PROJECT FINAL REPORT

Grant Agreement number: 212811

Project acronym: 4FCROPS

Project title: Future Crops for Food, Feed, Fiber and Fuel

Funding Scheme: Coordination and Support Action

Period covered: from 1/6/08 to 30/11/10

Name of the scientific representative of the project's co-ordinator[1], Title and Organisation:
Dr. Efthimia Alexopoulou, Responsible for Energy Crops, Biomass Department of CRES

Tel: +30 210 6603382

Fax: +30 210 6603301

E-mail: ealex@cres.gr

Project website address: www.4fcrops.eu

[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.

4.1 Final publishable summary report

4.1.1 Executive Summary

4FCROPS had as main aim to survey and analyse all the important parameters that expected to play an important in the successful establishment of non-food cropping systems alongside with the existing food crop systems. Through the accomplishment of its main objective 4FCROPS had as a potential impact to prove that a competitive bio economy through the production of both biofuels and biobased products could be a viable option for Europe.

4FCROPS followed several steps in order to survey and analyse the important parameters for the successful establishment of non-food cropping systems in the European agriculture, which were: to describe the agriculture situation in EU27, to record the market needs for food, feed, fiber and fuel crops, to estimate the land availability for the cultivation of non-food crops (fiber and fuel) in three timeframes now, in 2020 and 2030, to make a selection of the most promising non-food crops per climatic area and per final end use and in combination of the identification of the best rotation schemes, the yields and the raw material characteristics to propose possible cropping systems for Europe that in the case of annual crops cropping systems will participate both conventional and non-food crops, to examine to economic viability of the selected and/or proposed non-food crops by developing specific cases studies, to develop an environmental impact analyses as well as a life cycle analyses of the selected crop, to record the policies that foster the cultivation of non-food crops and to examine the co-existence between traditional and non-food crops and finally to examine the role of the 4fcrops in EU27 under contrasting future scenarios.

In EU27 the cultivated area is devoted to food and feed crops. The agricultural land is mainly used for the cultivation of arable crops. The arable land covers 61% of the total agricultural land in the EU27 accounting to 107Mha. The most important crops for EU are the cereals, corn, sugar beet, rapeseed and pea. 4FCROPS estimated that the current available land is around 13 Mha but from this land only 20% is being used for the cultivation of non-food crops. The total available land it is expected to increase in 2020 and to be 20.2 Mha and in 2030 to be 26.2 Mha. It was estimated that, keeping in mind that this is a lower limit due to the missing data, approximately 8.5 Million tons of biomass is in Europe used in existing non-food products next to fibres and paper and pulp. This is not including the demand for biofuels. At the same time it has been reported that with the target of 10% biofuels by 2020 25 Mha will be needed to cultivate with crops for biofuels production; 15 Mha will be used for liquids biofuels (biodiesel and bioethanol), 5 Mha for biogas and 5Mha for solid biofuels.

4FCROPS concentrated on a list of 15 selected non-food crops that categorized in five groups; oil crops for biodiesel production (rapeseed, Ethiopian mustard, sunflower), sugar and starch crops for bioethanol (sweet sorghum and sugar beet), fibre crops (flax and hemp), lignocellulosic crops (reed canary grass, giant reed, switchgrass, miscanthus, cardoon) and short rotation forestry crops (willow, poplar, and eucalyptus). Cropping systems per climatic area were developed that contained food, feed, and non-food crops (fiber and fuel crops). It is quite critical that both conventional crops (food and feed) and the non-food crops (fibre and fuel) to co-existence in a future European agriculture and the increase of the area of cultivation of the second group of the crops not to affect the quantities that are necessary in Europe to cover our needs. The final step of the project was to put the future crops for food, feed, fiber and fuel into novel context that will play a role in supporting the new biomass demands for energy and chemicals in the coming years and to define actions needed to make use of their potential in Europe. For this purpose the demands for biomass for energy and the chemical industry in Europe until 2030 were defined within 4 contrasting future scenarios. These scenarios are driven by more or less globalization (open vs. closed markets) and high or low regulation (sustainability is a strong or a weak driver for biomass based energy and chemicals). It was found that the total biomass demand (for energy and chemicals) under scenarios to be between 400 and 700 Mtons in 2020, increasing to between 550 and 800 Mtons in 2030.

4.1.2 Summary description of project context and objectives

The concept of cultivation crops for non-food uses is not new, but, in spite of considerable investment in research and development, little progress has been made with regards to the introduction of such products into the commercial marketplace. The IENICA consortium (*Interactive European Network for Industrial Crops and their Application*, www.ienica.net) carried out an estimation of the potential of plants to produce non-food crops and according to them, the potential was enormous, but the markets disorganized and frequently uninformed.

The need for the cultivation of non-food crops is supported by the following facts: a) the reform of CAP is going to lead to the release of agricultural arable land , b) there is an increasing need for fiber crops (to describe the needs for biobased products), c) there is great need for biofuels that will be produced from dedicated crops in order to meet the target of 10% biofuels by 2020 and d) the climate change that is going to force especially the south Europe to shift to other cultivations that will need less water, nitrogen that will have salt tolerance, in other words crops that will not need for intensive cultivation.

Regarding the use of the fuel crops for biofuels it should be mentioned that the target for 10% biofuels by 2020 is expected to lead to the cultivation of 25 Mha (*European Biomass Association*, www.aebiom.org): 15 Mha will be used for liquids biofuels (biodiesel and bioethanol), 5 Mha for biogas and 5Mha **for** solid biofuels. In 2007 the total biomass consumption to primary energy consumption in the EU was 89 million tons oil equivalent.

However, agricultural land use in the EU is already intensive in most regions and increased production of crops for non-food uses could cause additional pressures on agricultural biodiversity, on soil and water resources and on the food/feed markets. At current market prices the effect of competition between Bioenergy-biobased materials and food production for domestic food supply would be limited but would become more important with the assumed rise of the combined carbon permit and energy prices. The land available for growing bioenergy crops will be largely determined by the Utilized Agricultural Area (UAA), including set-aside that will be released from food and fodder production, as a consequence of a further reform of the common agricultural policy and productivity increases.

As different sectors – food, feed, fiber, and fuels – compete for land, the yielding potential of the future non-food crops has to be as efficient as possible in order to minimize the competition for land. In the long term, bioenergy crops provide the largest potential. This development will be driven by: additional productivity increases, further liberalization of agricultural markets and the introduction of high-yield bioenergy crops.

The *main objective* of the project was to survey and analyze all the parameters that play an important role in successful non-food cropping systems in the agriculture of EU27 alongside the existing food crop systems.

The ultimate scope of 4FCROPS will be achieved though the following specific objectives:

- Review of the agricultural land uses in EU27 and the prediction in short (2020) and longer terms (2030), so as to identify possibilities for non-food cropping systems for each time frame.
- Mapping of cropping possibilities like choice of crops, rotation cycles, yielding potential, raw material characteristics for each use based on regional potential levels, ecology and climate.
- Comparative cost analysis of the food and non-food crops in short and long term consideration and evaluation of the most critical socio-economic parameters, like farmers' income, rural development, and public acceptance and safety measures.
- Evaluate the most important environmental criteria (soil, water, air, climate, biodiversity, landscape) by means of an Environmental Impact Assessment (IEA) and a Life Cycle Analysis (LCA).
- Record of the existing policies and the driving forces in the future crops

- Development of scenarios for promising non-food cropping alongside food cropping systems, by defining systems' boundaries and evaluating the priorities and trends, in short and long time frameworks.
- To develop a whole dissemination plan that its main elements will be the website development, the project workshops and other dissemination activities (articles, presentations, fact sheets, leaflets, link with previous and on-going activities, etc.)

4FCROPS (www.4fcrops.eu) started in June 2008 and completed at the end of November 2010 with the participation of thirteen partners which were: *Center for Renewable Energy Sources and Saving* – Greece (project coordinator), *University of Catania* - Italy, *Agricultural University of Athens* - Greece, *Institute for Energy and Environmental Research* - Germany, *Agro Technology & Food* - Netherlands, *University of Bologna* – Italy, *National Institute for Agricultural Research* - Spain, *New University of Lisbon* – Portugal, *Institute for Natural Fibers and Medicinal Plants* - Poland, *University of Agricultural Science of Bucharest* - Romania, *National Agricultural Research Foundation* - Greece and *Baltic Renewable Energy Centre* - Poland.

Land Use in EU27

This work package started with a description of the current situation for the Land Use. This was categorized per region and crop type. A first approach was drafted by EC BREC based on the involvement in the RENEW project (www.renew-fuel.com) where a methodology for energy crops development was elaborated. The project partners who represent a representative range of EU 'agricultural' countries (Greece, Italy, Spain, Portugal, France, UK, Germany, Poland, and Romania) were commented and provided additional update input. Parallel to the description of the land use in EU27 a report that was evaluated the most important restricting factors for EU agriculture was delivered. The main factors restricting EU agriculture that were evaluated pre region and crop type were: (1) intensive cultivation of food crops, (2) climate change.

The input from the literature review and the findings of the project were the basic elements of the estimation of the land use in 2020 and 2030. The analysis of land availability was based on spatial agro-climate data and performed in GIS software. A major assumption would be that food production cannot be affected, else the food market risks to be distort, and thus the non-food crops can be cultivated only on a surplus land. Databases like Corine Land Cover, Soil Geographical Database, etc will be used in order to identify the terrain conditions. The final results will be European maps indicating possible development on non-food cropping systems.

Cropping possibilities

In the beginning of this WP a list of list of non-food crops was prepared. It should be taken under consideration the fact that many crop species are multipurpose in that they can be used to produce more than one (energy or another industrial product), for example hemp (oil, solid biomass and fibres). Some of the most common energy crops that were taken under consideration in this project are: oil crops, cereals, starch and sugar crops, cellulose and lignocellulosic crops. Maps of non-food crops agro-climate suitability are being drawn as a result of the analysis. A technical plan for the sustainable co-existence of food and non-food systems will be produced. Taking under consideration the following very important elements which are the cropping possibilities, the yielding potential and the raw material characteristics on the non-food crops (fiber and fuel) as well as the biotechnology improvement a report entitled "Report entitled "Cropping parameters (rotation, yields, biomass characteristics, biotechnology)" was prepared and will be updated before the end of the project. The combination of the list of the non-food crops, the report of the cropping parameters as well as the land use results with be the main elements of a report entitled "Cropping possibilities of selected non-food crops in the future agricultural systems" that was delivered in the second half of the second year of the project and was updated in the last month of the project.

Economic analysis and socio-economic impacts

A report was provided by AUA that clearly describing the methodology, which was based on state of the art methods for the economic analysis of crops and was compatible with current accounting principles as used in industry and commerce. The models allowed the development and maintenance of a large number of cases in European conditions, which made possible the direct comparison between conventional and "future crops" (non-food) and provide the basis for decision making under different goals. A documented collection of recent work on conventional crops economics and cultivation practices in was used in parallel with the development of case studies (based on AUA models) for selected countries on the most competitive conventional crops.

At the same time a documented collection of recent work on future non-food crops economics and cultivation practices whether applied in the EU was used. Given the results obtained so far all findings will be consolidated and put together into a policy document indicating economic priorities based on supply and demand conditions, taking into account the priorities of the states or regions, the farmers' point of view and the agricultural potential in each region.

Social impacts was evaluated in terms of parameters that was set, addressing issues like the value creation from non-food uses of crops, rural income generated, rural infrastructure/resource development, rural economic development, diversification of rural enterprises, and investment in non-food uses of crops, rural employment generation, and social acceptability. Favorable scenarios with non-food systems cultivated in parallel with food crop systems, which have positive social impacts was evaluated, based also on their economic and environmental assessment.

Environmental analysis

Using EIA, the local environmental impacts due to the production of the non-food crops was evaluated, with focus on parameters like erosion, implications on water resources and supply, biodiversity, etc. The influence of the crops itself and the choice of the farming location was investigated. Results were country/crop/field conditions specific. Overall interactions and similarities or equalities were pointed out.

Using LCA, according to the ISO 14040-43 standards, the environmental implications of all non-food crops under concern were assessed by comparing the products from these non-food crops to their fossil counterparts. The complete life cycles of all bio-products ("fuel=bioenergy, "fibers=biobased materials) will be taken into account. The whole production chain of each crop and resulting bio-product was included as well as agricultural reference systems, use of by-products and ashes, including all relevant conversion technologies under concern etc. Life cycle inventory parameters like primary energy demand, CO_2 or NO_X was used to describe resource demand, greenhouse effect, acidification, eutrophication, ozone depletion and human toxicity. For this, international standards were used.

Using a multi-functional assessment tool the best options for the production and use of a set of different non-food crops and resulting bio-products in the future was conducted.

Regulatory framework

The development and implementation of standards on non-food crops as energy and fibers sources is supported and regulated with the help of different technology policy instruments applied in an EU level with some of them being harmonized in a National level. A review of the existing policies for non-food crops in EU27 was implemented. Based on the findings of this review, emerging of best practices was reported and the key factors that led to success stories were pointed out.

Recommendations for safety measures should be taken in order to rule the coexistence of food with non-food crops in the EU27 agriculture. As each country has a different socio-economic and environmental situation and, as such, practices of biomass energy and biobased products also vary between the countries. The strategies for the promotion of biomass energy and biobased products should therefore also be different. A formation of a framework of strategic policy options that would take into account available raw material resources, market trends of biomass energy and industrial utilization, coexistence of food with non-food crops and existing policies in the target countries.

Best practices scenarios

Results from the WP1 to WP5 were aggregated into a document, describing from the point of view of crop production the most viable crops for non-food production (either energy production or biobased materials). In a second step a preliminary scheme of possible output markets, including application in energy, materials and chemistry were set up, and this was linked to the various selected crop. Also at present influence of policies on these end-users markets were described.

For the new crops to be successful, careful planning of the application development step and the linkage to end-markets is crucial. Therefore, the promising crop-application-market combinations will be defined. From these combinations the system boundaries will be mapped out. Experience has taught that simply defining end market and publishing these findings are by no means enough to raise enough interest of possible market parties to actually start using the new feedstock. The way forward is to first select the end market, based on broad evaluation.

The next step was to carefully map-out the functional advantages of, and the requirements to the alternative feedstock to this end-markets back to the crop options, while on the way defining the system boundaries for these crop-application-market combination. Special attention was also being paid to integration of various uses of the same crop, including the potential of using a sophisticated biorefinery concept to use the whole crop, without leaving any waste. Existing and new technologies had been taken under consideration.

A priorities list had been drawn up, focusing on the European situation of land-use, climate, cropping possibilities and policy boundaries. Together with the outcome of the system boundaries this was lead to selection of a number of systems of which scenarios towards development and market introduction was defined, with a special focus on the stakeholders that were need to be involved in order to reach the project results.

Dissemination and support actions

The 4FCROPS website (www.4fcrops.eu) constitutes the main communication tool for the efficient dissemination of the project deliverables. The data gathered and developed from the other work packages is being displayed in an effective and user-friendly way. The website contents all the information that is available to the public (description of the project, objectives, work packages, consortium, links, fact sheets, leaflet, etc.)

Five workshops had been scheduled in the frame of this project. In these workshops the scientific committee will attend the workshops. The scientific committee was established in the kick-off meeting of the project and is being consisted by the consortium and by key players that were propose from the consortium and were designed during the kick-off meeting.

4FCROPS has been selected for twinning opportunities with Canada and Argentina/MERCOSUR projects. In the EC-Canada twinning two workshops had been taken place; the first in Montréal (February 2008) and the second in Pisa (June 2009). In the EC-Argentina/MERCOSUR one workshop had been done in Buenos Aires (May 2009) and the second one will be scheduled for June/July 2010 in Athens. 4FCROPS will mainly participate in both twinning by establishing and maintain the web sites for both bilateral agreements (www.ec-canada.eu for EU-Canada twinning and www.ec-agrentina.eu for EU-Argentina twinning).

4.1.3 Description of the main S&T results/foregrounds

Land use in EU27

Review of the current situation for the land use in EU27

The agricultural land in EU27 is almost covers 40% (on average, 175 Mha, data 2006) of the total land. In the Scandinavian countries and in regions with high mountains, characterised both by adverse growing conditions of crops, the proposition of agricultural land is lower than 40% and higher for forests.

