subject of research for several years. The results obtained at present in field trials show encouraging prospects, with yields in fermentation sugars attaining 9 tonnes/ha for Jerusalem artichoke in Spain, and 5-6 tonnes/ha for sweet sorghum in Italy. Pedo-climatic requirements indicate a good adaptation to southern European regions, which are generally at a disadvantage for large industrial crops like wheat and sugar beet. They could in the future offer new farming possibilities and play a social and economic role in disadvantaged regions. However, the profitability of an industrial unit must be based on stable yields of raw materials. Research must be continued to better adapt these crops to their potential production regions, as well as optimise their behaviour and their farming conditions.

Short rotation forestry has been practised for several years in Portugal for pulp and paper purposes. Trials conducted in various European countries have made it possible to attain a certain reliability in relation to the selection of clones and farming conditions. However further optimisation of the selection procedure with the aim of producing more efficient and resistant clones appears necessary as well as optimisation of farming conditions. Similarly, it is necessary to continue research at the level of biochemical paths and of valorisation of all compounds contained in wood cellulose in order to maximise the transformation into ethanol.

4.4 EVALUATION OF BIOETHANOL PRODUCTION COSTS

The net production cost for bioethanol is a function of three major factors :

- the costs of the agricultural raw materials,
- the manufacturing costs (including the costs associated with financing the production units),
- the receipts from co-products.

4.4.1 Net production costs for bioethanol under current conditions

On the basis of a number of assumptions and calculations (more details are given in AD Annex section 3 and BU Annex), the net production costs would be as shown in Table 4.4, based on a feed wheat price of 170.47 ECU/tonne, and of 28.74 ECU/tonne for sugar beet (B quota price and 4 ECU/tonne transportation).

TABLE 4.4 CURRENT NET PRODUCTION COSTS FOR BIOETHANOL

Types of unit	Wheat		Wheat & EP2			Sugar substrates	
Capacities (hl/day)	2,000	5,000	8,000	3,000	5,000	2,000	5,000
Current net production costs for Bioethanol (ECU/hl)	52	49	48	53	51.5	50	46

Source : Consultants' estimates

These costings apply to the production of water-free ethanol and include environmental protection costs (purification of wastewater and processing gases, etc.).

4.4.2 Investment costs and economies of scale

Taking into account the absence of large scale existing units, all the analyses were based on data supplied by research and engineering companies. A summary is given in Table 4.5.

It appears that economies of scale are substantial between ranges of capacities exceeding 1000 hl/day, and capacities comprising 3000 and 5000 hl per day.

The economies of scale will be significant especially with regard to investment costs, and operating costs such as labour costs.

TABLE 4.5 INVESTMENT COSTS AND ECONOMIES OF SCALE

Types of units	Wheat		Wheat & EP2			Sugar substrates	
Capacities (hl/day)	2,000	5,000	8,000	3,000	5,000	2,000	5,000
Investment costs (in ECU/hl of daily capacity)	20,600	16,180	14,740	18,130	15,685	13,500	8,640
Manpower costs (in ECU/hl)	2.18	1.29	1.15	1.70	1.29	0.68	0.26

Source : Consultants' estimates

4.4.3 Overall production cost breakdown for bioethanol

The agricultural feedstocks costs represent approximately 70 % of the total production costs of bioethanol (not including receipts from co-products), in the case of production based on feed wheat (based on an intervention price of 170.47 ECU/tonne), or in mixed units (wheat and EP2). In the case of production exclusively from sugar substrates (juices), the costs of feedstocks represent 80 % of the total cost.

Conversion costs for these various cases are as shown in Table 4.6 (as a percentage of the total cost of production, excluding receipts from co-products).

TABLE 4.6 CONVERSION COSTS AS % OF THE TOTAL PRODUCTION COST (excluding receipts from co-products)

	TOTAL CONVERSION COSTS	INCLUDING INTEREST EXPENSES
100 % wheat units	30 %	16 %
Mixed units (wheat, EP2)	30 %	18 %
Sugar beet units	20 %	8 %

Source : Consultants' estimates

The receipts from co-products represent, as a percentage of the total inflows :

- . 25 % for 100 % wheat units (DDGS),
- . 20 % for mixed units (DDGS and vinasses),
- . 6 % for sugar beet units (vinasses and yeasts).

The information available regarding the costs of producing bioethanol from alternative feedstocks is limited. Nevertheless these costs appear to be comparable to those of bioethanol produced from sugar beet and wheat in the case of Jerusalem artichoke and sweet sorghum. Those from ligno-cellulosic materials are likely to be higher. Further research is needed to establish the extent of this comparability.

There are good reasons to believe that technical progress will result in reductions in conversion costs for sugar beet and wheat of between 15 and 20 % by the year 2000. These reduced costs, however, will not be inbuilt in the financial structure of plants established in 1987/88 but will be a consequence of innovations in plant design.

4.4.4 Costs associated with the transportation and storage of agricultural raw materials

The location chosen for bioethanol manufacturing units will reflect the need to minimise the logistic cost associated with the transportation and storage of the feedstocks, products and co-products.

Cost studies show that raw materials generate the highest transportation and storage charges. Thus, it will be necessary to locate bioethanol production units as close as possible to sugar plants or wheat storage silos (this is also a way of reducing investments).

In the case of mixed units (wheat-EP2), the share of wheat transportation costs is generally greater and one will therefore seek a location close to major grain silos.

The share of the total transportation cost of bioethanol and co-products (DDGS, etc.) appears to be the same, given similar means of transportation (train, truck, etc.). In the event of a unit being located close to existing pipelines, the advantage at the level of bioethanol transportation cost is then considerable.

4.4.5 Factors in changes of net production costs of bioethanol

4.4.5.1 Raw material costs

In the case of wheat, the actual cost taken into account is the intervention price for feed wheat (170.47 ECU/tonne). On the basis of the assumed increases in yields and productivity, calculations were made with annual reductions of this intervention price by 1 %, 2 % and 3 % in constant value.

The estimated cost price of EP2 falls within the problematic of combined costs : this price will be based both on the cost of sugar beet (B quota price : 24.74 ECU per tonne ; plus 4 ECU per tonne transported), a fixed term corresponding to processing costs in sugar plants, and on the selling price of molasses. The price of molasses (147 ECU/tonne of sugar) is linked to changes in market prices for sugar.

As in the case of wheat, calculations were made with successive annual reductions in the price of sugar beet of 0.5 %, 1.5 % and 3 % in constant value.

4.4.5.2 Price of the co-products

In the case of DDGS (at the current price of 161.76 ECU/tonne), the forecasts were based on the price of soya oilcake.

As regards vinasses, their initial value was estimated at 38.23 ECU/tonne (for vinasses which are not potash free), and their price changes reflect the price of potash.

4.4.5.3 Direct conversion costs

These are made up of charges relating to labour, energy consumption, consumable materials, and maintenance expenses.

Labour charges (including maintenance expenses) are forecast to increase by 1 % per year in constant value.

Energy costs are indexed on petroleum prices, and consumable prices remain constant.

Moreover, it is possible to forecast an overall reduction of approximately 15 to 20 % in all these costs by the year 2000. However, such a reduction can be envisaged only for new plants built by that date.

4.4.5.4 Interest expenses

There are various possibilities for financing arrangements ; and each arrangement will be based upon a set cost profile.

In the present case, we have considered as a basic assumption the principle of an average cost of capital (12 %), with the average cost taking into account the level of remuneration of the capital invested, regardless of its origin (loans, own funds, etc.). The annual cost of finance (repayment of the capital and interest expenses) is therefore equal to the constant repayment annuity, for the duration of the project (15 years).

The relationship between the net cost of production of bioethanol and the rate of remuneration of the capital invested is as shown in Table 4.7.

TABLE 4.7 RELATIONSHIP BETWEEN THE NET PRODUCTION COST AND THE RATE OF REMUNERATION OF THE CAPITAL INVESTED

Average rate of remuneration of the capital	Capital invested (wheat unit of 5000 hl) in millions of ECU	Interest Expenses (ECU/hl)	Net production cost ECU/hl
5 %	108.4	6.35	46
12 %	115.3	10.26	49
16 %	119.1	12.95	52

Source : Consultants' estimates

4.4.5.5 Forecast changes in net cost based on production of bioethanol during the period 1986 - 2000

The projections shown in Tables 4.8 and 4.9 were calculated on the basis of the assumptions presented above (sub sections 4.4.5.1 - 4).

TABLE 4.8 100 % WHEAT, UNIT CAPACITY 5000 hl/d
(net production cost in ECU/hl)

Annual rate of decrease of wheat prices	1986	1990	1995	2000
1 %	49	47.5	46.3	45.3
3 %		43.8	38.9	34.9

Source : Consultants' estimates

TABLE 4.9 MIXED UNIT, CAPACITY 5000 hl/d
(net production cost in ECU/hl)

Annual rate of decrease of raw materials prices	1986	1990	1995	2000
Wheat 1 % sugar beet 0.5 %	51.5	53.5	51.5	50.5
Wheat 3 % sugar beet 3 %		50.3	45	41.4

Source : Consultants' estimates

4.4.5.6 Projected level of support

Tables 4.10 and 4.11 show the level of supports required without and with a 70 ECU/tonne restitution, which would possibly be given by the EC, for two cases :

- 100 % wheat unit - Capacity 5000 hl/day
- Mixed unit (2/3 wheat - 1/3 EP2) - Capacity 5000 hl/day

TABLE 4.10 - PROJECTED LEVEL OF SUPPORT NEEDED IN VIEW OF NET PRODUCTION COSTS AND SELLING PRICE OF BIOETHANOL
Case of 100 % unit. Capacity 5000 hl per day
oil price : recovery scenario

	1986		1990		1995		2000	
	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B
1- Raw material price (intervention) ECU/Tonne	170.47	170.47	163.75	157.24	155.73	142.13	148.10	128.47
2- Net production cost ETOH ECU/hl	49	49	47.4	45.6	46.3	42.5	45.3	39.8
3- Selling price ETOH ECU/hl								
Ratio ETOH/gasoline 1.1	15.03	15.03	16.87	16.87	17.78	17.78	20.9	20.9
Ratio ETOH/gasoline 0.85	11.61	11.61	13.04	13.04	13.74	13.74	16.15	16.15
Ratio ETOH/gasoline 0.7	9.56	9.56	10.74	10.74	11.31	13.31	13.30	13.30
Difference 2 - 3 ECU/hl								
Ratio ETOH/gasoline 1.1	33.97	33.97	30.53	28.73	28.73	24.74	24.74	18.9
Ratio ETOH/gasoline 0.85	37.39	37.39	34.36	32.56	32.56	28.76	29.15	23.65
Ratio ETOH/gasoline 0.7	39.44	39.44	36.66	34.86	34.88	31.19	32	25.50
Difference 2 - 3 with EC Restitution 70 ECU/Tonne (18.29 ECU/hl)								
Ratio ETOH/gasoline 1.1	15.05	15.05	11.61	9.81	9.6	5.8	5.48	- 0.02
Ratio ETOH/gasoline 0.85	18.47	18.47	15.44	13.64	13.64	9.84	10.23	4.73
Ratio ETOH/gasoline 0.7	20.52	20.52	17.74	15.84	16.07	12.27	13.08	7.56

Source : Consultant's estimates

ETOH = Bioethanol

Scenario A : 1 % decrease in price
Scenario B : 2 % decrease in price

TABLE 4.11 - PROJECTED LEVEL OF SUPPORT NEEDED IN VIEW OF NET PRODUCTION COSTS AND SELLING PRICE FOR BIOETHANOL
Case of 70 % wheat - 30 % sugar beet (EP2) unit-capacity 5000 hl per day
oil price : recovery scenario

	1986		1990		1995		2000	
	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B
1- Raw material price (in ECU/Tonne)								
Wheat	170.47	170.47	163.75	157.24	155.73	142.13	148.10	128.47
Sugar beet	28.74	28.74	28.17	27.61	27.47	26.25	26.79	24.97
2- Net production cost ETOH ECU/hl	51.64	51.64	53.47	52.05	51.46	48.49	50.51	46.21
3- Selling price ETOH ECU/hl								
Ratio ETOH/gasoline 1.1	15.03	15.03	16.87	16.87	17.78	17.78	20.9	20.9
Ratio ETOH/gasoline 0.85	11.61	11.61	13.04	13.04	13.74	13.74	16.15	16.15
Ratio ETOH/gasoline 0.7	9.56	9.56	10.74	10.74	11.31	13.31	13.30	13.30
Difference 2 - 3 ECU/hl								
Ratio ETOH/gasoline 1.1	36.60	36.60	36.60	35.20	33.68	30.75	29.61	25.32
Ratio ETOH/gasoline 0.85	40.02	40.02	40.43	39.03	37.72	34.78	34.36	30.07
Ratio ETOH/gasoline 0.7	42.07	42.07	42.73	41.33	40.15	37.20	37.21	32.92
Difference 2 - 3 with EC Restitution 70 ECU/Tonne (18.29 ECU/hl)								
Ratio ETOH/gasoline 1.1	18.31	18.31	18.31	16.91	15.39	12.45	11.32	7.03
Ratio ETOH/gasoline 0.85	21.73	21.73	22.14	20.74	19.43	16.49	16.07	11.78
Ratio ETOH/gasoline 0.7	23.78	23.78	24.44	23.04	21.86	18.91	18.92	14.63

Source : Consultant's estimates

ETOH = Bioethanol

Scenario A : 1 % decrease in price for wheat, and 0.5 % for sugar beet.
Scenario B : 2 % decrease in price for wheat, and 1 % for sugar beet.

