The LP Model to Optimize the Biofuel Supply Chain

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Summary

The heavy dependence of the EU countries from the imported oil, a growing economic vulnerability caused by wider and almost unforeseeable price changes of the crude oil commodity, the global warming are some of the reasons that have induced the policy makers to incentive the production of domestic biofuels derived from agricultural biomasses. This paper analyzes the supply chain model of biofuel production by focussing the economic and environment potential benefits that production and use of these biofues might have for the primary sector and the society. The suggestions are that biofuels can be a promising renewable sources of energy; the positive perceived advantages are: less dependence on turbulent exporting countries, higher security from diversified domestic sources of energy, some environmental benefits derived from the capture of GHG emission.
This paper is structured as follows:
paragraphs 1 and 2 describe the scenario and the theoretical background; paragraphs 3 and 4 illustrates the problem specification and the algebraic formulation of the LP model addressed to test the sustainability of the supply chain named Biorefinery under the three assumptions hypothesized at the beginning, paragraph 5 reports some of the experimental results with comments and paragraphs 6 describes the main conclusions. This model of cogeneration is more efficient in terms of energy compared to other biofuel chains, and is more socially acceptable because fuel and food productions are complementary each others. The partial energy balance of the fuel and biogas are positive while the livestock energy balance is heavily energy consuming, the total energy balance is neutral.

1. Introduction

The entire EU fuel consumption in 2006 was estimated about 603 million tons of mineral oil equivalent in forms of oil and gas imported corresponding to the 80% of the total consumption; demand and supply rigidity caused the prices growth in the final 2007 and early 2008 soaring up to 100 $/barrel. The troubles caused by price fluctuation and the concerns for the climate changes have stimulated the debate about the renewable sources of energy from agriculture, attracting a keen interest of the policy makers and private operators for the opportunities (threats) offered by large scale biofuel exploitation. Expected economic and environmental benefits had the positive effects to invigorate the rural development debate by offering new economic opportunities for the exploitation of renewable energies in dedicated areas of the EU. A recent born Biofuel-TP working group identified the three main critical areas for the future of biofuels: i) biomass production with increase in yield per hectare and more efficient CO2 conversion processes (C4-Phothosynthetic Plants with Nitrogen assimilation) and the development of efficient supply logistics for both products and co-products; ii) advance in conversion technologies with continuous feedstock supply and quality; iii) progresses in the end use technologies with optimization of fuel-environment impact with more adaptation to the existing vehicle features. Current and innovative future technologies as the lingno-cellulose to ethanol conversion will enable fuels to be derived from a diverse portfolio of feedstock in a greater number of EU countries and regions with consistent increase in the biomass/biofuel conversion rate and less use of land.[1]

The intensive use of agricultural commodities for biofuel production: cereal crops for ethanol production (mais, barley, panicum, switchgrass) and oil crops (brassica, sunflower, soybean) for biodiesel production have determined a closer correlation between agricultural and crude oil price with emerging price leadership of the oil price.

