HELIA, **30**, Nr. 46, p.p. 85-102, (2007) UDC 633.854.78:631.527.85(631.421)
DOI: 10.2298/HEL0746085R

THE COGENERATION FARM

Rosa, F.*

Veterinary School of Medicine, University of Udine, Via delle Scienze 208, 33100 Udine, Italy

Received: October 10, 2006
Accepted: May 15, 2007

SUMMARY

The increasing demand for energy, growing scarcity of fossil fuel and environmental concern have stimulated the policy makers in US and Europe to search for alternative sources of energy and the agricultural sector can be a viable solution to this problem. This analysis is addressed to the study of a feasibility of the agro-industrial chain, including farms and industrial plants, to produce biofuel as though it were an "island economy", *i.e.*, a net energy exporter only if the energy and economic values of the **biofuel** and its co-products exceeds that of all direct and indirect energy inputs. More specifically, the analysis is dedicated to economic, energetic and ecological aspects of the energy cogeneration approach that complete the "Island Model"' and demonstrate to be more sustainable to afford competitively the economic and energetic problems. This model is based on sunflower crop used for production of biodiesel, while the co-product sunflower meal is used in the dairy production, the wastes are recycled in biogas production to generate electricity and heat, and the final residual compost is used for fertilization. This integrated farm energy cogeneration project (IFECO) requires to analyze the different steps of the agro-industrial chain and to afford investments in energy plants and operating costs; to manage the integrated agro-industrial energy chain more skilled labour is required; hence, the convenience to operate IFECO will depend on the capacity to organize and coordinate the many activities performed at different chain steps, with achievement of scale and scope economies. The macroeconomic targets as occupation, value added, import of energy products and inflation, justify the public intervention in programs directed to biodiel defiscalization and support of the energy crops such as soybean, sunflower and others. The results obtained from IFECO suggest that the total energy produced by sunflower chain is significantly superior to the energy spent, the economic gain is reflected in a considerable increase in the annual income and value of land from capitalization of permanent net farm income; finally, the life cycle GHG savings from displacing the fossil fuel (reduction in CO, VOC, PM10, SOx, Nox) are a valuable contribution that ameliorate the ecological conditions of the biosphere and must be considered as a market value if the Kyoto Protocol is to be applied.

Key words: renewable energy, biodiesel, cogeneration, sunflower

* Corresponding author: Phone at office: 0432-558314; cellular: 320.43.65.951; e-mail rosa@uniud.it

INTRODUCTION

The environmental concerns about fossil fuels and energy security have spurred the search for renewable energy and they convinced the policy makers to provide incentives for domestic biofuels production. To be a viable substitute for a fossil fuel, an alternative fuel must have: i) superior environmental benefits over the fossil fuel it displaces, ii) must be economically competitive, iii) must be producible in sufficient quantities to make a meaningful impact on energy demand, and it should also provide a net energy gain over the energy sources used to produce it. According to a study published by Hill *et al.*[**] in the Proceedings of the National Academy of Sciences, USA, based on data from farm balance, farm energy and fuel prices, it was demonstrated that the biodiesel from soybeans produces usable energy and reduces greenhouse gases more than the corn-based ethanol, making it more deserving of subsidies. The authors demonstrated the positive balance of energy, the economic competitiveness and the possibility to produce large amounts of biofuel without competing with traditional food markets; specifically, while the ethanol yields 25% more energy that the energy requested for production, the biodiesel balance is active for more than 93%. Regarding the emission figures, the biodiesel releases just 1%, 8.3% and 13% of the agricultural nitrogen, phosphorus and pesticide pollutants, respectively, per net gain energy. Compared with fossil fuels, the greenhouse gas emission is reduced by 12% with bioethanol and 41% with biodiesel. The advantages of biodiesel in respect to ethanol are the lower agricultural input (the need for nitrogen fertilizer by soybean is almost zero) and better conversion of feedstock to fuel. The limit of biofuel is the supply: even investing the entire agricultural land to produce soybean and corn, the biofuels supply would satisfy only 12% of gasoline and 6% of diesel demand. Transportation biofuel such as synfuel hydrocarbons or cellulose ethanol, if produced from low-input biomass grown on agriculturally marginal land or from waste biomass, could provide much greater supplies and environmental benefits than food-based biofuels.

Many US and EU farmers and their professional associations are presently in favor of the development of green energy markets from agricultural commodities. The USA (see the *Clean Air Act Amendments (CAA) of 1990* and the *Energy Policy Act of 1992)* and EU support the biofuels development by reducing the rate of excise duty for pure or blended fuels. Back in 2003, the EU Commission adopted a biofuels directive setting indicative targets: by 2005, the minimum share of biofuels should be 2% and it should gradually rise to 5.75% by the year 2010 (these quantitative commitments have not been applied before 2005 in order to allow enough time for member states to establish the needed production facilities). The mid-term renewable energy targets programmed in the EU require the investment, at the EU level, of 9% of the agricultural land of which:

** Departments of Ecology, Evolution, and Behavior and Applied Economics, University of Minnesota, St. Paul, MN 55108; and Department of Biology, St. Olaf College, Northfield, MN 55057

1. for biodiesel - 10 million ha invested in oleaginous plants to produce 14 billion l of biodiesel;
2. for ethanol - 5,1 million ha invested in cereals (corn, sorghum) and 0,6 million ha for sugarbeet to produce 13 billions l of bioethanol.

Market perspectives

In 2004, EU biodiesel production used about 4.1 MMT (million t) of rapeseed, or 27%, of a record EU crop of 15.3 MMT. In 2004, the EU harvested oilseeds at an estimated 7.5 million ha of which 60% was rapeseed, 29% sunflower seed, and 4% soybeans. The EU biofuel policy is more favorable to biodiesel production compared with ethanol due to climatic conditions that make the oil production from canola, soybean and sunflower more convenient and due to the higher productivity of biodiesel industrial process.