4.4.6 Production cost of bioethanol in existing units

Information obtained from existing bioethanol producers suggests that production costs in existing medium sized (1000 to 2000 hl per day) units may be similar to those of large new units. However, these cost estimates do not take full account of :

- the true cost of reinvestment to maintain the units,
- the cost of additional investment which would be required if these units were to form part of a major programme to produce high quality alcohol as a gasoline additive,
- the cost of additional investment which would be required for year-round production, using wheat in addition to sugar substrates.

If these factors are taken into account it is likely that the production costs in existing units will be similar to, or higher than, those in new units.

4.4.7. Inventory of bioethanol production units in the EC

Obtaining data relating to the existing bioethanol production capacities in the various EC Members is a difficult task.

It appears that the countries with the largest alcohol production capacities in Europe are : France, Italy, West Germany and Spain.

In these countries, sugar beet and wine substrates are mainly used. On the whole existing plants are designed to produce ethanol for human consumption and would need to be modified and/or extended to produce ethanol at the required water-free quality for use in the gasoline market.

France has an important distillation infrastructure linked to the sugar industry.

The units with the largest capacities are located in France, Italy and Spain (1000 to 1500 hl/day per unit).

Finally, in most of these countries, there is under-utilisation of potential distillation capacities.

4.5 ECONOMIC ANALYSIS OF OTHER POSSIBLE USES OF BIOETHANOL

Ethanol is one of the most important chemicals used in industry. Its solvent properties are utilised in producing a range of products and in numerous conversion processes undertaken in the food, pharmaceutical and cosmetic industries. The wide range of products includes lacquers, varnishes, inks, hydraulic fluids, soaps/detergents, deodorants, perfumes and antiseptics. In the case of the cosmetic industry, preference is often given to bioethanol and, in countries such as France and Italy, cosmetic manufacturers are required to use ethanol produced from biomass.

Currently the bulk of ethanol used as a feedstock in the EC chemicals industry for the production of ethylamines, ethyl esters, ethylvinyl ether and glycol ethers is produced synthetically from ethylene. Recently the use of synthetic ethanol for the production of acetic acid, butadiene, butylaldehyde, acetaldehyde and ethyl-hexanol has been largely replaced by other derivatives.

Technically there are no reasons why agricultural feedstocks such as wheat, sugar beet and potatoes cannot be used for the production of base chemicals such as ethylene and butadiene for use in the chemicals industry. Ethanol has been used as a feedstock for the chemicals industry in Brazil, where 13 per cent of current ethylene production capacity is based on ethanol. Although some additional capacity for producing ethylene from ethanol is being added, the proportion of total Brazilian ethylene produced in this way is not expected to increase. Sales into the chemicals market represent only about 5 per cent of total ethanol output in Brazil, and it is clear that the supply of ethanol for this purpose has shown only limited attraction to both ethanol producers and the chemicals industry.

The dehydration of ethanol to ethylene is the principal potential way in which any significant additional volume of ethanol might be used by the EC chemicals industry. Sources within the petrochemicals industry report that the cost of producing ethylene from ethanol may be described by the relationship :

$$Ey = (1.73 \times Et) + 50$$

Where :

Ey = cost of production of ethylene, in ECU

Et = price of ethanol, in ECU

This formula may be used to compute the ethanol values from estimated ethylene prices, as a preliminary approach to assessing the potential for ethanol in the chemicals industry.

The Consultants' own price projections for ethylene are shown in Table 4.12, and these are related to a price of ethanol using the above formula.

TABLE 4.12 ETHYLENE PRICE PROJECTION RELATED TO ETHANOL VALUE

YEAR	ETHYLENE PRICE	ETHANOL VALUE
	ECU/Tonne *	ECU/hl
1987	382	15.2
1990	410	16.4
1995	422	17.0
2000	477	19.5

* Prices in real (constant 1986) currency
Source : Consultants' Estimate

These figures are similar to an ethanol value of 1.1 times the price of premium petrol.

However, the current typical variable production cost of synthetic ethylene (net of co-product credit) is quoted by the same source as 200 ECU/tonne. This corresponds to a much lower threshold price for ethanol of 6.8 ECU/hl, which is well below any of the proposed values of ethanol as an octane booster. An ethanol price which was significantly higher than this might require ethylene producers to accept a reduction in their financial margins.

Since the conventional production of ethylene is associated with a number of co-products, and substitution of current feedstock by ethanol would disrupt this production process, it is unlikely that the chemicals industry would also be prepared to accept reduced returns by offering a price which is comparable with the value of ethanol as an octane booster.

Therefore, a preliminary analysis suggests that, in the absence of additional financial incentives, bioethanol production directed at the chemicals industry is likely to be even less viable than its production as an oxygenate.

4.6 ECONOMIC ANALYSIS OF ALTERNATIVE LAND USE

Examination of the existing pattern of land use within the EC Member States and the forecast of yield increases to the year 2000 indicate that production of all agricultural commodities will rise between 1986 and 2000. Traditional outlets for this increased production - the animal feed market, food for human consumption and exports - are unlikely to rise significantly.

At present, self-sufficiency in the key crops postulated as feedstocks for bioethanol production - namely wheat, sugar beet, potatoes and wine - is at 100 % (in the case of potatoes), or in excess of 100 %.

The yield of all crops grown within the EC, including potential feedstocks, is forecast to rise as a result of technological development. Levels of self-sufficiency will, therefore, undoubtedly increase, unless either alternative markets for the increased production can be identified or the area of land utilised by these crops is reduced.

The only feasible market of a sufficient scale to absorb this increased production is the use of bioethanol as a replacement for gasoline itself. Consideration of this market falls outside the scope of this study. The land area utilised by the key feedstock crops (29 % of the EC arable land and 4.5 million hectares of vines) is, therefore, likely to fall, unless stockpiles are to grow significantly. Such growth in stockpiles would necessitate substantially increased direct expenditure out of the Community Budget and further capital expenditure by the individual Member States responsible for funding these stockpiles. An area totalling 10/20 % of the existing arable land, is, therefore, unlikely to be required for the production of these crops.

Oilseed and vegetable protein crops represent a feasible use of this land, and markets for the potential increased production exist within the European Community. However, under existing EC pricing mechanisms, substantial expansion of the production of these crops would increase expenditure from the Community Budget very significantly. This would arise because the EC markets for these commodities are freely accessible to third countries. Costs of production within the EC are substantially in excess of both world prices and the costs of production in third countries. Burgeoning expenditure from the Community Budget would be required if the land area released were to be utilised by these crops. In addition, there can be little doubt that such an expansion would have adverse international trade repercussions.

TABLE 4.13 COMPARISON OF FINANCIAL SUPPORT FOR ALTERNATIVE LAND USES

LAND USE	SUPPORT ECU/ha	NOTES
Wheat for export A	390	1
Wheat for export B	449-545	2
Wheat for non food utilisations	649	3
Peas/Beans	400	1
Oilseed rape/Sunflower	771	1
Wheat for Bioethanol	872-920	4

NOTES :

1 Based on levels of support and crop yields recorded in the Agricultural Situation in the Community 1986 report,

2 Based on Consultants' estimates of average yields for the period 1990-2000, with 70 ECU/tonne restitution,

3 Based on the total restitution of 110 ECU/tonne given (from 1st July 1987) to wheat submitted to industrial processing for non food utilisations (Regulation n° 1009/86).

4 Based on Consultants' estimates of average yields and prices for the period 1990-2000, and assuming that the Community Budget provides support at the level of 70 ECU/tonne and the remaining support is provided by Member States :

Community Budget support :	449 - 545
Member States support :	423 - 375
	872 - 920

Table 4.13 compares the potential financial support which might be required from the Community Budget and/or Member States for some alternative forms of future land use. The figures for wheat are based on the estimated future level of Community support for wheat production (70 ECU/tonne) multiplied by different average yields during the period considered in this study. Figures for protein and oilseed crops are drawn from Eurostat data which summarise crop areas and payments from the EAGGF fund. They represent, therefore, the actual average levels of support applied to these crops in 1985.

The figure for bioethanol is also based upon the Consultants' financial models, using discounted cash flow. The required level of support has been defined as that which is necessary for an entrepreneur to achieve 12 % real return on total investment in bioethanol production. This level of support also corresponds to an ethanol value of 0.7 times the value of premium gasoline, wich may be required in order to gain maximum market penetration.

Table 4.13 demonstrates that all the proposed alternatives would represent a higher cost to the Community and/or Member States than the current cost of support for cereals, and that support required for bioethanol represents the highest financial cost by a considerable margin.

But it should be emphasized that if the total support for bioethanol is divided between the Community Budget and the Member States Budgets, the support from the Community Budget could remain the same as for export and is even less than that for non food utilisations or oilseed rape/sunflower.

Other land uses which have been proposed as an alternative to the above include the production of timber and fuel wood, either using traditional arboricultural methods or by short rotation forestry techniques. The Consultants' calculations suggest that these forms of land use would also require continued support from the Community Budget or the Member States, on land capable of producing average wheat yields. However, the information currently available is insufficient to adequately determine the level of support, if any, which might be necessary, in the light of potential technological developments. Further research into production systems, product utilisation and markets is required to assess the viability of these alternatives.

CHAPTER 5

ANALYSIS OF THE IMPLICATIONS OF A BIOETHANOL PROGRAMME IN TERMS OF THE BUDGET, EMPLOYMENT, ENVIRONMENT, ENERGY BALANCE AND COMPETITION

CONTENTS

5.1 Evaluation of the repercussions of protein co-products on the feedstuffs market (volume, price).

To be considered also:

- estimation of replacement of soya protein and corn gluten feed imports ;
- competition between co-products of bioethanol production (DDGS : Dried Distiller Grain and Soluble) and protein from corn in Italy.

5.2 Evaluation, in the context of efforts to ban leaded gasoline, of the implications for the environment of the production and use of various octane boosters.

5.3 Lessons to be drawn from experience in the USA, Brazil and Sweden : comparison with the situation in the Community.

5.4 Evaluation of the impact of a bioethanol-fuel progamme on imports of hydrocarbons (oil and natural gas). Analysis of implications for tax revenue.

5.5 Impact in terms of job maintenance or creation in rural areas, the food industry and repercussions in the oil and chemicals industries.

5.6 Evaluation of the availability of lead-free petrol and all octane boosters, including those from third countries.

5.7 Definition, with estimated figures, of the energy balance of bioethanol production. Comparison with competitive products of fossil origin (methanol, TBA, MTBE...).

5.8 Discussion of the budgetary aspects of these various points.

SUMMARY

On the basis of their protein content, the bioethanol co-products (vinasses, DDGS ...) which would be obtained from a level of production commensurate with the potential European market for bioethanol (31.4 million hl) would replace the import of 2.2 million tonnes of soya meal, i.e. almost 385 million ECU per year in import savings.

All the financial analyses include an allowance for capital and variable costs associated with environmental protection measures within the plants.

The effect on the atmosphere of the removal of lead from gasoline is perceived to be environmentally beneficial but further research may be necessary to examine the use of oxygenates and the possibly noxious by-products which may be produced.

Experience in the USA, Brazil and Sweden confirms that a high level of support is required to set up and maintain a large scale bioethanol programme ; without this support the programme become very vulnerable, particularly in an era of low oil prices.

The net effect of a bioethanol programme on the trade balance in hydrocarbons is likely to be small in comparison with the total volume of trade in the EC.

To be attractive, both for the petroleum industry and the agricultural sector, a bioethanol programme would require additional support from Member States to the current EC contribution for cereal export. However, due to the increases in tax revenues and the reductions in social welfare payments which would result from bioethanol production, the net financial effect on Member States may be, at best, neutral.

A bioethanol programme at the level of the expected potential market (29 to 31 million hl) would create a maximum of 23,000 to 39,000 jobs in rural areas of the EC.
On the other hand, possible job losses in the refining and petro-chemical sectors have to be considered.

The analysis shows a positive net output of energy for the production of bioethanol from agricultural feedstocks. The Consultants conclude that it is inappropriate to compare the energy balances for fossil-based oxygenates with those for bioethanol.

The total financial support required from the EC and Member States to encourage a bioethanol programme capable of capturing all the potential market is estimated at 1013 million ECU by the year 2000. This represents a level of support of 118 ECU per tonne of wheat. However, this required support would reduce if the oil prices were to rise and/or the cost of agricultural feedstocks were to fall at faster rates than the projected base case.

5.1 EVALUATION OF THE REPERCUSSIONS OF PROTEIN CO-PRODUCTS ON THE FEEDSTUFFS MARKET

To achieve a bioethanol production level of 2.5 million tonnes, i.e. 31.4 million hl from plants using sugar beet EP2 (1/3) and wheat (2/3), the following co-products would be produced :

- EP2 vinasses at 60 % dry matter : 0.87 million tonnes,
- DDGS at 90 % dry matter : 2.13 million tonnes
  (DDGS = DDG (Dried Distiller Grain) + DDS (Dried Distiller Solubles)).

With regard to the yield of DDGS production, we have ignored the existing 2 to 8 % variations according to the technological pathway adopted :

. Production of ethanol from crushed whole wheat (short pathway)

. Production of ethanol from wheat flour and re-incorporation of the brans in the downstream threshers (long pathway).