The agricultural land is mainly used for the cultivation of arable crops. Thus the arable land covers 61% of the total agricultural land in the EU27 accounting to 107Mha. Areas with very high contribution of arable land are very widespread across Europe, including: whole of Denmark, Bulgaria, south-east UK, plains of France, western part of Poland, eastern Germany, whole Hungary, etc. The agricultural land occupied by permanent grassland and meadows on average is 31%. In traditional livestock breeding areas they are dominant land use, i.e. whole of Ireland, western UK, west of France, part of Belgium and the Netherlands. Permanent grasslands are very important in less-favourable areas, mountainous areas and foothills, when only stock-rising activities are possible. Permanent crops have little share with average of 8% of agricultural land in the EU-27. Only in southern countries olives and vineyards have considerable contribution to the land use (Greece, Cyprus, etc.).

The cereals are the most important crops in EU27 and according to 2006 data covered a total area of 59.6 Mha that is equal to 56% of the arable land. Wheat is the most important cereal covered 29% of arable land on average, followed by barley and maize. Apart from cereals other important crop categories are oilseeds (17% of arable land) and sugar beet (12%). Oilseeds are dominated with rapeseed.

In the most productive areas of Europe cereals are mainly produced. Important areas for cereals cultivation in Europe concentrated in northern France, eastern England, north-western Germany, western Poland and Hungary. Commonly wheat is exchanged in the crop rotation with rapeseed and sugar beet, thus these regions are also main production areas for rapeseed and sugar beet.

Across Europe large differences in yields existed. The highest wheat yields are recorded in northern France and north-western Germany and came up to 8-9 t/ha on average in 2006. At the same time in southern and central-eastern Europe the yields were quite lower and the varied from 2-4 t/ha on average. These differences in yields are decreasing nowadays.

The superior function of agriculture is to supply food for the population. The EU is self-sufficient in food to a great extend, exporting large quantities of agricultural produce outside the EU. The citizens have affluent diet with broad variety of food items. Changes in the demand for food come from the shifts in diet rather than from growth of the EU population.

The EU agricultural sector is affected by the global market situation. The imbalance between supply and demand for cereals world wide resulted with very high producer price in 2007 and the beginning of 2008. This gave immediate response in the increased cereal cultivation area in 2008 in whole of the EU-27.

In the EU farmers are obligated to set-aside part of their land. The obligatory set-aside rate is established on a yearly basis and basically amounts to 10%. In 2006 the obligatory set-aside area amounted to some 8 Mha, and this includes only EU-15 member states. Apart from 5 Mha the rest 3 Mha belonged to a voluntary set-aside. From 2011 the set-aside obligation would also apply for the EU-10 member states, which would add 1 Mha, and Bulgaria and Romania would bring additional

0.5 Mha from 2014. Set-aside land can be used for non-food crops, i.e. energy crops or crops to produce biobased materials.

So, far a significant part of the set-aside land was used for energy crops. In 2006 oilseeds (mainly rapeseed) for biodiesel covered some 800,000 ha out of the 4 Mha of obligatory set aside. Apart from set-aside land energy crops are grown under the aid for energy crops as well as without any specific regime. In total the energy crop acreage in the EU-25 was estimated at 2.5 Mha in 2005. Most of the production (90%) is concentrated in Germany, France and the UK.

The increase in energy crop areas is determined by the demand for biofuels, which is stimulated by the biofuel policy. So far, most of the energy crops are oil, starch or sugar crops used for transportation biofuels. Perennial lingo-cellulosic crops are mainly used for heat and power production; however the total acreage is less than 100,000 ha in the whole EU. The Climate and Energy Package approved in December 2008 is expected to boost the energy crop sector. Perennial crops shall have an increasing importance. The area of energy crops is foreseen to expand significantly in a short term mainly on the set-aside land.

Non-food crops used for biobased materials have a long tradition in Europe. Most commonly these are materials such as natural fibers and substances, such as starch and oils. However, biomass is also broken into blocks i.e. lactic acid, ethanol, furans in order to build new product. The size of the biobased market is considerable: 780 out of some 4,000 products included in the Eurostat-Nace database are partly or fully based on biomass or can be potentially build from biomass.

The climate change impact on the land use in the EU is not well understood so far. The projections shows that the climate change and increasing CO2 concentration will increase crop yields compared to the baseline in north Europe while decreasing yields in southern Europe, especially in Spain, Portugal and south Italy and secondary in France and north Italy.

The most important driving forces for land use change in the EU are currently the demand and supply for certain crops and the rules of the Common Agricultural Policy. Decoupling payments from production under the CAP came out to free the farmer’s decisions what to produce. Thereby the land use corresponds to the market situation for specific crops.

The set-aside obligation proved to be a very effective to promote non-food crops production. Ingeneration in specific crop market, such as putting production quotas and/or setting an intervention market price, has a very strong and direct effect on crop areas. The specific policy targets such as biofuel targets proved to have an important impact on land use. The situation on global agricultural market has a visible effect on the allocation of crop areas in the EU; one example is the increase in the demand for cereals in the world.

List with the restrict factors for EU agriculture

The main restrict factor in EU agricultural is the intensive crop cultivation and production that requires uses of fertilizers, pesticides and water in the areas that needed (mainly in the Mediterranean area and in Atlantic zone). The intensive crop cultivation increases the biodiversity threats, the soil erosion and soil compaction. Another important restrict factor that expecting to play an important role in the future is the climate change and its effect in the European agriculture.

The most important crops in EU27 agricultural are the cereals (wheat, barley, maize and triticale), while important crops are sugar beets, rapeseed and pea. In order high yields to be recorded for the above mentioned crops there is for fertilization, water irrigation (especially in the South Europe) as well as for pesticides applications.

According to FAO the three quarters of the genetic diversity found in agricultural crops has been lost over the last century decrease in the genetic diversity continues. It should be pointed out that 90% of our food energy and protein comes from 15 plants and 8 animal species and with negative consequences for nutrition and food security. More than 50% of the global plant-based energy intake is being provided by wheat, rice and maize.

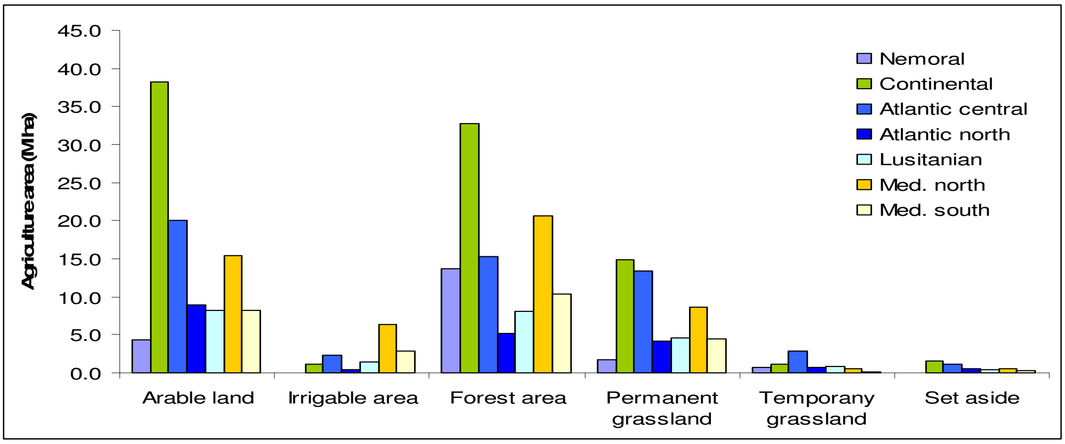


Figure 1 – Forest, agriculture (arable land, permanent and temporary grassland) and set-aside land partitioning in the selected bioclimatic zones of EU (as had been proposed by *Metger et al.,* 2005)

The most important factors in the decrease of the biodiversity are the expansion of the farm production as well as the intensification of the input use. At the same time some agro-ecosystems can (like the organic farming) can be quite useful for maintain the biodiversity. Farming is also dependent on biological services such as the provision of genes in order to develop improved crop varieties and livestock breeds, cross pollination and soil fertility that could be provided by microorganisms. In some cases the non-native species could cause damage to crops from alien pests and competition for livestock forage.

According the scenarios that have been developed about the effect of the climate change in the European agriculture the possibilities to successfully grow oilseeds, cereals, starch crops, and solid biofuels are expected to increase in north Europe, mostly due to higher summer temperatures, while are expected to decrease in southern Europe (e.g. Spain, Portugal, southern France, Italy, and Greece) due to water shortage. This trend is initially slightly visible (2020) and then it becomes much more pronounced (2080 scenarios) according to other global climate models (e.g. CSIRO2, PCM and CGCM). Spain appears particularly affected by climate change, which causes a drastic decline of many temperate crops in this area. Therefore, there is evidence that the choice of bioenergy crops in southern Europe will be restricted to a very small number of crops (e.g. sorghum, sunflower and miscanthus) unless alternative agronomy strategies (e.g. earlier sowing) or selection programs will provide new genotypes with higher drought adaptability. However, it should be underlined that other solid biofuels were not included in this analysis which can be expected to be more tolerant than miscanthus to drought (e.g. giant reed and switchgrass).

Market demands of the non-food crops in EU27

It was estimated that, keeping in mind that this is a lower limit due to the missing data, approximately 8.5 Million tons of biomass is in Europe used in existing non-food products next to fibres and paper and pulp. This is not including the demand for biofuels. Growth within this group of established applications is possible but will presumably be mainly accommodated within the existing chains. Natural rubber is not included in this listing since separate data could not be extracted.

This implies that the application of biomass for non-food products might increase by over 15- fold, when the chemical industry will start to seriously change their feedstock from naphtha to biomass.

On the other hand this demand is of the same order of magnitude as present demand for wood and fibre. Also, this shift in demand will definitely not occur overnight, since technology needs to be developed further and existing installation need to be depreciated before new investments are done.

Regarding the use of the fuel crops for biofuels it should be mentioned that the target for 10% biofuels by 2020 is expected to lead to the cultivation of 25 Mha (AEBIOM): 15 Mha will be used for liquids biofuels (biodiesel and bioethanol), 5 Mha for biogas and 5Mha for solid biofuels. In 2007 the total biomass consumption to primary energy consumption in the EU was 89 million tons oil equivalent.

These numbers can be compared to the feed demand of the EU, which is presented in chapter 8. In total the annual consumption of compound feed is approximately 143 Mton. Almost half of this amount is covered by feed cereals, whereas over 30% comes from oil (cakes) and fats. This amount is in the same order of magnitude as the total extra demand from the chemical industry. Other feeds, mainly roughage, but also simple concentrates and raw materials which are directly used on farm, are estimated to add up to between 45 and 200 Mton of dry matter. Total feed demand is thus estimated to be roughly twice as high as the potential demand from the chemical industry.

Food markets in the EU break down to approximately 50 Mton of cereals, about 6-7 Mton of vegetable oils, approximately 0.9-1 Mton dry pulses, approximately 30 Mton of potatoes plus an additional 6 Mton potatoes in the form of processed products, and approximately 15 Mton of sugar. Next to this comes a smaller range of vegetables, fruits and nuts. In total it adds up to approximately 140 Mton of biomass for human consumption (the dry matter content is obviously lower).

Land available for the cultivation of non-food crops now in 2020 and in 2030

According to this report the total available land for the cultivation of non-food crops now is around 13.2 Mha, while in 2020 it is expected to be increased and to be around 20.5 Mha. The projections that have been made in 4fcrops project showed that the available land for the non-food crops will further increased in 2030 and will be 26.2 Mha. The biggest available land for now and for 2020 was recorded in Spain (3616 ha), while in 2030 it is estimated that will be in Poland (4079 ha). The top five countries in all timeframes will be: Spain, Germany, Poland, France and Romania. These five countries with the contribution of Italy, Bulgaria and Hungary will be the eight European countries that now give the 80.9 % available land for non-food crops, in 2020 could give 81.7% and in 2030 could give 84.5%.

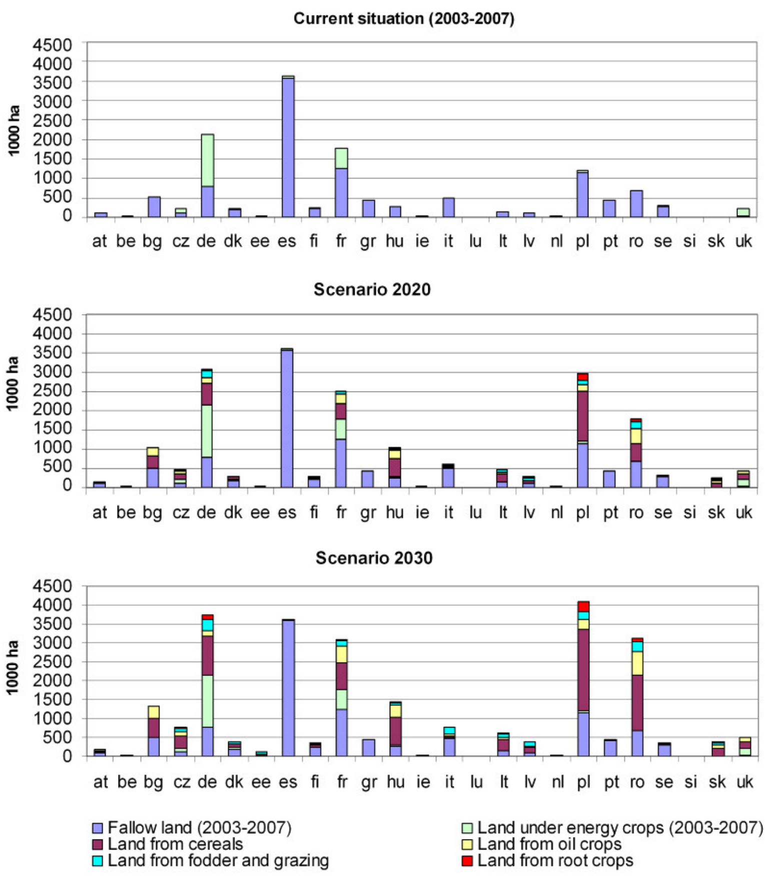


Figure 2 – Available land for the cultivation of energy crops now, in 2020 and in 2030

The results obtained from 4fcrops were compared with the results of two other studies that followed quite similar methodology (EEA, 2006 and EEA, 2007), while 4FCROPS used a completed different approach for 2020 and this comparison presented in Figure . However, the general overview is that countries with large agricultural land areas were found to be the major suppliers of land available for non-food crops in all three studies. The specific exception is Germany with huge reduction of land availability found between the results of the EEA (2006) study and (2007) and the UK, for which the results of 4F CROPS project show much lower land available than the EEA studies. Bulgaria and Romania were only investigated under the 4F CROPS project.

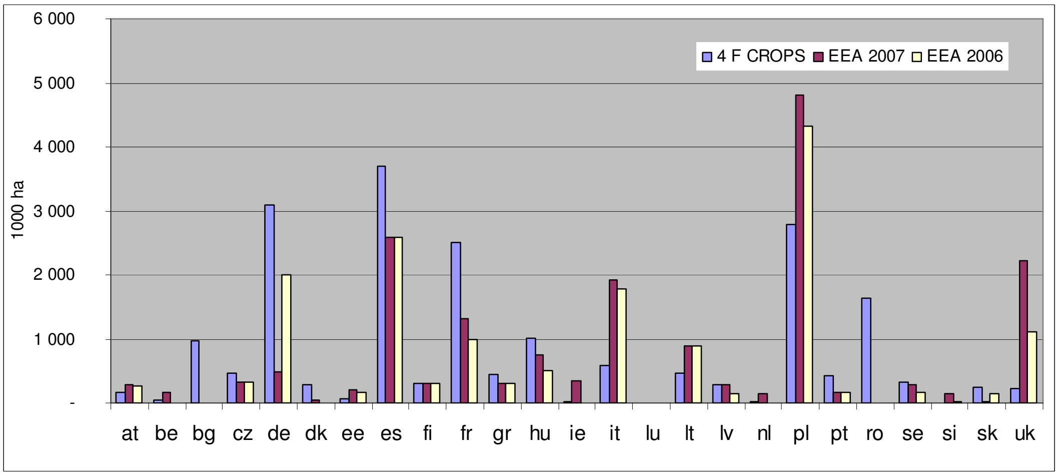


Figure 3. Comparison of the results on land available for non-food crops in 4F CROPS project and EEA studies (2006) and (2007)

Cropping possibilities

List of the non-food crops

In EU several crops have been tested as energy crops. Usually, the energy crops are classified in crops for oil production, for fiber, lignocellulosic crop, sugar and starch crops as well as woody crops. During the last two decades the research on all these crops that have been selected as energy crops was focused on production and management optimization. The research should focused on plant breeding for yields maximization, yields stability in different environments, rotation systems, cropping systems which will include soil no tillage, double cropping and multifunctional land use as well as potential land cultivation and low inputs.

