IFECO – Modelling the Agro-Fuel Chain for Energy Cogeneration

Franco Rosa
Veterinary School of Medicine, University of Udine,
Via delle Scienze 208, 33100 Udine, Italy
rosa@uniud.it

Paper prepared for presentation at the 1st International European Forum on Innovation and System Dynamics in Food Networks
Officially endorsed by the European Association of Agricultural Economists (EAAE), Innsbruck-Igls, Austria
February 15-17, 2007

IFECO – Modelling the Agro-Fuel Chain for Energy Cogeneration

Franco Rosa
Veterinary School of Medicine, University of Udine,
Via delle Scienze 208, 33100 Udine, Italy
rosa@uniud.it

Abstract

Policy makers are searching for viable strategies to produce alternative energies; the agricultural sector can become an important supplier of renewable energy. The paper will develop the IFECO (integrated farm energy cogeneration) approach, a conceptual model of farm though as it were an "island economy"[a] a net energy exporter as the energy output exceeds the direct energy (cultivation, cropping, plant protection, transport, harvesting, storage) and indirect energy (fertilizer, pesticide, machinery, plantationforce, others) used in sunflower cultivation.

IFECO is based on the cogeneration that is the production of different energies from a single agricultural commodity to achieve the three targets that make this project sustainable: i) economic sustainability: profits realized by selling tangible and intangible marketable goods; ii) energy sustainability: positive energy balance; iii) ecological benefits: reduce the GHG (Green house gas). The sunflower is used to demonstrate the feasibility of IFECO project: the seeds produce oil that transformed in bio-diesel (and FAME – Fatty acid methyl ester); the co-product, the sunflower meal/cake, representing approximately the 50% of the seed weight is exploited in the dairy enterprise; the animal wastes and glycerine that is the co-product of the trans-esterification are used in biogas production that feeds an electricity generator; the residual compost is separated in solid and liquid phase, this last one recycled in the farm with fert-irrigation; the solid residual is processed and delivered outside the farm.

The paper is organized as it follows: 1) introduction to the problem of the energy shortage; 2) description of the IFECO model as a block matrix with four integrated modules: i) agricultural module; ii) oil and biodiesel module; iii) dairy module; iv) biogas module; these modules work sequentially with three chains respectively: biodiesel, dairy and biogas; 3) definition of state variables used for simulating changes of IFECO; 4) sensitive analysis to predict changes in economic and energetic balances and generate different scenarios according with the actors' objectives or preferences; 5) use of the information of step 4 for a DSS to improve the farm decision making; 6) suggest farm organization and participations to adapt the IFECO to different farm characteristics, decisions, profit and risk distribution.

Preliminary results have confirmed the validity of the IFECO approach: i) the results suggest the total amount of energy produced different energy chain higher than the energy spent; ii) the net cash flow generated in the diversification of activities has contributed to improve both the farm economic balance and the land value; iii) the profit and risks distribution are better predicted along the chain by simulating different scenarios; iv) the GHG savings from displacing the fossil fuel (reduction in CO, VOC, PM10, SOx, Nox) is a valuable contribution to ameliorate the quality of the environment.

Keywords: *IFECO, Renewable energy, Biodiesel, Cogeneration, Sunflower, Simulation*

1. Introduction

Environmental concern, decreasing fossil fuel supply and the need for energy security have spurred the search for renewable energy and convinced the policy makers to invest in programs dedicated to domestic bio-fuels production. To be a competitive substitute, a bio-fuel strategy must achieve the following targets: i) reduced environmental impact by lowering the GHG; ii) increased energy balance, iii) reduced production costs compared to the fossil fuels.

In the recent paper "A European Strategy for Sustainable, Competitive and Secure Energy" the EU Commission has estimated an approximately 300 thousand new jobs in the EU by now, one million by 2010 and two million by 2020. US and EU farmers and representative Farmer Associations are increasingly interested in producing green energy from agricultural commodities: US (with the *Clean Air Act Amendments (CAA) of 1990* and the *Energy Policy Act of 1992)* and EU (directive 30/2003) support the conversion to bio-fuels (reduction of the rate of excise duty to pure or blended fuels). The biofuel production from agricultural commodity changes the farm organization: the first consideration is that approximately the 50% of the crop produces oil for biofuel and the other 50% is a co-product cake/panel. IFECO suggests a chain organization willing to exploit the energetic and economic opportunities of cogeneration to achieve three main goals:

1) microeconomic goals: multi farm activities with energy as the main product. This allows to diversify the food/feed demand and creates new agricultural opportunities in UE countries as Romania and Bulgaria;

2) macroeconomic goals: occupation, GDP, trade balance, inflation rate, can be achieved with adoption of "ad hoc" fiscal policy to incentive the agro-energy production. Expected investments are estimated in 250 billion € p.a up to the year 2020 and until 2030 of approximately 460 billion € p.a at constant 2000 price;

3) environmental goals: selling marketable intangible goods (Kyoto protocol).

The bio-energy production efficiency and the energy balance are still questionable depending on the commodity used to produce biofuel, agronomic practices, climate variability and other unpredictable events. Some researchers assess that the energy balance is still negative (Pimentel, 05); however, a study published by the "Proceedings of the National Academy of Sciences" by Hill and others, (2005[1]), demonstrates that the oil with the co-products obtained by using energy saving techniques generate more energy than the energy spent. Other positive side effects are the reduction of greenhouse gases (GHG) more than the Corn-based ethanol, making it more deserving of subsidies.[2] It is estimated that the ethanol energy balance yields a 25% surplus, while the bio-diesel energy balance is more than 93% and another positive result is the release in the atmosphere of 1%, 8.3% and 13% respectively of Nitrogen, Phosphorus and Pesticide pollutants per net gain energy. Nonetheless the Corn cultivation is preferred in US because its yield per Ha could arrive to be five times more than the production of sunflower or Canola.

The greenhouse gas emission of biofuel when compared to fossil fuels, are estimated to be re-

1. 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

2. for one joule of energy invested it is possible to return in the best conditions 8 joule of energy, hence Eroei = 8:1 while the Eroei for the bioethanol is 1.3:1. Many biotech Companies are studying new OGM plants to increase the energy efficiency of Mais, Swichgrass (Panicum virgatum), Soybean Canola and Sunflower.

duced respectively: the 12% with bio-ethanol production and 41% with bio-diesel production. The advantages of bio-diesel compared to ethanol are: lower agricultural input (the use of Nitrogen for Soybean is almost zero) and better feedstock conversion into fuel. Back in 2003, the EU Bio-fuel productions has caused negative environmental impacts related to the movement of agro-chemicals, especially nitrogen (N), phosphorus (P), and pesticides from farms to other habitats and aquifers. Agricultural N and P, transported by leaching and surface flow to surface, ground water, and coastal waters caused eutrophication, declining biodiversity, and higher quantity of nitrate and nitrite in drinking-water wells. Pesticides can move by similar processes. Lower levels of biodiesel blended into 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. Better cultivation method, agronomic practices and genetic selection contribute to reduce these negative effects.

However, the bio-fuel alone can not satisfy the total demand of energy: by using all available land to produce Soybean and Mays, the bio-fuels supply would arrive to satisfy only the 12% of gasoline and 6% of the diesel demand. Transportation bio-fuel such as synfuel, hydrocarbons or cellulosic ethanol, when produced from low-input biomass grown on agriculturally marginal land or from waste biomass, could contribute to increase the supply. Other sources as wind, eolic, solar in different applications, geothermal will increase the supply of renewable energies.

The EU Commission has adopted a Bio-fuels Directive (30/2003) setting indicative targets: by 2005, the minimum share of bio-fuels is fixed to 2 % and gradually increase to 5.75 % by the year 2010 (these quantitative commitments set out have not been applied before 2005 in order to allow the Member States to establish the needed production facilities) and 10% by 2020. The mid term renewable energy targets programmed by the EU require to invest a 9% of the agricultural land in agro-energy commodity of which: 1) 10 million Ha invested in oleaginous plants to produce 14 billion litres of bio-diesel; 2) 5,1 million Ha invested in cereals (Mais, Sorghum) and 0,6 mio Ha to Sugar Beet to produce 13 billions litres of bio-ethanol.