The composition of the EP2 vinasse and of the DDGS strongly suggests that these products should be directed to their natural markets : i.e., animal feed, with the following specific market differences :

. EP2 vinasse : ruminants exclusively

. DDGS (short pathway) : ruminants exclusively

. DDGS (long pathway) : ruminants exclusively

. DDG (long pathway) : ruminants and single stomach animals secondarily

. DDS (long pathway) : ruminants and single stomach animals significantly

The differences in markets between DDGS (long pathway) and its DDG and DDS components open specific valorisation perspectives with all the possible variants, depending on the rate of the DDS-DDG mix and/or the rate of re-incorporation, downstream, of the brans (extracted upstream).

Employing a linear formulation programme including an agricultural raw materials prices file, a specification file for cattle feed formulas, and a file listing the composition of various agricultural raw materials, including the co-products of the ethanol pathway, the consultants have determined the rates of incorporation of the co-products in the feed formulas as well as their prices. The results obviously vary according to the co-products and the feed formulas :

- Bovines : up to 40 % incorporation
- Porcines : up to 10 % incorporation
- Poultry : up to 5 % incorporation

An average weighted rate of introduction of co-products was set at 10 % all feeds, taking into account the place occupied by ruminants in the European livestock population.

In view of the standard composition of the co-products (dry) :

- 37 to 49 % protein (high protein content)
- 3 to 10 % cellulose
- 6 to 8 % ash

the incorporation of these co-products is done to the detriment of such protein-rich products as protein oilcake (primarily soya) and protein sub-products such as corn gluten feed (starch).

DDGS prices are strongly influenced by the leading prices for soya and corn gluten feed and, like these, have fallen by nearly 40 % in 3 years, and at present stand at :

- DDGS : 160 to 196 ECU/tonne, ex-works, depending on the market (captive or distant)

- EP2 vinasse : 65 to 83 ECU/tonne, ex-works, depending on the market (captive or distant)

The price projections for the years 1990 and 2000, as regards the co-products from the ethanol pathway, are similar to those forecast for soya and do not allow for valuation higher than current prices (in constant ECU). Based on previously defined analytical qualitative values and price levels, ethanol pathway co-products are very competitive. In addition, it appears that the quantitatively forecast production of 2.3 million tonnes of DDGS and 0.87 million tonne of EP2 vinasses would have a small effect on the agricultural raw materials markets supplying cattle feed. In fact, the total nutritional need of 134 billion fodder units (animal feed, Europe of 12), broken down among bovines (36 %), porcines (39 %) and poultry (22 %) is currently met by 97 million tonnes of cattle feed + 40 million tonnes of agricultural raw materials which do not transit through feed manufacturers, i.e. a total protein content approaching 26 million tonnes.

If we consider separately imports of soya and protein-rich grain, which amounted to 25 million tonnes in 1985, for a protein content of 12 million tonnes, co-products from the ethanol pathway would represent a potential saving of :

- DDGS : 2.13 million tonnes, i.e. 0.81 million tonnes of protein, i.e. 1.80 million tonnes of soya oilcake
- EP2 vinasse : 0.87 million tonnes, i.e. 0.17 million tonnes of protein, i.e. 0.38 million tonnes of soya oilcake.

It would therefore be possible to dispense with imports totalling 2.2 million tonnes of soya oilcake, i.e. nearly 9 % of present imports, i.e. in terms of saving for the Community's balance of trade, nearly 385 million ECU per year.

European production of protein-rich co-products would in any event have no effect on the sales of corn gluten feed resulting from starch production operations in France and Italy, especially from maize, since the European balance of trade in corn gluten feed shows a considerable deficit of almost 3.5 million tonnes per year.

5.2 IMPLICATIONS FOR THE ENVIRONMENT

The establishment of a bioethanol programme would enable the current pattern of land use to be continued, rather than land be diverted to uses such as set-aside or amenity use, which may be of relatively low economic value but are perceived as being environmentally less harmful. Hence, the production of feedstocks for bioethanol would have a similar long term effect upon the environment to current farming practices ; these include detrimental effects such as pollution of watercourses and aquifers by fertilisers, herbicides and pesticide residues ; increased hedge removal, etc. It must be noted, however, that land falling out of agricultural production and management may revert to a derelict condition which is not perceived by all parties to be environmentally beneficial. This would be particularly acute in urban fringe areas. Equally, the depopulation of rural areas which would result from such a scenario could have adverse environmental consequences.

Either new crops destined as feedstock for the production of bioethanol (e.g. Jerusalem artichokes, sweet sorghum) or the alternative forms of land use (in the event of a bioethanol programme not taking place) would have their own effects upon the rural environment. Potential positive effects include a greater diversity of wildlife, enhanced quality of landscape and improved amenity and recreational value.

An important aspect of bioethanol production, which has the theoretical potential to cause significant environmental impact, is the production of large quantities of waste products. The most important waste is the fermentation residue from which ethanol has been removed - the stillage. Typically, the rate of stillage production, without recycling, is 10-15 litres of stillage per litre of ethanol. Stillage normally has a dry matter content of between 5 % and 20 % and may have a biological oxygen demand (BOD) of over 40,000 p.p.m ; it is, therefore, highly polluting if released, untreated, into the environment.

The composition of stillage is greatly influenced by the type of feedstock. Stillage produced from wheat feedstock has a relatively high dry matter content and relatively low BOD. It poses, therefore, a lower threat to the environment than the larger volumes of high BOD stillage produced from some plants using sugar beet, molasses or intermediate sugar processing substrates such as EP2.

Furthermore, stillage produced from whole wheat has a relatively high value as an animal feed in comparison with stillage from sugar-based plants. So the necessary environmental protection measures involved in stillage treatment yield a useful return in the sale of co-products.

Stillage produced from sugar-based plants may also be dried and marketed as animal feed, but this is a high-cost operation and the feed is of relatively low value. Where the plant is based on whole beet (or associated with an existing sugar beet factory) the stillage may be added to the beet pulp residue and sold locally as a bulk animal feed, or dried for more distant transport.

In practice, such theoretical levels of potential pollution by stillage would be wholly unacceptable in a European context. Hence, in any practical postulated engineering design for a large scale European bioethanol programme, the provision of facilities to remove all risk of environmental pollution from stillage would have to be incorporated as a central feature of the plant design.

An additional consequence of using sugar-beet as a feedstock - if sugar-beet is grown specifically for bioethanol production rather than bioethanol being regarded as an outlet for products derived from the production and processing of sugar beet surplus to domestic market requirements - is the generation of large volumes of washing water which also has a potentially damaging BOD.

The processing plants would have a major local environmental impact. These include the transport of feedstock to the site and the transport of bioethanol from the plant, storage for feedstock and fuel and the provisions required for effluent, dry wastes and co-products. Such environmental impact would be minimised if plants were to be sited in industrialised areas (e.g. close to existing grain intervention stores or sugar beet factories). In some areas, this may involve location at some distance from regions of major feedstock production.

The environmental effects of the process of blending bioethanol with gasoline are perceived to be similar to those of incorporating alternative oxygenates. It is envisaged that such blending would take place at existing refineries and, given adequate environmental safeguards, the additional facilities required for incorporation would involve an extension of existing plants in industrial areas and would, therefore, have minimal environmental impact.

The environmental benefits of reducing or removing lead from gasoline are well researched and acknowledged. The test data on the emissions from the combustion of gasoline with the alternative oxygenates is less consistent. Blends with alternative oxygenates are reported to give an overall reduction of carbon monoxide, hydrocarbons and nitrogen oxides, but test data on emissions exhibit variation due to both different engine sizes and length of journey. The evidence is not clear cut at present and further research is required. Equally, there is no doubt that emissions of aldehydes, of which acrolein is the most harmful, would increase. The impact on health of such airborne aldehydes in European climatic conditions requires further assessment. The output of carbon dioxide from fermentation would not be significant on a regional or global scale and other process gas outputs are minimal.

A possible additional long term effect of bioethanol production should also be taken into account. This is the risk of bio-concentration which results when any new industrial process is introduced on a large scale. Ways in which bio-concentration might occur as a result of bioethanol production include the following :

- the accidental, or intentional, low-level, release of wastes into watercourses, allowing organic by-products or process chemicals to enter the aquatic food chain.

- the marketing of large quantities of co-products as animal feed, allowing possible harmful products to enter the human food chain.

- the generation of a range of unfamiliar organic compounds as a result of the combustion of ethanol in engines. If these are persistent they may enter the food chain, particularly in high-risk local environments such as motorway verges.

No factors likely to be subject to this kind of concentration have been identified in the Consultants' research, but this aspect should be taken into account when planning any future bioethanol programme.

The potentially adverse impacts of the wastes from bioethanol plants have consequences for the capital and running costs of the plant. It is clear from the above discussion that the cost of waste management is likely to be higher in a plant using sugar beet, than in one using only wheat. However, when bioethanol plants are sited next to existing sugar beet factories, certain facilities for waste treatment and environmental protection will already exist, and the extension of these facilities may be less costly than in a stand-alone plant.

All capital and running cost estimates used in the Consultants' models include an element for the cost of appropriate waste treatment and pollution control. As far as these can be isolated, the cost of investments for a waste treatment plant is at a level of 3 % of the total amount (anaerobic and aerobic treatments).

5.3. LESSONS FROM EXPERIENCE IN THE USA, BRAZIL AND SWEDEN

5.3.1 General

Substantial bioethanol programmes have been established in Brazil and the U.S. In the case of Brazil, a programme was originally introduced to reduce dependence on the volatile world sugar market and to reduce imports of petroleum (i.e. for balance of payments reasons). In the case of the U.S., a major objective was to reduce dependence upon imports of petroleum. Both governments required political will and a commitment to become involved in contributing towards production and, thereafter, towards subsidising the continued use of bioethanol as a gasoline additive.

5.3.2 Evaluation of experience

Commercial experience with blending of ethanol into motor gasoline in the U.S. and Brazil over the 1980-1985 period has been favourable, particularly taking the volume of ethanol blended as the major indicator. The extent of the programme in Sweden was probably too limited to draw such a conclusion. Similarly, these programmes have successfully created both direct and indirect employment. In the case of Brazil, these are estimated at 0.8 and 1.8 million jobs, respectively, whilst in the U.S. job savings/creation attributable to the gasohol programme were estimated at about 20,000 in 1982. Although this is relatively insignificant in terms of the total population, it assumes greater importance in the farm belt area where most of these jobs are concentrated.

However, this programme has been possible only with substantial assistance from governments and/or local authorities. In the U.S., for example, gasoline blends containing at least 10 % of ethanol qualify for a federal tax exemption of 6 cents/gallon and state tax exemption of up to 18 cents/gallon, making a total of 8-22 cents/gallon, depending on the State. On average, in 1985, the exemption totalled 8.7 cents /gallon, implying a net benefit to ethanol blends of 87 cents/gallon of ethanol, representing about 85 % of the equivalent raw material cost.

The drop in oil prices worldwide, which began in December 1985, has clouded the future of these programmes. In Sweden, ethanol blending ceased in October 1986 on economic grounds. In the U.S., it is forecast that "gasohol" blending could continue after 1987, but only on a smaller scale than at present, assuming a scenario of crude prices rising slightly faster than this report's base case, with federal and state tax exemptions at, or slightly above, current levels. However, in 1986 and 1987, this means only the lowest-cost producers are covering their cash costs, so that only they are forecast to survive.

Placing the U.S. experience in the context of the entire economy, the impact of "gasohol" on the government's costs could be slightly favourable in the future, with savings in price supports for corn slightly outweighing the loss of income from gasoline excise taxes. However, less favourable assumptions, e.g. slower recovery in oil prices, would reverse this conclusion. Moreover, a recent U.S. Department of Agriculture (USDA) Report on "Fuel, Ethanol and Agriculture : An Economic Assessment" concluded that these costs and savings were small compared to impacts in the private sector of the economy, where the added costs of food at the consumer level would always significantly exceed the positive effect on farm incomes if ethanol production was increased. Equally, similar savings would accrue if the federal and state gasoline exemptions were allowed to expire in 1992, and production of bioethanol for gasoline blending ceased.

These findings are summarized in the politically controversial conclusion to the USDA Report which states "Subsidised ethanol production is a very inefficient way to raise farm income. It would be much more economical to burn straight gasoline in our automobiles and pay farmers a direct subsidy equal to the amount they would receive as a result of ethanol production". It should be noted that spokesmen from the White House and U.S. Department of Energy have registered strong reservations concerning the validity of this report and the Department of Agriculture has recently been asked to undertake a more thorough investigation of the issues.

Evaluation of the economics of the Brazilian programme is more difficult, since there is a much larger volume of net ("hydrous") ethanol produced for alcohol-fuelled vehicles. Studies similar to those in the U.S. conclude that alcohol production in general must continue to be subsidised, with a negative impact on the national economy. Finally, it should be mentioned that the large investments required for the alcohol programme meant that only limited finance could be made available for oil exploration during the 1970's. Brazil has now found considerable oil reserves and is producing 0.6 million Bbls/day and could soon be self-sufficient. Whilst the alcohol programme has certainly reduced Brazil's dependence on imported oil, it may also be considered to be partly responsible for maintaining this dependence throughout the era of high-cost oil.

