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AGRICULTURAL BIOMASS AVAILABILITY FOR ENERGY CONVERSION IN ITALY

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The strong energy dependence of Italy from foreign countries and the problems relating to emissions of greenhouse gases push to explore alternative energy sources with low environmental impact, such as renewable sources.

In this paper the possible energy contribution of agricultural biomass in Italy is assessed, taking into account the amount of soil availability and on the other hand the energy consumption of the main activities, such as heating and transport.

Keywords: biodiesel, bioethanol, renewable sources, alternative energy sources

1. Introduction

Italy highly depends on the other countries with regards to energy: almost 85% of energy demand is imported. For this reason it is necessary to set up positive actions in this area, starting from energy-saving policies, to higher exploitation of national resources, to alternative sources of energy. Moreover the use of fossil fuels has a high impact on the environment. In this regard Italy has ratified the Kyoto Protocol, committing to reduce by 8% its emissions of greenhouse gases. In this context, it is necessary to evaluate the possible contribution to energy production of renewable sources such as wind, hydro, solar, geothermal, wood and agricultural biomass. Nowadays the yearly energy production from such sources is about 20 Mtoe, of which 5.7% comes from biofuels [1].

Concerning to the characteristics of the products, energetic crops can be divided in three categories: oleaginous, lignocellulosic and sugary and starchy ones. For the production of liquid biofuels oleaginous species and sugary and starchy ones are used. Some plants give an indistinct product, to be used in full, while others give differentiated products, to be valued properly (fruits, stems, seeds, ...). In the paper two cases are discussed:

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1. ***oleaginous plants*** for the production of biodiesel;

2. ***sugary and starchy plants*** for the production of bioethanol.

The biodiesel is used instead of diesel for heating and transport sector, while bioethanol is used as additive for gasoline. These species are already grown in Italy for other uses (especially for food one) and production techniques do not require changes depending on the intended use.

2. Materials and methods

Biodiesel

Biodiesel is obtained from the esterification process of vegetable oils and regenerated vegetable oils. The vegetable oil is reacted in excess of methanol in the presence of an alkaline catalyst. The final product is a mixture of some methyl esters not containing sulfur and aromatic compounds and with a high oxygen content (not less than 10%). Biodiesel can be used as fuel for vehicles and heating, both as a mixture with diesel fuel and as it is. In the past most of biodiesel was used for domestic heating in a mixture with diesel fuel, while only a smaller percentage was left for transport sector. In recent years the use of biodiesel as additive for diesel fuels for vehicles has grown considerably.

As for the transport sector, esters of plant oils can be used in all diesel engines on the market today, after a small change to use as they are, and without any change when they are mixed with diesel up to 20-30%. For the production of thermal energy pure biodiesel is used, without any major problems from the technical point of view. The replacement of the burners is not required, but only a modification of spray nozzles or some special adjustments could be necessary.

To ensure the biodiesel quality required by the market, the main raw material must be rapeseed oil or, alternatively, soy or sunflower ones.

With regard to the outturns of the different plants, we can consider that from a ton of crop 0.352 t of biodiesel (about 403 liter) using rapeseed oil and 0.371 t (about 424 liter) with sunflower seeds can be obtained, while production is significantly lower with soybeans (0.180 t, about 191 liter) [2].

The high costs of production, storage and final distribution mean that the use of vegetable oils is possible only with the exemption from excise duty. Until 2001, the exemption allowed biodiesel quota was 125,000 t y^{-1}, while from 2001 to 2004 it amounted to 300,000 t y^{-1}. With the Finance Act 2005 the quota has been reduced to 200,000 t y^{-1}, while the Finance Act 2007 has eliminated the exemption from excise duty for biodiesel. For 2007 it was planned to apply an excise duty at a rate equal to 20% of the correspondent excise duty on diesel used as fuel, not exceeding an annual quota of 250,000 t. The Finance Act 2010 reduced this quota to 18,000 t y^{-1} [3,4].

The biodiesel can reduce CO_2 emissions, cause a better combustion due to the greater presence of oxygen in the molecule, it is characterized by the absence of sulfur and PAHs, a PM_{10} lower production, lower emission of carcinogenic aromatic compounds and it is totally biodegradable. A Health and Safety Institute (UK) study concerning a diesel engine fueled with biodiesel shows that fine particular matter (PM_{10}) is reduced by 58% with a decrease of 76% of the carbonaceous fraction (soot), that is most harmful, because it is more absorbable during respiration and it cannot be reduced by catalytic reduction systems. Carbon monoxide is also reduced by 58% and aromatic compounds undergo a decrease of 68%: thus reducing the overall carcinogenic impact [2].

