UTILISATION OF BIOFUELS ON THE FARM

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1. INTRODUCTION

The recent increases in the cost of fossil fuels as a result of the strong energy demand of the fast industrially growing Asian countries and the on-going evolution of agriculture in Western countries, are leading to a more specific focus linked to energy issues in the rural areas with a possibly different perspective in respect of the past years. As a matter of fact, synthesizing the actual situation with focus on the rural environment, I would like to underline the following:

1 In Western industrial countries where renewable energy sources are provided incentives (i.e. Europe), the crops for energy production are considered as an opportunity to solve the low or even lacking profitability of the traditional crops;

2 In countries where agriculture is particularly developed and characterized by low costs (i.e. South America), the production of raw materials (sugar cane, soy bean, etc.) which can be partially addressed both to the production of fuels (ethanol, bio-diesel) and to food industry, is considered as a solution to better control the market trends. The Clean Development Mechanisms (CDM) deriving from the Kyoto protocol might have an impact on the picture in the mid-term;

3 In the rural least developed countries with a stagnating or depressed economy, the problem of energy (until now often partially solved through diesel generator units with the most different sizes – from a few kW up to 8-15 MW - become really tough and is damaging the development of the economically and socially less privileged groups in society.

In this very complex context, an issue of specific ad relevant interest for the scenarios (1) and (2) respectively is represented by the production of electricity on a small scale on rural level. More in detail:

- In Western countries the provision of incentives for the production of renewable electricity (Green Certificates, GC) is a reality (mainly deriving from the commitments contracted with the Kyoto protocol and the politics developed by the European Commission). In some European countries, for example, the GC may reach the value of 8/10 cent€ for kWh delivered to the network (to this value, the standard value of electricity – about 3/4 cent€/kWh - should be added). The mechanisms applied may be very different, and the attempt is to favour the small-medium size plants;

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- In the rural countries characterised by a weak economy (unfortunately the examples are various especially in Africa and in Asia) the production of electricity - actually limited by the high cost of the fossil fuels- is becoming an element of relevant importance for their social development and the consequent eradication of poverty. It is worth underlining how in these countries today the electricity is produced or sold with the same or superior- costs (in rural areas) if compared to those applied in the richest Western industrialised countries.

These further remarks lead to consider with interest, also in respect of the development of the mechanical and energy-targeted industry, the development of middle-sized machines and plants for the production of electricity from local sources of energy.
The subject is not new at all and a large bibliography is available on it. By the way, we would like to underline that :

- In the last years the technological offer from the industrialised Western countries in this sector has maybe been decreasing giving space to emerging economies (i.e. the Indian one);
- The remarkable development of the electronics allows today applications (also mechanical) that till a few years ago were unthinkable;
- The cost of fossil fuels (with special reference to diesel fuel) today is so high and the perspectives of its decrease so low to make the general interest much more relevant than it used to be in the past.

The production of electricity on a small scale is possible today with various solutions. The more feasible, generally speaking, seem to be the ones based on the use of biomass since it may be found almost everywhere (unlike for example wind energy and solar energy) and the electrical production may be relevant (from a few kW up to many MW). More in detail, the present available technologies for power generation which can be disseminated with reduced technical risk (from a general point of view) are: commercial turbines coupled with steam boilers; Otto engines coupled with gasifiers or boilers or fed with bio-fuels; ORC machines coupled with thermal oil boilers.
In Table 1 an overview of the technical aspects is underlined.

Among these solutions, in particular, the one based on the application of diesel generator sets modified for the use of vegetable oils seem to be very interesting. It is a technique that has been suggested several times but never developed in the proper way.
The current contribution aims therefore to focus on the issue.

2. POWER PRODUCTION BY VEGETABLE OILS: GENERAL CONSIDERATIONS

This solution shows the following positive aspects:

- Oleaginous crops are possible with all climatic conditions;
- The oil is extractable from oleaginous seeds with machines which might be very simple;
- The co-product from the pressing operation is a cake with an oil residue of 8-15% and it has often interesting characteristics to be used as a fertilizer or as feedstock;
- Diesel generator sets are globally not expensive in terms of investment, especially if compared to other technologies based on renewable sources;
- Their application is immediate;
- The changes requested for a proper operation with raw vegetable oils sometimes are not relevant.

Table 1. Power production from biomass with reference to small sizes: technologies and their main characteristics.