Prices quoted this year in major representative markets are 20% higher than the past year; the canola oil quoted at Rotterdam future in May 06 reached 680 $/t FOB, an increase of 30% in respect to the past year. This market situation for canola has determined the shift in demand for human consumption of sunflower oil that at current market conditions costs 160 $/t less than canola oil. According with the estimates of European Biodiesel Board, the EU biodiesel production in 2005 was 3.2 million t, an increase of 65% compared with 1.9 million t produced in 2004; for the year 2006 the production is expected to exceed 6 million t and imports to decline from 850 to 700 thousand t. Major producers are: Germany, with 1.7 million t obtained from canola production (+61%); France, 492 thousand t (+40%); Italy, 396 thousand t (+24%); Czech Republic, 133 thousand t; others, 494 thousand t cultivated in France, followed by Hungary and Spain. For this year, an increase of 2.2% in acreage is expected, corresponding to 2.1 million ha and the production estimated to increase +7%. Romania and Bulgaria are the main extra UE producers of sunflower.

Table 1: Biofuel production by member states

Country	Biodiesel			Ethanol			Total		
	2002	2003	2004	2002	2003	2004	2002	2003	2004
Germany	534	848	1226	0	0	26	534	848	1252
France	432	424	413	114	102	129	546	526	542
Italy	250	322	379	0	0	0	250	322	379
Spain	0	8	15	223	201	246	223	209	261
Denmark	11	49	83	0	0	0	11	49	83
Czech Republic	83	83	72	8	0	0	91	83	72
Austria	30	38	68	0	0	0	30	38	68
Sweden	0	0	0	64	64	64	64	64	64
The Netherlands	0	0	0	83	76	45	83	76	45
United Kingdom	4	11	11	0	0	0	4	11	11
Slovak Republic	0	0	19	0	0	0	0	0	19
Lithuania	0	0	8	0	0	0	0	0	8
Intervention stock	0	0	0	0	87	110	0	87	110
Total	1344	1783	2294	492	530	620	1836	2313	2914

Source: Eurobserver no. 167, May June 05

While the oil yield per ha obtained from different oilseed commodities fluctuates in a wide range between countries and regions, the basic productivity of the palm oil is a significant economic feature with a yield of about of 4 t/ha. In Europe, the rapeseed (assuming a 40% oil content and a gross yield of 3 t/ha) has an oil yield of about 2 t/ha and the sunflower seed (assuming a 45% oil content and a gross yield of 2.4 t/ha) has an oil yield of 1.08 t/ha while the high oleic variety has a yield of 1.2 t/ha almost the same as rapeseed under optimal conditions. To put in another way, one ha of oil palm can meet the vegetable oil needs of 133 people compared with 40 people from one ha of rapeseed and 19 people from one ha of "traditional" sunflowers (assuming 30 kg per head annual seed oil consumption in the European countries). Actually, the economic role of sunflower production is more complicated, notably by ecology and joint production factors.

The USDA Outlook for the oil commodity production 2006/07 made in June 2006 confirmed the growth of canola (*Brassica napus*) to 4.88 million ha in the 25 EU countries. Also the soybean investments were growing at a rate of 12% from 273 to 305 thousand ha while the expected production was estimated to reach 943 thousand t. Sunflower acreage increased by 2.2 but the production increased by 7.4%.

Table 2: Outlook for the oil seed in the EU-25

Commodity	2005/06	2006/07	% Change	Commodity	2005/06	2006/07	% Change
Investment in 000 ha: absolute values				Investment in 000 ha: %values			
Soybean	0,273	0,305	11.72	Soybean	3,87	4,21	8.78
Canola	4,762	4,876	2.39	Canola	67,53	67,32	-0.31
Sunflower	2,017	2,062	2.23	Sunflower	28,60	28,47	-0.46
Total	7,052	7,243	2.71	Total	100.00	100,00	0.00
Production in 000 t: absolute values				Production in 000 t: % values			
Soybean	0,874	943	7.89	Soybean	4.37	4.69	7.42
Canola	15,417	15161	-1.66	Canola	77.03	75.41	-2.10
Sunflower	37,24	4000	7.41	Sunflower	18.61	19.,90	6.94
Total	20,015	20104	0.44	Total	100.00	100.00	0.00

Source: our elaboration on USDA data

Table 3: Production in t per ha and energy conversion of major oil crops

Product	t/ha	Conversion ratio	Biodiesel*,t	Energy, MJ**	Co-products, t	Energy, MJ	Total
Canola	3.0	30-38%	1.08	39,420	Glycerine (0.09) Meal (1.02)	1,575 15,300	56,295
Sunflower	2,5	45%	1.25	40,150	Glycerine (0.11) Meal (1.25)	1,925 21,000	63,075
Soybean	3,4	20%	0.7	25,550	Glycerine (0.13) Meal (2.00)	2,275 30,000	57,825

* Biodiesel production is obtained from the transesterification reaction
** the following energy conversion index in MJ/t were used: biodiesel: 36.500; meal: 15.000; glycerine: 17.500.
Source: our elaboration from different sources of data.

Table 3 reports the data about the average yield per ha and the corresponding energy production of the most widely cultivated oleaginous commodities in Europe.

Oil prices of biofuel commodities

The valuation of the oil component of most oilseeds is subject to a varying degree of pricing pressure from the main alternative source of vegetable oils. The major share of receipts from rapeseed and sunflower production is from the oil component and prices which usually follow that of palm oil working as a leading indicator of the oil market; though in the EU sunflower seed oil usually has premium over soybean or palm oil. Price trends suggest the following considerations: prices of different commodities grow over time and fluctuate quite closely as suggested by Pearson correlation coefficients and by the RMSE computed on the margins. The price-time series seems to be cointegrated and the prices follow the leading indicator, palm oil price driving the other prices. This situation makes easier to predict the evolution of bio-fuel markets in the coming years and the experts have statistical instruments to suggest to the farmers the best decisions to optimize the cultivation.