A survey conducted by Trendmonitor in 2006[a] with interviews directed to 3,000 farmers in six European countries: Czech Republic, France, Germany, Hungary, Poland, and the UK has shown significant differences in bioenergy currently used by farmers in EU countries and strategies to adopt for future energy generation. Farmers were asked to evaluate eleven different bioenergy sources [b] as potential future contribution to their farming business and to detail any concerns. The results were the following:

Germany resulted to be the bioenergy leader with continuous investment in plants and activities facilitated by the government policies. Future planned bioenergy sources are: cereal combustion (12 percent) and plant oil used as fuel (9 percent). Six percent of German farmers are planning to start biogas production in addition to the 8 percent who already have plants in operation. The German farmers are the furthest ahead in all areas with a large proportion already using bioenergy plants. For the shortage in land, the sources of biomass are quoted as the top obstacle to future development in biofuel production.

France has positive plans to invest in seven of the eleven bioenergy listed in the survey and use bioenergy sources. The most favoured bioenergy sources are biodiesel (15 percent plant/ 20 percent usage) followed by rape seed oil (15 percent with plans). Other sources being planned are the cereal combustion (16 percent); biogas (7 percent); photovoltaic (11 percent) and wind energy (10 percent). Only 2-4 percent of French respondents are operating bioenergy plants, the most popular source being wood. Over half the French farmers surveyed currently use wood as a heating source and a further six percent have further plans in this area.

UK – Bioenergy usage low but wind energy dominates the future plans. Wind energy is cited as the major planned source of renewable energy with 12 percent of interviewed quoting this source. The UK survey has revealed that it had the lowest activity in nine of the eleven bioenergy sources with just one percent already having operational bioenergy plants. The two bioenergy sources currently used are wood for heating (16 percent) and biodiesel (3 percent). Comparing with other countries, both these usage rates are rather low. The major concern expressed by over a third of respondents is the lack of experience, followed by concern over fixed costs.

Poland and Hungary. Biodiesel and plant oil fuels actively considered Polish and Hungarian farmers most frequently cited plans to use biodiesel and also plant oil for fuel. Both these bioenergy sources show positive trends. 25 percent of Czech farmers plan biogas plants - Of all survey respondents, Czech farmers have declared the most positive investment intent in biogas (25 percent). The main concerns expressed by respondents in these three countries are: technology, financing and lack of experience.

a. The DLG 2006 Trendmonitor survey was conducted in 2006 using telephone interview techniques. Having invested 6.5 billion euros in 2005 alone, Germany is the world leader in bioenergy production technology, making it the ideal location to present related products and services. For further information, please contact: Dr. Claus Brodersen: Tel 49 69 247 88 300.

b. Biodiesel, vegetable oil, methanol, ethanol, biogas from slurry/solid manure, suitable plants, grain, co-substrates/solid wastes Solid biofuels split logs, chips, pellets, straw, grain, plant oil, organic residues Liquid biofuels Solar technology photovoltaics, solar thermal power technology, wind energy generators, transformers, transmissions, lubrication systems.

2. Theoretical framework

Both, the need to increase the competitiveness of Biofuel production by introducing technological innovation and advanced chain organization have determined the EU (Green Paper on Innovation) to incentive the cluster policies during the last decade (Raines, 2001, Porter, 1998, 2000). Following this approach, regional policies have received a great impulse for the local concentration of resources, utilities and organization dedicated to development able to attract human and capital resources from outside to be the drivers of competitive advantage.

The competitiveness of the agro-energy depends on an integrated cogeneration embedded in a local network to generate multiple energies from agricultural commodities exploited in a dedicated area to feed the processing plant of adequate size to guarantee returns from higher investments. The industrial and network organization theories support the evidence of upstream and downstream linkages in the development of integrated production processes and coordinated activities to generate the chain values added with the products and services in the hands of the ultimate users (Omta and others, 2001).

These two schemes are tied up: the energy sector is characterized by the presence of larger utility groups (ENEL, ENI, ENEA in Italy) holding the strategic control over the source and distribution of different sources of energy. These groups generate knowledge resources by financing research department, and research projects dedicated to advanced studies in geophysics, chemistry, nano-material, biotechnologies and speculative studies in marketing, forecasting energy supply-demand models with scenario simulations helping to understand the future of energy changes. The traditional separation between sectors (Agriculture, Manufacturing, Service) is narrowing since the companies that operate in the energy sector are tied up with farm enterprises as far both have common interest in working together in the integrated energy chain.

The structure-conduct-performance scheme (Scherer, 1970) is still worth to predict the implications of the structural changes in integrated agro-industrial chains. The **structure** refers to the group of enterprises involved in the ordinated sequence of processes and activities to realize specific energetic products and derived co-products used in multi-farming enterprises. The interest in the structure is dictated from the recognition that the development of the energy supply chains depends on the plant dimensions because in the commodity market the agricultural products are priced at the minimum cost of the most efficient plants.

The competitiveness of the agro-energy cogeneration is measured by a larger share of the value added depending on its capacity to integrate forward, and bypass the current buyers. However, the structural approach being rooted on the sector dimension doesn't take sufficiently into account the importance of geographic dimension, and the relations and actors involved in Agro energy system.

The Agro-energy chain is embedded in relational network whose configurations are varying according with the presence of primary resources available in a given geographic area (district or region) representing the driver of the local development. In this contest, the accumulation of strategic knowledge (ICT, nanomaterial, biotechnology) increases the potential of the endogenous growth. (cluster of innovation). Hence it is recognized the importance of the relations among enterprises working in primary and related energy sectors in a given regional cluster, forming the energy district with continuous exchange of information and services enhancing the farm/firm competitiveness. (Enright, 1998, Porter, 1998, 2000). Porter define the cluster "a geographic concentration of interconnected companies, specialized suppliers, service providers farms/firms operating in related industries and associated institutions co-operating together by pursuing common targets”. Universities, scientific parks, private research institute, service agencies, professional association and others work with different type of exchanges: licencing, spin off, start up, research partnership with University and other technology-transfer organizations play as well an important role in the diffusion of knowledge and development of new organizational models. (Debackere & Veugelers, 2005).

There is evidence of a certain cause-effect between the degree a firm is tied up in cluster activities and its internal organization and performance. This can be examined under two perspectives: a structural explanation of cluster embedness focusing on firm level characteristics or as an agency-centered focusing on the traits of individual economic agents affecting their capacity to co-operate and perform in the network organization. Therefore it is evident that the network effectiveness will depend from the capacity to exchange integrated knowledge among enterprises operating in different sectors, regions and stakeholders (Foster, 2003). Some authors have suggested a four stages scheme to explain the development of a cluster with consequences for the nature of the product, innovative design, higher performance and lower costs (in production, processing, distribution, control and transaction).

The first stage consists in collecting all disclosed information related to the technical innovation and the most suitable organization for the energy chain: biotechnologies for vegetable and animal productions, engineer technology for biofuel and biogas plants, storage plants and transport facilities. This is more focalized on the product and production line with calibration of the product for the different market outlets. The second stage regards the information flow of resources and products at different chain steps of elaboration according with the market demand. It is important to attract the best resources (human and material) to achieve the optimal chain performance. The third stage represents the supply of row material that depends on the agricultural sector: land dedicated to crop, potential land conversion in response to demand, supply of commodity from international markets. However, in order to attract competitive firms in the local cluster it is also necessary to have competent labour supply (Munn-Venn, 2004). The final fourth stage is referred to the source of financial capital to be provided with different strategies: in this innovative and risky sectors, venture capital is well suited for the purpose, nevertheless the attractiveness of the venture is related to the expected return compared to the risk. For this cluster different solutions can be hypothesized according with the prevailing private interest of the cluster and the collective interests of the society driving to a form of political participation.

