Agricultural planning and biomass energy: a GIS approach

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Abstract

Biomass could be a basic element of the world's future renewable energy system. Agricultural biomass can contribute to energetic balance by applications of many different conversion technologies to produce solid, liquid and gaseous fuels, providing heat, electricity and fuels to power vehicles. Various legislative EU actions have been undertaken, to support renewable sources of energies and to finance energetic crops.

On this theme, University IUAV of Venice, Department of Planning, carry out a National Research Project - PRIN- "Renewable sources, environment and rural landscape. Economical and estimative problems."

The aim of the project are: 1) optimize the utilization of agricultural biomass for energy, considering spatial constraints and opportunities to incentivate new agricultural activities; 2) find alternative sources of data that help spatial and economical analysis; 3) analyze of the problems regarding the siting of the plants, the appraisal of the technical features of a full-scale plant versus small scale plant, the transport and storage of biomass and the costs/benefits analysis.

The research methodology apply GIS (Geographical Information Systems) tool, for designing, managing the territorial processes, and decision support according to planning choices. Methods and results on a case study area within Veneto Region has been developed.

The research context

Many interests and policies converge on the question of energy production from biomass, these originate in different contexts and attempt to give answer of many new issues.

On one hand there is the acknowledgement of the declining reserves of fossil fuels and the need to find renewable alternatives while on the other hand, there are the increasingly dramatic climatic changes that puts the irresponsible use of traditional sources that generate CO_2 emissions in a critical position. Furthermore there is the need for a complete revision of agricultural and rural development policy one that leads to the introduction of the paradigm of the multifunctionality of agriculture.

Much has been written about the factors that highlight energy and climatic questions, and it's obvious that these are global concerns. With regard to these, the idea of agriculture not solely as a producer of food but also of services, recreation, environment or non-food goods, seems to give scope for new action, the potential of which still remains to be clarified, beginning with the the identification of the principal areas where biomass can be productive. The term biomass includes an extensive variety of organic material of animal or plant origin that can be used to produce energy. Consequently it refers to urban waste, forestry products, residue from sawmills and from the wood industry, wooden objects and products no longer in use, residue from agricultural activities, residue from the maintenance of urban parks, residue from agricultural industries, oil and vegetable oils, products from cultivation specifically concerned with this sector, as well as the liquid and solid waste from farms, liquid and solid waste from houses, sludge produced by cleaners, solid and liquid animal fat, animal meal and gas emissions from fermenting material (Enea, 2005). There are also different production supply chains that produce bio-diesel, bio-ethanol, biogas, or electric or heat energy produced from biomass. The release of carbon dioxide during the decomposition of biomass, which occurs both naturally and as a result of the energy conversion, is qualitatively equivalent to that which is absorbed during the growth of the biomass itself; therefore there is no net increase to the level of CO_2 in the atmosphere. The emissions during all phases of the production of bio-fuels can be reduced almost to zero if combinations of base materials and specific conversion processes are applied. (IAE, 2004) while the subsequent use of biofuels (for example ethanol) can significantly reduce the emissions of CO_2 in the transport sector. (Smeets et al, 2007). The use of biomass to supply energy would also make Europe less dependent upon imports from politically unstable countries or those at war, and therefore less vulnerable too.

Action strategies concerning biomass and definitions of its potential supply

Currently the European Union imports over 50% of its energy requirements. The energy question in the last ten years has become a strategic element in development and environmental policies. The importance of an adequate support for increasing the role of renewable energy sources is demonstrated by the financial backing for numerous projects (the system of aid for energy producing crops), and can be verified in the strategic documents, among which the European Commission Biomass Action Plan (2005) and the European Union strategy for Bio-fuels (2006)

Table I: EU biomass production potential. Source: Biomass Action Plan

MToe	Biomass consumption 2003	Potential 2010	Potential 2020	Potential 2030
Wood direct from forest (increment and residues)	67	43	39-45	39-72
Organic wastes, wood industry residues, agricoltural and food processing residues, manure		100	100	102
Energy crops from agricolture	2	43-46	76-94	102-142
TOTAL	69	186-189	215- 239	243-316