Bioethanol

Bioethanol is an alcohol obtained by fermentation of various agricultural products rich in sugars and carbohydrates, such as cereals and sugary crops. It can be mixed directly into gasoline in varying percentages, according to local regulations on the quality of gasoline. The maximum rates allowed are 20% or more in Brazil, between 5.7% and 10% in the U.S. and 5% in Europe. Over the indicated values running problems of the vehicles can be occur. The ethanol-gasoline mix can result in phase separation when in contact with even small amounts of water. For this reason ethanol is not compatible with existing fuel distribution system. This is obviously an overcoming problem, simply consider the case of Brazil, where bioethanol is used pure too. The prospects of use are therefore related to the choices made at political level. Bioethanol can also be used as raw material for gasoline additives such as ETBE (ethyl tert-butyl-ether), similar to MTBE (metilterz-butyl-ether), currently in use in unleaded fuel. The production cost of bioethanol is still very high, amounting to about 2 times that of gasoline, consequently, its use is closely tied to incentives established at a political level, such as exemption from excise duty.

To produce bioethanol from sugar beet is necessary first to separate the pulp from the juice. The pulp has a high moisture content, approximately 97%, and once dried can be used as animal feed. From the juice, its sugar content is equal to 88%, the bioethanol is obtained after processes of pasteurization, fermentation and distillation. From one ton of crop 0.0684 t (about 87 l) of bioethanol can be obtained. To produce bioethanol from wheat is necessary first to separate the straw, which may be used to produce biofuel too (from a ton of straw 0.261 t of bioethanol can be obtained). The wheat is then ground into flour, thus eliminating the bran. After the processes of hydrolysis, fermentation and distillation, the alcohol for the bioethanol is obtained. Even in this case the by-product can be used as animal feed. From a ton of wheat 0.29 t of bioethanol can be obtained [2].

The productivity of the plant and the outturn of biofuel production are the factors that should guide the choice of crop to use.

While, as regards the stage of production from agricultural biomass, steps, outturns, by-products and energy costs are known in details, the productivity of a crop can vary significantly. In fact, it depends on climate, soil characteristics, the use of fertilizer or not, farmer's expertise and exceptional conditions that can cause crop losses. Even data in the literature suffer from this situation and report different values within a range quite large. In addition, many of the works considered refer to places with different climate and characteristics of Italy, in particular the United States of America and Great Britain.

Since the crops considered are already farmed in Italy, it is appropriate to refer to productivities (t ha^{-1}) recorded in recent years [5]. The average values of last four years (2007-2010) are shown in Table 1. They are broken down by geographical area as productivity also depends on climatic factors.

Table 1

Productivities of the plant

Plant	Geographical area	Productivity [t $ha^{-1}y^{-1}$]
Rape	Northern Italy	2.6
	Central Italy	1.6
	Southern Italy	1.5
Sunflower	Northern Italy	3.1
	Central Italy	1.9
	Southern Italy	1.7
Soya bean	Northern Italy	3.3
	Central Italy	2.7
	Southern Italy	3.9
Sugar beet	Northern Italy	59.0
	Central Italy	45.3
	Southern Italy	41.5
Wheat	Northern Italy	5.5
	Central Italy	5.1
	Southern Italy	3.2

As it is clear from the 5th General Census of Agriculture (2000) in the decade 1990-2000 phenomena of abandonment of agricultural land and decrease of the number of farms have taken place. Therefore abandoned land is available for new crops, particularly for non-food ones. No definitive data of the last General Census of Agriculture (2010) also show a decrease in the utilized agricultural area (UAA), although with a less marked trend of the previous decade. Table 2 shows the hectares of UAA in the last 20 years, broken down by geographic area, and the resulting land now available for possible energetic crops.

Table 2

Utilized agricultural area (UAA): years 1990, 2000, 2010[6,7]

Geographical area	UAA [ha]			Land available [ha]
	1990	2000	2010	
Northern Italy	5,206,319.47	4,858,125.84	4,605,143.88	601,175.59
Central Italy	2,707,047.18	2,453,141.59	2,204,699.89	502,347.29
Southern Italy	7,132,532.00	5,901,384.71	6,075,342.13	1,057,189.87
Italy	15,045,898.65	13,212,652.14	12,885,185.90	2,160,712.75

3. Results

According to the productivity of the different plants, the possible maximum quantity of crop has been calculated for each geographical area. In Table 3 the amount of crop, obtainable if the whole Italian abandoned land were farm with the same kind of plant, is shown.