Firm characteristics	Local embeddedness
Sector	Local supply of commodity
Number and Size of enterprises	Import with partner agreement
Average Cost (scale economies)	Imports from market
Level of barrier to entry	Local or enlarged market
Activity performed	Local customers
Processing technology	Contractual agreements
Production technology	Hybrid forms
Product differentiation	Vertical integration

Figure 1. Firm characteristics and local embeddedness into the cluster
Oil production: mechanical and chemical extraction with solvent (exane) extraction

Consequently, the following research questions are relevant for the cogeneration project:

1. what are the activities to be coordinated in the agro-energy network to clear to the supply chain members' objectives behind their prevailing degrees of backward and forward integra tion
2. what is the optimal dimensions of the plant and coordinated activities to optimize the econo mic results and minimize the environmental impact;
3. what is the degree of network participation by defining the collaborative rules to avoid con flicts among partners and opportunistic behaviour.

The conduct in the cogeneration supply chain refers to the degree in which the relationships between upstream and downstream members are characterized by the following key relational variables: commitment continuity, trust, and dependence. The contractual relationship is influenced by the relational variables that determines whether it is to be placed on the continuum of market transactions on the one extreme and vertical integration on the other. The conduct depends from the recognition that the participation in the energy supply chains depends on the interaction of different agents with private or more general objectives of public interest with different degree of knowledge and market power. The benefits they gain from participation depend on the way in which the relationships with downstream supply chain members are targeted to the objectives.

The performance of the energy supply chain refer to energy production, reduction in GHG and economic benefits due to costs reduction for managing the agro-energy chain as a network chain and individual benefits to agents operating in the chain. Furthermore, the performance has three dimensions: effectiveness, efficiency and equity. Effectiveness is the degree of satisfaction of the ultimate customers concerning the energy price, environment quality, delivery quota, flexibility in supply and product diversification. Efficiency is the way to organize the all chain operations at lower cost by coordinating all physical flow of resources and information along the chain steps to fulfill the following targets: delivery time, furniture, logistics, quality standards, quality control, guarantee of the product, risk insurance. Equity is the share of the total contribution margin gained and the share of total supply chain bore by each supply chain member involved in the chain operations according with their participation and responsibility.

Efficiency and effectiveness influence make-versus-buy or "outsourcing" decisions of supply chain members and thus influence the structure of the agro-fuel. In turn all three dimensions of performance in a supply chain are influenced by the structure and conduct in that chain. Hence the questions pertinent to the research project are the following:

4. Evaluate the level of general performance in terms of effectiveness, efficiency and equity;
5. Evaluate the achievement of the specific economic, environment and energy bjectives?
6. Simulate the performance changes due to state variables;
7. Select the relevant indicators of performance of the IFECO model;
8. Simulate the regional policies effect for the network of innovation. (Gellynck, and others, 2006)

3. Modelling the agro-fuel chain

The IFECO is a multi-activity farming approach suitable to supply different energies from agricultural commodity able to feed the energy chain. The dedicated organization can assume different configurations: a single farm or pooled farms embedded in a cluster and organized in the network chain operating in a dedicated geographic space. The use of biochemical and physiological processes (photosynthesis, trans-esterification, ruminant metabolism, microbiological digestion), generate different energies that increase the energetic balance and the chain value added by supplying physical and intangible goods (reduction in GHG and production of renewable green energy) to be sold in different market outlets. It is possible to simulate alternative scenarios of the integrated energy production by changing the level of variables included in IFECO model. This represents a case study of decision support system (DSS) to improve the chain performance by predicting the foreseeable consequences deriving from the change of state variables.
The IFECO scheme is a block matrix working with four integrated modules:

1. Agricultural module: dedicated to the cultivation of sunflower "high oleic" varieties with low impact agronomic techniques to reduce energy consumption and the environment impact. It includes 20 variables: 15 are independent and 5 are calculated (from the independent one).
2. Industrial Oil processing module: the oil cycle is developed in three phases: 1) - mechanical oil extraction (by crushing the seeds); 2) - chemical extraction with solvent; frequently is used the exane; 3) - trans-esterification process for the biodiesel production.[1] The co-products of the industrial process are: meal/cake containing protein and glycerine used in the cosmetic industry or in the bioreactor. The module includes 14 variables of which 10 are independent.
3. Dairy module: dedicated to the dairy enterprise using meals/cake recycled from bio-diesel to feed the cattle producing milk and meat. The co-products represented by liquid and solid wastes, manure are recycled in bio-gas production; it includes 13 variables: 9 of them are independent.
4. Biogas module: liquid and solid wastes are recycled in the biogas plant to produce: a) heat, in part used in the farm, the exceeding supply is distributed to local communities via teleheating; b) to produce electricity sold to the General contractor. The final physical product is the organic compost rich in Nitrogen used as fertilizer to be spread in field in quantity not superior to 170 kg of N/Ha farm or sold outside after "ad hoc treatent". It includes 5 variables: 2 independent and 3 calculated (from independent). It includes 6 variables of which 2 are independent.

IFECO is an open system: to optimize the performance of the all chains it is necessary that every single module work at the optimal capacity but the dimension of the agricultural and industrial processes are different; this means to introduce external sources of energy (imported oil, biomass from municipal wastes, fried oil and others) to feed the plant at their optimal capacity.Similarly the animal husbandry need to introduce a lot of energy with feedstuff to integrate the panel/cake produced internally. For the purposes of this analysis the sunflower is the farm commodity used for co-generation, largely diffused in Italy for its optimal adaptation to local agronomic and climatic conditions.

---

1. Experiences in Germany demonstrate that the Canola Oil can be used directly in endotermic combustion engine

The optimal IFECO performance requires the following conditions:

i) a minimum land surface dedicated to agro-energy commodity;
ii) the existence of an organized agro-industrial network for bio-diesel production;
iii) a multi-farm organization performing different but complementary tasks and activities;
iv) inputs of row materials to feed the plants at their optimal level.
v) a contract scheme to define the vertical relations, risk and profit sharing;
vi) trading green, blue and white certificates with electricity delivery to general contractor;
vii) agreements with local communities to deliver heating to customers (tele-heating distribution)
viii) collaboration with the institutions in the farm cogeneration project, by covering the costs of energy justified by the intangible benefits received (environment, health, quality of life, pollution).

4. Material and Method

IFECO is the economic structure of the renewable energy system integrated with the agro-ecosystem model to predict and simulate the dynamics of soil organic carbon and nitrogen, the impact of climate and other events on the lyfe cycle of the crop commodity. The DSS elaborated from the University of Udine (Danuso, Rosa, 2007) emulate the soil organic carbon levels, nitrous oxide (N_2O) and nitrogen oxide (NO_x) emissions from soil, and inorganic nitrogen losses due to leaching (Parton *et al.,* 1996; Del Grosso *et al,* 2000, 2001). The cropping systems are simulated for a number of cultivation cycle for soil organic carbon and soil nitrogen dynamics. In cropping system, crop residues cover more than 60% of the soil surface to keep soil erosion at tolerable levels (Renard *et al.,* 1996; Nelson, 2002). Bio-diesel derived from sunflower is modeled as being produced in a traditional plant where also co-product glycerol and meal are produced. Another module of DSS emulate the economic and energetic consequences of the IFECO model. The reference functional unit is one Ha of farmland.

The system boundary in bio-diesel production includes agricultural processes, transportation of biomass and bio-diesel transformation, storage and transportation of bio-diesel to user. The balance method is used to assess the different advantages obtained with IFECO. The agricultural commodity used is the sunflower: it is assumed one Ha as the reference unit for the all computations..