In the view of the 4FCROPS a list of the most promising non-food crops per region and end-use was prepared (Table 1). For the preparation of this table two parameters were taken under consideration, which were: a) climatic constraints (rainfall, maximum and minimum temperature) and presence of water if needed, b) soil conditions (arable good soil, marginal soil). In case that the potential yields of the region are sufficient for industrial development (medium and large scale) other constraints to be considered are: existing varieties suitable to the region (breeding activity), propagation material, knowledge of agronomic practices (soil tillage, sowing methods, fertilization, crop protection, harvest time), mechanization (establishment and/or sowing, harvesting), logistics (transport and storage) and last but not least the farmers acceptance.

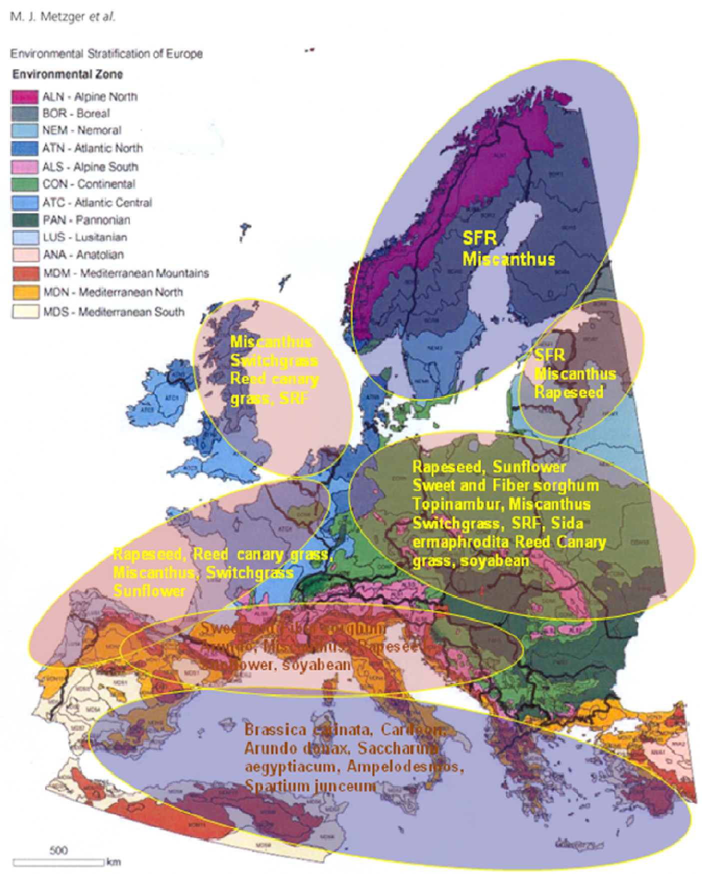


Figure 4. Promising non-food crops for each climatic zone in EU27.

As it is presented in the Table 1 the selected non-food crops were categorised in five groups according to the final end use (crops for biodiesel, for fiber, lignocellulosic crops, for bioethanol as well as crops for short rotation coppice). For each climatic area selected the most promising crops for each specific use.

Table 1. Proposed non-food crops for each climatic area and product

	MAIN PRODUCT				
Climatic area	**Oil**	**Fiber**	**SRF**	**Lignocellulosic**	**Sugar**
Nemoral	Rapeseed	Hemp	Poplar	Reed canary grass	-
Continental	Rapeseed	Flax	Willow	Miscanthus	Sugar beets
Atlantic central	Rapeseed	Flax	Poplar	Miscanthus, Switchgrass	Sugar beets
Atlantic north	Rapeseed	Hemp	Willow	Miscanthus, Switchgrass	-
Lusitanian	Rapeseed	Hemp	Willow, Eucalyptus	Miscanthus	Sweet sorghum
Mediterranean North	Sunflower	Hemp	Poplar	Giant reed	Sweet sorghum
Mediterranean South	Ethiopian mustard	Flax	Eucalyptus	Cardoon	Sweet sorghum

Rotation possibilities

Lately conventional agricultural systems have increased their dependence upon external inputs, mainly on fertilizers and pesticides. The increased dependence constitutes a challenge to the long-term productivity and sustainability of non-food crop and/or food crop systems because of environmental and logistics constrains. The importance of crop rotation, however, has been long recognized as an alternative system that can reduce agriculture's dependence on external inputs through internal nutrient recycling, maintenance of the long-term productivity of the land, avoidance of accumulation of diseases and pests associated with mono-cropping and increased crop yields). Crop rotation also can help to reduce soil erosion, improve soil structure, enhance permeability, increase biological activity, increase water and nutrient storage capacity, and increase the amount of organic matter in soils.

The aforementioned beneficial effects can be further improved by combining crop rotations with cover crops and reduced or no-tillage practices. Moreover, combining crop rotation and pesticides is an effective way of reducing pest populations. Fallowing is also used in combination with rotation systems to enhance their beneficial effects, especially in dryland areas where there are few alternative crops to choose. However, barriers that would stop farmers for adopting crop rotation systems are the need for diversified farm activities, and information, as well as more diversified equipments and storage facilities. Moreover, the rotation systems required management skills and higher knowledge. These barriers may be even more prominent in the case of new promising non-food energy crops.

Crop rotations are characterized by growing a wide variety of crops in a sequential system on a given cultivated land and by the associated management practices. Rotation plans are usually built around one or two leading crops, followed by one or more legumes and/or other crops. It is important, however, to include legumes in the rotation as they fix nitrogen, contribute to soil structure, to erosion control, to forage production, and cash hay and seed production.

Table 2. Climatic regions and rotation possibilities

Environmental zones	Suggested crop rotations
Nemoral	• Rapeseed – Cereal (wheat, barley, oat) – Cereal – Rapeseed
Continental	• Wheat (legume) – Maize – Sunflower – Sorghum – fallow • Flax – Wheat – Legume
Atlantic central	• Rapeseed – Cereal (wheat, barley, oat) – Cereal – Rapeseed • Flax – Wheat – Legume
Atlantic north	• Rapeseed – Cereal (wheat, barley, oat) – Cereal – Rapeseed • Flax – Wheat – Legume
Lusitanian	• Wheat (legume) – Maize – Sunflower – Sorghum – fallow • Rapeseed – Cereal (wheat, barley, oat) – Cereal – Rapeseed
Mediterranean North	• Wheat (legume) – Maize – Sunflower – Sorghum – fallow • Flax – Wheat – Legume
Mediterranean South	• Wheat (legume) – Maize – Sunflower – Sorghum – fallow • Flax – Wheat – Legume

In Table 2 presented the suggested crop rotations for each climatic zone, while in Table 3 the suggested crop rotations have been designed taken under consideration the fact that the end product and/or market will be the same for all the plants in each rotation.

Table 3. Climatic regions and rotation possibilities in a hypothetical scenario in which all crops participate in the rotation are exclusively dedicated to the production of feedstock for bioenergy purposes.

Environmental zones	Hypothetical suggested crop rotations	Feedstock supplied
Nemoral	• Rapeseed – Flax – Safflower	• Bio-oils
Continental	• Maize – Sugar beet – Sorghum • Rapeseed – Flax – Safflower	• Ethanol • Bio-oils
Atlantic central	• Rapeseed – Flax – Safflower	• Bio-oils
Atlantic north	• Rapeseed – Flax – Safflower	• Bio-oils
Lusitanian	• Maize – Sugar beet – Sorghum • Soybean – Ethiopian mustard – Sunflower • Rapeseed – Flax – Safflower	• Ethanol • Bio-oils • Bio-oils
Mediterranean North	• Maize – Sugar beet – Sorghum • Soybean – Ethiopian mustard – Sunflower • Rapeseed – Flax – Safflower	• Ethanol • Bio-oils • Bio-oils
Mediterranean South*	• Maize – Sugar beet – Sorghum • Soybean – Ethiopian mustard – Sunflower	• Ethanol • Bio-oils

* Some crops such as maize and sugar beet may require supplemental irrigation.

Yields of the selected non-food crops

In 4FCROPS the most promising ***crops for oil production*** considered rapeseed, sunflower and Ethiopian mustard. In Europe the most important crop for biodiesel is rapeseed. According to FAOSTAT (2007) the total harvested area was 6500 million ha, while at the same time the mean seed yields in Europe of the crop is 2500 kg/ha. The main producer is France followed by Germany, while important producers consider Poland and UK. Sunflower is another important oil crop fro biodiesel production with a total cultivated area in EU around 3300 millions/ha and mean seed yields 1900 kg seeds/ha. Ethiopian mustard is not a commercial crop like sunflower and rapeseed and has been tested only in small and large experimental fields with comparable seed yields with rapeseed and it is considered as a good choice in Mediterranean region.

The most important crops for ***short rotation coppice*** are: willow, poplar and eucalyptus. It is reported 13500 ha of willow in Sweden and 6000 ha in Poland, while the yields varied from 8-10 ton/ha/year. Commercial fields of poplar has been reported in Italy (5700 ha) and Spain (18000 ha). The potential yields of this crop are quite high. It has been reported yields 20 t/ha/y in experimental fields. Eucalyptus is also an important crop for SRC in Europe with potential yields of 32 t/ha/year. In Europe is being cultivated for paper and pulp production (mainly Portugal and Spain).

Lignocellulosic crops are important non-food crops for both solid biofuels and for second generation biofuels in the future. In this study were selected: reed canary grass, cardoon, switchgrass, miscanthus and giant reed. Reed canary grass is a perennial crop for northern Europe. It is the cultivated commercial in Finland with a total cultivated area around 20,000 ha; while in Sweden are 1,000 ha. Its realistic yields varied from 4 to 7 t/ha. In Finland has been set a target for 100,000 ha of reed canary grass by 2015. Miscanthus is another important crop that can be cultivated in whole Europe with yields that can reach 30 t/ha. Its realistic yields varied from 15 to 20 t/ha. It's a crop that needs water and thus it is not the best choice for the regions in Southern Europe with limited water irrigation. Switchgrass is a perennial crop with many varieties that can be cultivated successfully with whole Europe and can replace miscanthus in areas with limited water for irrigation. Giant reed is a perennial crop with quite high yields up to 35 t/ha for Southern Europe and with realistic yields between 15-20 t/ha. It has been exploited only in small and large experimental fields and it is considered as an excellent source for second generation biofuels. Cardoon is a perennial crop that can be used for both solid biofuels for whole crop and oil production from its seeds, while the whole crop could be exploited for second generation biofuels. It is a crop for the South Europe with dry yields that could reach 25 t/ha, while it's realistic yields are 10-15 t/ha.

Sweet sorghum and sugar beets were selected as important crops for ***bioethanol production*** (first generation biofuels). Sweet sorghum is an annual spring crop with quite high biomass yields that has been investigated the last two decades in several European research projects. Its yields can reach 40 t/ha dry matter yields and fresh biomass yields up 140 t/ha. Sugar beet is a traditional biennial crop. In EU27 the total harvested area in 2007 was 1.851 million ha and the top four producers countries by descending order were Germany 0.403 million ha, France 0.394 million ha, Poland 0.247 million ha and UK 0.122 million ha. The mean yields in EU are 521998 kg/ha.

The most important ***fibre crops*** for Europe are flax and hemp. Another important crop is cotton that is cultivated in South Europe and for this reason it has been investigated in not such a large extent in INF deliverable. Kenaf is another important fibre crop that is being presented in detail in 4fcrops but some presentations on this crop made in two out of the five project workshop. The presentations made by the Italian Company KEFITALIA that is producing insulations mats from this crop. Fibrous flax was cultivated in a total area of 95000 ha in Europe in 2007. Its yields are 10 t/ha in experimental fields and the long fibre yields were 2.8 t/ha and 0.7 t/ha of the short fibre yields. The realistic yields are 30 to 35% lower compared to the ones recorded in experimental fields. Hemp is being cultivated in quite small area compared to flax. In 2007 the cultivation area was 14915 ha; in 2008 the estimation was 12768 ha, while the forecast for 2009 was 18550 ha.

Raw material characteristics

Oil crops: The most important characteristics in terms of oil crops are the oil content of the seeds, the chemical composition of the oil. Rapeseed and Ethiopian mustard produce seeds with quite high oil content that for most of varieties and hybrids is higher than 40%. Both crops produce oils that are in fully accordance with the biodiesel standards. Sunflower seeds have oil content from 25 to 40 % but recently the high oleic varieties that have been produced give seeds with higher oil content and higher percentage in oleic acid.

Lignocellulosic crops: The ash content of reed canary grass varies from 1 to 8% and the net caloric value is 18 MJ/kg. The ash content of cardoon is the framework of bioenergy chains project was found quite high around 15%, while for miscanthus was 3%, for switchgrass 4.9% and for giant reed 4.75%. The gross caloric value in the same project found to be 3923 kcal/kg for cardoon, 4335 kcal/kg for miscanthus, 4267 kcal/kg for giant reed and 4178 kcal/kg for switchgrass.

SRC: The ash content of willow had been reported to be 2.9% and the net calorific value 18.62 MJ/kg. The corresponding values were for poplar 0.5-1.9% and 18.1 MJ/kg. For Eucalyptus it has been reported that the ash varies from 2-3% and the net calorific value for the eucalyptus wood is 18.94 MJ/kg, while for the bark 16.46 MJ/kg. It's should be mentioned that for soft woods the ash content varies from 1-2%, while the net calorific value is 18.97 MJ/kg.

Sugar crops: Sweet sorghum stems have high content in sugars that according to the variety and the harvesting time varies from 10 to 15%. Sugar beet is a traditional crop that is mainly cultivated for sugar production. From 100kg fresh sugar beets can be extracted 12 to 15 kg sucrose, 3.5 kg molasses and 4.5 kg dried pulp.

Fibre crops: The flax straw must be evened in the root part and arranged parallel in bundles of at least 2 kg (retted) or 2.5–4.0 kg (raw). Bundles should be bond with natural fibre string or flax straw. Retted straw can also be baled; raw straw – not. The thickness of the straw stems should be around 0.8mm.Very important parameter is the color of the straw. The light – grey, steel-grey and silver – grey colours of straw are demanded (at least for 70% of stems). For raw straw the color must be yellow (at least 65% of stems). For hemp dew-retted straw steel-grey, silver-grey and light-grey colors of straw are preferred, however also brown-grey, dark-grey and green-grey colors are acceptable for lower classes (at least for 70% of stems). For raw straw the color must be light yellow, dark yellow and green–yellow, however also light green, light brown, light grey (at least 65% of stems) and dark green and dark–grey straw is also acceptable for lower classes.

Biotechnology improvement

A review of the current status for selected non-food crops in terms of their genetics, genomics and breeding was carried out. Nowadays, the available literature forms the basis for current and future efforts to introduce and establish the selected non-food crops, along with strategies to produce new genetic material for biofuel, feed and fiber exploitation.

The research on sugar- producing crops such as *Beta vulgaris* L and *Sorghum bicolor* L was reviewed. Even though conventional breeding approaches led to substantial increase of sorghum and sugar beet yield and quality parameters, the progress for improving resistance to biotic and abiotic stresses is limited due to inadequate genetic resources. However, these genomic and genetic resources are emerging. Many molecular marker technologies have been developed and applied to studying patterns of genetic diversity in sorghum and sugar beet germplasm collections and to breeding programs. The whole-genome shotgun sequencing has produced a high coverage draft for sorghum genome and a draft of the sugar beet genome has been assembled and annotated. Mutants with traits of high-yield or digestibility have been identified, along with their underlying genes. *In vitro* culture techniques and genetic transformation approaches have also been widely exploited. These achievements open new avenues for sorghum and sugar beet improvement.