5.3.3. Relevance to the EC situation

The Brazilian experience is less applicable, mainly because the concentration of ethanol blended into gasoline is much higher than the levels contemplated in Europe. The Swedish experience, though quite limited, was at levels of ethanol blending closest to those proposed for the E.C. Apart from the 10 % level of ethanol blending permitted in the United States, the U.S. experience is considered to be broadly applicable to the EC.

5.3.4 Lessons to be learnt

All three countries confirm that a high degree of government support, both legislative and financial, is required to establish and maintain a large-scale bioethanol programme ; without this commitment, the projects become very vulnerable, particularly in an era of low oil prices.

As shown in PT Annex section 10, and AD Annex section 5, U.S. experience of ethanol pricing indicates that before the drop in oil prices, ethanol sales prices, adjusted for the available state and federal tax reliefs, averaged about 70-80 % of unleaded regular gasoline prices on a volumetric basis ; this is equivalent to about 60-70 % on a weight basis.

In the case of the U.S., the evidence appears to suggest that the structure of fixed support has been such that the benefits of subsidisation have accrued to the large distilleries operators rather than to the small operators or corn farmers. Blenders must also have benefited from the very low net ethanol prices in 1986, although this was not reflected in increased blending of ethanol. This demonstrates the importance of directing any subsidy towards the intended beneficiaries.

The U.S. experience also points to the dangers of allowing a subsidy system to distort an essentially free market. The effect of the extra subsidy of free corn from stockpiles was to reduce the 1986 4th quarter price for ethanol to the level of the tax subsidy, giving the blenders a net feedstock cost of zero. This extra subsidy brings about un-needed additional production, thereby further depressing prices, so that there is a risk the producer starts to call for still more subsidies. The situation continued until the end of 1986. At the same time, there does not appear to have been any significant increase in the volume of ethanol blended into gasoline. This suggests that the additional subsidy merely encouraged a price-cutting war between the alternative ethanol distilleries rather than promoting total sales of ethanol. Ethanol prices began to recover in 1987.

The Swedish plant, which is semi-industrial,is designed to be flexible in relation to its production, being capable of producing bioethanol as a primary product with DDGS as a co-product, or starch as a primary product with bioethanol and wheat gluten (for animal feed) as co-products. Such flexibility of design may well be of significance for the EC in specific cases.

5.4 EVALUATION OF THE IMPACT OF BIOETHANOL PRODUCTION ON IMPORTS OF HYDROCARBONS AND ON TAX REVENUES

5.4.1 Imports

The maximum available market for bioethanol has been estimated as 1.5 - 2.5 million tonnes. Therefore, the maximum impact of a bioethanol programme on the balance of trade would be the replacement of a similar quantity of hydrocarbon imports, in the form of crude or partly refined oil. At the extreme, if all the bioethanol produced were substituted exclusively for imported crude, the effect on the EC balance of trade would be an improvement of 200 to 340 million ECU per annum in 1990, rising to 250 to 410 million ECU in 2000, at the projected values under the recovery oil price scenario.

However, this figure is likely to be significantly reduced by a number of factors, including ;

- Both bioethanol production and feedstock production have a significant energy input which will, in part, be supplied by imported hydrocarbons.
- Any reduction in fuel economy of vehicles as a result of ethanol blending will lead to a compensatory increase in consumption of imported hydrocarbons. This is likely to have a very marginal effect.

The net effect of a bioethanol programme on the balance of trade in hydrocarbons is, therefore, likely to be very small in comparison with the total volume of trade in the EC.

It should be noted that a bioethanol programme would have an effect upon the trade balance in other commodities in addition to hydrocarbons, the effect being highly variable according to the commodity concerned.

5.4.2 Tax revenue

The creation of a bioethanol programme would contribute to the growth of the economies of EC Member States and would, therefore, generate tax revenues and savings in social welfare payments. However, this should be set against the requirement for tax relief or similar support if investment in bioethanol production is to be made attractive for entrepreneurs.

As shown by the Consultants' financial models, the level of support required would depend upon the value at which bioethanol could be successfully marketed. For the purpose of this discussion, it is assumed that a price of 0.6 to 0.8 times the value of premium gasoline is the maximum price at which the maximum potential market share (1.5 to 2.5 million tonnes) could be obtained.

The level of tax relief required from the Member States would also depend upon the support provided by the Community Budget. It is assumed here that support for a plant using all wheat feedstock might be set at 70 ECU per tonne of wheat.

The level of support required for an entrepreneur to achieve 12 % real return on total investment is shown in Tables 5.1 and 5.2.

TABLE 5.1 : ESTIMATE OF TOTAL MEMBER STATE SUPPORT REQUIRED TO ENCOURAGE INVESTMENT IN A BIOETHANOL PROGRAMME
(Assuming ethanol : premium gasoline price ratio of 0.7:1 Oil price recovery scenario)

SOURCE OF SUPPORT	SUPPORT REQUIRED PER YEAR					
	PER TONNE		PER HECTARE		TOTAL	
	ECU 1990	ECU 2000	ECU 1990	ECU 2000	MILLION ECU 1990	MILLION ECU 2000
Community Budget	70	70	449	545	360-600	360-600
Member States	66	48	423	375	336-561	248-413
TOTAL	136	118	872	920	696-1161	608-1013

Source : Consultants'estimates

If this level of Member State support was split in proportion to the projected market for bioethanol, the requirement for Member State support would be as shown in Table 5.2.

TABLE 5.2 : INDIVIDUAL MEMBER STATE SUPPORT REQUIRED FOR BIOETHANOL
(Assuming ethanol : premium gasoline price ratio of 0.7:1
Oil price recovery scenario)

MEMBER STATE	SUPPORT REQUIRED PER YEAR	
	Million ECU	
	1990	2000
FRANCE	84-140	62-103
WEST GERMANY	126-210	93-155
ITALY	42-70	31-52
UK	70-117	52-86
Others	14-24	10-17
TOTAL	336-561	248-413

Source : Consultants' Estimates

A precise determination of the effects of a bioethanol programme upon the tax revenues of each Member State is beyond the scope of this study. However, the Consultants have analysed the estimates prepared for France by the French wheat producers' association, based upon data obtained from the Commissariat du Plan. These suggest that, for France, additional tax revenues resulting from replacing gasoline by bioethanol would amount to 4.6 ECU/hl (17 ECU/tonne of feedstock), taking into account taxes on added value, on imports and savings in social welfare payments.

However, this tax benefit of 4.6 ECU/hl represents a comparison between the current situation, in which the export of surplus agricultural production is supported by the Community, and a proposed bioethanol programme. If it is accepted that the alternative to bioethanol production is not a continuation of the current situation but a removal of land from production (set-aside), the effect of bioethanol should be compared not with the current situation but with the position in the event of set-aside. The same analysis suggests that France would suffer a reduction in tax revenue of 17.4 ECU/hl as a result of set-aside, so the comparison in terms of tax revenue between set-aside and bioethanol is the sum of these two figures, 22 ECU per hectolitre (81 ECU/tonne of feedstock). This figure is comparable with the levels of additional support which the Member States might have to provide in order to encourage a bioethanol programme, as discussed above.

However, this analysis should be treated with caution since :

- it does not take into account any changes in support which might result from a set-aside programme,

- it is based upon data prepared by the French wheat producer's association who may be considered as an interested party,

- it is based upon an analysis of a single economy -France- which may not be representative of other Member States ;

- even with the French economy, the analysis is based upon broad estimates of fiscal effects, derived from general economic ratios. The application of these ratios to a specific sector of the economy may not be valid.

It seems reasonable to conclude that, at best, the net financial effect on Member States may be neutral, but that some net cost to Member States is the most likely projection.

It should be emphasized that this approach to the potential benefits of a bioethanol programme is a financial analysis from the point of view of a single Member State. It is not an economic analysis and is not directly comparable with the Consultants' own economic analysis, the results of which are summarised in chapter 6.

5.5 IMPACT ON EMPLOYMENT

The most reasoned estimate of employment created or maintained by a bioethanol programme has been prepared for France by the French wheat producers' association (A.G.P.B). The estimated extent of the impacts on employment are as follows :

(a) Direct employment on farms required for the production of feedstock. This is estimated for wheat on the basis of one employee per 80 hectares, and assumes that the alternative to feedstock production would be a labour extensive land use such as set-aside.
Estimated jobs created : 625 per million hectolitres.

(b) Indirect employment created by the need to provide farmers with raw materials.
Estimated jobs created : 300 per million hectolitres.

(c) Indirect employment created in construction and service industries by capital expenditure on bioethanol plants. This estimate is based on a 10 year plant write-off.
Estimated jobs created : 150 per million hectolitres.

(d) Direct employment in the bioethanol plant.
Estimated jobs created : 92 per million hectolitres.

(e) Indirect employment in industries supplying raw materials and services to the bioethanol plant.
Estimated jobs created : 76 per million hectolitres.

Estimates of indirect employment are derived from the relationship between income and employment in the appropriate sector of the economy, as recorded by the French Commissariat du Plan.

If these estimates are extrapolated to the whole EC, the employment created by a programme supplying the maximum market share of 1.5 to 2.5 million tonnes would be between 23,600 and 39,300 jobs. However, such extrapolation should be treated with caution since :

- the average ratios of income to indirect employment may seriously over-estimate the effect of additional expenditure at the margin;

- the ratios of land area to jobs, and income from indirect employment, used in France may not be appropriate for all Member States ;

- a write-off period of only ten years may overestimate the effect of capital expenditure ;

- the number of direct jobs in the bioethanol plant is higher than would be expected in large installations which would be used in a major programme.

The estimates should, therefore, be treated as the maximum, rather than the average, number of jobs which might be created.

If the number of jobs is compared with the projected total support for a bioethanol programme, this represents a cost per job of 25,700 ECU per year. However, this crude calculation does not take into account :

- possible job losses in the petroleum industry and related indirect employment ;

- fiscal effects of changes in employment ;

- fiscal effects of economic growth due to investment in a bioethanol programme.

These factors will have a large effect upon the real net cost per job.

The employment effects should be set against a background of change in both the agricultural and petroléum industries. The refinery industry has experienced a painful rationalisation in the period since the second oil price crisis (1979-80). The Commission has noted that the rationalisation process is continuing, with potential refinery closures projected to add another 5-10,000 direct job losses and between 15 and 30,000 indirect job losses. Against the possible jobs maintained/created in the rural sector, therefore, it should be considered that a large scale bioethanol programme would increase the pressure on the refining industry by reducing the crude throughput needed to meet the same level of gasoline requirements.

In the EC countries, during the period 1980 to 1985, employment in agriculture, hunting, forestry and fishing has declined by 987,000. This represents a compound annual rate of decline of 2.4 per cent. It is reasonable to suppose that a similar rate of decline will continue, representing job losses in excess of 180,000 per year. This total does not take into account any decline in jobs in the agricultural supply industries. In the absence of new markets for agricultural products, it is likely that the rate of decline in employment will accelerate.

Moreover, the bioethanol produced under such a programme would directly compete with the synthetic ethanol industry and with the oxygenate manufacturers located in the EC. Although this could result in the closure of one or more plants, each employing only 30 to 60 people, it should be emphasized that these operations are typically fully integrated with other petrochemical units at the same site. It is estimated by one of the major producers that the closure of their integrated synthetic ethanol plant would result in the closure of associated units, possibly including the ethylene cracker, thus jeopardising the future of the entire complex which, together with Head Office support staff, currently employs about 3000 people.

In the light of these developments, the potential impact on employment of a bioethanol programme is relatively small.

5.6 EVALUATION OF THE AVAILABILITY OF LEAD-FREE PETROL AND ALL OCTANE BOOSTERS, INCLUDING THOSE FROM THIRD COUNTRIES

This topic has been covered in section 3-1, which discusses the lead-free gasoline demand in the EC, and sections 3-2 and 3-4 which deal with the supply of lead-free gasoline from domestic refineries and the net export opportunities available to EC refiners. Similarly oxygenate availabilities, including those from third party countries are reviewed in section 3-3. Finally, section 4-2 reviews the potential demand for ethanol in the EC gasoline pool.

5.7 DEFINITION OF THE ENERGY BALANCE OF BIOETHANOL PRODUCTION

Very widely differing estimates of the energy balance associated with the production of bioethanol have been calculated in the technical literature. These have usually been expressed as a ratio, namely the ratio between energy output and energy input. Estimates of this ratio vary substantially depending on the method of calculation, the system boundary and the value ascribed to the co-products of the process. The ratio also depends on the energy recycling inside the system boundaries (see Appendix I, figure A.1). Independent of the degree of energy recycling and therefore a more appropriate measure of the energy efficiency is the net energy output, i. e. the difference between energy output and input, expressed per litre of bioethanol produced or per hectare of land utilised.

Various energy balances for the production of ethanol from sugar beet or wheat have been calculated for the study. The energy input takes into account not only the fuels used directly for feedstock production and for conversion into ethanol, but also all the fuels that are required to produce the auxiliary materials utilised and for feedstock transport. The most important of the auxiliary materials are fertilizers, which account for more than half of the energy input in the agricultural stage. The energy demand for the construction of the plant and a share for labour are not included in the energy input. The required values for construction and labour can not be precisely determined ; however, the Consultants' evaluations indicate that the corresponding values are only approximately 1 % of the thermal value of ethanol.