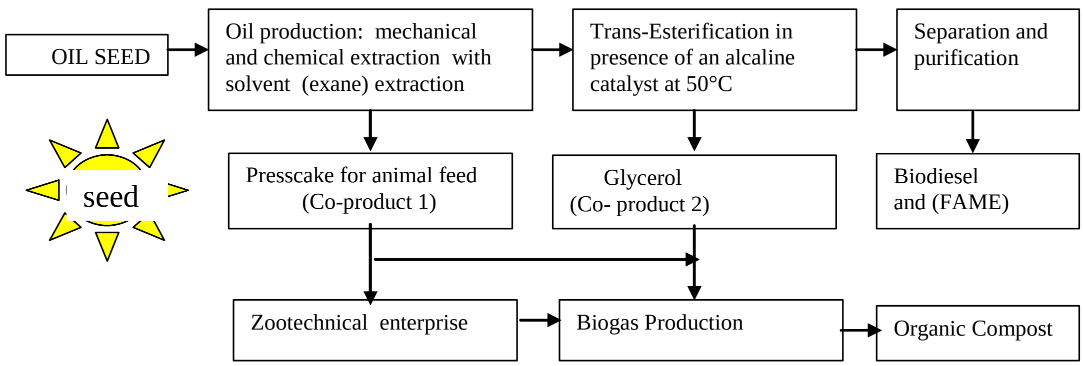


Figure 1. Scheme of the IFECO production by esterification of Vegetable Oil

Tab 1 - Sunflower energy balance * and costs per Ha

Item	Unit	Quantity	Kcal/unit	Kcal x 1000	Mj/Ha	MJ/liter	Cost $/Ha	Cost €/Ha
1) Agricultural stage								
Farm household energy use	hour (a)	8,6	40,000	344	144,03	0,10	111,80	86,00
Machinery production	Kg (b)	15	24,000	360	150,73	0,11	95,00	63,05
Farm fossil fuel	liter ©	180	10,000	1800	753,66	0,54	93,62	82,00
Nitrogen	Kg	60	17,600	1056	442,15	0,32	35,00	26,92
Phosphorus	Kg	30	4,667	140	58,62	0,04	19	14,77
Potassium	Kg	34	3,971	135	56,52	0,04	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	188,42	0,13	27,00	20,77
Herbicide/pesticide	Kg	3	100,000	300	125,61	0,09	45,00	34,62
Electricity	Kwh	10	2,900	29	12,14	0,01	1,10	0,85
Crop and biofuel Transport	Kg	675	0,222	150	62,81	0,04	81,00	62,31
Total production stage				4764,00	1994,69	1,42	520,05	400,00
Sunflower yield = 2,5 t/Ha	Kg	2500	2,000	5000,00	2093,50	1,50		
2) Industrial stage (e)								
Sunflower	Kg	2500		4764,00	1994,69	1,42	471,05	362,35
Electricity	Kwh	270		787,50	329,73	0,24	19,00	14,62
Steam	Kcal	1350000		1518,75	635,90	0,45	11,00	8,46
Cleanup water	Kcal	160000		180,00	75,37	0,05	1,30	1,00
Space heat	Kcal	152000		171,00	71,60	0,05	1,25	0,96
Direct heat	Kcal	440000		495,00	207,26	0,15	3,60	2,77
Losses	Kcal	440000		337,50	141,31	0,10	2,50	1,92
Stainless steel	Kg	300000		180,00	75,37	0,05	18,70	14,38
Steel	Kg	11		281,25	117,76	0,08	18,00	13,85
Cement	Kg	20		112,50	47,10	0,03	19,00	14,62
Total energy production + processing stage				8827,50	3696,07	2,64	565,40	434,92
Energy produced from biodiesel (f)				11250,00	4710,38	3,36		
Energy produced from meal (g)				1575,00	659,45	0,47		
Energy produced from glycerine (h)								
Total energy produced				12825				
Ratio production/consumptio				1,45				

* energy is calculated assuming the seed production equal to 2.5 Ha, the biodiesel equal to 1.25 ton and 1400 liters, the meal production is 1.25 t.;

(a) assuming a man working 1800 hours/year, utilizes an average of 8 thosand liters of oil equivalent and is paid $13/h or an equivalent 10€/h;

(b) Pimentel data, 1996; machinery costs are calculated per Ha and 10 year life cycle;

© caloric power of fossil diesel is 10 thousand Kcal/l; caloric power of bio-diesel is 9000 kcal/liter ; 1 kcal = 4,81 joule

(d) assuming 10 thosand kcal/kg;

(e) energy requested to process the one hectare seed production; the value is transferred from the first part ofthe table;

(f) Biodiesel production per Ha is 1.25 ton hence the caloris produced are 9000 x 1.25 = 11250

5. Results

Step 1 –Biodiesel production

Empirical evidences suggest the following sunflower data: 1/2,5/50/47 meaning: one hectare sunflower high Oleic hybrid produces in normal weather conditions 2.5 t of seed with the 50% of fatty acids of which, the 95% is oleic acid; hence the total quantity of oleic acid is .50 * .95 = .475 %. Hence from 1 hectare the oil produced is: 2.5 * .475 = 1.1875 t Oil and 1,313 t meal; proceeding with chemical extraction using exane it is obtained a further 5% of oil equivalent to 1,313 * 0.05 = 65.65 kg. The total oil produced is 1,25 t (the 50% of the seed weight), the integral meal is 1,25 t (50%); the final sum still will be 2.5 t. When the integral meal is cleaned from the tegument, the composition is the following: Oil = 1,25 t (50%) corresponding to 1,424 litres (density coefficient = 0,88); Cleaned Meal = 1,105 t. (44.20%); Teguments = 0,142 (5,68%).

The trans-esterification reaction starts with oil and alcohol combination to produce bio-ester (FAME = Fatty acid methyl ester) and glycerine in the following proportions: 1 t oil + 0,1 t. metil alcohol + Catalyst = 1 t bioester + 0,1 t glycerine. One Hectare of Sunflower produces: 1,25 t bio-diesel with the energetic conversion ratio equal to 1:3.2 (US Ministry for energy). This means that one unit of fossil fuel used produces 3.2 units of energy; however considering the total consumption of energy, the ratio will be reduced to 1:1.9. The conversion efficiency ratio is influenced by the factors as the: hybrids used and adaptation to soil and climate conditions, efficiency of photosynthesis.

Step 2 – Use of the co-products in the dairy enterprise

The sunflower meal (SM) is the co-product obtained from the industrial oil extraction and recycled in the dairy enterprise to generate energy from dairy productions. To understand the nutritional value of SM some technical information are required.
The daily FU[1] (Forage Unit) intake for a cattle in lactation of approximate 600 kg weight is the following: 5 FU the maintenance quota plus 10 FU, the production quota equivalent to the average production of 30 l/day for 310 days, plus 5 FU for the remaining 55 days; the total consumption is approximately 5000 FU /year. Assuming the sunflower meal represents the 15% of the diet its contribution to the cow diet will be 750 FU/year. The nutritional value of sunflower meal is on average 62 FU/100 kg of dried matter; by dividing the annual amount of FU per 62: 750/ 62 * 100 = 1210 Kg gives the quantity of the sunflower meal needed.[2] With the conversion index: 1 FU = 2100 kcal it is calculated the caloric balance: i) caloric consumption per cow: 5000*2100 = 10,5 mega-calories; ii) calories of the milk: 10000 * 630 = 6,3 mega-calories; iii) calories for one veal: 0,120 mega-cal.

1. FU namely Forage Unit is a measure unit for the diet of cattle in lactation: 1 FU is equivalent to 1 Kg of barley and generates 2100 Kcal.
2. The daily nutritional intake of a cattle in lactation includes: 20 kg of fiber of which: 3.5 kg (17%) are protein intake, hence the annual consumption per head is estimated to be 20*365 = 7.3 t fiber and 1.24 t protein. Assuming a daily consumption: 1.5 kg from integral sunflower meal (3/7 of the proteic fraction) and 2 kg from cleaned sunflower meal (4/7 of the proteic fraction) the annual consumption is 0.50 t (integral) + 0.65 t (cleaned) = 1.15 t; supplied with 1,025 t derived from sunflower seed (41%) production of one Ha to produce the integral meal and 1,475 t (59%) to produce the clean meal. The suggested optimal ratio between integral floor and clean meal is approximately .77:1.