A detailed overview of the current status of woody and herbaceous lignocellulosic feedstocks was provided. Short rotation coppice (SRC) is a specialised form of forestry plantation that involves the growing of high-yielding species such as Populus, Salix and Eucalyptus. *Populus trichocarpa* became the first tree to have its full genome sequenced. QTLs for growth trajectories, agronomic or longitudinal traits, osmotic potential phenotypic variation and analysis of biomass or wood chemistry have been detected in poplar. The interpretation of QTLs into marker-assisted selection (MAS) moves into the realm of commercial applications. Genetically engineered poplar trees with altered structural features of the lignin polymer, support the notion that there are significant opportunities to improve biomass utilization by exploiting the malleability of plant lignification processes. Plants of increased adaptability to various environments are of great interest. Transgenic poplar characterized by over-expression or silencing of PtFAD2 gene in poplar trees, lead to alterations of freezing tolerance. The synteny between willow and poplar genomes provides the evidence that poplar's genomic resources will be highly beneficial in willow's genomic research. Targeted breeding programs, underpinned with molecular marker and genomic research, can be developed focussing on the generation of high yielding, pest and disease–resistant elite willow genotypes. Eucalyptus research is also driven by the same technologies including the discovery of new sources of biodiversity for breeding programs, the application of high throughput approaches and genetic manipulation towards the identification of new genes for biomass yields. As an energy crop, *Cynara cardunculus* L is grown for its aboveground biomass. Efforts have been made in cynara genome research in order to develop genomic resources and tools for basic and applied genetics, genomics, and breeding research. QTL analyses on large metabolomic data set have been exploited in order to understand the function of specific genes and their role in metabolic pathways.

The status of current genomic research in potential fiber crops was also evaluated. Different marker systems have been developed for hemp's (*Cannabis sativa*) germplasm fingerprinting. The identification of molecular markers for specific traits, gathered in a saturated linkage map, could have a remarkable impact on hemp breeding. *Linum usitatissimum* (flax) is an annual crop that is grown for its fiber (fiber flax). Several types of molecular markers have been employed to analyze flax genetic diversity. Sixty three QTLs for eighteen important agronomic traits have been recently identified, providing new targets for manipulation using biotechnology. Kenaf's (*Hibiscus cannabinus* L) emergence from research into the world of commercialization is a slow process. In order to improve components of interest, efficient methods of transformation techniques have been developed using *Agrobacterium tumefaciens*, protoplast electrofusion or biolistic methods and somatic hybridisation.

Oil crops have considerably gained in importance to world agriculture and associated industries over the past 25 years. Brassica is a diverse genus containing over 100 species such as oilseed rape (*Brassica napus* L.) and Ethiopian mustard (*Brassica carinata*). The development of molecular tools to assist in selection and to develop novel genetic variation has represented a major landmark in Brassica oilseed breeding. The Brassica crops benefit from the close phylogenetic relationship with Arabidopsis, the model plant for forefront research on plant molecular genetics. A better knowledge of genetic determinism of oil content which will be relevant for the breeders to control the genetic advance of the crop has been accomplished by identifying numerous QTLs which control the oil content variance. Traits such as downy mildew resistance, high oleic acid content, and herbicide resistance are currently under investigation, although complex traits such as resistance to Sclerotinia, Phoma and Phomopsis stem canker are also taken into account.

Perennial grasses such as switchgrass (*Panicum virgatum* L) and miscanthus (*Miscanthus* sp) are attracting increasing interest as potential biofuel crops. To reduce greenhouse gas emissions by sustainable cultivation of switchgrass for bioenergy will require advances in feedstock features like yield quality and quantity or adaptation to diverse ecological/climatic zones. Additional target traits are the flowering time and the photoperiod sensitivity since they play a major role in biomass yield through determination of the growth period. Recently, the first complete linkage maps of two switchgrass genotypes became available, enabling efficient marker assisted selection (MAS) breeding strategies. Transgenic approaches will undoubtedly benefit the advance of cellulosic biofuel feedstocks. Transgenic switchgrass plants modified by RNAi lignin pathway gene constructs have been developed, and plants with decreased lignin and improved saccharification were identified. Miscanthus x giganteus is a perennial grass that produces superior biomass yields in temperate environments. Today, state of the art DNA analysis platforms are being employed to rapidly establish and fingerprint new elite varieties, exhibiting enhanced traits such as drought tolerance and rapid growth, which are highly adapted to arid regions. As is the case for switchgrass, the combinatory application of breeding and biotechnology to miscanthus improvement is promising.

In conclusion, biotechnological and molecular genomics approaches could enhance non-food crops production, quality, resistance to biotic and abiotic stresses, while reducing costs and minimizing any adverse effects on the environment. Genetic modification has been highlighted as the key to increase yields and environmental benefits, while reducing agricultural inputs. However, cultivation of GM crops in Europe is a controversial and sensitive issue and non-arguably more research is needed in order to understand GMs' complete role and influence to natural environment.

Cropping possibilities

Taking under consideration the list of the selected crops, the rotation possibilities of the selected annual crops, the yields and raw material characteristics cropping systems for each climatic area were developed.

The cropping system is a wider concept that implies a community of crops and relative management practices used to achieve this production with the aim to realize specific agronomic objectives, or in other words, the conjunction of the vegetal production of a given plot, including the space-time disposition of crops and the interaction between these and the resources of the farm, other farm activities and the physical, biological and technological factors. The prevailing economic situation, availability of agricultural equipments, availability of economic resources, markets and laws are also important factors to consider when planning a cropping system. However, in the present task the only ecologic and agronomic aspects are taken into consideration while the other factors (economic, energetic, environmental, social, etc.) are analyzed in the subsequent work packages.

In particular, the aim of this study was to define different scenarios based on (i) seven climatic zones (Metzger et al, 2005), (ii) two type of soil (marginal or agricultural), (iii) two level of input (conventional or reduction) and (iv) type of crop (annual, perennial, conventional and of new introduction).

First of all, ***climate*** is the basic criterion for distinguish various unit of utilization and the suitability of different areas for different crops. The environmental stratification of Europe suggested by Metzger et al. (2005) was used in the analysis, assuming similar environmental parameters where agriculture land could be suitable for non-food crops cultivation along with food, feed and fiber crops.

The nature and ***quality of soil*** is a function of soil forming, climate factors, topography, parent material, soil biota and time; for this reason, it is difficult to distinguish between "agricultural" and "marginal". According to McGee (1984), marginal soil is a very wide concept that could include several types and categories of soil and the marginality of soil could be ascribed to several factors such as water deficit, rainfall distributions, extremely hot or cold temperatures, lack of effective soil layer for rooting depth, soil with mechanical limitations because of large rocks, steep slopes, shallow or weathered. Moreover, the marginality of soils could be also linked to the economy and market oriented definitions, which implies that cultivation of marginal lands is justified only after a thorough assessment of the economic implications in term of input incurred as compared to the expected output (gross income minus production costs). For instance, land may be considered marginal for large scale mechanized crops, but of good quality for small scale non-mechanized farming, or vice-versa. A specific soil could be marginal for certain crops but of good quality for others. Example of poor rainfall and not well distributed during the crop growing cycle (e.g. South Mediterranean environments, with a mean annual rainfall of 550 mm concentrated during autumn-winter and prolonged drought summer) are conditions unsuitable for maize and/or other high input summer crops, while economical profitable for winter crops, such as winter cereals, able to grow well and benefit of the water stored during winter period. On the other hand, improvement in cultivation techniques and other technological inputs such as new cultivars (drought resistant, pest resistant, etc), adequate weed and pest control could contribute towards production in marginal soil, and thanks to this marginal soils can become profitable.

Extremely important when determining the agricultural production potential of a land, is to specify the management or production systems which are applied to the specified objective. According to the Food and Agricultural Organization (FAO, 1983) a generalized description of the three different levels of inputs and management could be the follow:

- High input level: methods applied at this level are based on advanced technology and high capital resources. Fertilizers, chemical weed and pest control used to achieve maximal yields or economic returns, as well modern mechanization methods. Appropriate soil conservation practices and ecosystem management, frequent exchanges with extension service and peers. Use of high yielding varieties and hybrids.
- Intermediate input level: these are methods practiced by farmers who follow the advices of agricultural services but have limited technical knowledge and capital resources. Agricultural techniques and adequate input to improve crop yields, but not to achieve maximum yields or economic returns. Some fallow and soil conservations techniques are applied. Use of improved cultivars, chemical weed and pest control.
- Low input level: this is usually rainfed condition. No significant use of input such as artificial pesticides and fertilizers or improved cultivars and machinery. Use of local cultivars, fallow periods practiced and low capital intensity with high family labor intensity and family based infrastructure. These are typical conditions of developing countries.

The cropping systems that were developed are presented for each climatic area is presented below.

NORTH EUROPE

In the **NEMORAL** climatic area were selected seven possible cropping systems which are: 1) willow (perennial), 2) willow (perennial), 3) Pea – Cereal (barley) – Rapeseed, 4) Hemp - Rapeseed – Pea, 5) Rapeseed-Cereal (barley)-Pea-Rapeseed, 6) Rapeseed-Flax-Sunflower and 7) Red clover-Rapeseed-Flax

In the **CONTINENTAL** climatic area eight cropping systems were selected, two of them including perennial crops, while the rest combine annual crops traditional and non-food crops and are: 1) poplar (perennial), 2) miscanthus (perennial), 3) Cereal (wheat)-Maize-Sunflower-Sorghum-Red clover, 4) Pea-Maize-Sunflower-Sorghum- Red clover, 5) Flax-Cereal (wheat)-Pea, 6) Maize-Sugar beet-Sorghum, 7) Rapeseed- Flax- Sunflower and 8)Red clover-Rapeseed-Cereal (wheat)-Flax.

In the **ATLANTIC CENTRAL** seven cropping systems proposed; three of them are with perennial crops, while the rest combine several annual crops and were: 1) Miscanthus, 2) Poplar, 3) Switchgrass, 4) Sugar beet-Cereal (wheat)-Pea, 5) Rapeseed-Cereal (wheat)-Pea-Rapeseed, 6) Flax-Cereal (wheat)-Pea and 7) Rapeseed-Flax-Red clover.

In the **ATLANTIC NORTH** ten cropping systems were proposed four of them are perennial crops, while the rest combined several annual crops (food and non-food crops): 1) Willow, 2) Poplar, 3) Miscanthus, 4) Switchgrass, 5) Rapeseed-Cereal (barley)-Flax, 6) Hemp-Cereal (barley)-Pea, 7) Rapeseed-Pea-Wheat, 8) Rapeseed-Cereal (barley)-Pea-Rapeseed, 9) Flax-Wheat-Pea and 10) Rapeseed-Flax-Red clover.

SOUTH EUROPE

In the **LUSITANIAN** climatic area ten cropping systems proposed; three were with perennial crops: 1) Eucalyptus, 2) Poplar, 3) Miscanthus, 4) Pea-Cereal (wheat)-Rapeseed, 5) Rapeseed-Cereal (wheat)-Hemp-Cereal (barley), 6) Wheat-Maize-Sunflower-Sorghum-Red clover, 7) Pea-Maize-Sunflower-Sorghum- Red clover, 8) Rapeseed-Cereal (wheat)-Pea-Rapeseed, 9) Maize-Sugar beet-Sorghum, 10) Soybean-Ethiopian mustard-Sunflower and 10) Rapeseed-Flax-Red clover

In the **MEDITERRANEAN NORTH** climatic area ten cropping systems proposed; three were with perennial crops:1) Poplar, 2) Miscanthus, 3) Giant reed, 4) Cereal (wheat)-Maize-Sunflower-Sorghum-fallow, 5) Legume (Pea)-Maize-Sunflower-Sorghum-fallow, 6) Flax-Cereal (wheat)-Pea, 7) Maize-Sugar beet-Sorghum, 8) Soybean-Ethiopian mustard -Sunflower, 9) Rapeseed-Flax-Safflower, 10) Sorghum-Soybean-Cereal (wheat)-Kenaf

In the **MEDITERRANEAN SOUTH** climatic area six cropping systems proposed; three were with perennial crops:1) Giant reed, 2) Cardoon, 3) Eucalyptus, 4) Ethiopian mustard-Cereal (wheat)-Legume (faba bean) - Sweet sorghum, 5) Faba bean-Cereal (wheat)-Ethiopian mustard-Sweet sorghum, 6) Flax-Cereal (wheat) - Legume (faba bean)

Table 4. Selected oil crops for biodiesel production

	Rapeseed	Ethiopian mustard	Sunflower
Area of origin	Asia and Mediterranean area	Ethiopia	Subtropical and temperate zones
Available genetic resource	Many varieties available	Many varieties available	Many varieties and hybrids
Photosynthesis system	C3	C3	C3
Yield (t ha-1)	Ireland 3.89, Romania 1.18	1.2 – 2.9 seeds; 3.0 – 16.0 biomass	Romania 0.7, Germany 2.6
Raw material characteristic	Oil content 40-45%	About 40% oil	More than 40% oil
Adaption range in EU	North EU as winter; South EU as winter or spring crop	Mediterranean and areas free of severe winter conditions	From cold to southern semi-arid
Rotation time	Annual	Annual	Annual
Establishment	Seed	Seed	Seed
Harvest time	Summer	Summer	Summer
Required machinery	Normal available	Normal available	Normal available
Fertilizers input (kg ha-1 N):	190 North EU, 140 South EU	lower than rapeseed	140
Pesticide and herbicides demand	Medium/high requirement	Sensitive to weeds	As traditional food crops

Table 5. Selected fibre crops and crops for bioethanol production

	Flax	Hemp	Sweet Sorghum	Sugar beet
Area of origin	Unknown	Central Asia	Central/Eastern Africa	Mediterranean and Atlantic coast of Europe
Available genetic resource	Many varieties available	Many varieties available	Many varieties and hybrids	Many varieties available
Photosynthesis system	C3	C3	C4	C3
Yield (t ha-1)	0.55 – 2.0 seeds and 4.0 - 10 straw	0.5 – 1.0 seeds, 12 – 22 straw	2.0 – 4.0 seeds 5 – more than 40 straw	Bulgaria - 12 Portugal - 75
Raw material characteristic	Seeds and fiber	Seeds and fiber	Seeds and sugar/lignocellulosic biomass	Sucrose, Molasses and pulp
Adaption range in EU	From North to South EU	From North to South EU	Southern EU	From North to South EU (irrigation in semi-arid regions)
Rotation time	Annual	Annual	Annual	Annual/biennal
Establishment	Seed	Seed	Seed	Seed
Harvest time	Late summer/fall	Summer	Fall	Fall
Required machinery	Normal farm equipments	Normal farm equipments	Normal farm equipments	Special farm equipments
Fertilizers input (kg ha-1 N):	20 - 90	90 - 120	50 - 200	90 - 180
Pesticide and herbicides demand	High requirement	Easy management	As traditional food crops	As traditional food crops

Table 6. Selected lignocellulosic crops

	Reed canary grass	Switchgrass	Miscanthus	Giant reed	Cardoon
Area of origin	Europe	North America	South East Asia	Asia and Mediterranean	Mediterranean
Available genetic resource	Many var. available	Many var. available	Many var. available	Wild genetic base	Wild genetic base
Photosynthesis system	C3	C4	C4	C3	C3
Yield (t ha-1)	11 – up to 15	10 - 25	10 - 30	7 - 61	15 - 22
Raw material characteristic	Lignocellulosic biomass	Lignocellulosic biomass	Lignocellulosic biomass	Lignocellulosic biomass	Lignocellulosic biomass/Oil seed
Adaption range in EU	Cold and wet regions of EU	Cold and warm regions of EU	Cold and warm regions of EU	Warm region of southernEU	Mediterranean regions
Rotation time	10 – 15 yrs	15 yrs	15 – 20 yrs	15 – 20 yrs	4 – 5 yrs
Establishment	seed	seed	Rhizomes	Rhizomes or stem cuttings	seed
Harvest time	Autumn/early spring	Autumn/early spring	Autumn/early spring	Autumn/early spring	Summer
Required machinery	Normal farm equipments	Normal farm equipments	Special farm equipments	Special farm equipments	Special farm equipments
Fertilizers input (kg ha-1 N):	50 - 140	0 - 70	0 - 100	50 - 100	50 - 100
Pesticide and herbicides	First year and post-harvest	First year and post-harvest	First year and post-harvest	First year and post-harvest	First year and post-harvest

Table 7. Selected SRF crops

	Willow	Poplar	Eucalyptus
Area of origin	Temperate and subtropical zones	Nothern hemisphere	Australia
Available genetic resource	Many clones available	Many clones and hybrids	Many genotypes
Photosynthesis system	C3	C3	C3
Yield (t ha-1)	8 - 10 yr-1	7 - 28 yr-1	10 – 25 yr-1
Raw material characteristic	Lignocellulosic	Lignocellulosic	Lignocellulosic
Adaption range in EU	North EU	Central and South EU	South EU
Rotation time	20 - 25 yrs	25 - 30 yrs	6 – 15 yrs
Establishment	Cuttings	Cuttings	Cuttings
Harvest time	Winter, every 3 – 4 yrs	Winter, every 3 – 7 yrs	Winter, every 2 – 3 yrs
Required machinery	Special farm equipments	Special farm equipments	Special farm equipments
Fertilizers input (kg ha-1 N):	80 – 150 yr-1	112 – 450 yr-1	60 – 125 yr-1
Pesticide and herbicides demand	During establishment and post-harvest	During establishment and post-harvest	During establishment and post-harvest

In the tables 4, 5, 6, 7 presented information about the selected non-food crops per final end use (area of origin, available genetic resource, photosynethesis system, yields, raw material characteristics, adaptation range in EU, rotation time, establishment, harvest time, required machinery, fertilizers inputs, pesticide and herbicides demand).