Table 4: Price (cent/pound) of US vegetable oil and fats

Year (b)	Oil price of different biofuel commodities (a)										
	Soybean	Cotton -seed	Sunflower	Peanut	Maize	Rape	Lard	Ed. Tallow	Mean	S.D	C.V
94/95	27,51	29,23	28,1	28,9	26,47	28,55	N/A	N/A	28,13	1,01	0,04
95/96	24,7	26,53	25,42	40,3	25,24	29,05	21,7	21,56	26,81	5,97	0,22
96/97	22,51	25,58	22,58	43,7	24,05	25,68	23,02	23,01	26,27	7,16	0,27
97/98	25,83	28,85	27	49	28,94	28,83	19,46	20,69	28,58	9,05	0,32
98/99	19,8	27,32	20,15	39,74	25,3	22,48	14,66	15,14	23,07	8,05	0,35
99/00	15,59	21,56	16,68	35,39	17,81	17,1	13,64	13,21	18,87	7,16	0,38
00/01	14,15	15,98	15,88	34,81	13,54	17,56	14,61	13,43	17,50	7,14	0,41
01/02	16,46	17,98	23,25	32,52	19,14	23,45	13,55	13,87	20,03	6,28	0,31
02/03	22,04	37,75	33,11	46,7	28,17	29,75	18,13	17,8	29,18	10,00	0,34
03/04	28,76	32,8	32,07	63,59	28,14	0	26,4	27,07	29,85	17,18	0,58

[a] Source: Ash *et al.* (2003).
[b] The year is beginning in October.

The integrated farm energy cogeneration project (IFECO)

Economic, ecologic and energy balances validate the farm strategy to produce renewable energy with the cogeneration approach defined an energy-efficient and environmentally-friendly method of producing at the same time different forms of energies likely: fuel, electricity (power), steam and/or heath in one process. With only one fuel it can be reached a system efficiency exceeding the 60%. Fuels used in cogeneration include natural gas, fuel oil, propane, bio-mass, bio-waste, and renewable energies such as wood or wood waste. The purpose of this application is to demonstrate that the integrated farm cogenerative energy approach (IFECO) will contribute to a significant improvement in the economic and energy balance by integrating physical, chemical, biochemical and physiological processes (trans-esterification, photosynthesis, ruminant metabolism and microbiological digestion) to produce alternative energies from products generated by agricultural activities performed in a unique farm: oil, biofuel, meal, dairy products, biogas (heat and electricity), composts, marketable in different market outlets. This farm, integrated in the Agro-Industrial chain, will be able to increase farm incomes and the energy balance and will mitigate the greenhouse effect (GHG). This approach may require the collaboration between the government, industry and farmers to optimize the value of energy production and it is justified by domestic and international advantages: i) expected macro economic targets given by the contribution of agriculture to GNP and occupation, new jobs created along the agro-industrial chain, reduction in commercial deficit balance due to fossil oil imports, and creation of marketable intangible goods represented by the clean environment; ii) microeconomic targets represented by increase in farm incomes, more market opportunities for farm commodities, increase in land market value; iii) at international level, new market opportunities are opened for the new countries such as Romania, Bulgaria, Slovakia, Serbia having great agricultural potentials.

The integrated farm energy cogeneration project (IFECO) focalizes the different farm integrated activities that make easier and less costly to transform the farm products into alternate forms of energies. The project includes:

1. the agro-industrial oil chain with: a) sunflower cultivation of high oleic varieties; b) industrial plant for mechanical extraction with crushing and chemical extraction with hexane; c) the oil conversion in biodiesel.[***] Two co-products are obtained with biodiesel production: high-protein meal used as animal feed and glycerine used in the cosmetic industry.
2. the dairy enterprise, to use the sunflower meal to feed cows;
3. the biogas plant, to recycle the liquid and solid wastes obtained from the dairy activity, used: 1) to produce heat of which a quota is recycled in the farm and the rest is distributed to local communities; 2) to produce electricity to be sold to the general contractor. The organic residual of biogas fermentation is used as organic fertilizer. For this project, the cogeneration requires the sunflower cultivation that in Italy matches with local agronomic and climatic conditions. The following conditions are required:
   - a minimum acreage dedicated to the cultivation of energy crops, sufficient to exploit the scale economies;

*** Experiences in Germany demonstrate that the canola oil can be used directly in endothermic combustion engines

- the constitution of a farm network to feed the industrial plants with a minimum efficient size to achieve scale economies;
- the participation of farmers in biofuel chain decisions and profit distribution;
- easy connection with the electric network and clear rules for energy payment (agreement with GRTE);
- agreements with local communities for heating distribution and facilities;
- participation of the government institution in the cogeneration farm project.

Life Cycle Environmental Effects

Biofuel production implies a negative environmental impact through movement of agrichemicals, especially nitrogen (N), phosphorus (P), and pesticides, from farms to other habitats and aquifers. Agricultural N and P are transported by leaching and surface flow to surface, ground water, and coastal waters causing eutrophication, loss of biodiversity, and elevated nitrate and nitrite in drinking-water wells. Pesticides can move by similar processes. Data on agrichemical inputs for corn and soybeans and on efficiencies of net energy production from each feedstock reveal, after partitioning these inputs between the energy product and co-products, that biodiesel uses, per unit of energy gained, only 1.0% of the N, 8.3% of the P, and 13% of the pesticide (by weight) used for corn grain ethanol. Low levels of biodiesel blended into fossil diesel reduce emissions of VOC, CO, PM10, and SO_x during combustion, and biodiesel blends show reduced life-cycle emissions for three of these pollutants (CO, PM10, and SO_x) relative to fossil diesel.