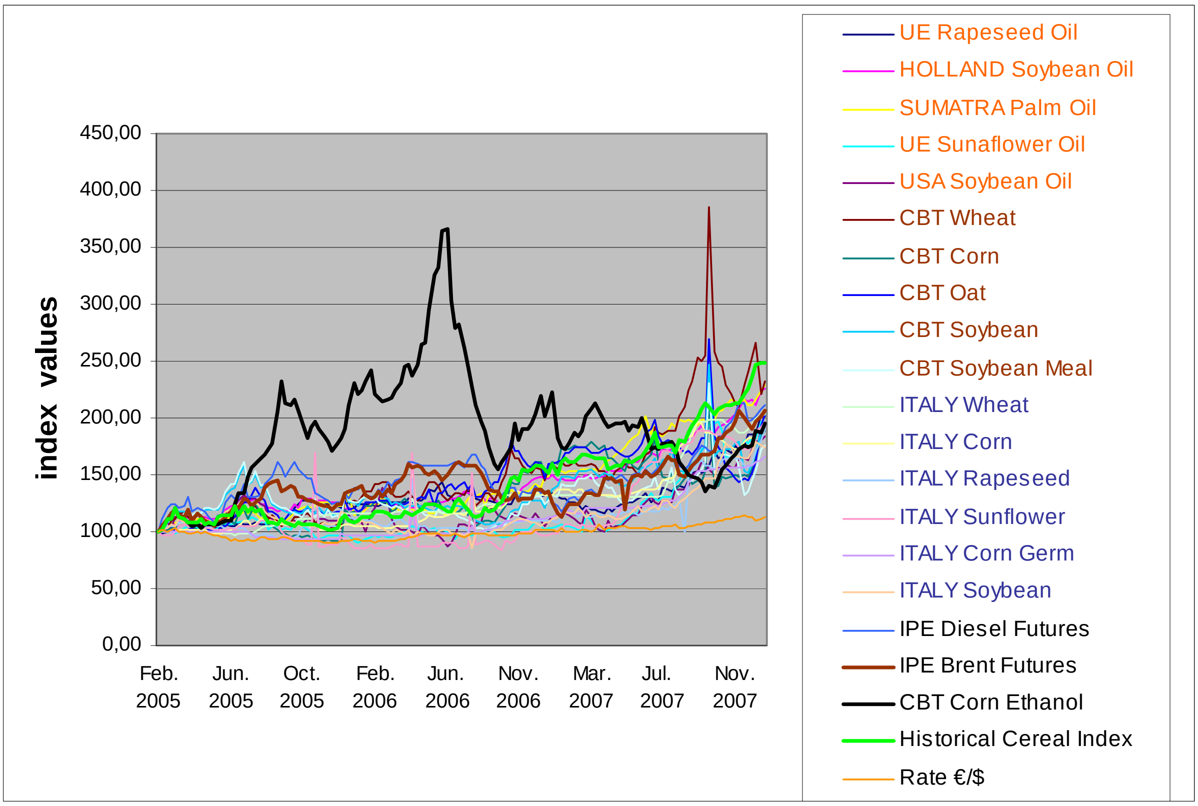

Figure 1. Weekly price index of Oil and agricultural commodities
Source our elaboration

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[1] At the present the maximum conversion rate is sugarcane (8) followed by Palm Oil (7); studies suggest that the Switchgrass (Panicum virgatum) with ligno-cellulosic technology can arrive to 5 meaning that for one unit of energy spent are obtained 5 units of energy not far from the maximum of the sugar cane .

Table 1. Pearson correlation coefficient of the 21 price variables

Price variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 - UE Rapeseed Oil	1,00																				
2 - HOLLAND Soybean Oil	0,87	1,00																			
3 - SUMATRA Palm Oil	0,80	0,97	1,00																		
4 - UE Sunaflower Oil	0,81	0,90	0,84	1,00																	
5 - USA Soybean Oil	0,74	0,83	0,77	0,91	1,00																
6 - CBT Wheat	0,81	0,89	0,87	0,88	0,78	1,00															
7 - CBT Corn	0,51	0,70	0,74	0,48	0,41	0,71	1,00														
8 - CBT Oat	0,58	0,74	0,79	0,56	0,45	0,79	0,89	1,00													
9 - CBT Soybean	0,62	0,83	0,83	0,80	0,75	0,84	0,75	0,75	1,00												
10 - CBT Soybean Meal	0,51	0,71	0,68	0,73	0,70	0,75	0,67	0,64	0,96	1,00											
11 - ITALY Wheat	0,91	0,93	0,90	0,90	0,81	0,93	0,62	0,69	0,75	0,65	1,00										
12 - ITALY Corn	0,83	0,93	0,90	0,87	0,77	0,91	0,67	0,75	0,76	0,65	0,96	1,00									
13 - ITALY Rapeseed	0,84	0,86	0,82	0,88	0,82	0,83	0,51	0,53	0,73	0,65	0,91	0,89	1,00								
14 - ITALY Sunflower	0,68	0,86	0,86	0,90	0,80	0,80	0,49	0,58	0,79	0,68	0,82	0,88	0,86	1,00							
15 - ITALY Corn Germ	0,82	0,95	0,94	0,92	0,83	0,92	0,69	0,70	0,83	0,72	0,95	0,95	0,91	0,88	1,00						
16 - ITALY Soybean	0,75	0,86	0,80	0,91	0,91	0,77	0,47	0,45	0,79	0,77	0,82	0,78	0,84	0,81	0,88	1,00					
17 - IPE Diesel Futures	0,85	0,78	0,69	0,76	0,65	0,68	0,34	0,43	0,56	0,45	0,76	0,71	0,72	0,67	0,70	0,67	1,00				
18 - IPE Brent Futures	0,87	0,80	0,73	0,76	0,66	0,72	0,42	0,50	0,60	0,49	0,79	0,74	0,74	0,68	0,73	0,67	0,97	1,00			
19 - CBT Corn Ethanol	0,22	-0,06	-0,10	-0,24	-0,35	-0,07	0,08	0,09	-0,16	-0,21	-0,05	-0,09	-0,16	-0,28	-0,21	-0,31	0,28	0,29	1,00		
20 -Historical Cereal Index	0,82	0,96	0,95	0,87	0,79	0,91	0,80	0,79	0,84	0,73	0,92	0,93	0,85	0,83	0,97	0,84	0,68	0,72	-0,11	1,00	
21 - Rate €/$	0,68	0,84	0,85	0,80	0,65	0,78	0,67	0,62	0,68	0,56	0,80	0,82	0,77	0,78	0,90	0,74	0,62	0,66	-0,20	0,89	1,00

At the present the following biofuels and originating crops are available for biofuel conversion:
A – Conventional (first generation) biofuels:
A1) - Biodiesel (fatty acid methyl ester, FAME, or fatty acid ethyl ester, FAEE) from oilseed plants.
1- Pure plant oil (sometime called straight vegetable oil, SVO) from rapeseed (RME), soybeans (SME), sunflowers, palm oil, coconuts and recycled cooking oils;
A2) - Bioethanol from alcoholic fermentation
2 - Bioethanol (E100, E85, E10, ethyl tetrabutyl ether or ETBE to avoid the inconvenients of the bioethanol) from grains or seeds: shelled corn, wheat, barley, sorghum;
3 - Bioethanol (E100, E85, E10, ETBE) from sugar crops: sugar beets, potato, sugarcane
B – Innovative (Second generation) biofuels;
4 - Bioethanol (E100, E85, E10, ETBE) from lignocellulosic biomass conversion, a technology commercially available from 2012. Eligible crops are: wheat straw, stower, switchgrass, short rotation woody crops, forest residues, mill wastes. Switchgrass (Panicum virgatum) is assumed to have yield increase over time ranging from 1.5 to 5%; Conversion coefficients of cellulose to ethanol are assumed to increase linearly for stower, straw and dedicated energy crops from 2015 to 2030 and conversion of feedstock to corn grain ethanol and biodiesel through 2019 and thereafter remain stable.
6 - Dimethyl ether (DME) from lignocellulosic materials: waste wood, short-rotation woody crops (poplar, willow),switchgrass. (Mc Aloon et al., 2000 ; De Latorre Ugarte and others, 2006)
5 - Fischer-Tropsch diesel from lignocellulosic materials: waste wood, short-rotation woody crops (poplar, willow), switchgrass.