Economic analysis

Economic analysis of the conventional crops in EU

In this report outlined the current situation and trends in EU agriculture with focus on the most popular crop cultivations in each country. The yields and the selling prices were also surveyed of about ten crops in ten EU regions that covered over 90% of the arable land of the European countries. It was found that land and labour costs as well as irrigation patterns may differ significantly between European regions giving rise to substantial variability in the cost of agricultural production. Energy and chemicals may also differ from region to region with a less significant effect on total production cost. The methodology for economic analysis was also described in detail.

The report is a collection of cost breakdown for the selected crops based on the same assumptions and following the same methodology. All the cases were analysed with the same software (ABC: Actual Based Costing that have been developed by the Agricultural University of Athens). For the selection of the crops has been taken under consideration all the crops covering more than 1% of the total arable land in each selected country.

In view of the revenue received by farmers at current selling prices, the cost of production of crops is too high for the achievement of profit in most of the crops that have been examined. The need for rotation of several crops is only making things worse. However, there are a good number of cases of profitable crop farming in several countries.

Among the most profitable examples are the cultivation of wheat in France, Germany, Sweden and the UK, the cultivation of sugar beets in Germany, Poland, Sweden and the Netherlands and the cultivation of Alfalfa in Italy and Romania. European subsidization of the farmers is compensating for their losses in all other cases and preventing them from abandoning their land.

Many of the conventional food and feed crops examined in this volume are also today being used for energy purposes, e.g. for the production of biofuels (wheat, corn, sunflower, sugar beets, etc.).

Nevertheless here they are analyzed with their conventional use in mind. For example, their selling price is the price of the products in markets for food purposes.

All costs are in the form of *annual equivalent costs*, which is important in the cases of multiannual crops. This insures that, for example, initial investment costs are reflected in the cost per tonne or per ha.

The cost of land is on the one hand its opportunity cost, which in turn depends upon its fertility or productivity with regard to possible plantations. In the case of Europe, since we assume that there is sufficiently large market for land, we have adopted the land rent as it is recorded in European and international statistics (Eurostat and FAO). Although the figures found in these databases may not be the best estimates of land rent, as well as other costs, they provide a common and consistent data reference, accessible to all and official. With regard to the cost of land, we have found that there are great differences among the European countries, which are partly explained by equally big land fertility / productivity differences. In other words, it seems that land is rewarded in proportion to the income it may offer to the farmer. In southern countries, where irrigation is required, there are also great differences in land rent between irrigated and non irrigated land, although in general, irrigation is profitable in spite of the extra cost of land.

In the tables that follow costs are first aggregated without the cost of land, which is in all cases one of the most important cost items, and the land rent is added afterwards. Moreover, all costs have been expressed in a "per tonne" of output form in order to facilitate comparisons among countries. However, in the appendix, we have also added the corresponding tables with the cost analysis "per hectare".

Economic analysis of the selected non-food crops

The economic analysis in the present project has paid attention to the aspects related to the financial performance of the examined crops. It has examined all parameters directly related to growers' profitability in an attempt to identify crops of possible interest for the profit maximising farmer in many different European countries and different climatic zones.

Costs and revenues of plants are measured against the opportunity cost of land which they occupy. Alternative uses have occurred in several cases, indicating that in several cases, these new crops (or in some cases well known crops from different usage perspective) can indeed be competitive within the established status quo.

However, the overall general conclusion is that non-food (future) European crops have a very promising future, although today, at current food and energy prices and in the absence of any financial support, most of them are not earning the opportunity cost of land. After all this is witnessed both in Europe and in America nowadays, where governments are directly or indirectly subsidising such initiatives in order to secure the continuation of cultivation of such crops for their environmental, economic and strategic advantages.

The oil producing crops (in most cases for food and non-food uses) are involved in tax exemption chains where the benefits are distributed along all the links of such chains. For example, tax exempted biodiesel. The recent experience of reductions of tax privileges in Germany shows how difficult it is for bioenergy chains to survive in Europe without some protection. Today, the pressures from America (Brazil, Argentina) are felt in Europe, where costs are much less flexible.

The situation is pretty much the same with sugar plants in the bioethanol industry. The energy products are also subsidised directly and indirectly both in Europe and in America. Once again, the competition comes from more or less the same countries, where the cost of production of plants such as sugar canes, sweet sorghum, etc. is much lower than in Europe. We have thoroughly tested sweet sorghum in various European regions and it was found that it will probably play a very important role in the bioenergy systems, because of its great adaptability and production stability in a very wide range of soil and climatic conditions.

Fibre crops such as flax and hemp were analysed in order to explore their potential for the future. They both produce various products (besides fibre) and their products are used in tens of different uses in industry. It was found with some exceptions, that, at today's economic conditions, flax is very marginal from an economic point of view, while hemp appears more attractive financially.

Perennial grasses, such as Miscanthus, Switchgrass, Cardoon, Giant Reed and Reed Canary Grass have been analysed for several climatic and political regions in Europe with their energy generation uses as the main product. These crops are either burned for the production of heat and electricity or pelletized for sale in the domestic and industrial sector. It was found that they may be better planted in surplus land, although their financial best was achieved when cultivated on good agricultural lands in spite of their increased land rent. In all cases it was revealed that the increase in productivity due to more fertile soil and increased level of inputs is more than compensated by the sales of higher output.

Socio analysis

4F crops (food, feed, fibre and fuel) is a concept recently introduced as potential outlet to the restructure of European agriculture aiming to provide opportunities for crop and market diversification, job creation in rural areas as well as farm income improvements through multiple end product uses. The introduction of 4F cropping systems can provide new opportunities for the EU agricultural sector in terms of land use, job maintenance, support of rural industries and new investments in supporting sectors such as machinery and fertilisers.

Two aspects were analysed for the selected non-food crops and countries with good potential for their cultivation: a) their qualitative performance under a set of defined economic, environmental and socio- economic factors and b) a quantitative analysis regarding the generated income and the potentials jobs (created/ maintained) directly or indirectly.

The main points of this work summarized below:

- This work illustrates a combined methodological approach of a quantitative matrix analysis and modeling capabilities along with the integration of cost data in the model and defining income and jobs generated for each crop.
- In general terms perennial crops with lower inputs and seed propagation (cardoon and switchgrass) perform well under this type of analysis as they have mostly beneficial impacts to the ecosystem as well as due to their high yielding potential are financially attractive options for farmers.
- At the other end of the spectrum, annual food crops like wheat and rapeseed have low performance due to lower yielding capacity, high inputs in herbicides & pesticides and relatively low economic & GHG abatement performance.
- The case studies analyzed represent the production and other agronomic characteristics of the climatic zone which each case study represents, but the both the financial data, costs and income/ jobs (land rent, labor cost, etc.) depend upon the agronomic management practices in the country of the case study.
- Regarding income and job generation, it is mostly the perennials and maize that exhibit the highest values with sweet sorghum following.
- On the country analysis, Italy presents the best scores for most of the selected crop options analyzed with Germany, France and Greece following.
- At the final point It is well worth mentioning that values are very crop & site specific and sensitivity analysis is required at the feasibility study analysis for each case.

The analysis estimated the income per land area (ha) and the additional jobs (direct & indirect) generated by the cultivation of each crop in the different countries (Figure 4).

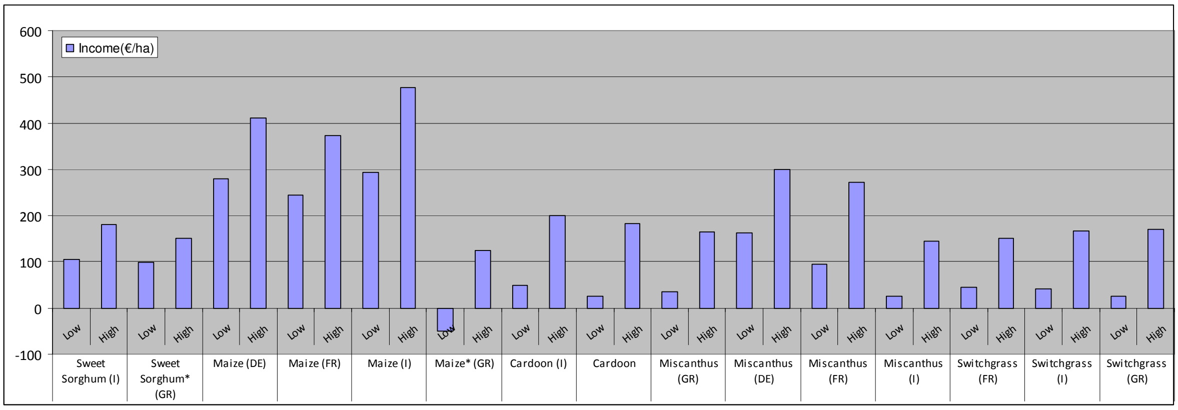


Figure 4. Income generated by the cultivation of the selected crops in each country.

According to figure 4 the most profitable options among the selected crops were maize in Germany, France and Italy for the high yielding case resulting at income above 360 €/ ha, while miscanthus in the German high case also have high income reaching 300 €/ ha. Values close to 200 €/ ha are exhibited by cardoon in the Italian & Greek high cases as well as switchgrass in the respective ones. Finally sweet sorghum has an income of 180 €/ ha in the Italian high case. It is well worth mentioning that values are very crop & site specific and sensitivity analysis is required if one would like to estimate more precise numbers for feasibility studies.

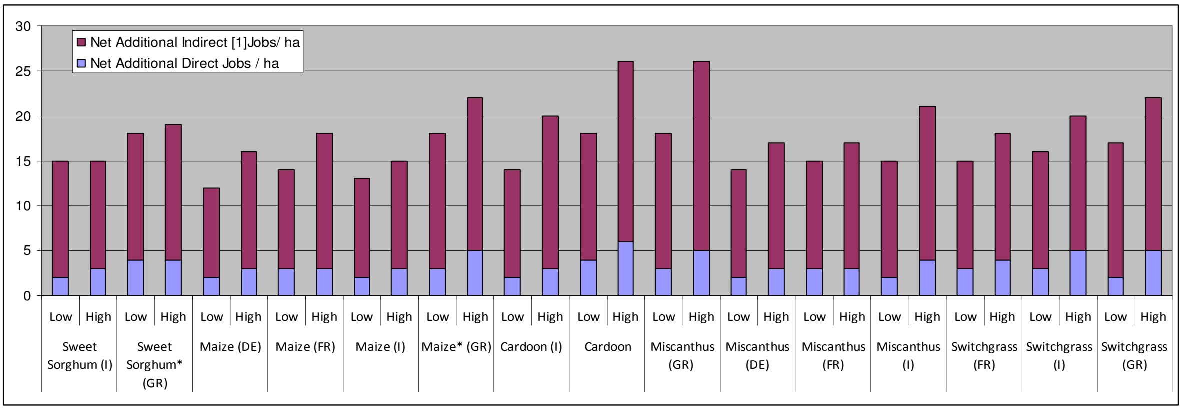


Figure 5. Jobs (direct & indirect) generated (per 100 ha) by the cultivation of the selected crops in each country.

In Figure 5 presented the jobs that will be generated by the cultivation of the selected crops in each country. Miscanthus & Cardoon in the Greek high case are the most labour intensive (due to irrigation and rhizome establishment for the latter) resulting to more than 25 jobs per each 100 ha of cultivated land. The rest of the crops exhibit values in the range of 15-20 jobs per each 100 ha of cultivated land, with sweet sorghum in Greece (both high & low cases) as well as switchgrass in the Greek & Italian high cases having the higher ones. As mentioned before, data are case sensitive so more detailed analysis is required at the feasibility study level.

Environnemental analyses

Environmental Analyses (EIE)

The main findings of the environmental analysis are listed below:

- EIE analyses suggest that growing energy crops do not inflict higher impact to the environment comparing to potato and wheat farming (regarding the studied categories). The assessed impact pathways rely primarily on management intensity and crop traits.

- Annual cropping systems (oil, sugar, fiber and food) are more management intensive than the remaining types, since they require more inputs and land disturbance build up less biomass and have shorter permanence periods. Thus they have a more negative impact on the environment than lignocellulosic and woody species.
- Annual crops do stand out as being more burdening than the remaining types regarding erodibility and biodiversity. Annual systems and woody crops are also more damaging to soil quality than herbaceous perennials. However, differences among crop types are not as evident in the remaining indicators. Further, each crop type often contains uneven outcomes among species, consequence of the environmental zone allocation but also on crop management options.
- Impact reduction strategies are limited to crop management options which can influence emissions, nutrient status and mineral ore depletion. All other impacts are site specific dependent, intertwined with crops traits. Therefore, the implementation of impact-lean bioenergetic agrosystems should root also on the adequacy between crop and location. For that, adding to the generic trends we hereby set, decision makers and stakeholders should assess site-specific factors (e.g. on-field emission fluxes, quality assessment of soil and groundwater, effect on local biodiversity and landscape).

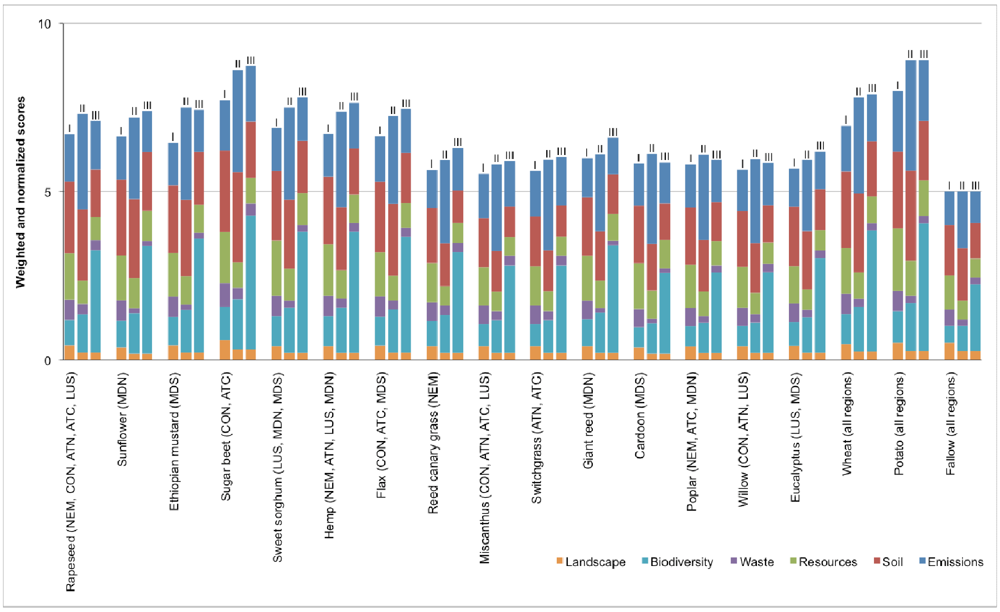


Figure 6 - Final environmental impact assessment of energy crops cultivation in Europe (I – WS1; II – WS2: III – WS3).