The sunflower oil chain: energy input and cost

To represent the sunflower chain, ha was taken as the reference unit measure for the computations. The sunflowers numbers are: 2,5/50/45; this means that, in normal conditions, one ha of high oleic sunflower renders 2.5 t of seed and assuming the 50% of oil rent and a 95% of oleic acid from mechanical extraction the total amount of oleic acid produced from one ha of sunflower is $2.5\times0.50\times0.95=1.1875$ t, and the meal is 1.313 t. The chemical extraction with hexane will produce additional 5% of oil equivalent to 1.313 t$\times$0.05=65.65 kg; hence the total oil produced is 1.253 t (50.12%), the integral meal is 1.247 t (49.88%) and the final sum is still 2.5 t. Without making a large error it can be assumed that 50% of the seed weight is oil[****] and the other 50% is integral meal. If the tegument is taken away from the integral meal, the composition will be the: Oil=1.253 t (50.12%) corresponding to 1.424 liters (see the density coefficient); cleaned meal=1.105 t. (44.20%); teguments=0.142 (5.68%).

**** The oil weight is transformed in liter by using the density coefficient 1.145.

The trans-esterification reaction requires oil and methyl alcohol to produce bio-ester and glycerin in the following proportions: 1 t oil+0.1 t methyl alcohol+catalyst=1 t biodiesel+0.1 t glycerin. For one ha invested in sunflower we obtain 1.253 t biodiesel that has an energetic conversion ratio equal to 1:3.2 (US Ministry for Energy) meaning that for each unit of fossil fuel consumed 3.2 units of energy are obtained; considering the entire consumption of energy the ratio will be reduced to 1:1.9. The conversion efficiency ratio will depend on genetics, photosynthesis, agronomic and climatic conditions.

Table 5: Sunflower energy inputs * and costs per ha

Item	Unit	Quantity	Kcal/unit	Kcal ×1000	Mj/ha	MJ/liter	Cost $/ha	Cost Euro/ha
Production stage								
Farm household energy use	hour (a)	8.6	40.000	344	1.44	0.05	111.80	86.00
Machinery production	Kg (b)	15	24.000	360	1.51	0.04	95.00	63.05
Farm fossil fuel	liter (c)	180	10.000	1800	7.54	0.22	93.62	82.00
Nitrogen	Kg	60	17.600	1056	4.42	0.13	35.00	26.92
Phosphorus	Kg	30	4.113	123	0.52	0.02	19	14.77
Potassium	Kg	34	3.176	108	0.45	0.01	11.33	8.72
Lime	1000 Kg	0	0.000	0	0.00	0.00	0.00	0.00
Seed	unit (d)	1=5 kg		450	1.88	0.06	27.00	20.77
Herbicide/pesticide	Kg	3	100.000	300	1.26	0.04	45.00	34.62
Electricity	Kwh	10	2.900	29	0.12	0.00	1.10	0.85
Crop and biofuel transport	Kg	675	0.252	170	0.71	0.03	81.00	62.31
Total production stage				4740.38	19.85	0.60	520.05	400.00
Sunflower yield = 2.5 t/ha	Kg	2500	2.000	5000.00				
kcal output/input				1.05				
Processing stage								
Sunflower	Kg	2500		16000		0.221	450.00	346.15
Electricity	Kwh	270		700		0.010	19.00	14.62
Steam	Kcal	1350000		1350		0.019	11.00	8.46
Cleanup water	Kcal	160000		160		0.002	1.30	1.00
Space heat	Kcal	152000		152		0.002	1.25	0.96
Direct heat	Kcal	440000		440		0.006	3.60	2.77
Losses	Kcal	440000		300		0.004	2.50	1.92
Stainless steel	Kg	300000		160		0.002	18.70	14.38
Steel	Kg	11		250		0.003	18.00	13.85
Cement	Kg	20		100		0.001	19.00	14.62
Total processing stage				19612		0.271	544.35	418.73

(a) assuming a person works 1800 h/year, utilizes an average of 8 thosand liters of oil equivalent and labor paid $13/h or 10Euro/h

(b) Pimentel data, 1996; machinery is rorated per ha and 10 year life cycle;

(c) caloric power is 10 thousand Kcal/l

(d) assuming 10 thousand kcal/kg

Table 6: Energy balance

Product	Input	Output	Rent
Biodiesel	0,27	1,00	3,70
Meal and Glycerine	0,60	0,66	1,10
Total	0,87	1,66	1,91

Sunflower meal and the cattle diet

Sunflower meal is used in cattle diet to provide the daily quantity of protein to satisfy the daily nutritional intake of a cattle in lactation; a current diet includes 20 kg of fiber of which, 3.5 kg (17%) must be represented by protein intake, hence the annual consumption is estimated at 7.3 t of total fiber and 1.2 t of protein. Assuming a daily consumption of 1.5 kg of integral sunflower meal (3/7 of the protein fraction) and 2 kg of pure sunflower meal (4/7 of the protein fraction) the protein requirement for one year is 0.50+0.65=1.15 t; for this it is required to have 1.025 t of sunflower seed (41%) to produce the integral meal and 1,475 t (59%) to produce the pure meal. The suggested ratio between integral floor and pure meal is approximately 0.75.

The UF***** requested by cattle in lactation is 820 UF/t of dried matter that is supplied with:

- Integral meal: 0.5 t×820=410 UF=5437.5 MJ;
- Pure meal: 0.65 t×820=533 UF=7115.5 MJ.