As the attached table shows The European Union has hypothesized a substantial increase in the supply of biomass for energy use in 2010, 2020 and 2030 compared with the production in 2003. “The potential for 2010 is 2½ times the contribution today. The potential for 2020 is 3 to 3½ times the contribution today, and the potential for 2030 is 3½ to 4½ times that of today. Forests, waste and agriculture all make a big contribution to this potential for growth. The increase from forestry comes from an increase both in fellings and in the use of residues. The increase from agriculture is driven by the reform of the common agricultural policy” (Biomass Action Plan, 2005), To estimate biomass potential is in fact not easy, not only due to the scarcity of useful databases but above all due to the variety of factors to take into consideration so that the evaluations are reliable (Holm Nielsen, Oleskowicz-Popiel, Al Seadi, 2007). There are many macro-level studies (IPCC, US EPA, World Energy Council, Shell, Stockholm Environment Institute) but there is a wide variation in the size of the land area under consideration ranging from 19 to 44 million hectares. It is now established in the literature that an analysis of the potential of biomass for energy use cannot be based on only one factor (Van Dam et al. 2007) but rather, must also consider specific regional aspects (Fischer, Schrattenholzer, 2001).
The policy maker at a local level in truth faces, or in some way must consider, at least four types of conflict that can result in different scenarios for the production of biomass for energy use; they can be synthesised as follows: a. conflict between functions within agriculture; b. conflict between the local area and the ‘outside world’ over the use of the territory; c. conflict between groups belonging to different productive sectors; d. conflict over the use of resources, particularly water.

The first type of conflict emerges when, to the customary problems of identifying an adequate database, which in some way can shed light on the resources, are added questions related to the implementation of the concept of multifunctionality in agriculture. The agricultural function supporting the production of energy comes up against economic expectations connected to the function of food production at a local level and in particular specific local products, or questions concerning the management of areas of natural beauty. The issue that the local public and private institutions must resolve is simply this: is a future non-conflict scenario possible in which the food production function and the landscape function are safeguarded compared with the energy function? Under what conditions? At an historical moment when Europe is using political measures in agriculture in the main part aimed at containing food production, it might seem paradoxical to raise this issue, but in fact it isn't. An evaluation is needed to determine up to what point it's useful to sustain the above-mentioned inverted trend. In a macroeconomic plan, it's possible to construct a simplified picture of the areas that could be released from food production, maintaining the areas necessary to satisfy food needs. In the construction of a scenario using biomass to produce energy, the local factors to consider are more numerous, and moreover involve being able to rely on geographically referenced databases that offer more reliable estimates of the resources available, for example in relation to the quality of the soil, the morphological conditions (that influence the yield), the accessibility of the land etc.

The second type of conflict compares the local context with the outside world (highlighting the disputes). This conflict revolves around the installation of the biomass conversion plants. The local policy maker has, in addition to planning the most appropriate sites in terms of accessibility and landscape impact, also to resolve the thorny issue of the supply of biomass: whether to import biomass from abroad or to limit the capacity to the quantity of biomass produced locally or perhaps in a national context? This conflict is furthered by the perception that conversion activity has a negative environmental impact and therefore that also the energy it produces will have negative outcomes.

The third type of conflict exists between those who support a short production supply chain and those who consider it more advantageous to have a long production supply chain. A short production supply chain means the capacity of the local farmer to transform the biomass within his own farm. This choice involves lower costs considering for example, the absence of transport and above all for the farmer the opportunity to have a low-cost energy supply and to gain benefits from the non-use of the energy network.

Alternatively, the long production supply chain supports a biomass production – transformation – distribution energy system that tends to transfer the economic benefits to the latter stages of the supply chain, generally outside agriculture.

A fourth conflict that is local rather than global in nature foreshadows a dispute between stakeholders over the use of water. An important factor in the definition of agricultural scenarios that favour energy production, in this case becomes the water needs of each crop; the conflict between agricultural functions thus becoming a conflict between crops.

Research objectives and methodology used. Biomass, from resource to potential

The National Research Project -PRIN- "Renewable sources, environment and rural landscape. Economical and estimative problems" carried out last year inside the IUAV- Department of Planning, the methodology and first results of which are to be described, is contained within a context of substantive and methodological questions already outlined. The focus is above all on agricultural resources: energy producing crops used specifically for the production of energy and agricultural residue resulting from the cultivation of food producing crops. It does not consider forestry areas, which are already widely commented upon in the literature.