The total energy output consists of the lower thermal value of ethanol and partly the energy value of the co-products. The energetic value of the co-products has been assessed with a view to their likely utilisation. The calculation of the energy balance is based on the following options :

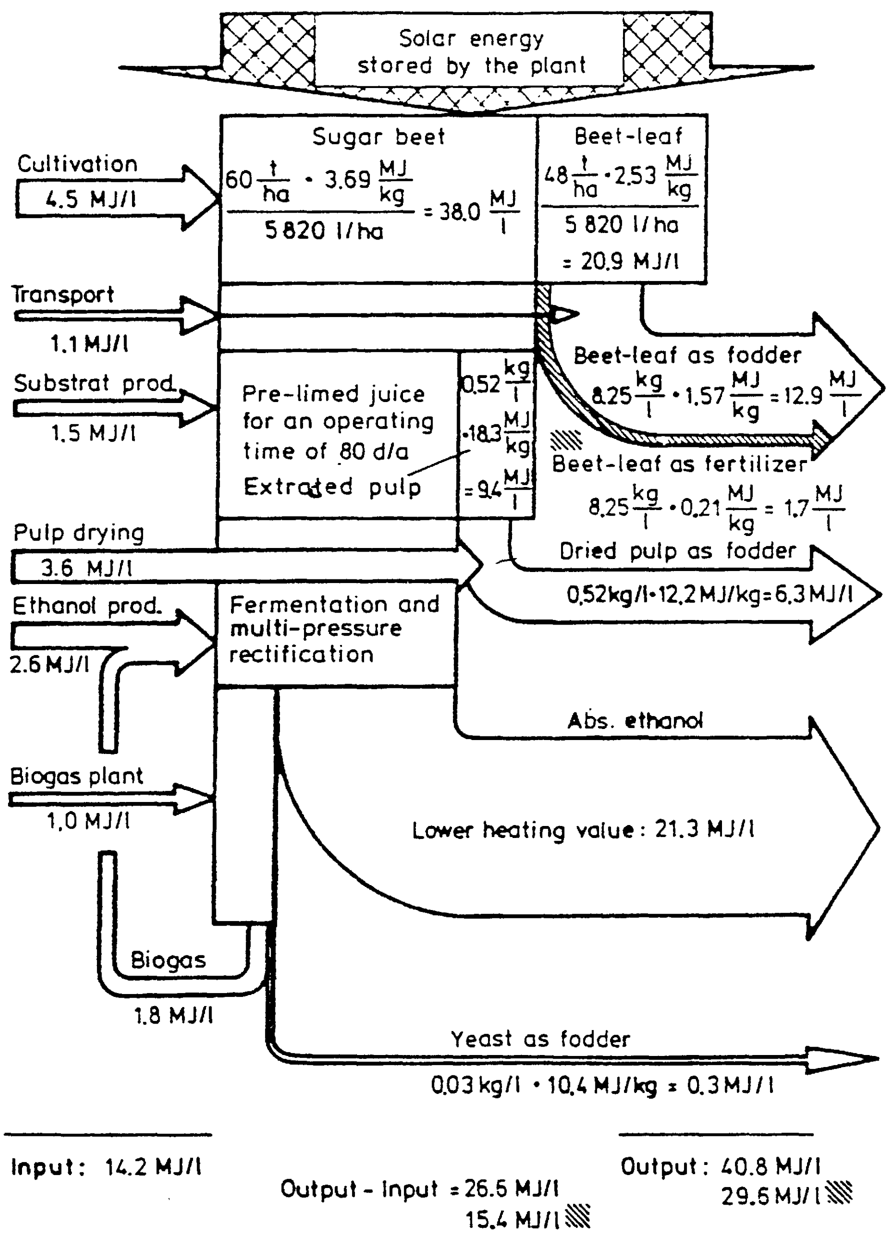
(a) the lower thermal value, if the co-products are used as fuels ;
(b) the metabolisable energy for ruminants, if the co-products are used as animal feed ;
(c) or, if the co-products are used as fertilizers, the amount of energy that would be needed to produce the substituted fertilizers.

The quantity of the energy output of the co-products decreases in the order of utilisation as fuel, animal feed and fertilizers.

Figures 5.1 and 5.2 show two examples for the energy balance of bioethanol production from sugar beet and wheat. The values of the energy inputs for the various process steps are listed on the left of the figure. The composition of the total energy output is shown on the right. The different cases for the energy output of the co-products demonstrate that the result is highly dependent on the assumptions about utilisation of the co-products. However, for all the cases shown, the net output is positive. For sugar beet the values are 26.6 MJ/l (155 GJ/ha), if the beet-leaf is used as animal feed and 15.4 MJ/l (90 GJ/ha), if the beet-leaf is used as fertilizer. The energy ratio results in 2.87 and 2.08, respectively. In the example for ethanol production from wheat, a high result for energy efficiency may be obtained if the straw is burnt for the energy supply, giving values of 40.3 MJ/l (100 GJ/ha) for the net output and 2.61 for the ratio.

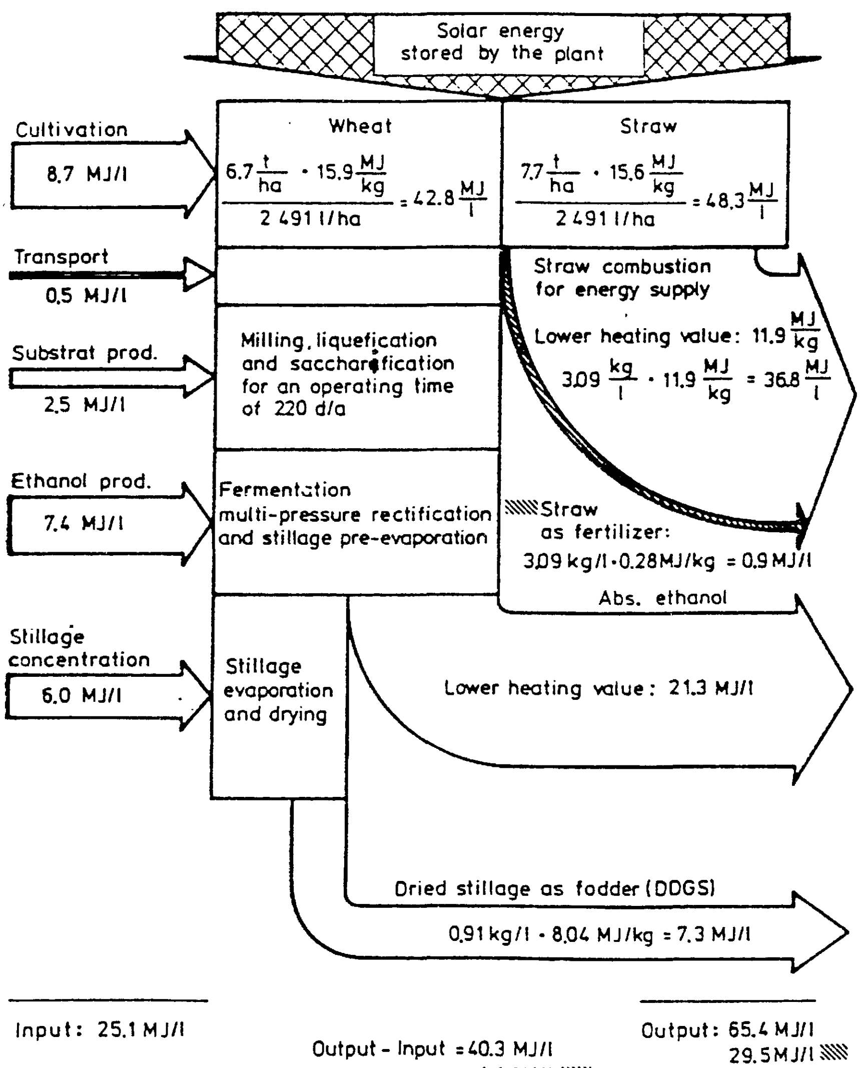
For a large scale bioethanol programme, however, it would not be practical to burn the straw in this way. Since this possibility is not considered in the calculations of the production costs of ethanol from wheat, it is more appropriate to value the energy content of the straw as a fertilizer. Consequently, for large-scale programmes based on wheat, the net output should be considered to be about 4.4 MJ/l (11 GJ/ha), giving a ratio of 1.18. Moreover, if it were feasible to burn the straw by-product from a large-scale operation as a direct fuel, consideration would have to be given to using the wheat itself as a direct fuel. In this case, the energy output, net of the cultivation energy, would be considerably greater than the 100 GJ/ha calculated for the bioethanol from wheat feedstock. Since the objective of energy analysis is to extend the life of fossil fuels, the additional energy recovered from burning the agricultural product in a boiler-house makes this route more attractive than that of bioethanol, i. e. the energy balance for the ethanol from wheat process could be considered inferior in comparison to this alternative route of direct use of wheat as boiler fuel.

FIGURE 5.1 EXAMPLE OF ENERGY BALANCE FOR SUGAR BEET



Source : Consultants' estimates

FIGURE 5.2 EXAMPLE OF ENERGY BALANCE FOR WHEAT



Source : Consultants' estimates

Energy balance calculations from other authors have been examined and, in cases where the assumptions underlying the calculations have been stated, analyses have been carried out. These analyses show that most of the published examples demonstrate a positive net output of energy from the production of bioethanol. However, a minority of the published calculations claim a negative energy balance. In cases where the energy balance results in a negative net output of energy the total input is substantially higher than in the calculations carried out for the present study and a small or zero output is ascribed to the co-products.

Analysis of the energy efficiency of conversion into bioethanol of various feedstocks indicates that all potential feedstocks have a positive net output of energy. Figure A.2 in Appendix I shows a comparison of the results for the various feedstocks. Two cases are included for sugar beet and wheat to demonstrate the possible range according to the utilisation of the co-products. Without the utilisation of the wheat straw for the energy supply, the ethanol production from sugar beet has the highest energy efficiency. In the future, sweet sorghum may well surpass sugar beet in terms of net output per hectare because of its potential high ethanol yield per hectare.

Finally, the consultants' analyses support the views expressed in a recent report prepared for the Commission by the Centre for European Studies which concludes that "there is no simple answer to the question of net energy from the incorporation of ethanol into petrol". The real argument is not about energy analysis but about the (financial) costs of ethanol production.

5.7.1 Comparison of the Energy Balance for Bioethanol with Oxygenates of Fossil Origin

There are immense problems involved in attempting to compare energy balances for bioethanol with those for fossil-based oxygenates such as MTBE :

i) Where should the system boundary be drawn ? (It is conventional in calculating energy balances for ethanol produced from biomass to consider the solar energy used in the agricultural stage to be outside the system boundary since it is a renewable source of energy. No equivalent flexibility exists for energy analysis of petrochemical processes such as the production of MTBE or GTBA which include the energy content of the feedstock in the calculation of the energy input required.

ii) Is it appropriate to compare ethanol, a component which is essentially a gasoline extender (its high sensitivity, high degree of butane back-out and the 5 % maximum permitted concentration mean that ethanol can only partially replace the use of lead which is being progressively prohibited on environmental grounds) with a product such as MTBE which is considered to be a gasoline enhancer (because of its superior blending characteristics, its similarity to gasoline, and the fact that it can directly replace the lead being removed from the gasoline pool) ?

For these reasons, the Consultants conclude that it is inappropriate to compare energy balances for the fossil-based oxygenates with those for ethanol deriving from agricultural sources. Notwithstanding this caveat, the Consultants' analyses suggest the following conclusions concerning the energy balances (including the energy content of the feedstocks) for the fossil-based oxygenates :

According to Voeste, the energy efficiency for the production of methanol from coal is 49 %. Similarly, the Consultants' analysis suggests an energy efficiency for MTBE production of about 66 % (more details are given in PT Annex section 13). However, given that each ton of MTBE blended into the EC gasoline pool reduces the amount of crude required in EC refineries by 1.25 +/- 0.10 tonnes, it may be argued that the energy efficiency of producing MTBE as a gasoline enhancer is of the order of 83 %. In that case, however, the energy analysis excludes the energy content of labour, plant and equipment, as in the case for the energy balance developed above for ethanol.

5.8 BUDGETARY IMPLICATIONS

The financial analysis has indicated that, in order for a bioethanol programme to be financially attractive in Member States, feedstock prices would need to be subsidised. For the purposes of this discussion, it has been assumed that :

(a) Bioethanol production would be based upon wheat, since it represents the feedstock which has the lowest economic cost in every Member State ;

(b) A bioethanol programme would be established in the EC whereby ethanol was produced in a number of Member States ;

(c) Three possible market scenarios for the year 2000 may be developed :

- a high price market for 0.1 to 0.6 million tonnes of ethanol
- a medium price market for 1.0 to 1.5 million tonnes of ethanol
- a low price market for 1.5 to 2.5 million tonnes of ethanol

TABLE 5.3 - BUDGETARY IMPLICATIONS OF A BIOETHANOL PROGRAMME (oil price recovery scenario)

ETHANOL PRICE	ETHANOL MARKET SIZE	WHEAT PRODUCTION AREA	SUPPORT REQUIRED			TOTAL SUPPORT
Ethanol:premium Gasoline ratio	Million tonnes	Thousand hectares	ECU/hl	ECU/tonne	ECU/ha	million ECU
			2000	2000	2000	2000
1.0 - 1.2 : 1 mid point 1.1 : 1	0.1 - 0.6	43 - 261	24	90	700	31-185
0.8 - 0.9 : 1 mid point 0.85: 1	1.0 - 1.5	427 - 666	29	108	840	369-553
0.6 - 0.8 : 1 mid point 0.7 : 1	1.5 - 2.5	666 - 1088	32	118	920	608-1013

Source : Consultants Estimates.