The caloric intake is measured with the relation: 1 UF=2100 Kcal; it can be estimated the annual consumption of calories for a cow equivalent to 10×10^6: or 10 megacalories; the milk has a caloric value of 65 kcal/liter, the annual production is 10,000 liters equivalent to 650 thousand and calories or 0.6 megacalories the ratio between production and consumption is 1:10.

From the waste produced in one year by a head of cattle weighting around 600 kg it can be obtained 304 m^3 biogas.

Table 7: Values of biogas and energy

Animal waste	Average production (m^3/kg L.W.)*	Total production (m^3)	Total production (t)	Biogas (m^3)	Electric energy (kwh)	Total Electric energy**	Thermal energy (kwh)	Total thermal energy **
Liquid waste	0.023	13.80	13.80	207	372.60	545.50 kwh (1,964 MJ)	745.20	1.091 kwh (3,928 MJ)
Solid waste	0.016	9.60	2.88	97	172.90		345,.70	

*conversion coefficient by ERSAL (Ente Regionale di Sviluppo Agricolo della Lombardia) for the computation of the average annual production of animal waste http://www.aquanetpc.it/download/files/cd_01/7_modelli_IPNOA.pdf)
**1 kWh=3,6 MJ
Source: our elaboration from data of AA.VV., year 2005.

***** UF is the unit measure of the caloric power of a ruminant diet.

Table 8: IFECO Energy production

Item	Unit	1 Ha	10 Ha	100 Ha	1000 Ha
Sunflower seed production	t	2.50	25	250	2500
Oil production (extraction with crushing and hexane)	t	1.25	12.5	125	1250
Meal production	t	1.25	12.5	125	1250
Cows (nc)	Number	2	20	200	2000
Electric power generator eg=kw/cow)	Kw	0.6	0.66	0.72	0.80
Working time per year=h/day × gg)	Hour	5000	6000	6500	7200
Electric energy produced per year (nc × eg × h × 0.3)	MWh	1.8	23.8	280.8	3456.0
Termic energy produced per year	MWh	1.64	21.66	255.5	3145

Table 9: Farm Production per ha and per year

	Unit of measure	Production
1) Sunflower seed cultivation	t	2.5
Of which:		
Seeds for integral meal	t	1.025
Seeds for clean meal	t	1.475
Integral meal	t	0.600
Clean meal	t	0.650
Total meal	t	1.250
2) Dairy activity	Unit	1
Production of milk (two cows)	t	20
Production of meat (two calves)	unit	2
3) Biogas production		
Production of slurry	m^3	13.80
Production of manure	m^3	9.60
Total production of biogas	m^3	0.304
Cows (nc)	Number	2
Electric power generator eg = kw/cow)	Kw	0.6
Working time per year = h/day × gg)	Hour	5000
Electric energy produced per year (nc×eg×h×0.3)	MWh	1.8
Thermal energy produced per year	MWh	1.64

Finally we present the total energy production per ha and per year of the biodiesel chain.

Table 10: The energy produced from the sunflower chain per ha and per year

Energy produced per Ha and per year		
Item	Kcal × 1000	MJ
Biodiesel (1)	10,000	41.87
Sunflower meal (2)	1,760	7.12
Electricity from biogas	1,548	6.48
Thermal energy from biogas	1,410	5.90
Milk: 2 cows producing 20 t milk (3)	1,300	5.44
Total	16,018	66.82

(1) 1000 Kg of biodiesel has an energy equivalent of 9 million kcal; assuming the production per ha of 1.20 t the total energy is $1.20\times9\times10^3$=10 million kcal;
(2) The sunflower meal contains 600 UF/t and the energy of 1 UF corresponding to 2100 kcal; then the energy value is 2100×600×1.4=600 UF/t
1 Kcal=4.18 J; 1 Kwh=860 Kcal=3.6 MJ=3.6×10^6J; see: http://www.unit-conversion.info/energy.html
(3) The energy contained in the milk is 65 kcal/liter'; hence the total energy per ha is 20000×65=1.3 million calories

Economics of biogas production

For the economic analysis, some assumption must be made about the investment and operational costs involved in biogas production. These costs change depending on technologies used, K/L ratio and plant size, management organization, contractual relations and others. While the estimates about biodiesel production are sufficiently supported by empirical data, the biogas production and use are relatively recent: the fermentation efficiency depends on the substrate composition and control of environmental conditions. Slurry and manure are the final products of the animal metabolism; eventually mixed with other organic materials, like corn, grass, lard and others these are fermented in an anaerobic process (microbial digestion) to produce biogas. The amount of waste produced varies with the type of animal, but on the average it ranges between 60 and 85 kg (wet basis) per 1,000 kg live animal mass per day in intensive production systems. The energy potential of these wastes is given by the volatile solids (organic matter) content, which ranges from 10 to 18% of the total wet waste or 75 to 85% of the dry weight (ASAE, 1997). The energy potential of the manure produced was evaluated using the following formula: 12×1012 to 25×1012 Btu annually depending on the method used for conversion (Parker *et al.*, 1997). This equates to 12 to 25 billion cubic feet of natural gas annually. The esothermic reaction is described as follows:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + 886 KJ (212 Kcal)

The caloric power varies between 18.81 MJ/m^3 (4,500 kcal/m^3) and 27.17 MJ/m^3 (6,500 kcal/m^3) (Bandieramonte *et al.*, 1998).

Here follow the results of a biogas production plant.