Step 3 – Biogas production

The biogas is a quite recent technology adopted by those farmers that produce considerable amount of organic materials: sludge, biomass, residual of farm processing and others, transformed into biogas with fermentation in reactors whose efficiency will depend mainly on the matrix composition and environment conditions.
To improve the rent of the fermentation process, the wastes are mixed with organic materials: silo-mais, grass, lard, other organic materials and fermented in anaerobic condition. The amount of waste produced per head changes with the animal specie; a rule of thumb suggests a ranges between 60 and 85 kg (wet basis) per t of live weight per day. The energy potential of these wastes depends on the volatile solids (organic matter) content, which ranges between 10 - 18% of the total wet waste or between 75 – 85 % of the dry weight (ASAE, 1997).

Table 2. Values of biogas and energy produced per head (0,6 t)

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**	Termic energy (kwh)	Total Termic energy **
Liquid waste	0,023	13,80	13,80	338	675	991 Kwh (3568 MJ)	844	1.239 kwh (4460 MJ)
Solid waste	0,016	9,60	2,88	158	316		395	

* conversion coefficient by C.R.P.A and ERSAL (Ente Regionale di Sviluppo Agricolo della Lombardia) for the computation of the average annual production of animal waste,
see 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.
(1) 1000 Kg of biodiesel produces 9 million kcal.; assuming the production per Ha of 1,25 t the total energy is $1{,}25 * 9 * 10^3 = 11250$ kcal x 1000;
(2) Conversion rate: 1 Kcal = 4.187 Joule ; 1 MJ = 10^6Joule; 1 Kwh = 860 Kcal =3.6 MJ = $3.6*10^6$ J;
for more information see http://www.unit-conversion.info/energy.html
(3) The energy of milk is 640 kcal/liter hence the total energy per Ha is 20000 * 640 = 12,80 million calories

In table 3 it is reported the summary of the farm productions

Table 3. Summary of the Farm Production per Ha and per year.

1) Sunflower seed cultivationt	Unit measure	Production
Total seed production	t	2,5
Seeds for integral meal	t	1.025
Seeds for clean meal	t	1.475
Integral meal	t	.600
Clean meal	t	.650
Total meal	t	1.250
2) Dairy enterprise		
Production of Milk (two cows)	t	20
Production of meat (two veal)	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	.304
Cows (nc)	Number	2
Electric power generator eg = kw/cow)	Kw	0,6
Working time per year = h/day x gg)	Hour	5000
Electric energy produced per year (nc x eg x h x .3)	MWh	1.8
Termic energy produced per year	MWh	1.64

The green energy market in Italy is based on the Green certificates (GC) which value is determined by the Legislative Decree n.79/99, (hereinafter named the "Bersani Decree"), that obliges the energy producers since the year 2002 to deliver a quota of the electricity delivered at least the 2% in form of renewable energy. The operators are required to file the GC (General contractor) with the Administrator of the National Circuits Network (hereinafter the "Administrator"). A new law 239/2004 (Marzano Law) reduced to 50 MWh the amount of "Green Certificate", previously fixed to 100 MWh. The price of GC for 2004 was approximately 10 €cent/KWh and its value is increasing.

6. Economic analysis of the Sunflower Biodiesel chain in Italy

The cost analysis follows the full cost scheme of the activities performed at the four steps of the Agro-industrial chain. The following assumptions are made:
i) the results are referred to year 2005;
ii) the cost per Ha are computed with reference to a farm of average size, technology, labour, and soil fertility, with crop rotation, located in Padana Plain;
iii) scale economies are referred to: i) crop production, ii) oil industrial plant, iii) biodiesel plant iii) animal herd; iv) biogas plant.

The analysis starts with the cost analysis of sunflower per Ha split in direct and indirect (general) costs. Among the direct costs the most important are materials: fertilizer, pesticide, seeds (23%), labour (14,4%) and rent machinery (12%), among the indirect costs the most important are land (24%) and general (12%). Costs are sensitive to change in scale dimension: the results of this analysis are reported in paragraph 7.

Table 4. Sunflower PRoduction Cost per Ha

Direct Cost	€	%
Fertilizer	49	6,71
Pesticide	70	9,59
Seeds	49	6,71
Miscellanea	3,5	0,48
Farm machinery	56	7,67
Rent Machinery	84	11,51
Labour	105	14,38
Total direct cost	416,5	57,05
Indirect cost	€	%
General Cost	84	11,51
Land cost	175	23,97
Taxes	42	5,75
Interest on operating capital	12,5	1,71
Total general cost	313,5	42,95
TOTAL FARMING COST*	730	100,00

Tab 5.1. Cost of phase 2: oil extraction:
(industrial stage 1+2)*

Material (Sunflower seed)	450
Processing costs	72,60
Total costs of Extraction Cost	522,60

* referred to the 1 Ha of sunflower seed production

Tab 5.2 - Cost of phase 3: trans-esterification (industrial stage 3)

Material, reagent, energy	39,872
Labour (L)	21,36
Capital (C)	52,688
Taxes (T)	14,57
Overhead (SG)	18,512
Total costs of Trans-esterification process	147,002

* referred to the 1 Ha of sunflower seed production

In the following tables are reported the costs for the two phases of the oil processing industry: oil extraction and trans-esterification. The costs of material are the most important in the extraction and represent the 86% of the total cost, while for the step 3 (trans-esterification) the cost distribution is more homogeneous. The cost of the entire biodiesel chain are 1400 € of which: the 52% are farm cost, 37 are processing cost (phase 1 + 2) and 11% are tranesterification cost.

Tab 5.2 - Milk Production cost in €/100 kg

Income	€/100 kg
Milk	35
Veal	1,8
Premium	2,2
Other	1
Total income	40
Direct cost	
Feeding	13
Energy	2
Depreciation	3,6
Mortgage	2,8
Veterinary	1,5
Taxes	2,5
Other costs	1,1
Total direct cost	26,5
Indirect cost	
Land	2,5
Labour	12
Machinery	2
Total indirect cost	16,5
Total cost (direct+indirect)	43
UL meat	5
Net production cost	38
Margin	2

7. The IFECO matrix

IFECO is a matrix composed by four modules to simulate alternative solutions of the three chains of the agro-energy system; each module contains a number of state (independent) and derived (dependent) variables: the variables named *ind* (independent) can assume any value in a discretionary predefined space; the value of cal (dependent) variables is derived from the independent ones. For instance: the land surface is an *ind* variable because its value is defined " a priori" in function of the characteristics of the farm; also the sunflower acreage is an *ind* variable because its value can be defined in the interval between 0 and 100% of the land surface. The surface dedicated to other cultivation is a *dep* variable because its value is derived from the difference between total surface minus the surface dedicated to sunflower.
The farm module has been reduced to twenty variables used to simulate different states and managerial decisions in term of crop choice, rotation, market choice or chain requirements. Most of the variables are *ind* offering the opportunity to generate a broad spectrum of alternative solutions. The results show the energy and economic balance of the basic solution and alternative solutions can be obtained by changing the value of *ind* variables according with the hypothesis to be tested.

Two information are of relevant interest:

- i) the energy efficiency calculated with the energy produced per Ha, the total energy produced by a specific module and the energy produced by the chain;
- ii) the economic efficiency measured by the profits realized by the modules and the profit distribution among the modules.

The variables used for simulation are split in three groups:

1) Economic variables: prices, costs, profits;
2) Physical variables: product quantity, energy production
3) Institutional variables: decisions of policy makers (milk price, biofuel taxes, biofuel quota etc);

Scale economies are assumed because the profits of the agro-energy chains heavily depend on the dimension of the activities performed in each of the four modules. Technology and management are the main determinants of scale economies: the first ones are justified by the technology indivisibility that imposes the use of plants with size and investments varying at fixed intervals. This has two implications:
i) the investments are growing according with dimension and generate barrier to entry due to financial constraints for the smaller competitors;
ii) the managerial skills affecting the farm results: scale economies are obtained by operating larger plants: decisions about planning the chain operation for production, inventory, transport have implications for the business results and the level of risk. The money cost of bureaucracy is far from inconsequential and in addition, organizational sluggishness rises with complexity. At critical point the diseconomies of large scale management overpower the advantages of scale by determining the U-shaped curve. (Scherer F. M., 1970).