The first step of the research, as already outlined in the previously cited cases, was the drawing up of a local list of agricultural resources that could, in different ways, be converted into energy. The evaluation of resources led subsequently to an evaluation of their potential, considering the possible conflicts between the various agricultural functions of the territory under investigation among which environmental, tourist, food etc

The case study is the Province of Rovigo, in the Veneto region, which has been for the last few years the site of a vigorous debate about the provincial Energy Plan, and in particular about the installation of biomass conversion plants. The research therefore aims to experiment with methods and instruments but also to answer some of the difficult questions being asked by local policy makers.

The elaboration and construction of the inventory were made possible thanks to the use of GIS instruments and a spatial approach to the problem.

This technology and geographically-referenced IT sources have been in use for some time at an international level. To calculate the potential energy in Europe for example, the EUROSTAT statistical sources were used and products from satellite imaging (Scholz, Gehrung, 2007), Landsat and Spot satellites in particular. In Italy the most important application has been the Biosit project (Bernetti, Fagarazzi, 2003). Needing to operate on a more detailed scale (from provincial to communal) such sources of information are not adapted for spatial resolution nor sometimes for temporal resolution. To fulfil the objectives of the research other IT sources were investigated and used which have allowed the real potential of a territory to be evaluated with greater accuracy. The use of ‘alternative’ sources of information have allowed another objective of the research to be introduced, that is how to give value to some archives already present within institutions and bodies, created for their own authorised management purposes but which contain information useful in other applied fields.

Research development and first results

The European studies that have estimated the energy-convertible biomass used two principal sources of information: on one hand statistical data and on the other satellite images. The limitation of this data is that it doesn’t take into account specific territorial characteristics but instead provides only average readings and therefore estimates of conversion that are useful only at a greater-than-regional level. As far as the satellite data is concerned the scale of representation and the detail it offers is the main problem: indeed current soil use maps have been mainly produced from images with a spatial resolution (in pixels) of 20/30 metres which corresponds to a scale of 1:100 000. These maps have a national and regional rather than local relevance.

This fact helps explain why the estimates of the future supply of biomass energy cited above vary so much from one piece of research to another depending on the sources of information used.

To build a realistic list of energy convertible agricultural resources, it is necessary to have at one’s disposal geographically relevant territorial data of a suitable space and time scale. Only in this way is it possible to measure and identify the agricultural resources and to compare them with other elements and characteristics of the territory that influence the yield and potential energy of those resources: the geomorphologic, climatic and natural historical characteristics. The first phase of the research aimed at creating the inventory, therefore concentrated on the tracing and elaboration of local information sources (provincial and larger-than-communal) of a territorial nature (in reality already geographically referenced database or archives that allowed a connection to geo-referenced sources).

The main sources consulted were the database AVEPA (Veneto Agency for Agricultural Payments) and the land register for a case-study area of the Province of Rovigo (geo- referenced).

AVEPA is the payment body for the Veneto region, responsible for the process of the delivery of agricultural aid, contributions and prizes made available at a community, national and regional level. To carry out its functions, AVEPA collects the applications from the farms and businesses for a single payment, and included in this application is information related to the type and variety of crops and the area cultivated in relation to single cadastral parcel.

This archive therefore contains annually updated information on the agricultural land use intentions of the farmers that have requested community aid, in addition specifying which of these will be turned over to the production of energy, giving details of types and varieties of crops. Such information is related to individual cadastral parcel. Thus it was possible to connect the AVEPA database to the previously fragmentary land register. To verify the potential and the truthfulness of the AVEPA database, a comparison with the data from the ISTAT 2000 agricultural census was carried out. To this end the various AVEPA groups were investigated as single crop types and put together again using the same method as the census. Overall the agricultural areas correspond, though there are some discrepancies between the groups. The re-assembly of the areas according to the specific crop varieties produced an optimal compatibility between the two databases..

The AVEPA agricultural area produced a re-assembled total of 114,027 hectares against the 114,003 in the census; wood cultivation totalled about 2,264 hectares against 3,534 hectares. The arable crops totalled 110,344 hectares in one case and 109,985 hectares in the other. Similar results has given the comparison with Rovigo Agricultural Inspectorate 2004 statistical data, just showing more sugarbeets and arable crops areas than AVEPA dataset.

The first result was the production of a very detailed agricultural-use map (see table II and figure 1) from which it was possible to carry out a first evaluation of the maximum energy conversion potential. The supply calculated in this way obviously does not take into account possible factors that could limit its reliability, in terms of productivity and cultivated areas. In other words the first phase ‘photographed’ a situation that needed to be reviewed bearing in mind:

- limitations of natural factors (the nature of the soil, slope, water needs,…)
- limitations deriving from the need to consider the compatibility of conversion with the environment, the landscape, the biodiversity and the cultural identity
- limitations of access

Therefore to refine the list some subtrahending elements were later introduced, or rather information relative to the determining elements and characteristics needed for the real energy calculation. The second phase of the research was aimed at calculating the subtrahending factors and the definition of the energy value of the crops.