In Figure 6 presented the final impact assessment of the selected non-food crops in comparison with land that cultivated with potato and fallow land under three weighting systems: WS1- all indicators have the same weight (landscape, biodiversity, waste, resources, soil and emissions), WS2 - greater emphasis on GHG emission drivers, namely N-fertilizer related emissions and soil degradation and WS3: greater emphasis on biodiversity.

Results show that the application of the weighting step aggravates the impact of all crops. Emphasis on biodiversity (WS3) in detriment to GHG emission drivers (WS2) inflicts a higher impact except for rapeseed, Ethiopian mustard, cardoon, poplar, willow and potato. However, if crops were to be sorted according to their performance, weighting would not significantly influence their relative position.

Life Cycle Analyses

The main target of this study was to indentify environmental advantages and disadvantages of bioenergy and bio-based materials from 15 future non-food crops in comparison to their fossil or conventional counterparts. The crops under investigation cover different crops groups (oil, fiber, woody and herbaceous lignocellulosic, sugar) and are cultivated in seven environmental zones within Europe.

All crops shown a certain potential for saving energy and greenhouse gases-regardless of the environmental zone that they are cultivated in and the purpose they are used for. However, in most cases these benefits are associated with ambiguous or even disadvantages impacts regarding acidification, eutrophication, summer smog, ozone depletion as well as human toxicity. Therefore, from a scientific point of view an objective conclusion regarding the overall environmental performance of bioenergy and biomaterials cannot be drawn. An overall conclusion has to be based on (subjective) value-choices, e.g. by ranking the impact categories in a given hierarchy (e.g. high, medium, and low priority). For instance, if – in line with the goals of the RE Directive (2009/28/EC) – energy saving and mitigation of GHG emissions are

subjectively given the highest priority, all bioenergy carriers and biomaterials assessed in this project are superior to their fossil or conventional equivalents.

The life cycle stages that make the largest contribution to the overall results of LCA analyses are: the cultivation, conversion and utilisation stages, while transport and provision of specific ancillary products have only a minor influence on LCA. The extent to which each stage contributes to the overall balance differs a lot among the pathways as well as among the environmental impact categories within one pathway.

- Regarding transport biofuel and biomaterials the conversion stage makes a large contribution. On the contrary, it is less important for bioenergy pathways (for example direct combustion).
- The cultivation stage is of high priority in terms of acidification, eutrophication and ozone depletion, which are nominated by nitrogen fertiliser-related field emissions.
- The conversion stage has the largest influence on energy and greenhouse gas balances due to the use of fossil energy carriers causing CO_2 emissions.
- The utilization stage has a considerable impact on acidification and eutrophication, mainly through NOX emissions.

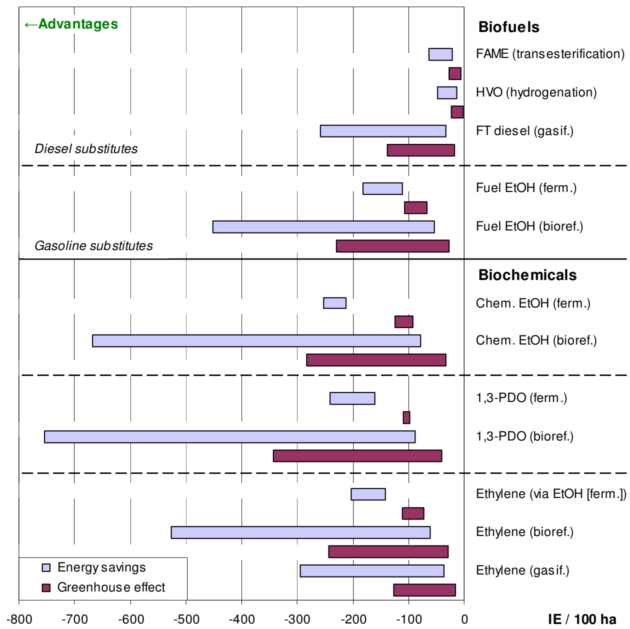


Figure 7. Results of the life cycle comparison for all main products that can be produced with different conversion paths; ranges cover all crops and environmental zones; FAME = fatty acid methyl ester, HVO = hydrogenated vegetable oil, FT = Fischer- Tropsch, EtOH = ethanol, 1,3-PDO = 1,3-propanediol.

Set of best options

The multi-functional dependencies were identified and the impacts of the methodological and data choices on the results were quantified.

- Agricultural reference system: In 4FCROPS project fallow and set aside land has been chosen as the default alternative land use in WP1 assumptions that only surplus land is used for the cultivation of energy or industrial crops. However, if food and feed crops were displaced causing direct and indirect land-use changes, the greenhouse emissions would be caused than by using fossil or conventional products. It has to be noted that research concerning indirect land use changes is still in its infancy and that a harmonised approach to account for indirect effects in life cycle assessments urgently needs to be developed.
- Accounting for co-products: The choice of method used to account for co-products influences the outcomes of the life cycle analyses. In this study, system expansion – also called substitution method – has been applied. Despite multiple options regarding the use of co-products and potentially larger variations in results, this method reflects reality more adequately and should therefore be preferred of policy analysis.

The main result of this study is that it is not possible to identify a single crop, product or conversion technology which is to be preferred from an energy savings and climate protection point of view. For a meaningful comparison of future non-food crops, it is essential to assess their entire life cycle as the overall environmental impact largely depends on what the biomass is used for, how efficiently it is converted and which fossil or conventional product it substitutes.

Regulatory framework

Bioenergy and biofuels had been promoted by several policies on European level which the most important ones are: While Paper on energy policy, White Paper on RES & Action Plan, Green Paper on security of energy supply, Directive 2001/77/EC on renewable electricity, Directive 2003/87/EC on emission trading, Directive 2003/30/EC on liquid biofuels and Directive 2004/8/EC on cogeneration. The major legislation stimulating the development of renewable energy was the Directives 2001/77/EC on renewable electricity and the Directive 2003/30/EC on liquid biofuels. The Directive 2003/30/EC on liquid biofuels aims at promoting the use of biofuels and set a European target of 5.75% substitution of conventional fuels with biofuels December 2010.

The new Renewable Directive (2009/28/EC) on the promotion of the use of energy crop from renewable energy sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. This Directive set a target for 10% biofuels by 2020 and at the same time each member state had to submit a Renewable Energy Action Plan by 30/6/2010. Regarding the use of the fuel crops for biofuels it should be mentioned that the target for 10% biofuels by 2020 is expected to lead to the cultivation of 25 Mha (AEBIOM): 15 Mha will be used for liquids biofuels (biodiesel and bioethanol), 5 Mha for biogas and 5Mha for solid biofuels. In 2007 the total biomass consumption to primary energy consumption in the EU was 89 million tons oil equivalent.

Table 4 - Countries where energy crops are cultivated in large areas in EU27 (AEBIOM 2007, AEBIOM 2009)

Country	Total area under crops (ha)	Short rotation forestry (ha)	Herbaceous crops (ha)
Austria	19630	100 ha willow	400 ha miscanthus
Germany	1356610	1000 willow/poplar	300 miscanthus and 500000 crops for biogas
Denmark	47900	3000 willow	
Finland	9440	-	20000 reed canary grass
France	527610	100 willow	1300 miscanthus
Italy	9800	5100 poplar	-
Poland	60200	6500 willow	1500 miscanthus/grasses
Sweden	20000	13000 willow	7000 reed canary grass 800 hemp
UK	191170	4000 willow	1000 miscanthus
Others countries	174840	-	-
TOTAL	**2417200**	**32800**	**552300**

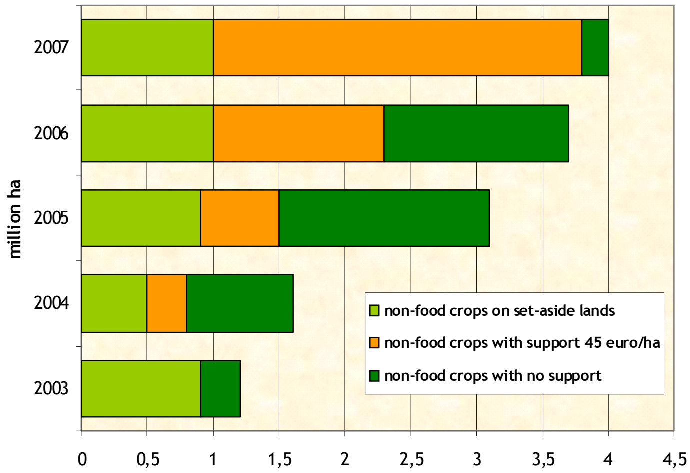


Figure 8. Area of cultivation of non-food crops in Europe.

The area of cultivation of energy crops has been estimated around 2.5 Mha (Table 4) and is referring mainly to oilseed crops (mainly rapeseed), short rotation forestry cultivations (poplar, willow, poplar) and on herbaceous crops (miscanthus, reed canary grass, hemp and crops for biogas).

In EnCrop project has been estimated that the total area of non-food crops in EU27 is around 4 Mha; 2.5 ha had been cultivated with the support of 45 euro/ha, 1 Mha on set aside land and 0.5 ha with out support.

In 2005 it is reported that the total area that is being occupied with non-food crops was 5,070,000 ha and 55% was for the production of energy crops (2,800,000 ha), while the rest for the production of crops for industrial use. More specifically, it is reported that starch crops were cultivated in an area of 900,000 ha, cotton in 460,000 ha, oilseed crops in 425,000 ha, sugar crops in 137,000 ha, medicinal plants in 113,000 ha and fibre crops in 135,000 ha (www.4fcrops.eu, 2nd project workshop).

It has been estimated that the potential of energy crops potential could be about 3EJ by 2050 in EU27 if our diet were moderate. The greatest possibilities to increase energy crop production are in Eastern Europe where the food product yields are reaching the level of those of Western Europe. The main bioenergy crops in the near future will be miscanthus, rapeseed, willow, poplar, reed canary grass, maize and wheat because for these crops have been intensively studied the last two decades n EU. Crops residues and dedicated energy crops together constitute 3-9 EJ of bioenergy potential. This is about 4-13% of the estimated total energy consumption in EU27 for 2020 (Biogas from manure is not included in these figures).

In order both food and non-food crops to co-existence in the future cropping systems that will have contain traditional crops (crops for food and feed) as well as non-food crops (crops for fibre and fuel) without affecting negatively the food security in European level it was proposed the land will be realized from food production only in the case that food demands will be met by the domestic production that is a conservative scenario. This mean that the land that will be realized from food production could be more than anticipated in 4FCROPS due to changes in market access, price differentials or abandonment of certain agricultural commodities production in EU countries. It has been estimated with the conservative scenario that have been developed in 4fcrops the total area that will be realized according to 4fcrops will be between 20 to 25 Mha between 2020 and 2030, while at the same time in order to meet the target for 10% of biofuels by 2020 an area at least 20 Mha will be needed. Even if the adequate land is available for the cultivation of fuel crops in order to reach the targets for 2020 social and ethical implications related to the trade-off between the food and non-food land as well as the direct and indirect land use change needed carefully to be considered and to fallow sustainability criteria.

Successful scenarios

The role of the 4fcrops in EU27 agriculture was investigated within 4 contrasting future scenarios taking under consideration the demands for biomass for energy and the chemical industry in Europe until 2030. These scenarios were driven by more or less globalization (open vs. closed markets) and high or low regulation (sustainability is a strong or a weak driver for biomass based energy and chemicals). As a base for our analysis we translated the bioenergy production in 2020 according to the recently presented EU 27 NREAPs (National Renewable Energy Action Plans) into biomass demands of different categories. For the analysis of the biomass demand for chemicals, it was used the potential replacement of fossil based chemicals (as presented in our previous report, D3) by biobased chemicals as a base for our analysis. Applying the logical assumptions on GDP growth, self-sufficiency, agricultural policy options, oil and CO2 prices, etc. within each scenario, we quantified the demand for different bioenergy categories and the biomass needed in 2020 and 2030. For the demand from the chemical industry the same exercise was executed.

- According to our estimations, 656 Mtons of biomass are required to fulfill the ambitions as laid down in the NREAPs of EU27. Of this biomass, 362 Mtons can be sourced from by- products and waste, 184 Mtons will be produced (extra) by crops in EU 27 and 110 Mtons of biomass will have to be imported.
- Using future scenarios, we estimate that the total biomass demand (for energy and chemicals) will be between 400 and 700 Mton in 2020, increasing to between 550 and 800 Mtons in 2030.
- In the current NREAPs the demand for biomass by the chemical industry appears not to be taken into account. However the demand for biomass for the production of chemicals could be substantial. Using future scenarios we estimate the demand for biomass by the chemical industry to be between 14 and 43 Mtons of biomass (DM) in 2020, increasing to between 28 and 66 Mtons (DM) in 2030.
- The biomass demand for chemicals can both compete and be in synergy with the demand for biomass to produce biofuels, heat and electricity.
- Competition is expected with regard to the demand for fermentable sugars. The demand by the chemical industry will amount to between 8 and 40 Mtons in 2020 and between 16 and 53 Mtons (DM) in 2030. This is roughly the same as the amount of fermentable sugars required for the production of biofuels (mainly ethanol).
- Synergy is expected with respect to biodiesel production based on oils and fats, leading to the production of glycerin which has a large potential in the chemical industry.

	Low regulation: Less focus on sustainability more focus on security of supply	High regulation: More focus on sustainability less focus on security of supply
Open Markets	**A1 GLOBAL ECONOMY** The Global Economy scenario depicts a world with fewer borders and less government intervention compared with today. Trade barriers are removed and there is an open flow of capital, people and goods, leading to a rapid economic growth, of which many (but not all) individuals and countries benefit. There is a strong technological development. The role of the government is very limited. Nature and environmental problems are not seen as a priority of the government.	**B1 GLOBAL CO-OPERATION** The Global Co-operation scenario depicts a world of successful international Co-operation, aimed at reducing poverty and reducing environmental problems. Trade barriers will be removed. Many aspects will be regulated by the government, e.g. carbon dioxide emissions, food safety and biodiversity. The maintenance of cultural and natural heritage is mainly publicly funded.
Local markets	**A2 CONTINENTAL MARKETS** The Continental Markets scenario depicts a world of divided regional blocks. The EU, USA and other OECD countries together form one block. Other blocks are for example Latin America, the former Sovjet Union and the Arab world. Each block is striving for self sufficiency, in order to be less reliant on other blocks. Agricultural trade barriers and support mechanisms continue to exist. A minimum of government intervention is preferred, resulting in loosely interpreted directives and regulations	**B2 REGIONAL COMMUNITIES** The Regional Communities scenario depicts a world of regions. People have a strong focus on their local and regional community and prefer locally produced food. Agricultural policy is aiming at self sufficiency. Ecological stewardship is very important. This world is strongly regulated by government interventions, resulting in restrictive rules in spatial policy and incentives to keep small scale agriculture. Economic growth in this scenario is the lowest of all four.

A1, Global economy

- In a future scenario driven by open markets and low regulation (**A1, Global Economy**), biomass (for energy and chemicals) will mainly be used in (or adapted to) the current infrastructure leading to a large demand for conventional options. This will require fermentable sugars (or ethanol) for fuels and chemicals and biomass to electricity in conventional plants. Due to high economic growth total demand will be large. However sourcing will be on the basis of cost and security of supply, leading to large imports and suboptimal use of by-products.
- Agriculture will be large scale and specialized in order to be efficient enough to compete on the world market.
- Lignocellulosic perennial crops (grasses) will play a limited role. Production will only be possible on surplus (marginal, low quality, abandoned) land which cannot be economically used for rotation crops. Production systems have to be efficient and large scale but are exposed to competition from cheap imported biomass
- Oil crops will have a large market though competition from imports is substantial.
- Sugar Crops will have a large market which includes biofuels and chemicals. Imported sugars (or ethanol) are inexpensive therefore the role of these crops will still be limited.