Five scale economies are considered by the IFECO model:
i) the sunflower production cost depending on the number of Hectares of sunflower cultivated;

ii) the milk production costs related to the dimension of the cattle herd (nr of cattle);
iii) the oil plant size and exploited capacity;
iv) the biodiesel plant and exploited capacity;
v) the biogas plant and exploited capacity.

The first two are determined by using data obtained from accounting statistics; the industrial plant costs are elaborated by using information from the current literature and data released by factories operating in the energy field; milk production costs are computed with data obtained from RICA-INEA statistics (Y variable) in function of the herd's size (X = number of cattle in the farm).
With the same procedure are estimated the scale economies regarding the biodiesel production costs and biogas cost . Results of estimations are reported below. The statistic significance of the all variables is accepted at the 5% level; the R square values measuring the goodness of fit are normally satisfactory, quoting .94 for milk cost function and .94 for biodiesel plant. Sunflower data are not enough to estimate a function in the region where the experiment is conducted; hence the function is estimated by plotting procedure, with minimization RMSE assumed as an indicator of goodness of fit. Biogas and trans-esterification plants are not considered for the scale analysis

Table 6. Estimation of average milk cost function for different plant dimension

Regression milk scale economies *

constant	herd size
4,9717178	0,112700182
0,296882	-0,028771077
0,9383135	0,097279734
106,47693	
1,0076281	0,066243426

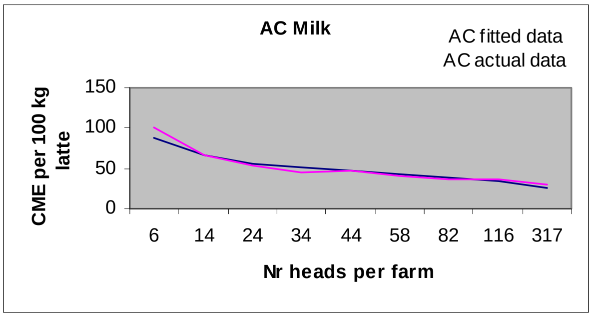
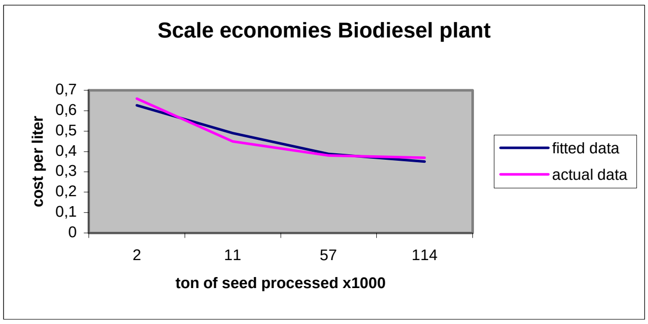


Table 7. Estimation of average cost function for biodiesel plant

Regression Biodiesel Plant

onstant	biodiesel size
,369522	-0,143027051
)877572	0,026161748
)372813	0,08182496
,888413	



1) Milk scale regression : Y = 4,97 – 0,113 X R square = 0,94*
2) Biodiesel scale regression : Y = - 0,369 – 0,143 X R square = 0,94*
3) Sunflower scale prod. Cost: $Y = K/ (a*(100 + X)) + b*X^2$ per a = 0,09, b = 0,0001K = 800

* estimates with data transformed into ln

The IFECO simulator works with four modules for a total of 53 variables: module 1 with 20 variables, module 2 with 15 variables, module 3 with 13 variables and module 4 with 5 variables; plus 4 variables scale economies.. (see table 7). Different scenario are simulated according with the specific query: production, market or political decisions.

In table 8 is reported the IFECO matrix organized in four modules with basic variables to be used to calculate the energy and economic data in standard conditions: sunflower production per Ha is equal to 2,5 t/Ha, the oil price is 560 €/t, the bio-diesel price is 720 €/t, the milk price is 320€/t. The milk production decision is assumed to be partially independent from sunflower production because the sunflower cake is just a complementary ingredient of the diet; the other feedstock are purchased outside the farm according with market conditions. Biogas production is partially dependent from the dairy enterprise decisions; many farmers are starting to produce biogas with mixed matrix composed by sludge, biomass and other available organic ingredients.

Table 8. Block matrix: modules and variable's values of the IFECO model

Module 1 - Farm enterprise

Var nr	Variables	type	unit	value	Prod in t/Ha
1	Acreage total	ind	Ha	80	
2	Soybean acreage	ind	Ha	0	3
3	Sunflower acreage	ind	Ha	10	2,5
4	Rapessed (Canola) acreage	ind	Ha	0	5
5	Mais acreage	ind	Ha	0	62
6	Triticale acreage	ind	Ha	0	60
7	Peanut (Arachis hypogaea)	ind	Ha	0	4
8	Wheath acreage	ind	Ha	0	10
9	Sorghum acreage	ind	Ha	0	900
10	Sunflower production: t/Ha	ind	t	3	
11	Sunflower price €/t	ind	€/t	180	
12	Aid 1 €/Ha	ind	€/ha	45	
13	Aid 2 €/Ha	ind	€/ha	40	
14	Price + aid	cal	€/ha	535	
15	Sunflower unit cost (varying with scale economies)	ind	€/ha	708	
16	Sunflower revenue per Ha	cal	€/ha	535	
17	Sunflower calories	ind	Mcal/t	5850	
18	Acreage dedicated to other crops	cal	Ha	70	
19	Other crop unit revenue (fixed)	cal	€/ha	580	
20	Other crop unit cost (varyng with scale economies)	cal	€/ha	539	

Module 2: Oil processing Industry

Var nr	Variables	type	unit	value
21	Oil production (stage 1 = pressing)	cal	t	1,175
22	Oil extraction (stage 2 = from cake with exane)	cal	t	0,063
23	Total oil production (stage 1 + 2) per Ha	cal	t	1,238
24	Meal (cake) production	cal	t	1,250
25	Glycerol production	cal	t	0,124
26	Oil price	ind	€/t	560,000
27	Oil average production cost	ind	€/t	261,000
28	Oil calories	ind	Mcal/t	9000,000
29	Biodiesel plant capacity	ind	ton	50000,000
	Biodiesel price	ind	€/t	650,000
30	Biodiesel average production cost	ind	€/t	0,147
31	Biodiesel calories	ind	Mcal/t	9000,000
32	Meal/cake price (1-2%)	ind	€/t	120,000
33	Meal/cake calories (610*2100)	ind	Mcal/t	1,281
34	Ethanol price*	ind	€/t	577,000
35	Glycerol price **	ind	€/t	1,300

Module 3: Dairy enterprise

Var nr	Variables	type	unit	value
36	Cows per Ha	ind	nr	2
37	Number of cattle per Ha	cal	nr	2
38	Total number of veals	cal	nr	152
39	meal/cake consumption (4 kg/day)	ind	t/head/year	1,46
40	meal/cake calories (4*360*0,61 UF* 2100Kcal	ind	Kcal/head/year	1844640
41	Other feedstock consumption (20 kg/day)	ind	t/head/year	7
42	Other feedstock calories	cal	kcal/head/year	9495360
43	Total calories per head per year (15 UF/day)	ind	kcal/head/year	11340000
44	Milk production per cycle per head	ind	t	10
45	Milk price	ind	€/t	320
46	Milk premium price	ind	€/t	0
47	Milk average production cost (scale economies)	cal	€/t	324
48	Milk calories	ind	Kcal/t	620000
49	Veal price	ind	€/head	180

Module 4: Biogas enterprise

Var nr	Variables	type	unit	value
50	Biogas production per head (0,6 t live weight)	cal	m3	496,800
51	Production electricity	cal	kwh/year	993,600
52	Green certificate value	ind	KWh	0,120
53	electricity value	ind	Kwh	0,070
54	Industrial plant size	cal	t	20000,000
55	Termic energy	cal	KWh	1242,000

8. Results

The main results of the energy balance for one Ha are the following: energy from bio-diesel is 11250 Kcal, the meal is 762 Kcal; the calories of alcohol consumption are compensated with glycerol production; the energy from the dairy activity is 12400 Kcal while the energy consumed is 24375 Kcal; the energy from biogas is converted in 7856,5 Kcal of electricity and 7854 Kcal of termic energy.To evaluate the economic convenience of alternative chain options, two hypotheses are considered:

- the first one assumes the separation between farm and industry: the farmers deliver the entire seed production and co-products to the industry and buy the meal and other inputs they need from the market.
- the second one assumes a vertically integrated agro-industrial complex in which farmers perform also industrial operations through a Society or a Cooperative organization.