Table II: layers used for the first part of the research and the creation of the inventory: a) agricoltural use map b) the yield per hectare calculation; c) Subtrahending layers for the determination of cultivated areas for energy production

a) Agricoltural use map	Layers and font
	Regional Numerical Technical Cartography (Veneto Region)
	Corine Land Cover – Land use map (Regional Agency for Environmental Protection –ARPAV)
	Cadastral parcels (Land and Property Register)
	Agricoltural land use data of the farmers that requested community aid on 2006 (Regional Agency for Agricultural aid payment – AVEPA)
	Statistical land use data on 2000 (National Agricultural Census 2000 ISTAT)
	Statistical agricoltural land use data on 2004 (Rovigo Agricultural Inspectorate)
b) The yield per hectare calculation	
	Monthly temperature and rainfall on 2006; others agrometereologic data (Regional Agency for Environmental Protection –ARPAV)
	Digital Terrain Model (Veneto Region)
	Road Network (Province of Rovigo)
	Soil map (Regional Agency for Environmental Protection – ARPAV)
	Geological map (Veneto Region)
c) Subtrahending layers	
- Anthropic/Natural risk areas	Burned areas (Veneto Region)
	Purification plant (Veneto Region)
	Waste water discharge (Veneto Region)
- Anthropic/Natural Interesting areas	Geological Sites
	Hystorical buildings/ typical rural buildings
- Protected areas	Natura 2000 Network Protectes Areas (Veneto Region)
	Nesting areas (Veneto Region)
	Istitutionally defined parks (Veneto Region)
	Landscape protected areas (Veneto Region)
- Tied up areas	Archeological Sites (Veneto Region)
	Forestry areas (Veneto Region)
	Humid areas/Lagoon (Province of Rovigo)
	Hydrogeologic risk area (Province of Rovigo)

The parameters necessary to calculate the transformation into energy were therefore applied. There are various units for the types of vegetation to be used for combustion (agricultural residue and wood and cellulose crops), among which is the energy content, expressed as heating power p.c.i kcal/kg of dry substance, and the yield per hectare.

For oil producing crops, that are more prevalent in the Veneto Region, it is the energy content expressed as the oil yield and the yield in biofuel per hectare that is the unit. Finally with the alcohol producing crops it is the yield of bioethanol per hectare that is the unit.

The crop types and their parameters for the Province of Rovigo have therefore been identified. From the total area the subtrahending factors have been eliminated thereby leaving the planted area on which the yield and total hectares can be effectively calculated.

If we consider the energy producing crops, among the wood and cellulose crops the AVEPA database contains information about hemp, thistles, panicum, poplar and rapid rotation copses.

The maximum energy obtainable from the combustion of these crop types is about 7 GWh/ year equivalent to less than one sixth of the annual requirements of the province’s agricultural sector.

This production value is very meagre in comparison with the real needs of the territory and makes clear that the biomass supply chain of production needs to be propagated more widely at a local level.

The agricultural residues considered were obtained from the cultivation of wheat and durum wheat, barley, oats, corn, vines and fruit trees. Noting the area in hectares, the average yield per hectare (t/ha) and the lower heating power kcal/kg, the annual maximum and minimum production was calculated (depending on the humidity). From this the energy produced as a result of combustion was calculated and shown in kTEP (equivalent tonnes of crude oil) and GWh (gigawatt hours). The energy obtainable in GWh from only the combustion of all the

agricultural by-products varies from 1,000 to over 2,000 GWh, the majority of which comes form corn stalks and cobs.
According to the Energy Plan of the Veneto Region the energy needs of the agricultural sector of the Province of Rovigo amount to about 55.6 GWh. The energy needs of the Provincial agricultural sector could potentially be completely satisfied through the combustion of agricultural residue. This rosy forecast must be accompanied by other considerations related to the cost of transport and to the building of local conversion power plants etc.., considerations that are in the development phase.