Table 5.3 demonstrates the total cost involved in supporting each programme.The table also shows the required support in the year 2000, taking into account a 1 % per annum reduction in feedstock prices and projected changes in oil price.

The total support required varies from 31 million ECU, at 4 per cent market penetration, to 1013 million ECU at approaching 100 per cent market penetration. Support per tonne or per hectare is much less variable, amounting to at least 90 ECU and 700 ECU respectively, even at the highest proposed value of ethanol.

If it is assumed that the current Community support for wheat is approximately 70 ECU/tonne, it is clear that continued additional support would be required from the Community Budget or the Member States to achieve even minimum market penetration. Although the projected support reduces over time, due to the falling price of feedstocks and the rising price of oil, the requirement never falls below 70 ECU/tonne, even in the high price/low volume case. In order to supply the maximum market, continued support of 118 ECU/tonne is required in the year 2000.

The requirement for subsidy is sensitive to both the ethanol price and the cost of feedstock. To reduce the requirement for support to levels comparable with current support for export wheat would require an increase in oil price of between 100 and 200 per cent or a reduction in feedstock price of 30 to 50 per cent.

It may be argued that the future world market for cereals is unlikely to absorb all the surplus wheat produced by the EC. Wheat which is not used for bioethanol or other internal consumption is, therefore, likely to be subject to intervention storage rather than export. At present, the Community contributes approximately 23 ECU per tonne per annum to storage costs. In the short term, therefore, the diversion of funds from direct support measures to the encouragement of a bioethanol programme may have an even greater impact on the Community Budget than that outlined above.

In comparison with the UK proposal for the Community Budget to fund a Set-Aside Programme, a bioethanol production programme would also require a substantial increase in Community Budget expenditure. For bioethanol production to be financially viable, the Community Budget would need to provide funding at a rate of between 700 and 920 ECU per hectare. This compares with the suggestion of the UK Government that a payment of 300 ECU per hectare would be an adequate incentive for farmers to be encouraged to take cereal land out of production.

This compares also to the present situation in which the wheat subject to industrial processing for non food utilisations receives a support of 109.6 ECU/tonne (from 1st July 1987), i.e. 647 ECU/ha, according to the starch and sugar regulation n° 1009/86.

CHAPTER 6

ECONOMIC COST/BENEFIT ANALYSIS

CONTENTS

6.1 BACKGROUND

6.2 APPROACH TO THE ANALYSIS

6.3 RESULTS OF THE ANALYSIS

SUMMARY

Economic cost/benefit analysis has been used to determine whether or not a bioethanol programme would be of net benefit to the EC as a whole, making allowance for fiscal effects ; distortions of the market through government intervention and the true economic value of land, labour and capital in the EC, as these are influenced by current developments in the European agricultural and petrochemical industries.
The results of this analysis indicate that the encouragement of a bioethanol programme is not in the interests of the EC under any of the range of assumptions used. A sustained real oil price in the range of $30 - 40 Bbl, or a reduction of over 40 % in the economic production cost of feedstock would be required to achieve economic viability. Both of these developments appear a very remote possibility at present.

6.1 BACKGROUND

6.1.1 General

The foregoing chapters of this report have been concerned with analysis of the detailed financial implications of a bioethanol programme for the petrochemical sector, the agricultural sector, the Member States and the Community Budget. However, financial analysis alone is inadequate to identify whether or not a bioethanol programme would be of net benefit to the Community as a whole. In order to determine this, it is necessary to carry out an Economic Analysis, the results of which are presented in this chapter.

The Economic Analysis has been carried out against a background of change in both the European agricultural and petrochemical industries. The features of these industries which are important to the Economic Analysis are summarised in the following sections.

6.1.2 Developments in the European Agricultural Industry

Since the signing of the Treaty of Rome in 1957 the development of agriculture in the EC has been largely determined by the Common Agricultural Policy (CAP). This has sought to apply reasonably uniform wholesale prices for many of the principal agricultural commodities. However, for a number of reasons, prices have been, and still are, maintained at levels in excess of world prices. The differential in prices has been financed by a combination of higher consumer prices and support measures funded from the Community Budget.

Encouraged by price stability, and backed by rapid technical innovation and adoption, farmers in the EC have achieved large increases in production of all agricultural commodities. This has been achieved at a time of relatively static EC demand, and self-sufficiency in many products has now been achieved or exceeded. Despite recent initiatives to restrict wholesale price incentives, output continues to expand and, unless there are further fundamental changes in the CAP, this trend seems likely to continue.

Produce which is surplus to internal EC demand has been available for export. However, the world market for agricultural products is currently characterised by static demand and over-supply, and there seems little likelihood that exports can rise further without the risk of alienating many important trading partners. Even the continued expansion of output of those crops in which the EC is not self-sufficient (principally protein and oilseed crops) may risk damaging these wider trade relations.

Against this background, it is clear that a continuation of the current trends will lead to further increase of stocks in public storage and escalating storage costs funded from the Community Budget. Eventually, these budgetary pressures will become unacceptable.

6.1.3 Development of agricultural land use and land opportunity cost

The current agricultural situation in the Community has major consequences for future agricultural land use. Four alternative developments may be envisaged :

- Output per hectare may be reduced as a result of farmers reducing inputs in response to pricing measures. This seems improbable on arable land.
- New crops, for which substantial new markets arise, may be introduced. There is currently no prospect of this occurring.
- Large new markets for existing crops are developed. No such markets have been identified.
- Land use changes from agricultural production to alternatives of relatively low economic output.

In the Consultants' view, only the final option is likely to absorb a significant area of land and, in the context of this study, this therefore represents the alternative to the use of land to produce feedstock for bioethanol production.

The Consultants conclude that the transfer of land from its current use to the production of feedstock for a bioethanol programme will not involve any net loss to the EC as a whole ; land is no longer a scarce resource. This is reflected within the Consultants' economic analysis by the assumption that the economic opportunity cost of land is zero.

6.2 APPROACH TO THE ANALYSIS

6.2.1 Cost/benefit analysis

In the absence of a specified technique for the evaluation of agricultural projects within the EC, the Consultants have adopted the technique accepted by the International Agencies. This technique is based upon two distinct, but inter-related, approaches namely :

(a) Economic Analysis - is the project in the overall socio-economic interests of the Member State and/or of the EC ?

(b) Financial Analysis - is the project in the financial interests of entrepreneurs operating within the Member State and, if not, what changes in fiscal arrangements (taxation, subsidies etc) does the Member State and/or EC need to make in order to make the project financially attractive for entrepreneurs ?

The principal reason why this dual approach is required is that governments throughout the world intervene in the operation of markets and, in particular, agricultural commodity markets. The EC is no exception and maintains price levels within its domestic markets for agricultural products at levels which are not precisely related to costs of production or world commodity price levels.

The two approaches to the Cost/Benefit Analysis - Economic Analysis and Financial Analysis - are inter-related insofar as they are based upon the same physical production models, but are based upon fundamentally different cost price assumptions. An understanding of the difference between the two approaches is essential in order to comprehend the Cost/Benefit Analysis.

6.2.2 Economic analysis

The economic analysis is based upon the assumption that, within each Member State and within the EC as a whole, there is a finite availability of funds for investment. There is a surplus of demand for this investment and only if a project exceeds a certain defined Return of Capital is it considered worth while for the Member State or EC to invest in that project. The analysis treats the production of agricultural feedstocks and their subsequent processing into bioethanol and related co-products as a single integrated system.

The approach is based, initially, upon the definition of the economic opportunity cost of land. This cost is a measure of the economic net benefit to the Member State and/or EC of a marginal unit of land. It must be emphasised that this is not the rental or capital value of land. The costs of feedstock production and processing are then calculated. In the economic analysis, these costs are economic costs rather than financial costs. The adjustments include the removal of taxes and subsidies from the financial costs and adjustment of labour costs to acknowledge the fact that, if the project were not creating or maintaining employment, there would still be an economic cost to the Member State and/or the EC.

6.2.3 Financial analysis

The financial analysis is based upon the actual costs and prices which the entrepreneur in the Member State or EC would face. Thus, the price of agricultural feedstock, for processing into bioethanol, is taken as the price at which it could be purchased in the market place by the processor. The results of financial analysis may be used to estimate a financial return on the entrepreneur's investment, in order to assess its attractiveness.

6.2.4 Interpretation of analysis

The dual approach described is required because, in economic theory, it can be stated that, if a project is in the economic interests of a Member State and/or the EC, it is then in the economic interests of that Member State and/or the EC to make any necessary adjustments in its fiscal arrangements (taxation, subsidies etc) to ensure that financial conditions for entrepreneurs are such as to secure the implementation of the project.

This approach has required the Consultants to assemble disaggregated cost data for both agricultural production and processing into ethanol and to define economic investment conditions in the specified Member State. Comprehensive data for such an analysis are not available within the European Commission nor, in some instances, within the Member States. The Consultants have, therefore, needed to make such professional judgments as may be required and have constructed their economic and financial models in such a way as to enable variations in key inputs to be made. Information for Spain is available neither within the European Commission nor readily from national institutions. The Consultants have made every effort to secure such data but, to the best of their knowledge, appropriate information has not been collated.

Economic and Financial modelling has been carried out over a 15 year time frame for a series of agricultural feedstocks and for varying sizes of bioethanol production units at various crude oil price scenarios. The results of this analysis for each Member State have been aggregated to reflect the impact on the EC. This analysis has been used to assess the viability of producing bioethanol in those countries within the Community presently producing large surpluses of potential feedstock.

6.2.5 Critical factors in the analysis

As with the financial analysis discussed in the main body of the report, the economic viability of a bioethanol programme is crucially dependent upon the economic value of gasoline and upon the economic cost of feedstock, net of co-product value. The oil and gasoline price scenario has been discussed in earlier sections of this report. The economic cost of feedstock is considered in the next section.

6.2.6 Comparison of alternative feedstocks

The Consultants have estimated the economic cost of production of a range of alternative bioethanol feedstocks. The estimates are based upon :

- physical input/output relationships derived from national sources ;
- economic prices derived by the Consultants from a range of international data sources, reflecting the value of inputs/outputs to the EC as a whole.

The results of the analysis are shown in Table 6.1. This table clearly demonstrates that wheat represents the preferred feedstock in economic terms.Economic cost/benefit analysis was, therefore, applied to model plants, based upon : (a) all wheat feedstock and (b) wheat feedstock supplemented by sugar beet.

TABLE 6.1 : ECONOMIC COST OF FEEDSTOCK PRODUCTION
(Net of co-product credit)

FEEDSTOCK	ECONOMIC PRODUCTION COST *
	ECU /hl Bioethanol
Wheat	9.5
Sugar Beet	22.0
Potatoes	50.0
Wine	72.0
Maize	16.3
Jerusalem Artichokes	23.0

* Average of available Member States

Sources : Consultants' estimates, based on national data

6.3 RESULTS OF THE ANALYSIS

6.3.1 Summary of results

The results of the economic analysis for the two types of plant are summarised in Table 6.2. The results are presented in terms of Economic Internal Rate of Return (EIRR) and Net Present Value (NPV), parameters which measure the extent of economic benefit accruing to the EC as a whole from investment in a programme. If the EIRR shows a return which is greater than the opportunity cost of capital for the EC (in which case the project has a positive NPV), this suggests that the project would provide a net economic benefit.

The analysis was based upon the most optimistic of the proposed oil price scenarios, at a range of ethanol values and at two different commissioning dates. Delayed commissioning improves the viability of the project since oil prices are projected to rise in real terms and the value of the ethanol output in the early years after construction is, therefore, improved.

6.3.2 Conclusions drawn from results

(1) The results of the analysis suggest that the encouragement of a bioethanol programme is not in the economic interests of the EC under any of the range of assumptions made.

(2) Although the models are relatively sensitive to the economic production cost of feedstock and to bioethanol value, the extent of the variation required for the models to show a net economic benefit is very large.

(3) An oil price in the range of $ 30-40/Bbl., or a reduction of 35 % - 45 % in economic production cost of feedstock, would be required to achieve economic viability.

(4) In the light of these results, the encouragement of a large scale bioethanol programme cannot be justified on economic grounds at the present time.