In table 9 are reported the results of the standard solution: the values of the state variables are the average values referred to the year 2005.

Tab 9. IFECO – Basic solution

		Energy Production total			Economic Balance (total)		
Module 1: Farm enterprise	Unit	quantity	Kcal*1000	Mjoule	Income (€)	Cost (€)	Profit (€)
1) Sunflower acreage	Ha	10	146250	612348,75			
Seed production	t	25,00			5350,00	7079,46	-1729,46
Other vegetable crops	Ha	70,00	1067625,00	4470145,88	40600,00	37751,44	2848,56
Total cultivated area	Ha	80,00					
Total Crop activity			1213875,00	5082494,63	45950,00	44830,90	1119,10
Module 2: Oil processing Industry							
Oil production (1)	t	11,75					
Oil extraction (2)	t	0,00					
Oil (total)	t	11,75	105778,13	442893,01	6930,00	2610,00	4320,00
Biodiesel (FAME)	t	11,75	105778,13	442893,01	8043,75	1,82	8041,93
Meal (Cake) sold	t	12,50	7625,00	31925,88	150,00	0,00	150,00
Alcohol	t	1,18	-5288,91	-22144,65	0,00	678,16	-678,16
Glicerol*	t	1,18	5077,35	21258,86	0,00	0,00	1,53
Bal 1 - Oil + Cake	t	24,25	113403,13	474818,88	7080,00	2610,00	4470,00
Bal 2 - Cake + Biodiesel		36,01	219181,25	917711,89	15123,75	2611,82	8191,93
Module 3: Dairy enterprise (cattle)							
Number of cattle	nr	160,00					
Meal (cake)	t	233,60	-295142,40	-1235761,23			
Other feedstock	t	1168,00	-1519257,60	-6361131,57			
Total energy for feed consumed	kcal		-1814400,00	-7596892,80			
Total esplicit cost for feed	kcal						
Cattle cost (labour, capital, general)	€						
Total cost	€					454197,94	
Milk production	t	1600,00	99200,00	415350,40	512000,00		
Premium (32,2 €/t)	€						
Total	€						
Veals	t	152,00	240,00	1004,88	360,00		
Total dairy balance	€		-1714960,00	-7180537,52	512360,00	454197,94	58162,06
Module 4: Biogas production							
Biogas production	m3	96000,00	480000,00	2009760,00		28776,00	
Electricity from biogas	Kwh	192000,00	165120,00	691357,44			
Green certificate value	c/Kwh				23040,00	0,00	23040,00
Electricity value	c/Kwh				13440	0,00	13440
Gross Termic energy (Biogas LV)	Kwh	240000,00	206400,00	864196,80			
Net Termic energy (Biogas SV)	Kwh	111111,11	95555,56	400091,11			
Compost							
Total biogas balance					36480,00	28776,00	7704,00

It is observed that the profit distribution is non homogeneous along the Agro-energy Chain: at the farm level, the profit realized with Sunflower is negative and only the profit realized with other cultivation compensate the loss; the final value is 1119 €.

These results suggest that it could be more convenient for farmers to operate a short chain to produce directly the bio-diesel needed for farm operations that at the present conditions will be more convenient than to buy normal diesel. To improve further the economic results it will be more convenient to organize a pool of farms to exploit the scale economies.

The results of the oil processing industry (module 2) are analyzed with assumption regarding the specific form of chain management selected by partners. If press-cake are recycled in the dairy enterprise then their value is zero. Most frequently oil and cake are considered industrial products sold outside the agro-industrial energy chain; in this case the dairy farmers will buy the all feedstock they need from the feed industry.
Depending on the degree of vertical integration the options are to consider oil-cake production or the oil-cake-biodiesel production: for the first option the profit is 4470, for the second option the profit is 12512.
The dairy enterprise management is quite independent from the first two modules: the organization of labour, feeding, and milk production are marginally influenced by the decisions taken in the farm management or the oil processing industry. Even in case of recycling cake the quantity will not affect significantly the size of the herd because the daily nutritional intakes are satisfied partially by farm production and mainly with market purchases. The profit is equal to 58162 € that is the best result obtained comparing the four modules. This positive result is due to the milk price that is relatively high while the costs are lower due to the effect of scale economies.

Finally the biogas allows to add another 7704 € and the final cumulated profit is 80.000 €. The profit distribution along the chain is the following: 1,14% is the profit quota of the farm enterprise, the 15,7 is the profit realized by the oil industry, the 73,16 is the profit of the dairy enterprise and the 9,7 is the profit for biogas production. These data suggest that with an adequate choice of integrated multifunctional organization it is possible to improve consistently the profit of the farm.

To understand more in detail the direct and cross effects of changes in selected state variables for the integrated modules, a simulation on the IFECO matrix has been performed. With the simulation more information are gained about the energy and profit changes under different production and market hypotheses. These simulations are performed by selecting one state variable for each module and observing the changes in terms of energy and profits. The simulation assumes:
1) scenario 1 - the production level for module 1 varying in a range between 1,5 and 3.5 t/Ha with average value equal to 2,5; these are the border production limits observed in North-East regions of Italy; the changes in production are related with changes in energy production and profits that are reported in the table 10. The break even analysis is directed to find the critical value for the selected variable driving the profit to zero; in this case the critical value is around 2 t/Ha.
2) scenario 2 - the biodiesel price varying in the range between 520 and 580 €/t and average value equal to 560 €/t and the break even at value around 200.
3) scenario 3 – the variable is the milk price which is simulated in the range between 300 and 330 €/t the average value is 320 and the break even value is around 284.
4) scenario 4 – the variable is the biogas production: values are simulated in the range between 400 and 600 with break even at 305 cubic meters

Table 10. Simulation with IFECO matrix

Variable values	Energy production				Profit				
	Sunfl. Seed	Biodiesel	Electricity	Termic	Module 1	Module 2	Module 3	Module 4	Total
	Kcal*1000	Kcal*1000	Kwh	Kwh	€	€	€	€	€
Scenario 1 - variable = sunflower production t/Ha									
1,5	87750	63466,88	136719,36	79120	-681	1638	58162	5840	64959
1,9	109980	79545,15	136719,36	79120	0	-2480	58162	5840	61522
2	117000	84622,50	136719,36	79120	219	3054	58162	5840	67275
2,5*	146250	105778,13	136719,36	79120	1119	4470	58162	5840	69591
3	175500	126933,75	136719,36	79120	2019	5886	58162	5840	71907
3,5	204750	148089,38	136719,36	79120	2919	7302	58162	5840	74223
Scenario 2 - variable = biodiesel price €/t									
199	146250	105778,13	136719,36	79120	1119	0	58162	5840	65121
520	146250	105778,13	136719,36	79120,00	1119	3975	58162	5840	69096
540	146250	105778,13	136719,36	79120	1119	4223	58162	5840	69344
560*	146250	105778,13	136719,36	79120	1119	4470	58162	5840	69591
580	146250	105778,13	136719,36	79120	1119	4718	58162	5840	69839
Scenario 3 - variable = milk price €/t									
330	146250	105778,13	136719,36	79120	1119	4470	74162	5840	85591
320*	146250	105778,13	136719,36	79120	1119	4470	58162	5840	69591
310	146250	105778,13	136719,36	79120,00	1119	4470	42162	5840	53591
300	146250	105778,13	136719,36	79120	1119	4470	26162	5840	37591
283,65	146250	105778,13	136719,36	79120,00	1119	4470	0	5840	11429
Scenario 4 - variable = biogas production m3/head									
305,4	146250	105778,13	84046,08	48637,7778	1119	4470	58162	0	63751
400	146250	105778,13	110080	63703,7037	1119	4470	58162	3208	66959
500*	146250	105778,13	137600	79629,6296	1119	4470	58162	5840	69591
600	146250	105778,13	165120	95555,5556	1119	4470	58162	7704	71455

* values with asterisk are average values referred to 2005
values in the grey cells correspond to the break even point

9. Conclusions

The purpose of this research was to demonstrate that the bio-diesel production from agricultural commodities is feasible if the following three requisites are fulfilled: net energy gain, environmental benefit and economic convenience. Then it was structured the IFECO scheme based on the integration of different stages of the Agro-industrial chain addressed to produce biodiesel as a main product and recycling the co-products of the bio-diesel production respectively panel/cake and glycerol in the farm. The purpose of IFECO was to demonstrate the possibility to improve the energetic and economic balance by using alternative options. The energy of the co-product meal is converted into dairy energy (milk and meat) that allows to increase the value added of the production by converting 120 €/ton of meal into 320 €/ton of milk and 200 €/ton of meat.

