HERBACEOUSENERGYCROPS:
A GENERAL SURVEY AND A MICROECONOMIC ANALYSIS *

GIUSEPPE CASERTA

ENEA, Department of Technological Innovation, Via Anguillarese 301, 00060 Roma, Italy

VITTORIO BARTOLELLI and GIOVANNI MUTINATI

RENAGRI, Via Tommaso Grossi 6, 00184 Roma, Italy

ABSTRACT

Liquid fuels (bioethanol and biooil) derived from herbaceous crops are considered beneficial for the environment and human health especially if they are used as fuels for motor vehicles, The choice of the most suited crop to be cultivated for liquid biofuel production depends on many factors; the most important being the economic convenience for farmers to cultivate the new energy crop in place of the traditional ones (for example, wheat). In order to analyse the conditions which favour the cultivation and selling of specific energy crops, a simple methodology is proposed, based on the calculation of the "threshold price" of the energy crop products The "threshold price" is the minimum price at which the primary products of the energy crop, i.e.: roots, tubers, seeds etc., must be sold in order to obtain a gross margin equal to that usually obtained from the traditional crop which has to be replaced by the energy crop. As a case-study, this methodology has been applied to twelve Italian provinces where the cultivation of six energy crops, both in productive lands and set-aside lands, is examined. The crops considered are sugar beet, sweet sorghum and topinambour useful for bioethanol production; and rapeseed, sunflower and soya, which are usually employed for the production of biooil.

KEYWORDS
Liquid biofuels, herbaceous energy crops, farmer profitability, threshold price.

*** The study has been performed under the responsibility of the Italian Biomass Association *in the* frame of Task *VIII* of the *IEA/Implementing* Agreement on *Bioenergy***

1. INTRODUCTION

The need to divert areas of fertile land from food crops to non-food crops is becoming more and more pressing, since million tons of surplus foodstuffs have been accumulating in many Countries, and especially in the European Union (EU).

Many questions arise in trying to find alternative uses for the surplus agricultural lands. For example:
-Which types of alternative vegetable species are to be planted?
-Are vegetable fuels the most attractive non-food products?
-Which are, if any, the expected benefits of energy plantations?
-Will the farmers be willing to cultivate the alternative plants, and what conditions will they claim?

At present, these questions cannot be exhaustively answered especially if the alternative crop is conceived for the sole purpose of producing vegetable fuels (biofuels) as substitute for fossil fuels. The investigations so far performed by national institutions and international organisations are incomplete with often contradictory results, so that a sound analysis is impossible at the moment. In fact, only a few Countries are interested in investing human and financial resources in the crop fuel sector, and international scientific co-operation up to now has been very informal. Moreover, in facing the problem, a systemic approach has seldom been adopted, and some important non-technical aspects often have been neglected.

Apart from the need to investigate further some scientific and technical aspects, the first step to be considered when dealing with herbaceous energy cultures, is the choice of the most promising crops for fuel production. This choice depends on:
- the kind of fuel desired by the energy market;
- the possibility and the economic convenience for the farmer to cultivate herbaceous crops suited for producing the raw material to be converted into the desired fuel;
- the convenience for the transformation industry to get the raw material and to convert it into useful fuel;
- the existence of a fuel distribution network;
- the energy balance of the whole chain; and
- the environmental balance.

This paper is not aimed at providing an exhaustive answer to all the above questions, nor at giving suggestions for filling the present gaps of the crops-to-fuel system. The purpose of this work is to outline some basic concepts underlying the implementation of the biofuel system, focusing attention on the need to explore in more detail one of the most important non-technical barriers related to the use of agricultural crops for energy purpose, i.e., the economic convenience for farmers to divert some hectares of fertile lands from food crops to fuel crops, or to produce the latter on set-aside lands.

Focusing the work on the agriculture side of the energy crop system is justified by the following reasons:
- The cultivation of any kind of energy crop is the primary and most important phase that affects the whole system both from technical and economical points of view;
- The cost balance for producing and selling the energy products is the weak link in the chain;
- This work has been performed in the frame of the Other Biomass Crops Activity of the Task VIII of the IEA Bioenergy Agreement, dealing with the efficient and environmentally-sound biomass production systems.

2. BIOFUELS ON THE MARKET

The choice of vegetable species to be cultivated for energy purpose depends primarily on what kind of energy product needs to be introduced into the market. Liquid biofuels seem to be the most appropriate energy products that can be obtained from herbaceous crops, since they look promising in decreasing the pollution level caused in some microenvironments, such as urban centers, by cars and other motor vehicles fuelled by fossil fuels
Two kinds of biofuels are usually considered as substitutes for fossil fuels, or as enhancers of some specific fuel properties such as octane or cetane numbers:

-vegetable *oils (biooils)*, both in the form of crude oils, extracted by some oil-bearing plants, or chemically modified oils (methyl or ethyl esters); the fossil counterpart of vegetable oils is diesel oil;

-*ethyl* alcohol *(bioethanol)*, obtained from sugary crops, or its chemical derivative, i.e., ethyl tertiary butyl ether (ETBE); the fossil counterpart of ethanol is gasoline and that of ETBE is the MTBE (methyl ether).