The three points focussed by the policy agenda are: energy security with diversification of biofuel supply; economic sustainability of the biofuel project; environmental protection with CO2 reduction commitment. The recently enhanced European Biofuels Technology Platform is a concrete expression of this interest: its aim is to implement the major proposals outlined in the vision report “Biofuels in the European Union, a vision for 2030 and beyond”, made by the Biofuels Research Advisory Council (BIOFRAC group launched in 2006) and presented in the Report “Biofuels in the European Union – A vision for 2030 and beyond” a long-term view on how to overcome the technical and non-technical barriers for biofuel market deployment in the European Union for the next years.[1] The success of the actions mentioned in the EU biofuel agenda depends on a number of factors: i) progress in biofuel technology to increase the productivity of the biomass with cost reduction by the exploitation of scale economies, ii) technology diffusion and vintage effect in different technological applications and supply chain organization to make easier adaptation to a large number of farm, iii) land substitution based on cost and prices opportunities offered by biofuel production, iv) development of organizational models of biorefinery through efficient supply chains with cluster and network development to make easier the technology diffusion.

The convenience for farmers to adopt these strategies depends also on the opportunities offered with the remuneration of positive environmental externalities (green certificates) and the government to restore the economic efficiency by using fiscal instruments with tax reduction and subsidy policies (Baumol and Oates, 1988). The first positive externality regards the environment: the GHG externality is reduced with biofuels whose emissions are lower than fossil fuels, and even less with the forthcoming lignocellulosic technology. Another positive externality is the achievement of a higher level of national security; by now Europe is much less secure as a nation being dependent on imported oil for 80% of domestic consumption, with about half of that coming from countries that are politically unstable or unreliable. Converting to domestically supplied renewable sources is considered to be an important way to lowering this security cost.

2. Theoretical background

In developing the theoretical model, security and externality are introduced in two alternative model of biofuel production: 1) option A considers the oil production from oil crop processed in the biodiesel chain; 2) option B – is the integrated cogenerative chain represented by seed oil, oil and panel/cake production livestock enterprise and biogas production.

The following long run cost functions are defined for these two options:

1) $CA = CA\ (PA, QA)$

2) $CB = CB\ (PB, QB)$

CA and CB are assumed to be the cost functions for option A and B; PA and PB are vectors of input prices; QA and QB are the two options’ output. Both options use primary and intermediate inputs such as labour, capital, energy and other factors. These two options determine different

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[1]

An EU Strategy for Biofuels: Commission Communication 2006
http://europa.eu.int/comm/agriculture/biomass/biofuel/com2006_34_en.pdf
Biomass Action Plan December 2006
http://europa.eu.int/comm/energy/res/biomass_action_plan/green_electricity_en.htm
Winning the battle against climate change: Commission Communication 2005
http://www.europa.eu.int/comm/environment/climat/pdf/comm_en_050209.pdf
Promotion of the use of biofuels and other renewable fuels for transport Directive 2003/30/EC
http://ec.europa.eu/energy/res/legislation/doc/biofuels/en_final.pdf
Restructuring the Community framework for the taxation of energy products and electricity Directive 2003/96/EC

cost structures and different marginal costs such as: MCB(QB) > MCA(QA), for all values of QB = QA. With the price of liquid biofuel P being an increasing function of the price of crude oil Po, the biofuel producer's decisions are assumed to be driven by the external conditions of fossil fuel market.
Benefits – The production of the liquid fuel generates two types of social benefits:
i) E - the environmental benefit due to GHG reduction;
ii) N - the national security benefit due to less price volatility and continuity of energy supply.
In addition it is assumed that the two options are: homogeneous, in regards of national security (N), because they procure the same marginal benefit from biofuel production, but they are heterogeneous in terms of environmental benefits (E). The option B procures more marginal environmental benefit compared to the option A because of the additional benefits of the biogas production (capture of male-odorant gas emission (ammonia, mercaptane), reduction of Nitrogen leaking in vulnerable areas (maximum admitted quantity is 170 Kg/Ha).

Assuming that the positive externalities E and N are linear homogenous functions of the output Q the implications are:

(3) Ei = aiQi, for i = A, B and ab > aA, for i = A. B
Ni = bQi for i = A, B and bA = bB = b initial assumption

Here ai and bi denote the environmental and security marginal benefits respectively. Now it is assumed that the government wish to take into account these external benefits by correcting the market failure with compensation. To determine the optimal production level under these options it is defined the following social optimization model for given input prices of PA and PB.