Biogas production: technical evaluation

Category: Cows

No. of heads: 1000

Average live weight per head: 650

Table 11.1: Sludge production of the herd

Sludge production					
Liquid		Solid total		Solid volatile	
kg/p.h./d	tot Kg/day	%	tot Kg/day	% d m.	tot Kg/day
55	55,00	10.06	5,831	90	5,247

kg/p.h.×d=kg per head per day
d=day
p.h.=per head
SV=solid volatile
d.m.=dried matter

Table 11.2: Fermentable material

Material introduced	Quantity introduced		Total solid waste		
	kg/day	%	%	change	kg
Milking water	40.001	42.1	3.00	0.5-3	1.2
Sludge	55.001	58	10.06	6-20	5.830

Table 11.3: Biogas and methane production

Solid volatile			Biogas production			Methane production		
% d.m.	Range	Kg	mc/kg SV	Range	mc/day	%	mc/day	Total mc/year
85	65-90	1.02	0.35	0.32-0.36	357	58	207	75,555
90	65-90	5.247	0.35	0.32-0.36	1,835	58	1065	388,725

Table 11.4: Energy production

Generator efficiency	%	38
Thermal energy used	%	40
Thermal energy dissipated	%	10
Thermal energy used	%	10
Thermal energy dissipated	%	1
in use	hour/day	24
in use	day/year	340
in use	hour/year	8.16

Table 11.5: Energy production

Electricity				Heating			
Power		Energy		Power		Energy	
Gross	Net	Day	Year	Gross	Net	Day	Year
kw e	kw e	kwh e	kwh e	Kw th	kw th	kw th	kw th
190	169	4,062	1,381	310,300	155,200	3,724	1,266

The energy market in Italy is regulated by law: presently the value of Green Certificate (GC) is determined by the Legislative Decree no 79/99, (hereinafter named the "Bersani Decree"), that obliges all energy users or producers to insert, since the year 2002, in the national electric network at least 2% of the total amount of energy used in previous year in form of renewable energy. To obtain this result, interested operators are required to file the GC with the Administrator of the National Circuits Network (hereinafter "the Administrator"). A new law 239/2004 (Marzano Law) reduced the amount of “Green Certificate”, to 50 MWh previously fixed to 100 MWh. The price of GC for 2004 was approximately 10 Eurocent/KWh and is currently increasing.

Table 12: Economic balance of biogas production for 1000 cows

Income	Unit value Euro/Kwh	Kwh	Total value	Note
Green Certificate	0,10892	1.80	0.196	average
Self-consumption			1.8	average
Electric energy sold	0,08	1.80	0.144	AEEG 34/05
Electric energy purchased		0	0	average
Thermal energy sold	0	1.64	0	average
Total income			265,030	year
Costs per head	Euro /day			
Maintenance	75.34		24,862	average
Biomass	0		0	average
Industrial water	0		0	average
Labor	0		0	average
Other			0	average
Total costs			24,862	year
Net cash flow				
Total income			265,030	year
Total costs			24,862	year
net cash flow			240,167	year
Investment				
Total			684,681	
State contribution			0.000	
Net investment			684,681	
PBP (Pay back period)			2.9	year

Evaluation of the sunflower biodiesel chain in Italy

The economic analysis is the balance of the different steps of the sunflower chain. The cost analysis is a full costing using the “activity-based costing” scheme that allows to obtain the information about the costs of activities performed by the plants working at different steps of the agro-industrial chain. The following assumptions are made:

1. values are referred to one ha and to the year 2005,
2. the farm is a dairy farm of average size estimated at 100 ha situated in Pianura Padana using the practice of cultural rotation;

3. the industrial plant for oil crushing plus chemical extraction has a working capacity of 50 thousand t.

Table 13: Products and market value for one ha of sunflower cultivation

Product	Quantity (t)	Value Euro /t	Turnover
Seeds	2.4	265	636*
Oil (crushing and chemical extraction)	1.253	560	701,68
Meal (1-2% oil)	1.147	120	135,600
Total			837,280

*Price with integrations determined with the inter-professional agreement

Table 14: Economic balance of biodiesel chain Euro /Ha

Income from:	Euro /Ha	%
Biodiesel (final product)	925.6	77.91
Glycerin (byproduct 1)	142.4	11.99
Meal 1-2% oil (byproduct 2)	120	10.10
Total income	1188	100.00
1 - Costs of phase 1: sunflower production (farming stage)		
Technical input*	141	
Of which seed for cultivation		
Custom hire (machinery)	140	
Non-machinery labor	15	
Land charge / rent	90	
Miscellanea	14	
TOTAL FARMING COST	400	100
2 - Cost of phase 2: mechanical and chemical oil extraction (industrial stage 1)		
Material (sunflower seed)	346	
Processing	72.58	80.00
Total extraction cost	418.73	100.00
3 - Cost of phase 3: trans-esterification (industrial stage 2)		
Material, reagent, energy	39,872	27.18
Labor (L)	21,36	14.56
Capital (C)	52,688	35.92
Taxes (T)	14,24	9.71
Overhead (SG)	18,512	12.62
Total trans-esterification process	146,672	100.00

Assuming to participate in an integrated agro-industrial chain managed as a cooperative organization; in this case the farmers will add the net income of the industrial chain. The total cost for industrial processing is 947 Euro/ha but because farmers are involved in the business, the cost for seed is not considered to avoid duplication. The net income obtained by selling the industrial products (biodiesel+glycerin) is 707.73 Euro/ha and the net biodiesel income is 347.5 Euro/ha, that will be added to net farm income to obtain 3622.5 Euro/ha.