TABLE 6.2 : SUMMARY OF RESULTS OF ECONOMIC COST/BENEFIT ANALYSIS OF BIOETHANOL PRODUCTION

ASSUMPTIONS		WHEAT FEEDSTOCK		WHEAT/SUGAR BEET FEEDSTOCK	
Commissioning Date	Ethanol value	EIRR	NPV	EIRR	NPV
	% of premium gasoline	%	Million ECU	%	Million ECU
1988 *1	100	-18.2	-110.9	-33.8	-162.5
	90	-24.5	-130.3	-39.3	-182.0
	60	-42.1	-188.4	-52.3	-240.6
1998 *2	100	+1.0	-30.6	-11.0	-80.7
	90	-5.1	-58.5	-20.1	-108.9
	60	-31.7	-142.4	-45.5	-193.5

* 1 : Assuming "Recovery oil price scenario"
* 2 : Assuming "Unstable oil price scenario"

Source : Consultants' estimates

Key Assumptions : Plant size : 1,650,000 hectolitres per year
$ to ECU exchange rate : 1:1
Construction period : 24 months
Opportunity cost of land: zero
Opportunity cost of capital : 6.5 % (Weighted mean of six Member States)

APPENDIX I

SUPPLEMENTARY DATA

TABLE A1 - BLENDING CHARACTERISTICS OF OXYGENATED FUELS

	MTBE	GTBA	OXINOL-50	METHANOL	ETHANOL	M3E3
Volume blended % of base	10	7	8	3	5	6
Typical						
RONC	118.0	104.7	117.6	130.0	120.0	120.0
MONC	101.0	95.3	97.2	95.0	99.0	98.0
RVP, PSI	8.0	15.0	29.0	76.0	22.3	37.5
SG	0.746	0.750	0.770	0.796	0.794	0.795
Low end of Ranges						
RONC	115.0	103.0	115.0	120.0	115.0	115.0
MONC	98.0	93.0	95.0	90.0	95.0	95.0
RVP, PSI	8.5	20.0	40.0	90.0	30.0	45.0
SG	0.746	0.750	0.770	0.796	0.794	0.795

Source : Consultants' estimates

TABLE A2 - ROTTERDAM PRICES
($/Tonne)

	Premium Gasoline (0.15gl/liter lead)	Regular Gasoline (0.15gl/liter lead)	Butane Market	Butane Fuel	Octane (clear)
1983 QI	299.8	280.0	334.4	178.0	2.61
QII	308.8	294.8	295.4	180.2	1.84
QIII	309.4	295.0	279.5	185.8	1.92
QIV	296.5	278.1	281.1	188.6	2.45
1984 QI	277.4	256.2	257.3	193.5	1.63
QII	283.4	272.4	232.4	204.6	1.47
QIII	268.0	255.6	219.6	196.8	1.65
QIV	256.7	244.7	252.0	203.5	1.60
1985 QI	245.7	232.9	234.2	203.1	1.71
QII	291.6	273.0	211.1	162.7	2.68
QIII	292.7	262.6	213.8	156.2	3.69
QIV	279.5	260.4	246.5	157.8	2.55
1986 QI	188.3	169.4	152.6	117.6	2.52
QII	176.8	152.3	84.7	64.4	3.37
QIII	167.7	132.2	75.3	66.3	4.73
QIV	153.8	134.3	115.4	81.2	2.59

Sources :

Premium, regular gasoline : Platt's Oilgram Price Report (maximum of reported range)

Butane (market) : Platt's LP Gaswire

Butane (fuel) : calculated on the basis of fuel oil prices and relevant heating values of butane and fuel oil

Octane : calculated on the basis of price differentials between premium and regular gasoline, considering a delta of 6 octanes between their respective clear RONs. (Note that there is a 7.5 octane delta between their respective pump RONs. However, the different lead susceptibility behaviour for Premium and Regular grades results in a lower delta in their clear RONs.

FIGURE A.1 COMPARISON OF THE ENERGY RATIO (OUTPUT : INPUT) AND THE ENERGY DIFFERENCE (OUTPUT - INPUT)

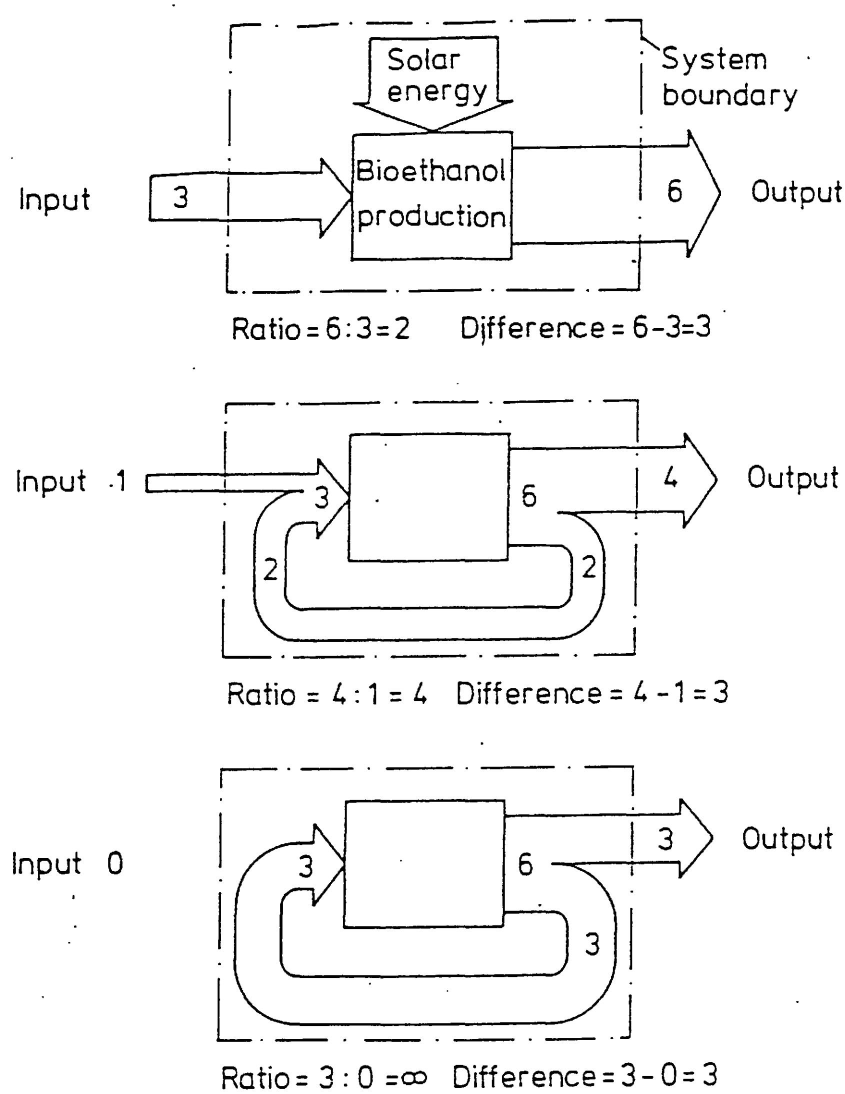
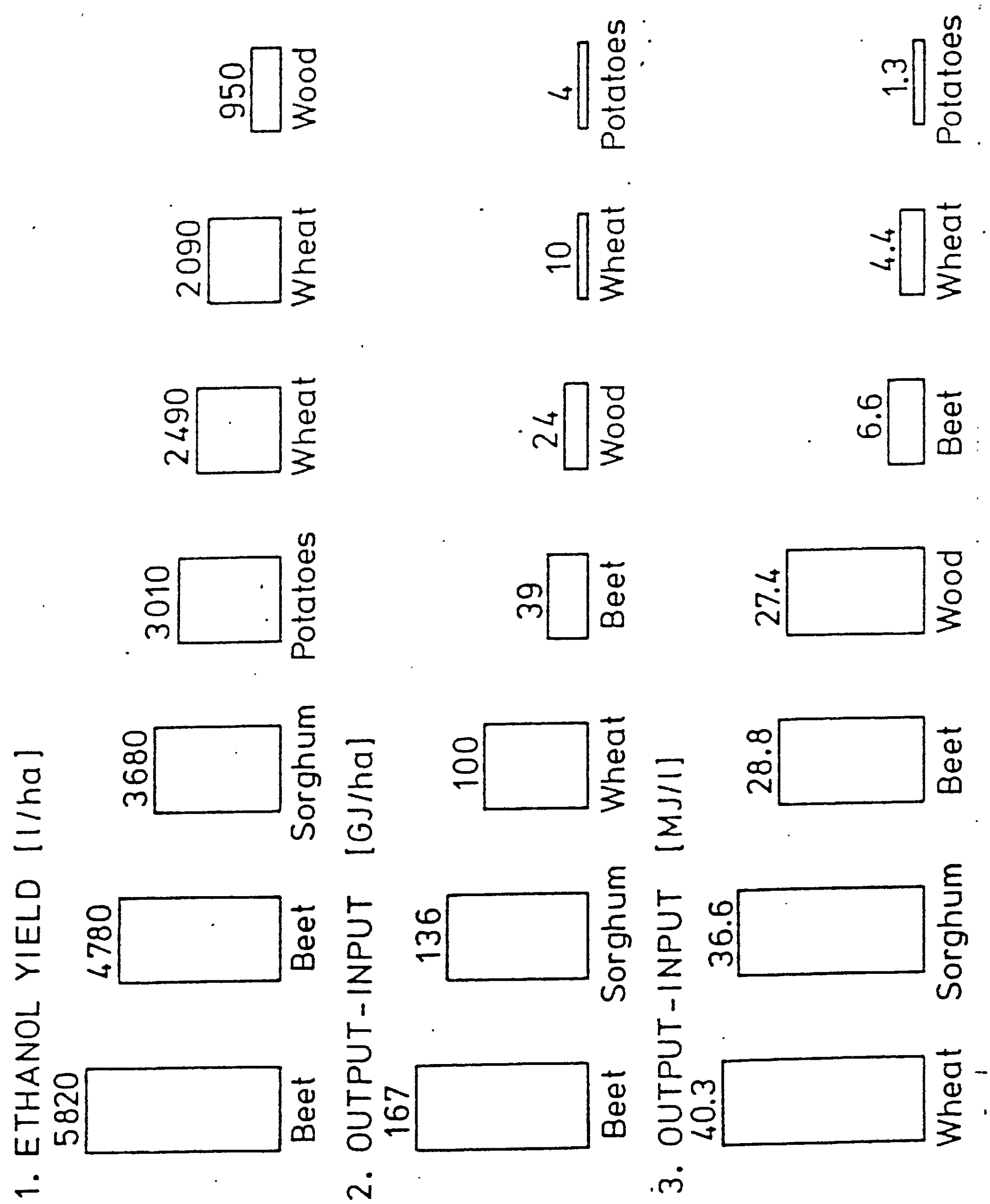


FIGURE A.2 COMPARISON OF ENERGY ANALYSIS FOR DIFFERENT FEEDSTCKS



APPENDIX II

DRAFT CONTRACT AND TERMS OF REFERENCE

STUDY CONTRACT

between

THE EUROPEAN COMMUNITY

and

PRODAR - AGRO DEVELOPPEMENT S.A.R.L.

PARPINELLI TECNON S.R.L.

LAURENCE GOULD CONSULTANTS LIMITED

TECHNISCHEN UNIVERSITAT CAROLO-WILHELMINA ZU BRAUNSCHWEIG

N° EN3B-0113-C (CD)

The European Community (hereinafter referred to as "the Community") represented by the Commission of the European Communities (hereinafter referred to as "the Commission") represented for the purpose of the signature of this contract by the Director General for Science, Research and Development, or its authorised representative.

of the one part

and

PRODAR-AGRO DEVELOPPEMENT S.A.R.L. (hereinafter referred to as "PAD"), whose registered office is situated at 40, rue Lauriston , F - 75116 Paris, represented for the purpose of the signature of this contract by Mr. F. Millet, Director, or its authorised representative(s),

PARPINELLI TECNON S.R.L.(hereinafter referred to as "PT"), whose registered office is situated at Via Egadi 7, I - 20144 Milano, represented for the purpose of signature of this contract by Dr. A.M. Falconi, Managing Director, or its authorised representative(s),

LAURENCE GOULD CONSULTANTS LIMITED (hereinafter referred to as "LGC"), whose registered office is situated at Birmingham Road, Saltisford, UK - Warwick CV34 4TT, represented for the purpose of the signature of this contract by Mr. H.D. Thompson, or its authorised representative(s),

TECHNISCHEN UNIVERSITÄT CAROLO-WILHELMINA ZU BRAUNSCHWEIG (Institut fur Landwirtschaftliche Technologie und Zuckerindustrie), (hereinafter referred to as "TUB"), whose principal office is situated at Langer Kamp 5, D - 3300 Braunschweig, represented for the purpose of the signature of this contract by its Kanzler, or its authorised representative(s), (hereinafter referred to as "the Contractors"), acting jointly and severally,

of the other part,

have, in order to carry out a study in pursuance of the Non-Nuclear Energy programme (Energy from Biomass) on the basis of a decision of the Council of Ministers of the European Communities (hereinafter referred to as "the Council"),

AGREED TO THE FOLLOWING :

Article 1 - Definitions

For the purpose of this contract

" the Study " means the work, task or project set out in Annex IV to this contract,

" the Standard Conditions " means the provisions and conditions specified in Annexes I, II and III to this contract which shall apply to PAD, PT and LGC, and in Annexes I, II and V to this contract which shall apply to TUB,

other expressions shall have the same meaning as specified in the Standard Conditions.

ANNEX IV

"STUDY ON THE PRODUCTION AND USE OF BIOETHANOL IN THE EC

A. Purpose : Cost/benefit analysis of production and use of bioethanol as a gasoline additive in the European Community. Study and quantification of the implications of such a programme in terms of agriculture, technical knowhow, cost, energy supplies, competition, employment and industry.

B. Plan of Study : Each of the points listed below should be investigated from the point of view of the Community of Twelve for the period 1986 to 2000. Detailed socio-economic evaluation for the following countries : Belgium, F.R. of Germany, Spain, France, Italy, Netherlands, United Kingdom.

3. Problems of Oxygenated Fuels - Lead-Free Petrol

3.1 Evaluation of the overall market (existing and potential) for lead-free petrol and, consequently, the market for octane boosters.

Covered by PARPINELLI TECNON.