4) $$\underset{QA,QB}{Max}\ (w) = \sum_{i=A,B}[\ P(Po)*(Qi)+\alpha iQi+\beta Qi-Ci(pi,Qi)\ ]$$

where [w] denotes social welfare and P (Po) is the oil price from the agricultural commodity, to be a function of the fossil fuel price and Ci is a function of the ith price and quantity.
The following first-order conditions will determine the optimal production levels in presence of external benefits:1

5) $P(Po) + \alpha i+\beta = MCi(pi,Qi)$ for i referred to options A and B
The marginal cost of the option i will be equal to the marginal revenue plus environmental and security benefits; then Q*A and Q*B are the potential optimal production levels. It is assumed a scheme of compensation based on production subsidy.

Subsidy
To achieve Q*A and Q*B, the following subsidies should be paid to firms *A* and *B*:
(6) SEi =α i, for i = *A* and *B (environmental externality)*
SNi =β , for i = *A* and *B (national security equal for the two options)*

Here SEi, and SNi, are the subsidies per unit of output to be paid by the government to compensate the environmental and security benefits; the difference is that SEi is different for options A and B while SNi is constant. The subsidy rate combination for options A and B are the following: rate: SA =αA, + β and rate SB = $\alpha\beta$ + β. These subsidies allow to choose the optimal production level Q*A and Q*B by combining option A and B.
Because both options have the same marginal national security benefits, the government should

consider a higher total subsidy per unit for option B, because SB > SA, and this implies that a uniform subsidy rate is not an optimal policy when the firms' marginal environment benefits are not the same. (in our case option B is superior to A due to the Biogas benefits) and production of B should be supported at a higher level according with superior environmental benefits. How could be evaluate such benefits? In the following figure (2) are reported two production levels corresponding to the two options reported in (5), while the incentives are referred to the reduction in fiscal duties (1) for producing biofuel and green certificates (2) working as a shifter of the fiscal duty line. Hence two optimal solutions with Q*A and Q*B are found producing the best social welfare impact.

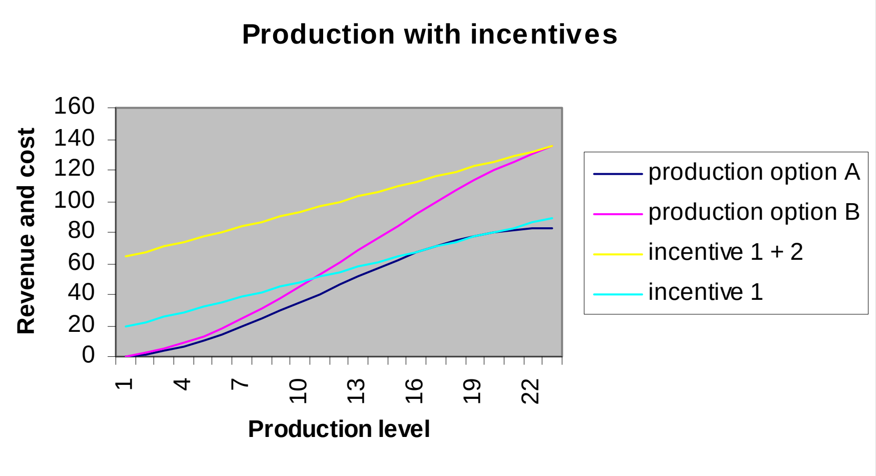
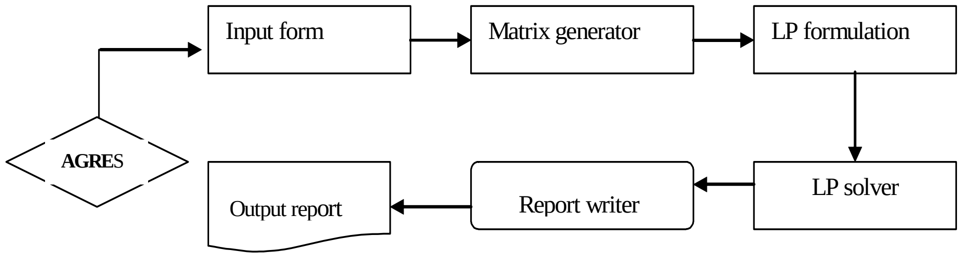


Figure 2. Optimal production with incentives

3. Problem specification

The model is formulated in order to get information from simulation of AGRES activities, focussing on farmer decisions when changes in the price of the main variables occur. The AGRES model is composed by input form, matrix generator, report writer and output developed in sequence.



The overall model design functions as follows: once the AGRES supply chain model has been defined the input form with data is translated into a matrix and starts the processing. The matrix generator takes the data and integrates with stored data to generate the LP problem that is solved in the next step. The solution is read by the report writer and creates a set of reports visualized in the output report and used for making decisions. The LP problem is designed to generate a static equilibrium of the supply chain that starts at the farm level with the crop rotation most frequently adopted by farmers, a processing plant installed into the farm for the oil production and the livestock enterprise with the biogas production; the oil processing into biodiesel (trans-esterification) is made with a domestic plant also. The model focalizes the farmer's decisions and risk (implicit): budgeting and farm planning as important management achievement derived from the combinations of prices and consequences for the activity level all over the production lines with value changes in the objective function. The adopted crop rotations is the following:
first year: double cropping triticale + soybean; second year: double cropping barley + corn silage;
for an estimated amount of 250 gigacalories equivalent to 1050 gigajoule per hectare.
The model is structured to integrate the different steps of the supply chain AGRES: 53 variables (activities) and 40 constraints represent at the present the structure of the biofuel production system. The chain model works as an interconnected block of activities: each block is characterized by a number of constraint of resources and transfer activities to connect the blocks of the chain processing. Some questions to be solved with this program are summarized in the following table.