Table 3

Production of plant obtainable from the abandoned land

Plant	Production [t y^{-1}]
Rape	3,990,287.31
Sunflower	4,601,485.97
Soya bean	7,454,389.45
Sugar beet	102,092,955.32
Wheat	9,245,089.71

Starting from the previous data of crop production, biodiesel and bioethanol amounts are calculated, using the outturns of each plant. Moreover the total amount of energy (MJ y^{-1}) obtainable from the different plant is calculated too, considering that the biodiesel lower heating value is 37.8 MJ kg^{-1} and the bioethanol one is 26.72 MJ kg^{-1}. Data are shown in Table 4.

Table 4

Biodiesel and bioethanol amounts and resulting energy ones.

Plant	Biodiesel		Bioethanol	
	$t\ y^{-1}$	$GJ\ y^{-1}$	$t\ y^{-1}$	$GJ\ y^{-1}$
Rape	1,404,581.13	53,093,167	-	-
Sunflower	1,707,151.30	64,530,319	-	-
Soya bean	1,341,790.10	50,719,666	-	-
Sugar beet	-	-	6,983,158.14	186,589,986
Wheat (straw included)	-	-	3,959,959.27	105,809,945

As shown in Table 4, the maximum amount of biodiesel by farming abandoned land would obtain with sunflower oil, while the maximum amount of bioethanol would obtain with sugar beet culture.

After determining the maximum amount of biodiesel and bioethanol from dedicated crops obtainable in Italy, it is advisable to compare the results with the current energy consumption. As previously mentioned, biodiesel can be used in place of diesel fuel for vehicles or heating, while bioethanol can replace gasoline. It is to compare with each other different types of fuels, fossil and renewable, which have different densities and different calorific values. To make a comparable basis, it is necessary to refer to the toe, which means the necessary tons of oil equivalent to produce the same energy. The conversion factor used is as follow: 1 kJ $\rightarrow 23.9 \times 10^{-9}$ toe.

The potential energy contributions of biodiesel and bioethanol are shown in Tables 5 and 6, in which the consumption of diesel and gasoline for transport sector and diesel for domestic heating refers to the year 2007 [8].

Table 5

Potential energy contribution of biodiesel

Activities	Diesel consumption [ktoe]	Biodiesel [ktoe]	Biodiesel contribution
Transport sector	26,008	1,542	5.93 %
Domestic heating	2,282	1,542	67.58 %

As you can see in Table 5, biodiesel could replace a large share of diesel used for domestic heating, but it is necessary underline that nowadays in Italy more than 70% of energy for domestic heating comes from natural gas use, while diesel is used only for 13-14%.

Table 6

Potential energy contribution of bioethanol

Activities	Gasoline consumption [ktoe]	Bioethanol [ktoe]	Bioethanol contribution
Transport sector	12,466	4,460	35.77 %

A different raw material which can be used to produce bioethanol is constituted by byproducts of wine production. A study from 2006 by Nerantzis and Tataridis [9] has estimated that the amount of ethanol obtainable from wine production is about 6% of the whole amount of final product. In Italy the wine production of the last year was 44,693,177 hl [5] (considering that the wine density can be approximated to 1 kg l^{-1}, 4,469,317.7 t of wine have been produced during 2010). Starting from the byproducts of wine industry, according to Nerantzis and Tataridis, it is possible to obtain 268,159.06 t of bioethanol equal to 171 ktoe. The amount is not so relevant, therefore more assess would be needed to evaluate the economic convenience of obtaining bioethanol from wine industry by-products.

4. Conclusions

Considering the energy situation in Italy, it is necessary to evaluate the use of alternative energy sources. From the assessments made on the use of non-food crops for biofuel production emerges that the production currently achievable is far from which is the consumption of fossil fuels in Italy nowadays. This is especially true in the case of biodiesel for the transport sector, while it is interesting to note that if all the available land would be used for growing sugar beet, the resulting production of bioethanol could replace more than one third of current gasoline consumption. But it is necessary underline that production costs and excise duty on biofuel are hampering the development from an economic point of view.

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