B1, Strong Europe

- In a future scenario driven by open markets and high regulation (**B1, Strong Europe**), biomass (for energy and chemicals) will be used in an efficient way to support GHG emission reduction policies. This will lead to a demand for large volumes and efficient use of biomass.
- Adaptation of infrastructure to accommodate available biomass, including fast introduction of advanced options (second generation, algae) and production of functionalized chemicals from biomass.
- Agriculture will be efficient and will have to comply with internationally accepted sustainability demands.
- The role of lignocellulosic perennials crops will be relevant on surplus (marginal, low quality, abandoned) land. Due to their low environmental impact the crops will have an advantage in the market over other (imported) biomass. Policies will be in place to “reward” these crops for low impact production. The biomass will also be used for the production of advanced (2^{nd} generation) biofuels and chemicals.
- Oil crops have a large market and have to comply with sustainability demands. At the same time imports are possible if they comply with sustainability demands. Crops will have to be highly productive and produce high quality by-products (e.g. proteins) to acceptable and competitive. Furthermore competition is expected from novel alternative options that will become relevant before 2020 (e.g. FT diesel and oil from algae).
- Sugar crops will have a large market but will also be exposed to competition from imports (sugar and ethanol). Efficient large scale production agriculture and processing is required to be able to be competitive.

A2, Continental Markets

- In a future scenario driven by limited globalization and low regulation (**A2, Continental Markets**) the market for bioenergy will be driven mainly by security of supply and cost. Some subsidies and targets will define the market.
- The role of lignocellulosic perennial crops will be limited as they do not fit into the agricultural (rotation) systems; surplus land is limited and policies favour conventional rotation agriculture.

- A set-aside system may provide some possibilities but the perennial nature is problematic (10-15 years).
- Oil crops will have a good EU market fitting in the existing agricultural system and fuel industry. Alternatives (FT diesel and, algae oil) will not become relevant until after 2020.
- Sugar Crops will have a smaller market than under other scenarios. Lack of competition will limit scale increases.

B2, Regional Communities

- In a future scenario driven by limited globalization and high regulation (**B2, Regional Communities**) the market for bioenergy will be driven by sustainability demands (GHG emission reduction). Demand will favor efficient use of by-products and waste and biomass from crops that have a low environmental impact and limited or no competition with food production.
- The role of lignocellulosic perennials will be relevant on surplus (marginal, low quality, abandoned) land, though the availability of land will be limited due to competition from ecological agriculture and other demands requiring land.
- Oil crops will have a good (EU) market fitting in the existing agricultural system and fuel industry, proteins will also have a high value. However, oil crops are expected to rapidly encounter competition from novel advanced (2nd generation) options such as FT diesel and oil from algae).
- Sugar crops will have a good market and will provide feedstock for smaller scale bio-refineries. Competition from alternative sugar sources (second generation lignocellulosic sugars) is expected to become relevant before 2020.

4.1.4 Potential impact (including the socio-economic impact and the wider societal implications of the project so far) and main dissemination activities and exploitation of the results

4.1.4.1 Potential impact

The potential impact of the 4FCROPS was through its main objective with was "to survey and analyse all the parameters that play an important role in the successful establishment of non-food cropping systems in the agriculture of EU27 alongside the existing food crop systems" is to prove that a competitive bio economy through the production of biofuels and biobased products could be a viable option for Europe.

In order to answer positive that the non-food crops could be a viable option for a competitive bio economy for Europe several steps in 4FCROPS projects were followed. First of all the European agriculture situation was examined taking under account the Common Agricultural Policy and the restrict factors of EU agriculture, then the markets needs for food, feed and non-food crops (fibre and fuel) were recorded. One critical question that had to be answered is any available land in EU27 exists now and what is going to happen in 2020 and 2030. Then several non-food crops were examined and the most appropriate non-food crops per final end use and climatic area. Taking under consideration the list of the selected non-food crops, the yields and raw material characteristics the cropping possibilities of the selected annual crops the set of most promising cropping systems per climatic area were developed that contained food, feed, and non-food crops (fiber and fuel crops). It was also examined the proposed cropping systems from the economic point of view. For the selected crops environmental impact assessment as well as life cycle analysis was carried out. It is quite critical that both conventional crops (food and feed) and the non-food crops (fibre and fuel) to co-existence in a future European agriculture and the increase of the area of cultivation of the second group of the crops not to affect the quantities that are necessary in Europe to cover our needs. The last step to fulfil the main objective of this project was to put into context novel the future crops for food, feed, fiber and fuel that will play a role in supporting the new biomass demands for energy and chemicals in the coming years and to define actions needed to make use of their potential in Europe. For this purpose the demands for biomass for energy and the chemical industry in Europe until 2030 were defined within 4 contrasting future scenarios. These scenarios are driven by more or less globalization (open vs. closed markets) and high or low regulation (sustainability is a strong or a weak driver for biomass based energy and chemicals).

European agriculture situation

The agricultural land in EU27 covers 40% of the total land and is estimated (data 2006, FAOSTAT 2007) that is around 175 Mha. The agricultural land includes arable land (61%), permanent land crops (8%), permanent grasslands and meadows (31%). It should be noted that in most European countries the arable land accounts between 69 and 89% of the total agricultural land. In Sweden, Finland and in largest part of Bulgaria the arable land corresponds to 90% of the total agricultural land. The lowest contribution of the arable land is found in the northern UK, in whole Ireland, in some Alpine regions of Austria, in southern France, Spain, Greece, and Italy as well as to whole Portugal.

It has been estimated that the total fallow land in EU27 is 21.4 Mha and corresponds to 20% of the total arable land. In most regions the fallow land varied from 4 to 9%. In most regions of Spain and in southern Portugal corresponds the largest share of fallow land due to the dry climate that cause difficulties in crops cultivation.

The most important crops in EU27 are cereals. Among cereals the most important is wheat. It should be noted that there are large variations on cereal yields in Europe and thus yields 8-9 t/ha are found in northern France and north-western Germany, while in southern and central-eastern Europe the yields varied from 2 to 4 t/ha. Apart from the cereals quite important crops in EU agriculture are rapeseed, sugar beet, maize and pea. According to FAOSTAT database (2008) within the arable land the most important crop is wheat and cultivated in a total area of 24.6 Mha, followed by barley on 13.2 Mha, maize on 7.75 Mha, rapeseed on 6.5 Mha (the most important oleaginous crop in Europe), triticale on 2.5, sugar beet (important crop for both food and no food production) on 1.78 and pea on 0.6 Mha.

The most important restricting factors in EU agriculture are the intensive cultivation and production that requires uses of fertilizers, pesticides and water in the areas that needed (mainly in the Mediterranean area and in Atlantic zone). The intensive crop cultivation increases the biodiversity threats, the soil erosion and soil compaction. Another important restrict factor that expecting to play an important role in the future is the climate change and its effect in the European agriculture.

The EU Common Agricultural Policy had during the last decade been performed to reduce overproduction, reduce environmental impacts and improve rural development. The support of agricultural sector through CAP evolved alongside growing recognition of the strong links between agricultural production and biological conservation. The use of the agricultural land is the main parameter for the decline of the biodiversity in Europe. The intensification of the agricultural land as well as the technological development of the technological development of the agricultural sector in combination with the changes in the human diets as well as the urbanization affects a lot the use of the agricultural land. In Europe the more fertile lands have been intensified while the poor lands have been subject to abandonment or afforestation where this is possible. The low intensity farming systems with high nature value are gradually and steadily disappeared. Through the maintenance of the biodiversity the agricultural production as well as the related practices is more sustainable and cost-effective. Further changes in the land use are expected with the introduction of the biofuels farming systems (EU through the Directive 2009/28/EC) is expected by 2020 the biofuels to contribute 10% on the transport sector.

Market needs for the cultivation of non-food crops (fiber and fuel crops)

The need for the cultivation of non-food crops is supported by the following facts: a) the reform of CAP is going to lead to the release of agricultural arable land , b) there is an increasing need for fiber crops (to describe the needs for biobased products), c) there is great need for biofuels that will be produced from dedicated crops in order to meet the target of 10% biofuels by 2020 and d) the climate change that is going to force especially the south Europe to shift to other cultivations that will need less water, nitrogen that will have salt tolerance, in other words crops that will not need for intensive cultivation.

The present market needs of non-food crops had been recorded in the view of this project. It was found that the present non-food markets exist and they have a considerable size. The use of biomass is for the largest part covered by wood, although a market for other non-food crops exists, in terms of volume of resource input this market is about 1/10 of the wood and fibre market. It is expected that when the chemical industry will start to use more biomass instead of naphtha, an additional market of similar size as the present day non-food market arises.

Regarding the use of the fuel crops for biofuels it should be mentioned that the target for 10% biofuels by 2020 is expected to lead to the cultivation of 25 Mha (AEBIOM): 15 Mha will be used for liquids biofuels (biodiesel and bioethanol), 5 Mha for biogas and 5Mha for solid biofuels. In 2007 the total biomass consumption to primary energy consumption in the EU was 89 million tons oil equivalent.

Available land for the cultivation of non-food crops

In the framework of this project the available land use was estimated for three time frames now, in 2020 and 2030. The total available land for the cultivation of non-food crops now is estimated around 13.2 Mha, while in 2020 it is expected to be increased and to be around 20.5 Mha. The projections that have been made in 4fcrops project showed that the available land for the non-food crops will further increased in 2030 and will be 26.2 Mha. The biggest available land for now and for 2020 was recorded in Spain (3616 ha), while in 2030 it is estimated that will be in Poland (4079 ha). The top five countries in all timeframes will be: Spain, Germany, Poland, France and Romania. These five countries with the contribution of Italy, Bulgaria and Hungary will be the eight European countries that now give the 80.9 % available land for non-food crops, in 2020 could give 81.7% and in 2030 could give 84.5%.

Nowadays only 80% of the total available land remained fallow, while the rest is being cultivated by bioenergy crops. The increase in the available land in 2020 and in 2030 according to the work that have been done in 4FCROPS has been estimated that will derived from the technological agricultural improvements as well as taking under account population prospects. It has been estimated that the surplus land in twenty years from now will come mainly from cereal cropping areas and secondary from oilseed cropping. Thus, the countries or the regions that have large areas covered by cereals will be the ones that mainly offer surplus land for non-food cultivation in the future. It should be noted that in the available land use estimations of this project it was taken consideration the fact that the land will be release from food production only in the case that food demands will be met by the domestic production that is a conservative scenario. So, land realized from food production could be more than anticipated due to changes in market access, price differentials or abandonment of certain agricultural commodities production in EU countries.

Rotation possibility and non-food Cropping systems

During the last two decades several non-food crops have been examined for energy and biomaterials production. In 4FCROPS a list of 15 non-food crops have been selected to be examined in more detail taking under consideration the end use and the climatic area in EU27. The yields and the raw material characteristics of these crops were recorded as well as the possibility of the annual non-food crops to be introduced into rotation systems. As far as crop rotations are concerned, they relate to a temporal sequence of crops on a given cultivated land that is necessary to be done because the crops that deplete soil resources should be alternated with crops that replenish those resources. Rotation plans are usually built around one or two leading crops, followed by one or more legumes and/or other cash crops. It is important to include legumes in the rotation as they fix nitrogen contributing to soil fertilization, soil acidification, and weed control when short season forage crops are cultivated and to forage and seed production.

Parameters that were taken under consideration for the proposed crop rotations that contained both annual food and annual non-food crops were the climatic conditions in the cultivation area, role of the crop in the rotation, avoidance of mono-cropping (pests and diseases accumulation), economic significance, management practices, increased crop yield, reduced soil erosion, improved soil structure (enhance permeability, biological activity), increased water and nutrients storage capacity, increased organic matter, rooting depth and last but not least the climate change scenario.

Cropping system is a wider concept which implies a community of crops and the relative management practices used to achieve this production with the aim to realize specific agronomic objectives, or in other words, the conjunction of the vegetal production of a given plot, including the space-time disposition of crops and the interaction between these and the resources of the farm, other farm activities and the physical, biological and technological factors. The prevailing economic situation, availability of agricultural equipments, availability of economic resources, markets and laws are also important factors to consider when planning a cropping system. In 4FCROPS the non-food cropping systems were developed on both agricultural and marginal land and with low and high inputs.

Economic analysis of the selected non-food crops

The economic analysis that carried out on the fifteen selected crops lead to the overall general conclusion that non-food (future) European crops have a very promising future, although today, at current food and energy prices and in the absence of any financial support, most of them are not earning the opportunity cost of land. After all this is witnessed both in Europe and in America nowadays, where governments are directly or indirectly subsidising such initiatives in order to secure the continuation of cultivation of such crops for their environmental, economic and strategic advantages.

The oil producing crops (in most cases for food and non-food uses) are involved in tax exemption chains where the benefits are distributed along all the links of such chains. For example, tax exempted biodiesel. The recent experience of reductions of tax privileges in Germany shows how difficult it is for bioenergy chains to survive in Europe without some protection. Today, the pressures from America (Brazil, Argentina) are felt in Europe, where costs are much less flexible.

The situation is pretty much the same with sugar plants in the bioethanol industry. The energy products are also subsidised directly and indirectly both in Europe and in America. Once again, the competition comes from more or less the same countries, where the cost of production of plants such as sugar canes, sweet sorghum, etc. is much lower than in Europe. It has been thoroughly tested sweet sorghum in various European regions and it was found that it will probably play a very important role in the bioenergy systems, because of its great adaptability and production stability in a very wide range of soil and climatic conditions.

Fibre crops such as flax and hemp were analysed in order to explore their potential for the future. They both produce various products (besides fibre) and their products are used in tens of different uses in industry. It was found with some exceptions, that, at today's economic conditions, flax is very marginal from an economic point of view, while hemp appears more attractive financially.

Perennial grasses, such as Miscanthus, Switchgrass, Cardoon, Giant Reed and Reed Canary Grass have been analysed for several climatic and political regions in Europe with their energy generation uses as the main product. These crops are either burned for the production of heat and electricity or pelletized for sale in the domestic and industrial sector. It was found that they may be better planted in surplus land, although their financial best was achieved when cultivated on good agricultural lands in spite of their increased land rent. In all cases it was revealed that the increase in productivity due to more fertile soil and increased level of inputs is more than compensated by the sales of higher output.

Socio impacts

The introduction of 4F cropping systems can provide new opportunities for the EU agricultural sector in terms of land use, job maintenance, support of rural industries and new investments in supporting sectors such as machinery and fertilisers. In 4FCROPS through a combined methodological approach of a quantitative matrix analysis and modelling capabilities along with the integration of cost data in the model and defining income and jobs generated for each of the selected non-food crops. The case studies analysed represent the production and other agronomic characteristics of the climatic zone which each case study represents, but the both the financial data, costs and income/ jobs (land rent, labour cost, etc.) depend upon the agronomic management practices in the country of the case study.

It was found that the perennial crops with lower inputs and seed propagation (cardoon and switchgrass) perform well under this type of analysis as they have mostly beneficial impacts to the ecosystem as well as due to their high yielding potential are financially attractive options for farmers. At the other end of the spectrum, annual food crops like wheat and rapeseed have low performance due to lower yielding capacity, high inputs in herbicides & pesticides and relatively low economic & GHG abatement performance.

Regarding income and job generation, it is mostly the perennials and maize that exhibit the highest values with sweet sorghum following. On the country analysis, Italy presents the best scores for most of the selected crop options analysed with Germany, France and Greece following. It should be mentioned that values are very crop & site specific and sensitivity analysis is required at the feasibility study analysis for each case.

Environmental impact assessment and life cycle analysis of the non-food crops

The expected environmental consequences of cultivating a set of selected non-food crops were investigated. Environmental Impact Assessment (EIA) on those selected crops suggested that growing energy crops do not inflict higher impact to the environment comparing to potato and wheat farming. The assessed impact pathways rely primarily on management intensity and crop traits. Annual cropping systems (oil, sugar, fiber and food) are more management intensive than the remaining types, since they require more inputs and land disturbance build up less biomass and have shorter permanence periods. Thus they have a more negative impact on the environment than lignocellulosic and woody species. Annual crops do stand out as being more burdening than the remaining types regarding erodibility and biodiversity. Annual systems and woody crops are also more damaging to soil quality than herbaceous perennials. However, differences among crop types were not as evident in the remaining indicators. Further, each crop type often contains uneven outcomes among species, consequence of the environmental zone allocation but also on crop management options.

The selected non-food crops show a certain potential for saving energy and greenhouse gases – regardless of the environmental zone they are cultivated in and the purpose they are used for. However, in most cases these benefits are associated with ambiguous or even disadvantageous impacts regarding acidification, eutrophication, summer smog, ozone depletion as well as human toxicity. Therefore, from a scientific point of view an objective conclusion regarding the overall environmental performance of bioenergy and biomaterials cannot be drawn. An overall conclusion rather has to be based on (subjective) value-choices, e g. by ranking the impact categories in a given hierarchy (e.g. high, medium, and low priority). For instance, if – in line with the goals of the RE Directive (2009/28/EC) – energy saving and mitigation of GHG emissions are subjectively given the highest priority, all bioenergy carriers and biomaterials assessed in this study are superior to their fossil or conventional equivalents.