Figure 1: the agricultural-use map

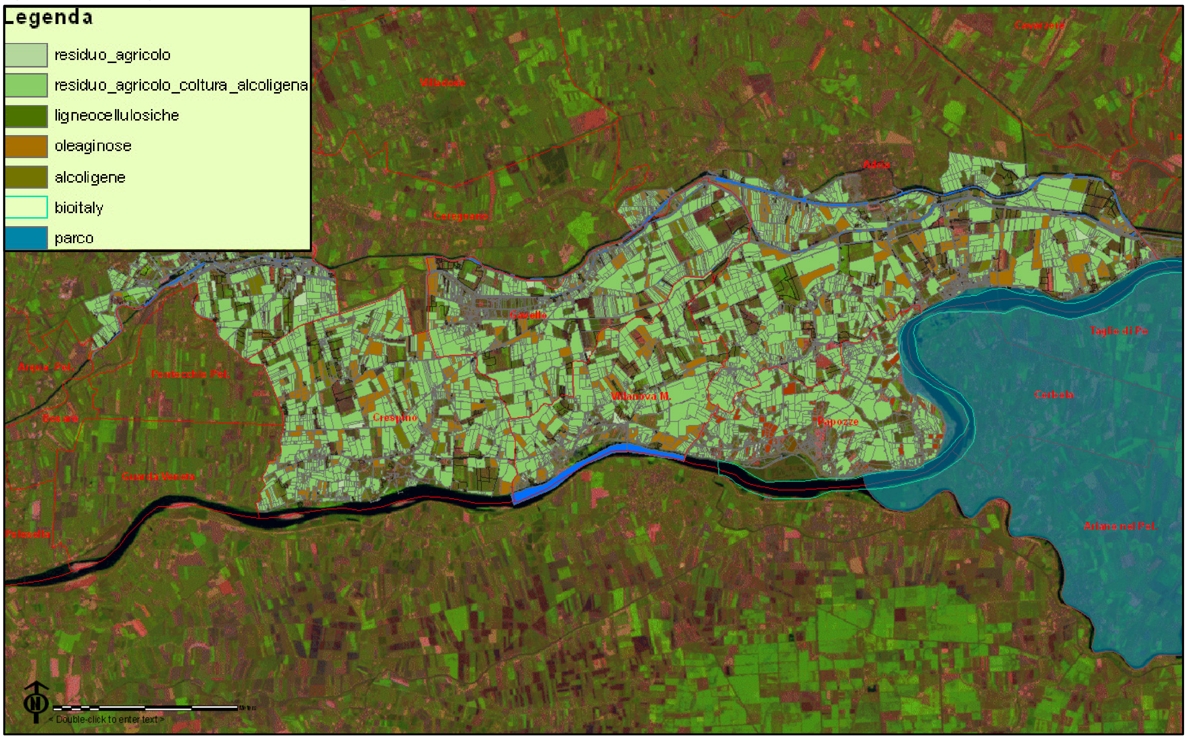

Figure 2: Subtrahending layers for the determination of cultivated areas for energy production