Table 15: Balance of the integrated energy cogeneration farm based on one ha and two cows

Product	Production per year	Value in Euro/ha
A) Income		
Sunflower seed	2,5 t/ha×180 Euro/t*	450
UE integration	premium 1	45
Regional integration	premium 2	40
Milk	2×10 t×320 Euro /t	6400
Meat	2 Calf Frison breed	400
Electricity	1.8Mwh (price of GC=10 c/Kw)	180
Total farm income		7525
B) Costs		
Sunflower cultivation	One ha with hired labor/machinery	400
Dairy costs	Accounting data	3450
Electricity cost	Accounting data	200
Total cost		4050
Net farm income		3475

This sunflower price is determined by the inter-professional
Agreement between producers and industry
Source: data elaborated by the author from different sources

The nominal value of the ha will be determined with the capitalization of the net farm income assuming a capitalization ratio equal to 5% to obtain a capital value equal to 65,500 Euro per ha; including the biodiesel income the value will increase to 72,450 Euro /ha.

Table 16:

Voice	Chain management	
	Independent	Cooperative
	Value Euro/t	Value Euro/t
Farm income (see table 11)	7525	7525
Farm cost	3475.00	3475.00
Net farm net income	4050.00	4050.00
Industry income biodiesel+glycerol(1)	1068.00	1068.00
Industrial cost of which		
a) seed	450.00	
b) processing	72.58	72.58
c) trans-esterification costs	146.67	146.67
Total industrial cost	669.25	219.25
Net industrial income	398.75	848.75
otal net income		4898.75

(1) it is assumed the meal is given to farmers
Industrial net income

CONCLUSION

With the integrated production system and the co-generative farm, a possibility is demonstrated of improving their economic, energetic and ecological balances; the farmers are playing a new role as producers and sellers of different form of energy (fuel, foods, heating, electricity). The results obtained are quite positive when compared with other arm activities and justify the higher investments and management skills required to manage this complex production system. These results are obtained in a quasi-competitive situation: productions are subsidized and fuels are de-fiscalized in accordance with the current law. Future improvements are expected by improving the scale dimension and coordination among the different chain stages. Future expectations are good: the demand for biofuel is high and farm won't have to worry if the biofuel policy will be in favor of farm productions. Finally, according to the Kyoto protocol, the ecological benefits procured by green energy will be priced in future and they could offer another market opportunity.

REFERENCES

Brunori, G., Rossi, A., Balducci, E., 2003. Valutazione della fattibilità economica ambientale e socio-territoriale dello sviluppo della filiera Biocarburanti in Toscana, in "BIOVIT: Biolubrificanti per l'Industria Toscana", D.to di Agronomia e Gestione dell'Agrosistema, Sezione di Economia Agraria ed Ambientale.

Canadian Agricultural New Uses Council, 2004. Biodiesel and Other Chemicals from Vegetable Oils and Fats, Agriculture and Agri-Food Canada.

Ceddia, G., 2005. The Impact of Agro-Biotechnology on the Canola Seed Industry and Canola Productivity: Technological Lock in?) ICABR International Conference on Agricultural Biotechnology: Ten Years After.

Enguidanos, M., Soria, A., Kavalov, B., Jensen, P., 2002. Techno-Economic Analysis of Biodiesel Production in the EU: a Short Summary for Decision Makers, EU Commission Joint Research Center, Report EUR 20279 EN.

Griffin, J.M., Steele, H.B., 1986. Energy: Economics and Policy, 2nd Edition.

Hill, J., Nelson, E., Tilman, D., Polasky, S., Tiffany, D., 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels, Proceedings of the National Academy of Sciences.

Klein, S., Rosemberg, N., 1986. An Overview of Innovation, *In*: Landau R., N. Rosemberg (*eds*), "The Positive Sum Strategy: Harnessing Technology for Economic Growth" National Academy Press, Washington D.C.

Morana, C., 2005. Energy Substitution in Italy: an Economic Evaluation, F. Angeli (*ed*)., Milano.

Outlaw, J., Collins, K.J., Duffield, J.A., 2005. Agriculture as a Producer and Consumer of Energy, CABI Publishing Co., Cambridge MA.

Phillips, P.W.B., Khachatourians, G.G., 2001. The Biotechnology Revolution in Global Agriculture: Invention, Innovation and the Investment in Canola Sector.

Pimentel, D., Patzek, T.W., 2005. Ethanol Production Using Corn, Switchingrass, and Wood; Biodiesel Production Using Soybean and Sunflowers, Natural Resources Research, 14: 65-76.

Rosa, F., 2006. Energie rinnovabili dal settore agricolo: Network Analysis *In:* a cura di F. Rosa, "Sentieri dell'innovazione nel territorio, dinamiche di sviluppo ed aggregazione - Il caso Italia-Romania", Forum, Udine.

Quaim, M., De Janvry, A., 2003. Genetically Modified Crops, Corporate Pricing Strategies and Farmers Adoption: the Case of Cotton BT in Argentina, American Journal of Agricultural Economics 85(4): 814-828.

Riva, G., *et al*, 2006. Agroenergie: filiere locali per la produzione di energia elettrica da girasole, Progetto PROBIO, Regione Marche.

Shumaker, G., *et al*, 2003. A study on the feasibility of biodiesel production in Georgia. Center for Agribusiness and Economic Development, University of Georgia.

Sutton, J., 1998. Technology and Market Structure: Theory and History. MIT Press, Cambridge, Massachusetts.

Vannozzi, G.P, Nicli, M., 2006. Materie prime rinnovabili: le prospettive di utilizzo di colture oleaginose per filiere alimentary ed energetiche. *In:* a cura di F. Rosa, Sentieri dell'innovazione nel territorio, dinamiche di sviluppo ed aggregazione - Il caso Italia-Romania, Forum, Udine.

Van Thuijl, E., Deurwaarder, E.P., 2006. European Biofuel Policies in Retrospect, Energy Research Centre of the Netherlands, ECN-C-06-016, pp. 1-50.

Zhang, Y., Dubé, M.A, McLean, D.D., Kates, M., 2003. Biodiesel Production from Waste Cooking Oil: Economic Assessment and Sensitivity Analysis, Bioresource Technology 90: 229-240.