Figure 3. Agrees model components and cycle

The farm module option B has a number of variables for the activities to be performed through the three connected steps: crop production, animal husbandry and biogas production.
These rotations were selected by observing some farms recently converted to energy production using “ad hoc”crop rotation and recycling the manure to produce biogas and the digested organic residual from the biogas to integrate the soil fertility. AGREES offer the best performance using the indicators of the three objectives to be achieved (see fig. 1). The crop have three possibilities: production, harvesting and selling; this routine is sequentially used to program the LP allowing a greater flexibility in farm management decisions. (Beneke, Winterboer). The second module is the animal husbandry that includes ten variables, nine of them representing the nine categories of dairy subjects to produce milk and co-product meat, the tenth one is the milk selling. This module is sequentially related to the biogas module that recycles the livestock's waste from the animal metabolism eventually mixed to crop silage to increase the productivity of the fermentation process. The output is the biogas that co-generate electricity and heat. Finally the digested residual is used to reintegrate the organic soil fertility; this material is considered for the energetic and economic evaluation equivalent to the chemical fertilizer saved.

4. Algebraic notation of the problem: resource constraints and transfer activity[1]

The problem consists in combining the activities of AGRES that are correlated in almost fixed proportions to produce intermediate or final products (i.e 2,5 t of sunflower seed produce 1 t of oil and 1,5 t of meal that is converted into 1500 FU to produce 3000 liter milk and so..) in plants with fixed capacity. The LP formulation is the following:

7) $$\text{Max} \sum_{j=1}^{n} c_j x_j - \sum_{j=1}^{p} d_k q_k$$

8) $$\sum_{j=1}^{n} q_{kj} x_j - q_k \leq hk, \qquad k = 1,2,..\ p$$

9) $$\sum_{j=1}^{n} e_{ij} x_j \leq bi, \qquad i = 1,2,..\ m$$

10) $$\sum_{k=1}^{p} f_{L,K} q_k \leq gL, \qquad L = 1,2,..\ r$$

Legend

J is the activity index ranging from 1 to n
cj is the return per unit of the product j (intermediate or final)
xj is the number of units of the product j assembled
k is the input index
dk is the cost per unit of input k
qk is the number units of input k
qkj is the coefficient corresponding to the amount of input k used in assembly one unit product j
i is the index of product restriction
eij is the use of the ith limit in assembling one unit of product j
bi is the limit of the ith product restriction
L is the index of input purchasing restriction
fLK is the use of of the Lth input purchasing restriction by one unit of input k
gL, is the limit of the input purchasing restriction L
hk is the firm endowment input K

Description of the equation role

Equation 7 maximize the returns to product less the costs of input i.e. the gross margin of the sequential activities performed in a chain organization;

Equation 8 insures that the use of input k in the activities is less than or equal to the firms initial endowment plus new purchases;

Equation 9 insures that the production is less than or equal the ith product constraint;

Equation 10 insures that the input purchases satisfy the purchasing restriction L

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[1] The dual version is presented in the appendix

Table 3. Optimization for the four steps of the AGRES model

1 - Agricultural - crop production:
  - Determine the most profitable and less risky crop rotation;
  - Determine the surface to be dedicated to specific crops in the rotation;
  - Determine the price range that changes the combination of farm activities;
  - Determine the convenience to sell or allocate crops, products and co-products in farm
  - Determine the size of related processes: crop-oil-animal husbandry-biogas production;
  - Determine the level of resources to be achieved outside the farm;

2 - Processing biofuel
  - Cost-opportunity to choose between short or long chain (oil used in farm, selling or biodiesel)
  - Size of the processing plant based on cost and scale economies and feeding potentials

3 - Agriculture - Animal husbandry livestock enterprise
  - Determine the optimal size of the herd
  - Determine the optimal level of milk production
  - Determine the effect of milk price over production level
  - Determine the optimal combination of milk or energy production from the available biomass
  - Determine the optimal size of biogas production from animal waste (sludge/slurry, biomass)

4 - Agriculture - Biogas production
  - Determine the level of biogas production
  - Determine the level of electricity and heat
  - Determining the optimal combination of input (matrix): animal waste, crop and others

A matrix layout of the LP formulation is reported in fig. 3; the rows represent the constraints or transfer activities and columns are the activated processes of AGRES.
Max Z = is the objective function (OF) to be maximized where c = (p – cv) is the gross margin with expected positive sign of the real activities obtained from the difference between the value of sales minus the direct variable costs and represents the contribute to the increase of the OF. The negative values in the OF refer to those activities recycled inside the AGRES: this means that these activities generate only costs usually referred to growing and harvesting farm crops. Once the value of the OF has been determined, by subtracting the indirect fixed costs the net farm income are obtained, covering the costs of resources capital and labour brought by the farmer(s).