3.2 Evaluation of production capacities and costs, prices and availabilities of oxygenated fuels of fossil origin (existing and potential) in competition with bioethanol (TBA, methanol, MTBE, synthetic ethanol).

Covered by PARPINELLI TECNON.

3.3 Analysis of present level of use of all oxygenated fuels as lead replacers in gasoline, taking account of their cost and physico-chemical properties. Calculation of incremental octane improvement cost.

Covered by PARPINELLI TECNON.

3.4 Economic analysis of production of lead-free petrol in refineries.

Covered by PARPINELLI TECNON.

4. Technico-Economic Analysis of Bioethanol Production System

4.1 Analysis of the overall market for ethanol of fossil or agricultural origin (production, origin, destination).

Covered by AGRO DEVELOPPEMENT and PARPINELLI TECNON.

4.2 Estimation of the potential market for bioethanol according to different offer prices in the motor fuels industry. Evaluation of quantities of agricultural feedstocks and land resources involved.

Covered by AGRO DEVELOPPEMENT, PARPINELLI TECNON and TECHNICAL UNIVERSITY in BRAUNSCHWEIG.

4.3 Forward analysis of availability, quantity and cost of agricultural feedstocks in the Community (present crops and alternative crops).

Covered by AGRO DEVELOPPEMENT and TECHNICAL UNIVERSITY in BRAUNSCHWEIG.

Present crops : wheat, sugar beet, wine, potatoes ;
Alternative crops : Jerusalem artichoke, sweet sorghum, lignocellulosic materials (short rotation forestry).

4.4 Evaluation of bioethanol production costs (process, investment, yields, economies of scale, storage and transport of agricultural raw materials, etc) and prospects for technological progress in this field. Situation outlook as regards imports of bioethanol from third countries. Inventory of production units in the Community, capacities and location.

Covered by AGRO DEVELOPPEMENT and TECHNICAL UNIVERSITY in BRAUNSCHWEIG.

4.5 Economic analysis of other possible uses of bioethanol (chemicals industry).

Covered by LAURENCE GOULD CONSULTANTS.

4.6 Economic analysis of other options in competition with the conversion of agricultural raw materials to bioethanol : evaluation of opportunity costs, taking into account other possible uses of land resources.

Covered by LAURENCE GOULD CONSULTANTS.

5. Analysis of the Programme's Implications in Terms of the Budget, Employment, the Environment, Energy Balance and Competition

5.1 Evaluation of the repercussions of protein co-products on the feedstuffs market (volume, price).

Covered by AGRO DEVELOPPEMENT.

To be considered also:

- estimation of replacement of soya protein and corn gluten feed imports ;
- competition between by-products of bioethanol production (DDGS) and protein from corn in Italy.

5.2 Evaluation, in the context of efforts to ban leaded gasoline, of the implications for the environment of the production and use of various octane boosters.

Covered by LAURENCE GOULD CONSULTANTS.

5.3 Lessons to be drawn from experience in the USA, Brazil and Sweden : comparison with the situation in the Community.

Covered by AGRO DEVELOPPEMENT and PARPINELLI TECNON.

5.4 Evaluation of the impact of a bioethanol-fuel progamme on imports of hydrocarbons (oil and natural gas). Analysis of implications for tax revenue.

Covered by LAURENCE GOULD CONSULTANTS.

5.5 Impact in terms of job maintenance or creation in rural areas, the food industry and repercussions in the oil and chemicals industries.

Covered by LAURENCE GOULD CONSULTANTS.

5.6 Evaluation of the availability of lead-free petrol and all octane boosters, including those from third countries.

Covered by PARPINELLI TECNON.

5.7 Definition, with estimated figures, of the energy balance of bioethanol production. Comparison with competitive products of fossil origin (methanol, TBA, MTBE...).

Covered by AGRO DEVELOPPEMENT, TECHNICAL UNIVERSITY in BRAUNSCHWEIG and PARPINELLI TECNON.

5.8 Discussion of the budgetary aspects of these various points.

Covered by LAURENCE GOULD CONSULTANTS.

6.Economic Cost/Benefit Analysis

Covered by LAURENCE GOULD CONSULTANTS.

C. Division of work : The contractors have divided the partial studies of the subjects as mentioned above (point B) which can be summarised as follows :

- Consultant PARPINELLI TECNON
  - Points 1 + 3.6 ....(entirely)
  - Points 2.1, 2.2, 3.3, 3.4, 3.5, 3.7 ....(partially)

- Consultant AGRO DEVELOPPEMENT
  - Points 3.1 ....(entirely)
  - Points 2.1, 2.2, 2.3, 2.4, 3.3, 3.7 ....(partially)

- Consultant LAURENCE GOULD CONSULTANTS
  - Points 2.5, 2.6, 3.2, 3.8, 6 ....(entirely)
  - Points 3.4, 3.5 ....(partially)

- Consultant TECHNICAL UNIVERSITY in BRAUNSCHWEIG
  - Points 2.2, 2.3, 2.4, 3.7 ....(partially)

The presentation of the study report shall follow the Plan of Study as mentioned under point B with the addition of :

- an introduction (including the mandate of the study)
- an executive summary
- a final section in each of the three main chapters covering summary and conclusions.

Where more than one consultant is involved on a particular subject (e.g.B.2.2), the participating groups bear a common responsibility for the report on the section concerned and in particular for the conclusions formulated.

The four contractors share a common responsibility for the executive summary of the entire study report.

D. <u>Duration of study</u> : A draft final report shall be presented by 30th November 1986 and the final report by 1st February 1987.

E. Officers responsible for the study :

W. PALZ, Head of the Division DG XII/E-1
E.J. STENDEVAD, Head of the Division DG VI/A-2

APPENDIX III

GLOSSARY OF TECHNICAL TERMS AND LIST OF ABBREVIATIONS

GLOSSARY OF TECHNICAL TERMS

Antiknock Index (AKI)

Also known in the U.S. as the Posted or Pump Octane No, the AKI is simply the numerical average of the Research and Motor Octane numbers, i.e. : $AKI = \frac{RON + MON}{2}$

Although AKI is often taken as a measure of the Road Octane number, they are not the same and may differ significantly in the case of some components, particularly the alcohols.

Blending Properties

The blending value of hydrocarbon components, whether referred to octane or volatility or any other characteristic, depends to some extent on the composition of the base to which they are added. This dependence is usually not strong in the case of hydrocarbon components added to all-hydrocarbon base fuels, but may be very strong in the case of oxygenated additives in hydrocarbon base fuels.

Discounted Cash Flow

Benefits and Costs are dispersed through time. Discount factors are applied to the cash flow thereby allowing the costs and benefits occurring at differents points to be expressed in terms of present values.

Cost/Benefit Analysis (Economic Analysis)

Analysis which measures and compares the present value of benefits and costs of a particular project. Both benefits and costs are measured in terms of their effect upon a whole economy and are, therefore, valued using Economic Prices (see below).

Economic Analysis

See Cost/Benefit Analysis.

Economic Internal Rate of Return (EIRR)

The discount rate which brings the net present value of the economic cash flow to zero. This figure is normally compared with the Marginal Value of Capital (Government Discount Rate) to assess the viability of the project.

Economic Prices

Are used to measure the value of a project input or output to a whole economy. They may be derived from adjusted world market prices, where the goods are traded on that market, or from appropriate adjustments to financial prices, where the goods are only traded internally. The most significant difference from financial prices is usually removal of taxes and subsidies.

Engine Knock

At or beyond a critical compression ratio, every spark ignition fuel will self-ignite with an audible explosion (detonation). This phenomenon is commonly referred to as knocking.

EP2

Substrate obtained after the second crystallisation of the juice from sugar beet.

Financial Analysis

Analysis of the project in financial terms using current market values and costs throughout.

Financial Prices

Prices at which goods are normally traded in the market.

Financial Internal Rate of Return (FIRR)

The discount rate which brings the net present value of the financial cash flow to zero.

Gasoline

Gasoline is a volatile mixture (blend) of liquid hydrocarbons, generally containing small amounts of additives, suitable for use as a fuel in spark ignition internal combustion engines. Gasoline is chiefly derived from crude petroleum. The main processes to manufacture gasoline in the refinery are catalytic reforming and catalytic cracking. In the former process naphtha, a light boiling fraction from crude, is catalytically converted to produce about 75 % reformate and 25 % gas (hydrogen, methane, ethane, propane and butane). Butane is the predominant gas and up to 10 % may be blended into gasoline depending upon local volatility specifications. The catalytic cracking process is used to break down the heavier components of crude into gas and distillates, thus greatly increasing the yield of gasoline and middle distillate which can be obtained from crude oils.

Marginal Value of Capital (Government Discount Rate ; Opportunity Cost of Capital)

The expected net economic benefit to be obtained by applying capital to a given project in a given economy ; normally expressed as a percentage. This value is applied to the economic cash flow, to obtain the net present value.

Motor Octane Number (MON)

Motor Octane Number (MON) is the octane number of a motor gasoline determined in a special laboratory test engine, under high "engine severity" conditions, giving a rough measure of the high-speed knock properties of the gasoline. Since high-speed knock occurs at high engine speeds, it is inaudible to the motorist and is therefore more likely to result in damage to the engine.

Net Present Value

The present value (i.e. discounted) of the net cash flow. This represents the difference between the total of the discounted costs and the total of the discounted benefits.

Octane Number

The octane number of a fuel is technically defined as a number equal to the percentage by volume of iso-octane in a mixture of two primary reference fuels (iso-octane and normal heptane) having the same resistance to detonation (engine knock) as the fuel under consideration in a special test engine. It is a measure of the anti-knock value of a gasoline and, in the case of the special test engine, the higher the octane number the higher the anti-knock quality of the gasoline.

Octane Rating

This is an attempt to quantify the difference between fuels in their resistance to self-ignition (knocking).

Opportunity Cost

The value of any benefit forgone elsewhere by using an input in a particular project. The opportunity cost principle is most usually discussed in relation to Economic Prices but is, in fact, equally applicable to some forms of financial analysis. In strict economic theory, the opportunity cost should represent the value in the best alternative use. (Opportunity Cost of Capital - see Marginal Value of Capital).

Oxygenate

An oxygen-containing, ashless, organic compound, such as an alcohol or ether, which may be used as motor fuel either alone or in blend with hydrocarbons.

Research Octane Number (RON)

Research Octane Number (RdON) is the octane number of a motor gasoline determined in a special laboratory test engine, under mild engine severity conditions, giving a rough measure of the low-speed knock properties of the gasoline. Low-speed knock may be detected by motorists as a "pinking" noise upon starting-up the engine.

Road Octane Number (RdON)

Road Octane Number (RdON) is the octane number of a motor gasoline determined during actual road testing, covering the entire range of operating conditions. Apart from the intrinsic quality of the gasoline tested, the Road Octane Number also depends on the make of the engine of the vehicle and reflects the severity of the engine/vehicle combination. In general, the Road Octane Number of neat hydrocarbon gasolines lies between the RON and MON values.

Sensitivity (of petroleum products)

Sensitivity is defined as the difference between RON and MON.

Sensitivity Analysis

Reworking of an analysis to test what happens to earning capacity if a given factor is changed.

Switching Values

(Part of the sensitivity analysis). The percentage change in a selected variable that reduces or increases the Net Present Value to zero or the Benefit : Cost Ratio at a given discount factor to 1 : 1.

Terminal Value (Salvage Value)

The remaining value of capital assets at the end of the project's life.

Volatility (RVP)

Volatility is the ability of a gasoline to evaporate. This characteristic is important for engine operation with respect to starting, warm-up under cold ambient conditions and vapour lock during warm ambient conditions. The Reid Vapour Pressure (RVP) is commonly used as a measure of volatility in gasoline blends.

Water Tolerance

Water tolerance is the volume of water in gasoline required to cause phase separation.

LIST OF ABBREVIATIONS USED IN THE REPORT

ARCO	:	ATLANTIC RICHFIELD Co.
DDGS	:	Dried Distiller Grain and Soluble
EP2	:	Sugar substrate obtained after the second crystallization
GTBA	:	Gasoline Grade Tertiary Butyl Alcohol (sold by ARCO, contents 95 % of TBA)
IBA	:	Iso-butyl alcohol
IPA	:	Iso-propyl alcohol
M3E3	:	Blend of methanol/ethanol in equal parts. The suffixes indicate the concentration of methanol and ethanol in the finished gasoline.
MTBE	:	Methyl Tertiary Butyl Ether
RVP	:	Reid Vapour Pressure (see Glossary, "Volatility")
TAME	:	Tertiary Amyl Methyl Ether
TBA	:	Tertiary Butyl Alcohol

European Communities — Commission

Cost/benefit analysis of production and use of bioethanol as a gasoline additive in the European Community

Prepared by:
Agro Développement, France
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Document

Luxembourg: Office for Official Publications of the European Communities

1987 — 140 pp. — 21.0 × 29.7 cm

EN

ISBN 92-825-7581-0

Catalogue number: CB-50-87-170-EN-C

Price (excluding VAT) in Luxembourg:

ECU 34.80 BFR 1 500 IRL 27 UKL 24.10 USD 40

Price (excluding VAT) in Luxembourg:
ECU 34.80 BFR 1 500 IRL 27 UKL 24.10 USD 40

OFFICE FOR OFFICIAL PUBLICATIONS
OF THE EUROPEAN COMMUNITIES

L-2985 Luxembourg

ISBN 92-825-7581-0

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