Technology	*GASIFIERS FOR THERMAL ENERGY PRODUCTION*	*OTTO/DIESEL ENGINES FED BY GASIFICATION GAS OR BIOGAS*	*OTTO ENGINES FED BY ALCOHOL*	*DIESEL ENGINES FED BY VEGETABLE OILS*	*STEAM SETS FED BY VARIOUS BIOMASS FUELS*	*STIRLING SETS FED BY VARIOUS BIOMASS FUELS*	*ORC (ORGANIC RANKINE CYCLE) FED BY VARIOUS BIOMASS FUELS*
Operative flexibility	Medium	Medium	High	High	Medium	Medium	High
Management	Relatively problem-free with the simplest versions (fixed-bed types)	Relatively simple when the gas is cooled and filtered	Similar to fossil fuel-fed models	Fairly simple when the oil has been filtered and degummed	Relatively simple depending to the working pressure.	Fairly simple when air is used as working fluid	Simple
Most obvious limitations	i) automatic fuel feeding may be complicated; ii) small devices require frequent start-ups and shut-downs; iii) the fuel has to be prepared	i) engine feed system has to be modified; ii) the use of fossil fuels could no longer possible; iii) engine cleanness has to be checked continuosly	i) possible mixture's instability (gasoline-alcohol); ii) traditional engines operating on alcohol alone have to be modified substantially	i) precombustion Diesel engines are better; ii) the components' condition must be checked constantly	i) treated water is necessary; ii) simplest models are based on reciprocating steam engines, not easy to find.	i) hard to find on the market;	i) hard to find on the market; ii) smaller machines are under development
Auxiliary machinery needed	Device for preparation of the fuel		Plant for alcohol production	Mechanical oil extractor	Plant for water treatment	Depending on the type of boiler	
Recommended technical solution and its technological level	Fixed-bed gasifiers	1500-3000 rpm/l engines with water cooling to make possible the thermal recovery and good fuel filtering. Self-exciting generators without sliding elements. Simple transformation (for the use of vegetable oils) does not require special equipment, but a good understanding of this field is still necessary. For the use of alcohol injection engines are recommended.			Technological level is connected to the working steam pressure	Engines are available in small numbers, then it is difficult to recommend a specific version	Thermal oil boiler working at 250-300 °C
Suggested fuel	Small, prism-shaped pieces of wood		-	-	Any type depending on the boiler	Depending on the boiler	Any type depending on the boiler
Energy yields (%)	2.5-3 m^3 of gas/kg of wood. 10-11 m^3 are needed to obtain the same energy potential of 1 kg of Diesel fuel	Biomass to electricity (small sized plants): 10-22%	Alcohol to electricity: 15-25%	Oil to electricity: 20-30%	Biomass to electricity: simplest models (small sized): 5%; improved models: 5-10%	Biomass to electricity: using helium as working gas: 20-30%; using air as w.g. 5%	Biomass to electricity (irrespective to the size): 12-15%

The negative aspects are mainly the following:

- The cost of oils is sometimes high;
- It is not easy to obtain an oil with the proper characteristics; i.e. with a low content of solid particles;
- It is necessary a certain basic knowledge to make a diesel engine with vegetable oils work.

The positive aspects are difficult to be monitored for the other cases (for example the production of electricity through a Rankine cycle) that seem in general to be more complex and above all more expensive in terms of investment, making therefore the solution particularly interesting. In the past specific engines have been designed for the use of raw vegetable oil (the Elsbett engine developed in the 80's maybe has been the most popular modern proposal in this sense) but the lack of a real market led gradually to the absence of an industrial offer.
Therefore, to encourage industrial initiatives, some typical examples of this application are analysed in the paper.

3. ENERGY BALANCE OF A CHAIN BASED ON THE UTILISATION OF SUNFLOWER OIL

In this paragraph is analyzed a chain that is currently proposed by the Technical University of Marche for Central and Southern Italy. The lay-out of the chain is described in Figure 1 respectively analysing 2 different realities.

Energy analysis of the field operations. To reach the target the energy inputs and outputs of the seed production phase have been defined through data on about 50 ha sown with sunflower. A split has been made between the fields managed by farm contractors (Table 2) and directly by the farmers (Table 3).