Recently the use of biofuels has become of ever more current interest even if it is still confined to a level of demonstration projects and proposals.

Biooil

The principal European experience deals with the use of biooils rather than of bioethanol. Biooil has been used since the second half of 1991 in Zurich and Vicenza. Urban buses in thse two cities have run more than 200,000 kilometers with no operational and driving problems. Furthermore, in Rouen 200 buses have experienced the use of biooil mixed with diesel oil up to 33%. Many other cities in France and in Germany (Dunkirk, Vierzon, Friburg, Kiel) have in operation vehicles, both buses and taxis, fuelled with esterified vegetable oil in a neat form or mixed with diesel oil. In Italy about 1000 biooil-fuelled vehicles are in operation, 100 of which are under monitoring tests. After several hundreds thousands of kilometers, the results are very satisfactory as far as operation, ease of driving and overall performance are concerned.

Oleaginous crops which are usually considered for the European and American agriculture realities are rape, sunflower, soya; palms are also considered in Asia. The oil is extracted from the seeds of these plants by means of mechanical or chemical methods.The crude oils are easy to produce and, in principles, they could be used in engines but, to be employed, they require engines with a pre-combustion chamber or ad-hoc designed engines.

Bioethanol

The interest in bioethanol has been up to now limited to some extra-european Countries, such as USA (10 million litres per day), Brazil (32 million litres per day), South Africa (1 million litres per day). Large-scale programmes on bioethanol for running public and private cars were launched in USA, Brazil, Sweden, Zimbabwe as a consequence of particular sugar market situations. A blend of bioethanol and gasoline is generally used, ranging from 10% to 22% ethanol. In Europe, if one excludes some limited demonstration trials, no trade network has been established, given also the uncertainty of EC policy on this topic. However, the trend is to use ETBE instead of ethanol, for its better handling and engine operating properties.

The vegetable species commonly used for ethanol production are sugar cane, maize, sweet sorghum, sugar beet.

The characteristics of the most common energy crops, the cultivation practices, the agricultural inputs and outputs have been the object of other co-operative networks and the relative results may be found published elsewhere[1-4]; therefore, they will not be repeated here.

3. THE EXPECTED BENEFITS OF USING BIOFUELS

The environmental concern is a key point, the only one that currently justifies the use of biofuels in place of fossil fuels, in spite of the higher production cost of the former. The environmental and health reasons for using biofuels are well summarized by S.R. Booth[5]:

"-A minimum oxygenate level reduces air pollution. USA law requires all gasoline in 41 large cities to contain oxygenates to reduce pollution. EC specifications allow oxygenated but do not have a minimum oxygenates limit. Ethanol contains almost 1/3 oxygen. This oxygen improve combustion and car pollution can be reduced by at least a 1/4 within existing EC gasoline specification limits. A similar EC programme will remove millions of tons of dangerous gases from the air we all breathe. This saving can be achieved in a short time in contrast with all other strategies to reduce air pollution.

-Large volumes of dangerous aromatics can also be removed from gasoline when ethanol is used. This includes benzene, which is known to cause cancer. Ethanol has a far higher octane value than usual gasoline components Ethanol at 5% allows the replacements of about 7% aromatics.

-There is no sulphur in biofuels. This is most important for the protection of historical buildings so important in all EC Countries.

-Biodiesel emits less particulate (black soot). Many historical monuments on main roads are again covered with black soot from diesel only a year after cleaning. These particulate are also a serious health problem.

-Carbon dioxide emissions are lower than for gasoline as a consequence of the lower content Carbon atoms in ethanol and biodiesel. "

Without any doubt, the potential environmental benefits linked to the use of biofuels are the key for the penetration of these materials into the energy sector, even if this penetration will be limited to some market niches. But, initially, one must face the problem of growing the most suited plant species, and therefore, the conditions which favour the energy crop cultivation must be examined as first step. This is accomplished in the following section.

4. THE PROFITABILITY OF THE SELECTED ENERGY CROPS

The aim of this sudy is to provide a simple tool for evaluating the economic convenience for the farmer to cultivate a given energy crop instead of a traditional one. The basic concepts is that the farmer will choose an energy crop (considering the latter as “convenient”) only if the gross margin of this crop (GM,) is equal or higher than that provided by the traditional food crop (GM_f). This statement leads to the definition of the so called “Threshold Price” (TP), that is, the minimum price at which the product of the energy crop must be sold in order to obtain a gross margin equal to that of the traditional crop. If the actual selling price of the energy product is higher than the threshold price, then the economic convenience for the farmer to cultivate the energy crop in place of the traditional crop will occur.