The integrated farm energy cogeneration approach supported the evidence that the three conditions could be fulfilled if: i) dimension of the plants (farm and industrial) are appropriately selected to obtain adequate scale economies, ii) the agro-industrial operations are integrated; iii) the economic gain procured by the introduction of energy out of the agroenergy system is superior to the costs.

The bio-diesel chain has demonstrated to produce at least a 45% of energy surplus. The total energy produced depends on climatic conditions: in an optimal situation the energy produced is more than the double of the energy consumed: these values are confirmed by research findings of other authors. (Hill and others, 2006).
The contribution of IFECO to improve the ecological conditions (life cycle assessment) is also important: the environmental impact is done with our IFECO version of the island model. The emission of GHG are reduced from displacing biodiesel (i.e from energy gained in producing bio-fuel and adding this amount to the net GHG) released on farms. In particular carbon dioxide, various Oxides (CO, NOx, Sox) and odorous emission due to fermentation are reduced consistently;
The economic balance is calculated using the chain simulation model in four stages: i) farm enterprise, ii) oil processing industry (with three phases: oil extraction by crushing, oil extraction with solvent and trans-esterification); iii) dairy enterprise; iv) biogas production.

Two management solution are hypothesized the first one assumes the independent chain management with two partners: farmers and processors acting independently. Farmers can operate at different level of specialization among the three options: cultivation, dairy activity and biogas production. The second option assumes an integrated chain management actually realized with a cooperative organization managed by farmers.
In the first case the profit in standard conditions (see table 10) is slightly positive for the farm enterprises,(1119 €) positive for biogas (5840 €) and largely positive for dairy enterprise (58162 €) all these represent the 92% of the agro-energy chain. The cooperative solution

The integration with cooperative is economically more interesting but it needs to evaluate the risk that the farmers could incur by facing the management of the industrial bio-fuel activities. With the first solution farmers decisions to produce sunflower are oriented by the fixed price (determined with the inter-professional agreement); in the second case the net cash flow depends more on the market outlets condition and stimulate the farmers to take more risks.
Scale economies must be taken into account because affect substantially the economic results. It has been estimated that a minimum efficient dimension of the oil processing plant will require: sunflower production of 20 thousand Ha equivalent to 50 thousand t of sunflower seed in normal weather condition; a minimum herd of 150 milk cow and a biogas producing metane to operate an electric generator of 1 MW[1] power.

Farmers can play a new role as producer and seller of different form of energies (fuel, foods, heating, electricity). The results obtained demonstrate that IFECO is a feasible solution and produce positive net cash flow compared to other farm activities and justify both the higher financial investments and management skills to operate this complex production system.
These results are obtained in a quasi competitive situation: productions are subsidized and fuels are tax reduced according with the current legislation on the green energy production. Further improvements are expected by improving the scale dimension and the coordination through the different chain steps.

Future prospects are good: the demand for biofuel is growing and farms won't be worry about the product allocation of their commodities because of the growing political interest for farm energy productions will increase the next years the demand for agricultural commodities dedicated to energy production. Finally according with the Kyoto protocol the ecological benefits procured by the green energy offer another market opportunity.

1. MW mega watt is a measure of power

7. References

Bondioli P., (2003), “From Oilseed to Industrial Products: Present and Near Future of Oleo-Chemistry”, Italian Journal of Agronomy, 7, pp 129-135

Brinkman N., M. Wang, T. Weber, T. Darlington, (2005), “Well to Wheels analysis of advanced fuel vehicles systems: a north American study of energy use, greenhouse gas emission and criteria pollutant emissions.” National Lab., Argonne, Ill.

Brunori G., A. Rossi, E. Balducci, (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”, 3th ICABR International Conference on Agricultural Biotechnology: Ten Years After

Debackere & Veugelers, (2005), “The role of Academic technology transfer organization in improving industry science links” Research Policy 34, 321-342.

Enguidanos M., A. Soria, B. Kavalov, P. Jensen, (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.

Foster M., A. Meinhard, I. Berger, (2003), “The role of social capital, bridging, bonding or both?”, Toronto, Ryerson University.

Gellynck X, B. Vermeire, J. Viaene, (2006), “ Innovation in the Food sector: regional networks and internationalization” Journal on Chain and Network Science 6, 21-31.

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

Hill J., E. Nelson, D. Tilman, S. Polasky, D. Tiffany, (2006) “Environmental, Economic, and energetic costs and benefits of Biodiesel and Ethanol Biofuels”, Proceedings of the National Accademy of Sciences.

Klein S., N. Rosemberg, (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.

Koc A.A., S. Aksoy, T. Dolekoglu, (2005), “The Oilseed Market in Turkey: Measuring the impact of policies on consumption and trade patterns”, Journal of International Food & Agribusiness Marketing, 17, pp. 39-63

Morana C., (2005), “Energy Substitution in Italy: an Economic Evaluation”, F. Angeli eds., Milano.

Munn – Venn T., R. Voyer, (2004), “Cluster opportunity cluster of risk”, The Conference Board of Canada, Canada, p. 32.

Omta O., J. Trieneken, G. Beers, (2001), “The knowledge domain of chain and network science”, Journal of Chain and Network Science, 1, pp 78-83.

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

Perlack R.D., L.L Wright, A.F. Turhollow, R.L. Graham, B.J. Stokes, D.C. Erbach, (2005), “ Biomass as a feedstock for a Bioenergy and Bioproducts Industry: the technical feasibility of billion ton annual supply”, Oak Ridge National Lab. Oak Ridge, TN, ORNL Publication Nr TM 2005/66

Phillips P.W.B., G.G. Khachatourians, (2001), “The Biotechnology Revolution in Global Agriculture: Invention, Innovation and the Investment in Canola Sector”, Biotechnology in Agriculture Series N° 24, CABI Publishing, New York.

Pimentel D., T.W. Patzek, (2005), “Ethanol production using Corn, Switchingrass, and Wood; Biodiesel production using Soybean and Sunflowers”, Natural Resources Research, 14, pp 65-76.

Porter M., (1998), “On the competitive advantage of Nations”, London, Macmillan;

Porter M., (1998), “Clusters and the new economics of competition”, Harvard Business Review, Nov-Dec., pp 77-90

Porter M., (2000), “Local competition and economic development: local clusters in a global economy”, Economic Development Quaterly 14, pp. 15-34.

Raines P. (2001), The cluster approach and the dynamics of regional policy making (N° 47), Glasgow, European Policy Regional Center.

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

Riva G. and others, (2006), “Agroenergie: filiere locali per la produzione di energia elettrica da girasole”, Progetto PROBIO, Regione Marche.

Scherer F.M., (1970), “Industrial Market Structure and Economic Performance”, Rand Mc Nally College Publishing Company, Chicago

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 Hystory”, MIT Press, Cambridge, Massachusset.

Vannozzi G.P, M. Nicli, (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., E.P. Deurwaarder, (2006), “European Biofuel Policies in Retrospect”, Energy Research Centre of the Netherlands, ECN-C-06-016, pp. 1-50.

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