Here following are reported the groups of real activities:
i) production/harvesting crops;
ii) husbandry activities: raising and feeding livestock;
iii) production of energy from manure and sludge;
iv) marketing: purchasing/selling products at different steps of the chain;
v) buying or hiring inputs and services including labour and capital;
vi) transferring inputs or intermediate products from one activity or time period to another;

It is usually possible to combine several functions within a single process; the most frequent one is the combination of growing, harvesting and selling activity. In this case it is important to calculate the coefficients to obtain reliable results. Consumption of resources and costs were obtained from different sources.[1]
The constraints are imposed on the amount of available resources of land, labour, number of milk cows and biogas capacity; they specify the maximum quantity of available resources signalled by the number in the right and side of the equation. The transfer equations are used to transfer the activities from one side to another of the technical matrix; actually the structure of

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1.The regional extension service ERSA (Regional Institute of agricultural development), INEA the regional branch of the national institute of agricultural economics and Agronomic Department of the Faculty of Agriculture, University of Udine .

AGRES requires to integrate the flow of the activities performed in a sequence: a) inside the same stage to move real activities from one side to another, i.e from crop production to crop harvesting and from crop harvesting to crop use or crop selling; b) to transfer the products from one stage of the chain to another of the same chain i.e the sunflower processed to produce oil and meal; c) to transfer the product from one chain to another: i.e the co-product meal (press-cake) derived from the oil processing to cow milk and the residual product manure to biogas production. With the accurate knowledge of the production system layout, the transfer equation allows the maximum flexibility to the problem because it allows the output of one activity to be transferred to other activity. The coefficient values specify the amount of resource used or the amount of output transferred when the activity is increased one unit.

Rotation is an agronomic practice used to improve the soil structure and fertility; rotation must be programmed with the introduction of a sequence of crop activities into the model and consequently the land allocation will be as follows: first year: triticale-soybean; second year: barley – corn silage. With crops cultivated in plots of the same area; the rotation is assumed to be one activity hence the amount of land unit required for a two year crop rotation is 2 ha and the consumption coefficient for the resource land is 2. The second problem regards the repeated surface; is case when the same plot is used for two crops cultivated in the same year like the triticale-corn; this doesn’t change the land allocation procedure. Purchasing and selling products or services are activities needed for different purposes: i) to increase the amount of resources used in various activities at different levels and to remove the boundary of limiting resources; ii) to sell the marketable products, iii) to maintain a sufficient cash flow with a good level of liquidity avoiding expensive capital loan.

Subjective restraints may be imposed in order to achieve other than business objectives as the preference for risk or to take into account also the group of stakeholders and public interests as the natural resource preservation, reduction in CO2, security and other relevant goals of social interest.

4.1 List of variables

The following tables 3 and 4 report the activities, constraints and price simulations.

48 activities are included in the objective function that will maximize the gross margin of real variables. Here following is the list of the variables split in six groups:

i) crop activities: the first 21 variables (with the exception of alfa alfa purchasing are referred to the

four crops activities of the rotation: production/harvesting activities compare in the OF with negative sign because they do not traded but are recycled inside the AGRES; purchasing/selling activities compare with positive sign in the OF because they are the gross margin;

ii) meal activities: soybean pressing is transferred from soybean storage; meal purchasing and selling are market activities;

iii) livestock activities is the list of variables X27…X35 linked in sequence for the turnover of the milk cows; the market activity X36 is given by the milk selling; Coefficients were collected from different sources (Rosa and others);

iv) biogas production is the list of variables X37..X41; inputs are triticale, corn silage and animal waste; these activities are simply transfer from crop, straw, livestock. Coefficients were determined

by using values of conversion collected from technical publications (Rosa, Chiumenti)

v) electricity production is the list of variables X42..X47; are transfer activities from the inputs that are the same for biogas production;

vi) labour purchasing is alone in this group.

5. Results and comments

Table 3. Variable and constraints of the rotation (1) triticale- soybean, (2) barley-corn silage repeated surface

Activities	
Tritical production (ha)	X1
Tritical silage harvesting (ton)	X2
Tritical selling (ton)	X3
Tritical purchasing for biogas (ton)	X4
Corn silage production (ha)	X5
Corn silage harvesting (ton)	X6
Corn silage selling (ton)	X7
Corn silage purchasing for biogas (ton)	X8
Barley production (ha)	X9
Barley harvesting (ton)	X10
Straw harvesting (ton)	X11
Barley selling (ton)	X12
Straw selling (ton)	X13
Corn grain purchasing (ton)	X14
Alfa alfa purchasing for feed (ton)	X15
Soybean production (ha)	X16
Soybean harvesting (ton)	X17
Soybean seed selling (ton)	X18
Soybean seed pressing (ton)	X19
Soybean oil selling (ton)	X20
Soybean oil use (ton)	X21
Meal storage	X22
Meal purchasing (ton)	X23
Meal selling (ton)	X24
Fuel purchasing (ton)	X25
Total fuel consumption (ton)	X26
Rearing and selling bulls (heads)	X27
Rearing female calves, 3 months (heads)	X28
Selling female calves, 3 months (heads)	X29
Rearing heifer calves, 6 months (heads)	X30
Rearing heifer calves, 12 months (heads)	X31
Selling heifer calves, 12 months (heads)	X32
Rearing heifer calves, 24 months (heads)	X33
Rearing milk cow (heads)	X34
Rearing and selling cull cows (heads)	X35
Milk selling (ton)	X36
Biogas production from tritical (mc)	X37
Biogas production from straw (mc)	X38
Biogas production from corn silage (mc)	X39
Biogas production from sludge (mc)	X40
Biogas production from manure (mc)	X41
Elt power from tritical biogas (kWh)	X42
Elt power from straw biogas (kWh)	X43
Elt power from corn silage biogas (kWh)	X44
Elt power from sludge biogas (kWh)	X45
Elt power from manure biogas (kWh)	X46
Total elt power selling (kWh)	X47
Labor purchasing (h)	X48