LA GRANJA EN LA CUAL SE UTILIZAN LA ENERGÍA TERMAL Y LA ENERGÍA ELÉCTRICA COMBINADA

RESUMEN

La necesidad creciente de energía, cada vez mayor falta de combustibles fósiles y el cuidado creciente del medio ambiente, han incitado los creadores de la política en los EE.UU. y en Europa, de iniciar una búsqueda de las fuentes de energía alternativas, y el sector agricultor podría ofrecer una solución eficaz para este problema. El objeto de este trabajo es la investigación de las posibilidades de producción de biocombustible en las granjas y en las plantas industriales, como si fueran ellos el ejemplo de la "economía isleña" es decir, de ser exportadores de la energa neta, si el valor económico de la energía, biocombustibles y sus productos secundarios, supera el precio de las inversiones directas e indirectas en la producción de tal energía. El análisis está dedicado especialmente a los aspectos económicos, energéticos y ecológicos del acercamiento de la producción de energía doble, que completa el modelo isleño y que demuestra que es suficientemente sostenible para aguantar la competencia en el sentido económico y energético. Ese modelo se basa en la plantación de girasol que se utiliza para la producción de biodiesel, mientras que el producto secundario, es decir, la tortilla de girasol, se utilizaría en la producción de productos lácteos, el residuo se reciclaría en la producción de biogás para la producción de la corriente eléctrica y calor, y el compost final se utilizaría de fertilizante. Tal proyecto de una producción doble integral de energía en las granjas (IFECO), requiere analizar diferentes fases de la cadena agroindustrial y destinar fondos para la construcción de plantas energéticas y los gastos operativos; para el manejo de la cadena energética agroindustrial integral, se necesita la mano de obra calificada; por ello, la eficiencia de utilización del proyecto IFECO, dependerá de la habilidad de organizar y coordinar numerosas actividades en diferentes segmentos de la cadena. Las metas macroeconómicas, como empleo, valor añadido, importación de productos energéticos e inflación, justifican la intervención estatal pública en los programas orientados hacia defiscalización de la producción de biodiesel, como hacia la dotación de los cultivos energéticos, como soya, girasol, *etc*. Los resultados obtenidos en el proyecto IFECO, indican que la cantidad total de la energía producida en la cadena de producción de girasol, es significativamente mayor que la energía invertida, y el beneficio económico se refleja a través de un significante incremento de ingreso anual y del valor del terreno, a través de capitalización del ingreso neto de la granja permanente. Y finalmente, el ahorro en el ciclo de calentamiento global sustituyendo el combustible fósil (reducción de la emisión de CO, VOC, PM10, SOx, NOx) es una valiosa contribución al mejoramiento de las condiciones ecológicas de la biosfera, lo que debe ser tomado en consideración como valor mercantil, si se aplica el Protocolo de Kyoto.

FERME OÙ LES ÉNERGIES THERMIQUE ET ÉLECTRIQUES SONT UTILISÉES CONJOINTEMENT

RÉSUMÉ

Le besoin de plus en plus grand d'énergie, la rareté de plus en plus grande de carburants fossiles et le souci de plus en plus marqué pour l'environnement ont incité les responsables aux Etats-Unis et en Europe à se mettre à la recherche de sources alternatives d'énergie ; le secteur agricole pourrait offrir une solution efficace à ce problème. Le but de ce travail est d'étudier la chaîne agro-industrielle pour produire du biocarburant dans les fermes et les centrales industrielles comme si elles étaient un exemple "d'économie des pays insulaires" c'est-à-dire comme si elles étaient des exportateurs d'énergie nette seulement dans la mesure où la valeur économique de l'énergie, du biocarburant et de ses coproduits excède le prix des investissements directs et indirects de la production de cette énergie. L'analyse est consacrée particulièrement aux aspects économiques, énergétiques et écologiques de la démarche de production d'énergie double qui complète le modèle insulaire et qui montre qu'il est suffisamment durable pour soutenir la concurrence au point de vue économique et énergétique. Ce modèle est basé sur la culture du tournesol utilisé dans la production du biodiesel tandis que le coproduit, la farine de tournesol, serait utilisée dans l'industrie laitière ; les déchets seraient recyclés dans la production de biogaz pour la production de courant électrique et de chaleur et le compost final serait utilisé pour la fertilisation. Un tel projet de production intégrale double d'énergie dans les fermes (IFECO) exige qu'on analyse les différentes phases de la chaîne agro-industrielle et que l'on réserve des investissements à la construction d'usine énergétiques et aux frais d'exploitation; une main d'œuvre plus qualifiée est nécessaire pour la gestion d'une chaîne agro-industrielle énergétique intégrale ; c'est pourquoi l'efficacité dans l'utilisation du projet IFEO dépendra de la compétence à organiser et coordonner les nombreuses activités dans différentes parties de la chaîne. Les buts macroéconomiques comme l'emploi, la valeur ajoutée, l'importation de produits énergétiques et l'inflation justifient une intervention de l'État dans les programmes orientés vers la défiscalisation de la production de biodiesel et des subventions aux cultures énergétiques comme le soja, le tournesol, *etc*. Les résultats obtenus dans le projet IFECO démontrent que la quantité d'énergie totale produite dans la chaîne de production du tournesol est significativement plus grande que l'énergie investie et le profit économique se reflète dans une augmentation importante du revenu annuel et de la valeur du sol par la capitalisation du revenu permanent de la ferme. Enfin, l'économie dans le cycle global par le remplacement du carburant fossile (réduction des émissions de CO, VOC, PM 10, SO_x, NO_x) est une contribution précieuse à l'amélioration des conditions écologiques de la biosphère, ce qui doit être pris en considération comme valeur marchande si on applique le Protocole de Kyoto.