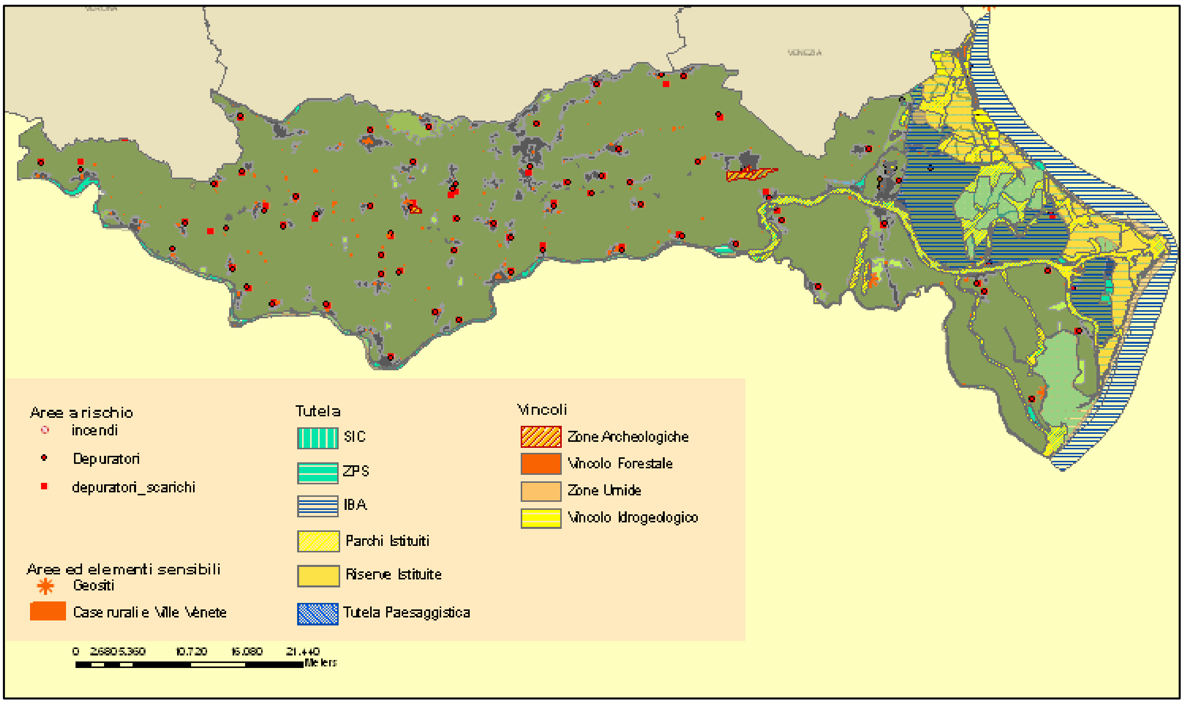

Table III shows some results related to the total area under cultivation and the maximum annual yield and maximum energy production per crop type.

Crop	Area (ha)	Rovigo Min.Prod. tons/y	Rovigo Max.Prod. tons/y	Rovigo Min. Energy Prod. kTEP	Rovigo Min Energy Prod. GWh	Rovigo Max Energy Prod. kTEP	Rovigo Max Energy Prod. GWh
Wheat	18425	70475	82912	29.2	340	34.4	400
Durum wheat	2780	9452	11120	3.9	46	4.6	54
barley	1045	3553	4180	1.2	14	1.4	16
oats	25	85	100	0	0	0.0	0
rice	916	4.030	5038	1.5	18	1.9	22
corn stalks	47078	117695	235390	48.8	568	97.7	1136
corn cobs		56.494	94.156	24.6	286	41.0	476
Vine trees	370	647.5	1295	0,3	3	0.6	7
Fruit trees	1719	1547	2578	0, 7	8	1.1	13
Total	72358	263979	436770	110.3	1282	182.7	2124

Oil producing crops are cultivated to produce vegetable oil: they provide a raw material (seeds) for the production of crude oil with a high energy content, therefore useful in the production of bio-fuels or in both the production of thermal energy and electricity. In this case crops used for food production have also been considered, like sunflowers and soya. From the conversion and combustion of vegetable oil obtained from these plants it is possible to generate about 755 GWh per year. This value is purely hypothetical as it would be impossible to convert all the cultivated sunflower and soya into oil or bio-diesel, but it still offers an insight into the maximum potential of this type of cultivation.
The alcohol producing crops under consideration are sugar beet, corn and wheat. Given that corn and wheat are produced for food, the previously mentioned considerations also apply in this case. The maximum yield of bio-ethanol is 206,000 tonnes.
The third phase of the research set itself the task of integrating the evaluation of a territory's energy resources, drawn from spatial analysis, with factors capable of expressing other functions of agriculture in a social and economic and land-use conflict context. The result of this analysis identifies the possible transformation scenarios of agricultural resources into sustainable energy from a economic, social and environmental point of view.
To the results obtained in the second phase of the research was added information gained from interviews conducted with people working in the territory: the Farmer's Association, local politicians and the staff of some Research Institutes. Three possible scenarios for the development of the energy supply from local biomass were identified from the current research:

1. current scenario: conversion of wood and cellulose crops to produce energy
2. dragging scenario: integration of the food and energy functions
3. potential scenario: prevalence of the energy function over the food function

The first hypothesis gives value only to cultivation already geared towards the production of energy, like poplar trees and copses, and to set-aside areas, currently unemployed. In this case no conflict exists between the agricultural and energy functions and in any case the cultivation of these crops currently does not furnish a particularly developed or widespread supply. The reasons for this are varied but in particular:

- the intrinsic limits of polyannual cultivation (high cost of planting, harvest after at least 10 years)
- the lack of promotion of this type of cultivation at a local level
- the lack of sharpness national and European incentive policy aiming agricultural energy transformation