The method, then, relies on the calculation of above-cited two basic economic parameters: the gross margin (GM) and the threshold price (TP).

The gross margin of a culture is given by the difference between the income coming from the saleable product and the variable costs for its production. That is:

$$GM = (Q x P + S - C) \qquad (1)$$

Where:

Q is the amount of saleable products and by-products
P is the selling price of the products and by-products
S represents the subsidies and incentives in force
C represents the variable costs for the energy product production
The convenience for the farmer to cultivate the energy crop in place of the food crop begins to occur when:

$$GM_e \geq GM_f \qquad (2)$$

where the index "e" and "f" refer respectively to the energy crop and the food crops.

In a given area and for a given culture some factors (such as the amount of product, subsidies, variable costs and the gross margin for the traditional food crop) can be considered well defined and constant. The only variable, which has an influence on economic convenience of the new culture is the selling price of the energy crop product. The value of the price that satisfies the equation (2) is the threshold price TP.

The threshold price is given by:

$$TP = \frac{GM_f - S_e + C_e}{Qe} \qquad (3)$$

For calculating the threshold price, the gross margin for the traditional crop, the subsidies that can be provided to the new energy crop, as well as the specific variable costs and the yield of this new crop must be known,

There are also cases in which set-aside lands can be used for cultivating energy crops instead of food productive lands. In fact, the UE agricultural policy requires that a percentage of productive lands is set-aside for food, providing also a subsidy for that. Energy crops are permitted to grow on these lands, giving and additional margin to the farmers. In this case, the reference income are given only by the set-aside subsidies, and the reference gross margin is the difference between the subsidies and some expenses that the farmer must incur for keeping the set-aside soil in good condition.

From the above, two types of threshold prices must be considered for each energy crop: one related to the cultivation of the energy crop on productive land (TPp), and another for cultivating the same crop on set-aside land (TPs). The need of distinguishing between productive and set-aside lands arise from the different levels of subsidies which affect them.

The threshold prices should be compared with the selling prices of the primary products considered for energy use in order to assess the farmer's profitability. But, at present, there is no well founded energy market for these primary products, so that the comparison has to be made with the selling prices of the same products in the food market.

Additional indications about the economic convenience of using herbaceous crops for liquid biofuels production are provided by the evaluation of the incidence of the raw material cost on the total cost of the final energy products (bioethanol or biooil). The total cost of biofuels has three components: cultivation, transformation and distribution; but if the cultivation cost of a given crop is itself higher than the market price of the traditional energy products (gasoline or biodiesel), this crop must not be considered.

5. A CASE-STUDY: THE SITUATION IN TWELVE ITALIAN PROVINCES

The study has examined the situation in twelve italian provinces, with the purpose of calculating the prices which could stimulate the farmers to cultivate an energy crop on productive soil in place of wheat taken as traditional reference crop, and in set-aside soil instead of leaving the soil fallow. The detailed calculations and formulations are collected in a data-base volume; some results are synthetically shown in the following tables where the minimum and maximum figures of different parameters involved are reported.

The analysis has concerned six herbaceous crops:

- sugar beet, sweet sorghum and topinambour, which are the most promising crops for bioethanol production;
- soya-bean, sunflower and rapeseed, usually considered for biodiesel production.

These herbaceous crops are more or less present throughout the Italy and their primary products (roots, tubers, and seeds) are mainly used for food and feed markets. For each of twelve provinces, which are representative of North, Center and South Regions, as well as of different altitude levels, a careful investigation has been performed concerning the determination of the hire price for agriculture machines and for other technical tools, land capitals etc. With reference to the last agriculture census (1991), the yield of wheat has been obtained. Furthermore, taking into account the pedo-climatic conditions and the soil characteristics of the examined provinces, the yields of the energy cultures have been calculated.

With these data in hand, the cultivation costs of the energy crops have been obtained (Table 1). Table 2 reports the gross margin coming from the cultivation of wheat and the ones related to the set-aside conditions Different subsidies expected from growing crops on productive and set-aside lands are indicated in Table 3. Then, the yield of the primary products of the energy crops are reported in Table 4. In Table 5 the estimated threshold prices are indicated with reference to productive and set-aside lands. In the last column of Table 5 the selling price of the crop primary products is also indicated with reference of 1994. Finally, the costs of the agricultural phase referred to the volume unit of the final fuel products (liter of bioethanol or biooil) are reported in Table 6.