In the former case, the direct[1] consumptions represent about the 41% of the global consumptions, and a further 43% is represented by the energy content of the materials used for the fertilization (in direct[2] consumptions). In the latter case the direct consumptions affect global consumptions with a lower percentage (29%) while the indirect ones represent the 71% of the total. The 60% out of the 71% is the energy content of the materials used for the sole fertilization.
Therefore, a total value of about 21.260 MJ/ha of total energy consumptions has been recorded.
The seed then goes under the process of extraction where two products are obtained: the oil (usually about the 30-35% over its whole mass) and the oil seed cake (the vegetable part of the seed with an oil residue) that might be used as a livestock feed[3]. During the division process of the materials, the energy consumption is normally proportional to the mass object of the analysis, therefore in this case the total energy consumption is reduced to the value of 7.500 MJ/ha[4].

Extraction phase. The oil extraction process on small scale is made through first cold pressing normally with a mill[5] which substantially squeezes the seeds making the oil come out from the oil cells; the oil is then filtered and drained. In this case too to determine the energy requirements real tests have been made on a small oil pressing system designed for industrial purposes. The direct consumptions are represented by the electrical energy used for the extraction and filtration phases. The energy indirect costs are on the contrary referred to the primary energy used for the manufac-

[1] Mainly the consumptions of combustible and of lubricating oil of machinery and equipment.
[2] The energy consumptions "incorporated" in the materials and the machinery used for the cultivation. For the latter a sort of energy depreciation of the machinery is evaluated. In general, the highest value is referred to fertilizers.
[3] Owing to the need of improving the traceability of the food.
[4] These techniques are used in LCA methodologies. More in detail, a reference is made to "allocation".
[5] In industrial processes a chemical extraction washing the cake with exane follows .

ture of the materials of the mill, for the filters and for the pump. Globally, the former are about 1.066 MJ/ha, and the latter about 110,2 MJ/ha, with a total of about 1.176 MJ/ha. Also in this case the energy consumptions are allocated in two flows, and to the oil-one is assigned a global energy consumption of about 410 MJ/ha[6].

Table 2. Synthesis of the energy analysis on the seed production phase made by the farm contractors.

Crop management practices	*Indirect energy consumptions (MJ/ha)*					*Direct consumptions (MJ/ha)*	*Total (MJ/ha)*
	Tractors	*Implements*	*Fertilizers and seeds*	*Herbicides*	*Total*		
Ploughing	107	89,7			196,7	1.479	1.675,7
Harrowing	86	63,5			149,5	985,9	1.135,4
Rolling	23	34,8			57,8	265	322,8
Water irrigation	5	7,9			12,9	114	126,9
Seeding	32	3,7	70		105,7	379	484,7
Harrowing	13	3,3			16,3	151	167,3
Fertilizing	10	1,10	14.900		14.911,1	61	14.972,1
Weeding	8	2		1.512	1.522	95	1.617
Threshing	529				529	1.331	1860
Transport	25	8			33	2.355	2388
Total					*17.534*	*7.215,9*	*24.749,9*

Table 3. Synthesis of the energy analysis on the seed production phase made directly by the farmers.

Crop management practices	*Indirect energy consumptions (MJ/ha)*					*Direct consumptions (MJ/ha)*	*Total (MJ/ha)*
	Tractors	*Implements*	*Fertilizers and seeds*	*Herbicides*	*Total*		
Ploughing	205	92			297	2.840	3.137
Harrowing	75	79			154	1.420	1.574
Seeding	75	462	70	1.211	1.818	521	2.339
Fertilizing	6	1,10	7.586		7593,1	61	7.654,1
Threshing	529				529	1.331	1.860
Transport	21,5	6			27,5	1.189	1.216,5
Total					*10.418,6*	*7.362*	*17.780,6*

Energy conversion. The high energy content of sunflower oil (LCV of about 38 MJ/kg) is transformed into electrical energy by diesel engines. The bibliography on the subject points out how these applications are limited, but their possible use is underlined. Tests are being made on generator units with a power from 120 to 350 kW_e outlining interesting results and the real possibility, with slight changes, to use diesel engines[7].The energy analysis underlines how the energy consumptions of the transformation are basically (besides the engine's lubricating oil) the indirect ones which are estimated to be about 400 MJ/ha.

Energy balance. In Table 4 is outlined the global energy consumption of the chain which is about 8.310 MJ/ha. Considering the production of seeds and the average yield of the generator units the output in terms of net electrical energy is about 2.500 kWh. Therefore, the energy consumption necessary to generate 1 kWh of electricity is about 3,32 MJ (which is 0,92 kWh of primary energy).