Therefore action is needed to realise the full potential of this type of cultivation.
The second scenario defined as dragging, imagines a situation where the food function is integrated with the energy function based on the use of agricultural residue, wood and cellulose cultivation and set-aside areas to produce energy. As has been pointed out already, the entire energy needs of Rovigo's agricultural sector could be met with only a partial conversion of agricultural residue.
However the formulation of this scenario must take into account the landscape and naturalistic functions. The Province of Rovigo is characterised by zones that are of particular environmental relevance that belong to the

Nature 2000 Network (Dir. 79/409/CEE, Dir. 92/43/CEE), by the presence of the Delta Po river natural park and by nature and bird watching trails. The protection of the countryside and biodiversity is therefore considered more important than the energy and conversion functions. Furthermore the removal of agricultural by-products might cause the loss of organic material from the soil and consequently the European Union (Biofuel Progress Report, 2007) strongly opposes this practice in areas of particular naturalistic interest.

The third scenario hypothesises the prevalence of the energy function and foresees the use of some crops 'subtracted' from the food function, in particular the alcohol and oil producing plants. The strong transformation of cultivation for energy production, take into consideration three factors: the safeguard of "local food requirements" (in terms of nutritional requirements of local residents), soil attitude, structure, dimension and pattern of farms (the feasibility transformations depends on less or strong farm pattern).

Of course this scenario is the most problematic, simply because it subtracts to food productions also areas required to provide food products for animals. In particular the use of cereals for foraging is in sharp contrast with their potential use as an energy source. The possible increase in the price of grain cereals (corn and barley) for energy transformation would cause an increase in the cost of animal foraging thus destabilising the local markets. In research terms, this scenario is the least developed.

Finally it is important to bear in mind the importance of safeguarding typical local products, in particular Delta Po Rice, Polesano white Garlic, Lettuce from Lusia that are important elements in the local economy and its development.

The fulfilment potentiality of one scenario instead of another strongly depend on future orientations of common agriculture policy. Should the local policy maker just wait for events to happen and for the market to do its job?

There is of course a high risk that this could happen, due to sector policies' custom to avoid any dialogue with the territorial planning and, basically, due to the incapacity to create synergies amongst financial incentives, zoning plan and regulations.

We are facing a new challenge in terms of planning in Italy, a country traditionally careless to rural problems, and also a request for new competences from the local policy maker. Recent developments in strategic planning could be the framework within we could find some answers.

References

ENEA- Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, (2005). Rapporto: Le fonti rinnovabili 2005. Lo sviluppo delle rinnovabili in Italia tra necessità e opportunità, Roma, Ed. ENEA.

IAE- International Energy Agency, (2004). World Energy Outlook. Paris, IAE Publications.

Edward M. W. Smeets et al.,(2007). A bottom-up assessment and review of global bio-energy potentials to 2050. Progress in Energy and Combustion Science. Vol. 33, 56-106.

Communication from the Commission of 7 December 2005 - Biomass Action Plan. COM(2005) 628 final - Official Journal C 49 of 28.02.2005.

Commission Communication of 8 February 2006 entitled "An EU Strategy for Biofuels" [COM(2006) 34 final - Official Journal C 67 of 18 March 2006].

Jens Bo Holm Nielsen, Piotr Oleskowicz-Popiel, Teodorita Al Seadi, (2007). Energy crop potentials for bioenergy in EU-27. 15th European Biomass Conference & Exhibition From Research to Market Deployment Berlin, Germany 7-11. 05 2007.

IPCC, Climate Change 2007: The Physical Science Basis; Summary for Policymakers. The IPCC 4th Assessment Report.

Jan Van Dam et al., (2007). Biomass production potential in Central and Eastern Europe under different scenarios. Biomass and Bioenergy, Vol. 31, 345-366.

Günther Fischer, Leo Schrattenholzer, (2001). Global bioenergy potentials through 2050. Biomass and Bioenergy", vol. 20, pp.151-159.

Yvonne Scholz, Julia Gehrung, (2007). A European Inventory of Straw and Forest Wood for Energy Use Generated with Simulated Net Primary Productivity Data. 15th European Biomass Conference & Exhibition From Research to Market Deployment Berlin, Germany 7-11.05. 2007.

Iacopo Bernetti, Claudio Fagarazzi, (2003). BIOSIT: una metodologia GIS per lo sfruttamento efficiente e sostenibile della "risorsa biomassa" a gini energetici. Firenze Centro Stampa 2P.