From the analysis of 84 Italian case-studies, some indications may be inferred. Firstly, most of the crops examined show threshold prices for cultivation on set-aside lands higher than the ones relative to the cultivation on productive lands. The different level of subsidies affect these results. Sweet sorghum and topinambour are the sole exceptions since they do not benefit by any subsidy if cultivated on productive lands.

As far as the oil-bearing plants for biodiesel production is concerned, the rapeseed grown on productive lands is the most promising crop. For this crop, in fact, the cost of the agricultural phase is well below the price (inclusive of taxes) of fossil diesel fuel; therefore, there are ample margin for accommodating also the transformation and distribution costs. However, soya is the less convenient crop because the agricultural costs already exceed the price of gasoil. Sunflower is lying in an intermediate position: its depends on local situations.

All the sugary plants for bioethanol production show agricultural phase costs lower than the gasoline price, whatever the type of land is considered.

Finally, as it is obvious, the threshold price decrease as the crop yield increases. This fact emphasises the need of promoting further R&D programmes for improving the plant productivity.

5. CONCLUSIONS

Energy crops, selected on the basis agricultural concerns, must be further studied taking into account the transformation and distribution industry concerns. Only at the end of this complex path one can be sure that the energy crop arising from these successive screenings is worthy of consideration.

It is, however, evident that some opportunities exist for selected herbaceous crops to be used as fuel producing plants. Perplexities may derive from still unsolved problems of agricultural, technological, commercial and political nature. This is mainly due to the lack of cooperative efforts among different actors involved in the system. A great contribution to overcoming these barriers could arise from the establishment of national and international networks, involving scientific institution as well as agricultural and industrial organizations.

tab 1. Cultivation costs of some energy crops (ECU/ha)

CROP	minimum			maximum			average		
	direct	indirect	total	direct	indirect	total	direct	indirect	total
Sugar beet	928	453	1381	2143	860	3003	1557	799	2356
Sweet sorghum	599	261	880	1166	516	1682	970	636	1606
Topinambour	650	699	1349	1563	1093	2656	1122	1025	2147
Soy	364	238	602	1164	901	2065	887	621	1508
Sunflower	631	292	923	1269	917	2186	901	638	1539
Rapeseed	319	260	579	900	680	1580	634	463	1097

tab. 2 Gross margins coming from the cultivation of wheat and from the set-aside subsidies (ECU/ha)

REFERENCE	minimum	maximum	average
Wheat cultivation	71	460	196
Set-aside land	23	334	147

tab. 3 Subsidies expected from growing crops on productive and set-aside lands (ECU/ha)

CROP	Productive land	Set-aside land
Wheat	178	----
Sugar beet (ECU/ton)	5	----
Sweet sorghum	----	270
Topinambour	----	270
sov	540	----
Sunflower	540	270
Rapeseed	540	270

tab. 4 Yield of the primary products of the energy crops (t/ha)

CROP	PRODUCT	YIELD		
		minimum	maximum	average
Sugar beet	Root	12.0	50.0	32.0
Sweet sorghum	Stalk	20.0	85.0	52.0
Topinambour	Tuber	20.0	80.0	49.0
Soy	Grain	1.3	5.0	3.2
Sunflower	Grain	1.0	4.5	2.7
Rapeseed	Grain	1.0	3.0	2.0

tab. 5 Threshold prices for the primary products of energy crops grown on productive and set-aside lands (ECU/t)

CROP	minimum productive	minimum set-aside	maximum productive	maximum set-aside	selling prices of primary products
Sugar beet	31	37	96	93	50
Sweet sorghum	14	9	56	45	----
Topinambour	16	10	37	30	----
Soy	91	200	321	323	165
Sunflower	95	215	516	520	217
Rapeseed	89	187	298	351	204

tab 6 Cost of the agricultural phase referred to the unit of fuel product (ECU/1000 l)

CROP	minimum productive	minimum set-aside	maximum productive	maximum set-aside	average productive	average set-aside
Sugar beet	278	332	869	835	517	541
Sweet sorghum	156	101	622	504	282	212
Topinambour	171	106	416	334	267	194
Soy	412	908	1460	1468	785	1099
Sunflower	215	488	1174	1182	535	715
Rapeseed	147	424	678	797	346	590

REFERENCES

1. G. Riva, Vegetable Oil Fuels, IEA Information Report 93:1, Bioenergy Agreement, Task VIII, 1993.
2. G. Caserta Ed., Proceedings of the Seminar on Vegetable Oil as Transport Fuels, Pisa, Italy, May 14-15 1993; IEA Bioenergy Agreement, Task VIII and X, 1994.
3. Biofuels: Application of biological derived products as fuels or additives in combustion engines; EU, DG XII, EUR 15647 EN,1994.
4. Biofuels, IEA Policy Analysis Series,1994.
5. S.R. Booth, private communication.