[6] As unit of reference the hectare is used, where, under average conditions, about 2 t of seeds might be obtained.
[7]In synthesis, the vegetable oil, when compared to diesel fuel, shows a higher viscosity, and a different behaviour both with the materials which the engine is made of (above all the plastic and rubber components) and with lubricating oils. The viscosity is checked with the temperature of the combustible (which may be increased up to 90 °C); the problems with the materials are solved through the substitutions with proper products and depletion of lubricating characteristics trying to limit the losses of vegetable oil and avoiding the use of the specific vegetable oils which might produce polymerisation phenomena (as for example soy oil).

It is worth underlining then how the production of one unit of electricity, even considering all indirect consumptions, needs an investment, in terms of fossil resources, remarkably lower in respect of the investment necessary for the standard technologies used today[8]. Such consumptions might by the way be significantly reduced above all in agricultural processes.
The environmental balance – limited to greenhouse gases – outlines how the production of 1 electric kWh implies CO_2 emissions of about 0,24 kg.

Table 4. Synthesis of the total consumption (direct and indirect).

Phase	*Total energy consumption (MJ/ha)*	*Incidence rate (%)*
Agriculture	7.500	90
Oil extraction	410	5
Energy conversion	400	5
Total	*8.310*	*100*

[8] As a matter of fact, the system object of the analysis is a sort of “cycle” with an efficiency of about 110 % against an average maximum rate of 45% (considering the indirect consumptions).

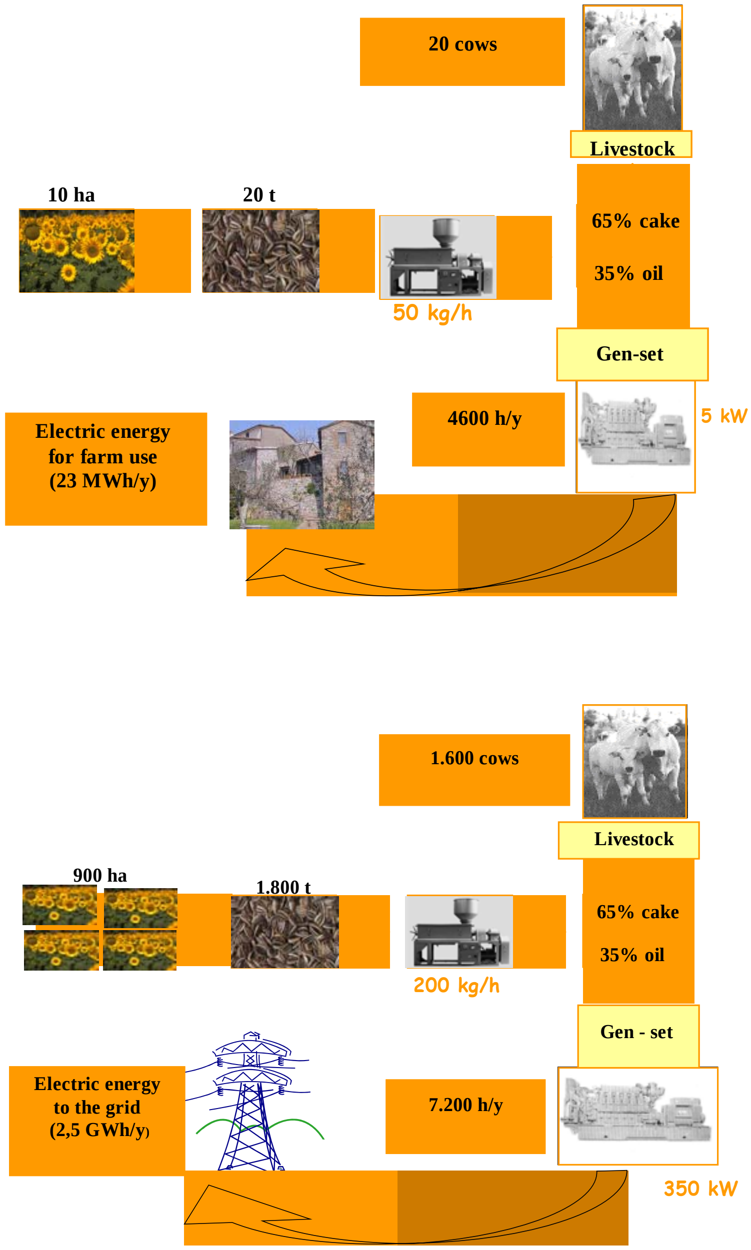

Figure 1. Basic figures for energy chains based on the transformation of sunflower oil into electricity. These layouts have been proposed for Italy and the bigger system (350 kW) is considered the most interesting by the final users.