Constraints			
Rotation 1	Ha	1	=120
Rotation 2	Ha	2	=120
rotation tritical-soybean	Ha	3	=0
rotation barley-corn sil.	Ha	4	=0
labour (family) 3 UNITS	hour	5	<=6600
transfer tritical from field to store	ton	6	=0
transfer corn silage from field to store	ton	7	=0
transfer soybean from field to store	ton	8	=0
transfer barley from field to store	ton	9	=0
transfer barley from store to selling	ton	10	=0
transfer straw from field to store	ton	11	=0
transfer corn grain to feeding	ton	12	=0
transfer alfa alfa to feeding	ton	13	=0
transfer soybean to selling/pressing	ton	14	=0
transfer soybean oil to use/selling	ton	15	=0
transfer meal in storage	ton	16	=0
transfer meal to feeding/selling	ton	17	=0
tot fuel stock	ton	18	=0
fuel consume	ton	19	=0
bulls	n. heads	20	=0
female calves (0-3 months)	n. heads	21	=0
female calves (0-3 months) selling	n. heads	22	=0
calves (3-6 months)	n. heads	23	=0
heifer calves (6-12 months)	n. heads	24	=0
heifer calves (6-12 months) selling	n. heads	25	=0
heifer calves (12-24 months)	n. heads	26	=0
milk cows	n. heads	27	=0
cull cows	n. heads	28	<=450
transfer milk to selling	ton	29	=0
transfer triticale silage to biogas	ton	30	=0
transfer straw to selling/biogas	ton	31	=0
transfer corn silage to feeding/biogas	ton	32	=0
transfer sludge to biogas	mc	33	=0
transfer manure to biogas	mc	34	=0
digester biomass needs	mc	35	<=20857
digester min needs	mc	36	>=14600
elt power from tritical silage biogas	mc	37	=0
elt power from straw biogas	mc	38	=0
elt power from corn silage biogas	mc	39	=0
elt power from sludge biogas	mc	40	=0
elt power from manure biogas	mc	41	=0
total elt power	kWh	42	=0

In table 4 are reported the results obtained by simulating events related to market prices for mais, soybean and gas-oil; for each price three levels are hypothesized.

Table 4. Results of the price simulation for the rotation triticale- soybean and barley-corn silage

Silage (Trit-Mais) *€/ton*	Soybean *€/ton*	gas-oil *€/liter*	electr. *€/kWh*	milk price *€/liter*	obj. func. *Gross margin*	tractor fuel	soybean use	digestor used volume *(% volume)*	of which				
									sludge	manure	triticale	corn	straw
15	35	0,9	0,3	0,3	918609,76	gas-oil	press+oil sell.	100%	55%	1%	0%	45%	0%
15	40	0,9	0,3	0,3	919747,59	gas-oil	grain selling	70%	78%	1%	1%	0%	20%
15	45	0,9	0,3	0,3	931152,46	gas-oil	grain selling	92%	59%	1%	1%	0%	39%
17	35	0,9	0,3	0,3	941427,68	gas-oil	press+oil sell.	70%	78%	1%	0%	21%	0%
17	40	0,9	0,3	0,3	947120,92	gas-oil	grain selling	70%	78%	1%	1%	0%	20%
17	45	0,9	0,3	0,3	958638,26	gas-oil	grain selling	92%	59%	1%	1%	0%	39%
20	35	0,9	0,3	0,3	977785,61	gas-oil	press+oil sell.	70%	78%	1%	0%	0%	21%
20	40	0,9	0,3	0,3	988245,09	gas-oil	grain selling	70%	78%	1%	1%	0%	20%
20	45	0,9	0,3	0,3	999943,29	gas-oil	grain selling	92%	60%	1%	1%	0%	39%
15	35	1	0,3	0,3	916982,29	gas-oil	press+oil sell.	100%	55%	1%	0%	45%	0%
15	40	1	0,3	0,3	918120,13	gas-oil	grain selling	70%	78%	1%	1%	0%	20%
15	45	1	0,3	0,3	929524,75	gas-oil	grain selling	92%	59%	1%	1%	0%	39%
17	35	1	0,3	0,3	939800,22	gas-oil	press+oil sell.	70%	78%	1%	0%	21%	0%
17	40	1	0,3	0,3	945493,45	gas-oil	grain selling	70%	78%	1%	1%	0%	20%
17	45	1	0,3	0,3	957010,79	gas-oil	grain selling	92%	59%	1%	1%	0%	39%
20	35	1	0,3	0,3	976158,15	gas-oil	press+oil sell.	70%	78%	1%	0%	0%	21%
20	40	1	0,3	0,3	986617,63	gas-oil	grain selling	70%	78%	1%	1%	0%	20%
20	45	1	0,3	0,3	998315,58	gas-oil	grain selling	92%	60%	1%	1%	0%	39%
15	35	1,1	0,3	0,3	915562,71	gas-oil	oil sell.&use	100%	55%	1%	0%	45%	0%
15	40	1,1	0,3	0,3	926131,21	gas-oil	grain selling	100%	55%	1%	0%	45%	0%
15	45	1,1	0,3	0,3	950131,21	gas-oil	grain selling	100%	55%	1%	0%	45%	0%
17	35	1,1	0,3	0,3	938380,64	gas-oil	oil sell.&use	70%	78%	1%	0%	21%	0%
17	40	1,1	0,3	0,3	948949,14	gas-oil	grain selling	70%	78%	1%	0%	21%	0%
17	45	1,1	0,3	0,3	972949,14	gas-oil	grain selling	70%	78%	1%	0%	21%	0%
20	35	1,1	0,3	0,3	974738,57	gas-oil	oil sell.&use	70%	78%	1%	0%	0%	21%
20	40	1,1	0,3	0,3	985307,07	gas-oil	grain selling	70%	78%	1%	0%	0%	21%
20	45	1,1	0,3	0,3	1009307,07	gas-oil	grain selling	70%	78%	1%	0%	0%	21%

450 milk cows
240 Ha cultivated land
2000 mc digestor used
250 kwh cogeneration

Price fluctuations; the prices of the electricity and milk were assumed constant because their level is the result of political decisions. In total there were 27 lines of results split in nine sections. The results suggested the following considerations.

The results of section one are equal to results of section 2; the difference is explained by the gasoil price changing from ,9 to 1 (+ 11%); this change did not influence the chain decisions.

A) By examining the first section, the following consideration are made: the soybean price was more influential on chain decisions: at the lower price the soybean was pressed and the oil was sold, the digestor capacity was used at the 100%, the most of the digestor feeds were the sludge and corn in proportions 54,6% and 44,6%. The increase in soybean price to 40 €/ton determined these changes: the soybean was sold in grain, the digestor was working at the 70% level of capacity, the feed composition was: 80% sludge and 20% straw.

The further increase in soybean price at 45 €/ton caused: the soybean still sold in grain, the digestor used at the 92% capacity and feed with 59% of sludge and 39 % of straw.

Finally, the value of the objective function remained almost unchanged with price increase from 35 to 40; the change in the OF was greater (+1,1%) with price increase from 40 to 45 due to the higher quantity of electricity sold. The results of section 4 are only scalar different due to the higher price of gas-oil while the OF values are inferior due to higher fuel costs.

B) Comments on the sections 2,3,5,6. These sections report the same chain results, then the first section is commented and the following will be compared to this one. The growth of the Mais price from 15 to17 determined a use of the 70% of digestor capacity feeded with 78% of sludge

and 21% of corn silage; the soybean was pressed and the oil was sold. The increase of soybean price to 45 determined the use of digestor's capacity to 92% feed with 59,4% of sludge and 39% of straw. With soybean price passing from 35 to 40, the objective function increase by 0,61% and from 40 to 45 the increase was 1,21%. These results didn't change for the other sections, the combination of activities remained the same; the OF changes were due to the price changes.
C) Comments on the sections 7.
The specific features of this section is the prices of Mais and soybean the same as those reported in section 1, while the price of gas-oil was increased to 1,1 from the previous value 0,9. The simulation was performed with the soybean prices that didn't determine any change in activity combination: the digestor capacity was exploited at the 100% level by feeding with 55% of sludge and 45% of straw.
D) Comments on the sections 8 and 9
In section 8, the price of Mais was assumed to be 17 €/100 kg: the change in the soybean prices, didn't affect the digestor capacity exploited at 70% neither the feeds that wer 78% sludge and 21% straw and the OF increased by 1,1 and 2,5% corresponding to the soybean price changes respectively from 35 to 40 €/100 Kg and for 40 to 45 €/100 Kg.

6. Conclusion

The purpose of this paper was to demonstrate the validity of the AGRES model representing a biorefinery chain able to achieve the three goals: net energy gain, environmental benefit and the economic sustainability. The AGRES was based on the integration of different stages of the Biofuel chain that produced biodiesel as the main energy product, glycerol and panel/cake are co-products recycled in the livestock activity. The energy of the panel cake was converted into dairy energy (milk and meat) that allows to increase the value added of the production by converting 120 €/ton of panel cake in 320 €/ton of milk and 200 €/ton of meat per year.

This approach supported the evidence that the three conditions could be fulfilled if: i) the size of the plants (farm and biofuel industry) are appropriately selected to achieve scale economies, ii) the agro-industrial operations are coordinated ; iii) the economic gain procured by the introduction of energy option is superior to the total costs of the supply chain.

The optimization process is a compromise solution obtained by structuring the LP matrix with three modules each one connected to the others in an ordered sequence of operations performed in the agro-energy plan. The total energy produced depends on the farm organization and external climatic conditions: in an optimal situation the energy produced is considerably higher than the energy consumed including also the energy used for building assets and machinery: these values confirm the findings of other authors. (Hill and others, 2006). The contribution of AGRES to improve the ecological conditions (life cycle assessment) is also important: the environmental impact is done with our AGRES 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.
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 with production of milk and meat; iv) biogas production with generation of electricity and heat. The final values of the objective function are: economic goal value equal to 912991, total electricity sold equal to 95.900 KWH and reduction of CO2 equivalent to 25%.

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