The selected non-food crops are not necessarily superior to existing traditional crops. Traditional crops, for which there are already mature and efficient technologies, should be preferred over new crops and biofuels for which technologies might still be immature. In particular for the conversion of herbaceous lignocellulosic crops, which are especially climate friendly, there are still considerable technological difficulties. Difficulties concern the gasification as well as the enzymatic decomposition and fermentation of lignocellulosic biomass for ethanol production. Such crops should be produced at a large scale only after these technological difficulties have been solved. Until then existing and mature traditional biomass use systems can be drawn on.

Besides the technological difficulties, the perennial lignocellulosic crops cannot be integrated into existing annual crop rotation systems. Therefore, the area available for such crops is further limited. The most advantageous crops from an environmental point of view do not necessarily show the best economic results. Economic incentives could become necessary at a farm level if the cultivation of the most environmentally efficient crops is expanded. However, since the combination of environmental and economic results in this study is based on different system boundaries, no statements can be made on the macroeconomic costs of additional CO2 savings via the support of especially climate friendly renewable raw materials.

Co-existence of food and non-food crops

In order both food and non-food crops to co-existence in the future cropping systems that will have contain traditional crops (crops for food and feed) as well as non-food crops (crops for fibre and fuel) without affecting negatively the food security in European level it was proposed the land will be realized from food production only in the case that food demands will be met by the domestic production that is a conservative scenario. This mean that the land that will be realized from food production could be more than anticipated in 4FCROPS due to changes in market access, price differentials or abandonment of certain agricultural commodities production in EU countries. It has been estimated with the conservative scenario that have been developed in 4fcrops the total area that will be realized according to 4fcrops will be between 20 to 25 Mha between 2020 and 2030, while at the same time in order to meet the target for 10% of biofuels by 2020 an area at least 20 Mha will be needed. Even if the adequate land is available for the cultivation of fuel crops in order to reach the targets for 2020 social and ethical implications related to the trade-off between the food and non-food land as well as the direct and indirect land use change needed carefully to be considered and to fallow sustainability criteria.

The role of the 4fcrops in EU27 under contrasting future scenarios

The role of the 4fcrops in EU27 agriculture was investigated within 4 contrasting future scenarios taking under consideration the demands for biomass for energy and the chemical industry in Europe until 2030. These scenarios were driven by more or less globalization (open vs. closed markets) and high or low regulation (sustainability is a strong or a weak driver for biomass based energy and chemicals). As a base for our analysis we translated the bioenergy production in 2020 according to the recently presented EU 27 NREAPs (National Renewable Energy Action Plans) into biomass demands of different categories. For the analysis of the biomass demand for chemicals, it was used the potential replacement of fossil based chemicals (as presented in our previous report, D3) by biobased chemicals as a base for our analysis. Applying the logical assumptions on GDP growth, self-sufficiency, agricultural policy options, oil and CO2 prices, etc. within each scenario, we quantified the demand for different bioenergy categories and the biomass needed in 2020 and 2030. For the demand from the chemical industry the same exercise was executed.

A total quantity of 656 Mtons of biomass are required to fulfil the ambitions as laid down in the NREAPs of EU27. Of this biomass, 362 Mtons can be sourced from by-products and waste, 184 Mtons will be produced (extra) by crops in EU 27 and 110 Mtons of biomass will have to be imported. The total biomass demand (for energy and chemicals) under scenarios is expected to be between 400 and 700 Mton in 2020, increasing to between 550 and 800 Mtons in 2030. In the current NREAPs the demand for biomass by the chemical industry appears not to be taken into account. However, the demand for biomass for the production of chemicals could be substantial especially compared to the biomass demand for production of biofuels.

Using future scenarios we estimate the demand for biomass by the chemical industry to be between 14 and 43Mtons of biomass (DM) in 2020, increasing to between 28 and 66 Mtons (DM) in 2030. The biomass demand for chemicals can both compete and be in synergy with the demand for biomass to produce biofuels, heat and electricity. Competition is expected with regard to the demand for fermentable sugars. The demand by the chemical industry will amount to between 8 and 40 Mtons in 2020 and between 16 and 53 Mtons (DM) in 2030. This is roughly the same amount as the amount of fermentable sugars required for the production of biofuels (mainly ethanol).

It is recommend taking into account the demand for biomass by the chemical industry (including effects of competition, e.g. for fermentable sugars and synergy between the production of Fischer Tropsch biodiesel and glycerin) when developing biomass energy policies and targets. This will require much more detailed knowledge about the biomass demands of the chemical industry than is currently available in the public domain.

4.1.4.2 Dissemination activities and exploitation of the results

Since 4F CROPS was a coordination and support action project the dissemination of the findings was a key action with high importance. For this reason a dissemination plan had been drawn up at the outset of the project. The main elements of the dissemination plan were: the development of the 4F CROPS web-site, the organisation of the projects thematic workshops, presentation to projects results in European and International Conferences, articles to conferences/journals, fact sheets for the most promising non-food crops, leaflets, etc.

The project website www.4fcrops.eu developed that constituted the main communication tool for the efficient dissemination of the project deliverables. The data gathered and developed from all work packages displayed in an effective and user-friendly way. The project website is a key tool that disseminate information to the target tools and the European Commission, through the public area, and at the same time facilitated the communication among the project partners', through the Intranet. The website had been planned to content all the information that could be available to the public (description of the project, objectives, work packages, consortium, links, leaflet, etc.)

The www.4fcrops.eu intranet was the place for sharing common subjects such as documents, presentations, images etc. It was planned to be a restricted area and only registered members (provided with a user name and password) could submit or view the information. Users of the Intranet were the members' of the consortium and the member of the scientific committee.

Five thematic workshops were carried out in the frame of this project. In these workshops the members of the scientific committee attended the workshops.

The Scientific Committee consisted of members of the consortium and stakeholders selected for their broad knowledge of the issues and in-depth expertise in one or more key areas, each one being a stakeholder in a position to influence the future of the non-food markets. The Scientific Committee represented the following segments: farmers/farm groups, agricultural equipment manufacturers, end-product processors or potential processors, end-product users or potential users, environmental groups, local authorities' representatives, research institutes and laboratories and market actors.

Scientific Committee of the 4FCROPS project

Steering Committee	Invited stakeholders
Dr. Efi Alexopoulou, CRES	**Dr. Ralph Sims, IEA Bioenergy**
Dr. Ewa Ganko, EC BREC,	**Dr. Uwe Fritche - OeKO**
Prof. Luciano Cosentino, UNICT	**Prof. Yiolanda Papatheohari, AUA**
Prof. Peter Soldatos, AUA.eco	**Prof. Jesus Fernadez, UPM**
Dr. Guido Reinhardt, IFEU	**Dr. Katri Pahkala, MTT**
Dr. Wolter Elbersen, A&F	**Prof. Melvyn Askew, Census-Bio**
	Dr. Neil Harker, LACOMBE-CANADA
	Dr. Rainer Jannsen, WIP
	Prof. Spyros Kyritsis, AUA
	Dr. Eleftheria Athanasiadou, CHIMAR
	Dr. Luigi Pari, CRA-ING
	Prof. Anfrea Lazzeri, UNIPI
	Mr. Nikos Chatziyiannis, Pellets
	Dr. Massimo Veccheit, CETA
	Dr. Gail Taylor, SOTON
	Dr. Valerio Zuccini, KEFI ITALIA
	Dr. Efthimios Efthimiadis, Bios Agrosystems
	Dr. Alex Gablenz, Elaion Company
	Dr. Martin Knapp, KIT
	Dr. Juan Carrasco, CIEMAT
	Dr. Serge Braconnier, CIRAD
	Dr. Nicola di Virgillio, IBEMET

The scientific committee compiled the results of each workshop and then the findings upload in the project web site. In each workshop key invited speakers had key presentations such as the presentation of success stories in European level, like the case of the company KEFI that produced mats from kenaf fibres in Bologna, the case of the successful of the rapeseed in the agricultural systems in Germany for biodiesel production, the CHIMAR in Greece that produce successful resins from woody crops, etc.

The five thematic workshops are listed below:

1st Workshop (organised by INIA and CRES, month 4, Bologna, Italy) entitled **"Market needs for non-food crops (fibre and fuel crops) and how can fit to the available agricultural land in EU27"**

2nd Workshop (organised by UNIBO and CRES, month 10, Madrid, Spain) entitled **"Which are the key future non-food crops in EU 27"**

3rd Workshop (organised by USASB and CRES in month 18, Poznan, Poland) entitled **"Can the production of non-food crops be environmental friendly and economic viable?"**

4th Workshop (organised by CRES in month 24, Lyon, France) entitled **"Towards a successful insertion of the non-food crops in the EU agriculture".**

5th Workshop (organised by UNINOVA and CRES, month 30, Lisbon, Portugal) entitled **"Successful scenarios for the establishment of future non-food-crops in EU27"**

Other dissemination activities apart from project website and project thematic workshops are listed below:

- *Presentations of the projects findings to relevant Conferences and Symposiums* (European and International such as European Biomass Conference, European Agronomy Conference etc.)
- *Presentations in national events* (seminars or conferences) that dealing with the future crops in the local agriculture in each country. These events targeted in a wider audience (not only to policy makers but also to farmers, etc.)
- Articles of the projects findings to relevant conferences, workshops, symposium, journals and newspapers
- *Leaflets* that highlighted the project objectives and project progress until the delivery date
- *Posters* that were created for the advertisement of each thematic workshop (the leaflet will be firstly prepared in English and then will be translated in the four languages of the countries where the four workshops will take place
- Five *Fact sheets* with the most promising non-food crops as well as fact sheets for every successful story (concerning a successful use of a non-food crop in order to produce either energy or bio-based products) that were hanged in the web site. As fact sheets will be focused on specific topics they were produced after the completion of each workshop and will be distributed in local events etc.
- *Twinning opportunities* with the EC-Canada twinning on biofuels and biomaterials as well as with EU-Argentina/MERCOSUR twinning on soil, plant and food.
- *Links with every relevant previous* or on –going research activity regarding the non-food crops (such as IENICA Network, EUROCROP network, etc.)
- *Links with relevant societies or organisations* to non-food crops such as "The Association for the Advancement of Industrial Crops – AAIC (www.aaic.org)", "The National Non-Food Crops Center – NNFCC (www.nffcc.co.uk), etc.

The articles that were composed in the view of 4FCROPS for conferences and journal are presented below.

Presentations of the projects findings to relevant Conferences and Symposiums

1. Articles that were presented in the European Biomass Conferences (www.conference-biomass.com)

- **16th European Biomass Conference, (Valencia June 2008)**
  Alexopoulou, E., Christou, M. and I. Eleftheriadis. 2008. 4FCROPS: Future Crops for Food, Feed, Fiber and Fuel (***poster presentation***).

- **17th European Biomass Conference (Hamburg June 2009)**
  E. Alexopoulou, S. L.Cosentino, P. Soldatos, G. Reinhardt, W. Elbersen, A. Monti, J. L. Tenorio, A.L. Fernando, R. Kozlowski, Chimpeanu, D. Millioni, M. Kiprioti and E. Ganko. 2009. 4F CROPS: CROPS FOR FOOD, FEED, FIBRE AND FUEL (**poster presentation**).

- **18th European Biomass Conference (Lyon, May 2010)**
  E. Alexopoulou, S. L.Cosentino, R. Kozlowski and M. Christou. 2010. Future non-food crops (fuel and fibre) in EU27: Yields and raw material characteristics (oral presentation)
  E. Alexopoulou, S. L.Cosentino, P. Soldatos, G. Reinhardt, W. Elbersen, A. Monti, J.L. Tenorio, A.L. Fernando, R. Kozlowski, Chimpeanu, D. Millioni, M. Kiprioti and E. Ganko. 2009. 4F CROPS - A European project for the successful establishment of the non-food cropping systems in the EU27 alongside the existing food crop systems (poster presentation).

- **19th European Biomass Conference (Berlin, June 2011)**
  E. Alexopoulou, M. Christou, S. L.Cosentino, P. Soldatos, G. Reinhardt[4] N. Rettenmaier, W. Elbersen, E. Krasuska, A. Monti, A.L. Fernando, M. Mackiewicz-Talarczyk, C. Panoutsou, Walter Zegada, P. Duarte, D. Millioni, J. L. Tenorio, D. Scordia and G. Testa. 2011. 4FCROPS – Survey and analyse the parameters that play an important role in the successful establishment of non-food cropping systems (oral presentation).

2. Articles that were presented in the European Agronomy Conferences (www.esagr.org)

- **10th Congress of the European Society for Agronomy, 15-19/9/08, University of Bologna, Italy**

ALEXOPOULOU, E., CHRISTOU, M. and I. ELEFTHERIADIS. 2008. 4FCROPS – Future Crops for Food, Feed, Fibre and Fuel. In Italian Journal of Agronomy, Rivista di Agronomia, Vol. 3, No. 3, 473-474pp (***oral presentation***).

- **11th ESA Conference, AGRO2010, The international week around Agronomy, Montpellier, 29/8-3/9/10**

E. Alexopoulou, S. L.Cosentino, R. Kozlowski and A. Monti. 2010. Key future non-food crops in EU27. In Proceedings of Agro2010 the Xith ESA Congress, August 29th-September 3rd, 2010, Montpellier, France, 435-436pp (***poster presentation***).

3. International Conference and Exhibition on Bioenergy entitled "Bioenergy: Challenges and Opportunities", April 2008, Portugal

Alexopoulou, E., Christou, M. and I. Eleftheriadis. 2008. 4FCROPS: Future Crops for Food, Feed, Fiber and Fuel. Proceedings of the International Conference and Exhibition on Bioenergy "Bioenergy: Challenges and Opportunities", 6-9 April 2008, Universidade do Minho, Guimaraes, Portugal (***oral presentation***).

4. WEEK OF THE NATURAL FIBRES, SCIENTIFIC WORKSHOP AND EXHIBITION ON TEXTILES AND NON-TEXTILES APPLICATIONS (ARAD, ROMANIA)

- R. Kozlowski, J. Mankowski, J. Kolodziej, *M. Mackiewicz-Talarczyk, P.Baraniecki. 2009. BAST FIBROUS PLANTS RAW MATERIALS CHARACTERISTIC AND THEIR APPLICATIONS. In *"WEEK OF THE NATURAL FIBRES*". SCIENTIFIC WORKSHOP AND EXHIBITIONS ON TEXTILES AND NON-TEXTILES APPLICATIONS. FAO/ESCORENA EUROPEAN COOPERATIVE RESEARCH NETWORK ON FLAX AND OTHER BAST PLANTS AND ESCORENA SYSTEM, 21-26 June, 2009, UNIVERSITY „AUREL VLAICU", Arad, Romania
- R. Kozlowski, K. Heller, J. Mankowski, J. Kolodziej, A. Kubacki, L. Grabowska, M. Mackiewicz-Talarczyk, P. Baraniecki, M. Praczyk, H. Burczyk, P. Kolodziejczyk. 2009. YIELDING POTENTIAL OF BAST FIBROUS PLANTS IN EUROPE. In *"WEEK OF THE NATURAL FIBRES*". SCIENTIFIC WORKSHOP AND EXHIBITIONS ON TEXTILES AND NON-TEXTILES APPLICATIONS. FAO/ESCORENA EUROPEAN COOPERATIVE RESEARCH NETWORK ON FLAX AND OTHER BAST PLANTS AND ESCORENA SYSTEM, 21-26 June, 2009, UNIVERSITY „AUREL VLAICU", Arad, Romania

5. SECOND CONFERENCE OF THE ITALIAN SOCIETY OF BIOENERGY AND AGROINDUSTRY, 4-5/5/09, Rome, Italy

- Zegada-Lizarazu W**.** and Monti A. 2009. Energy crop rotation possibilities. Second conference of the Italian Society of Bioenergy and Agroindustry (**SIBA**) CRA - Consiglio per la Ricerca e la sperimentazione in Agricoltura, 4-5.05.2009. Rome, Italy.

6. XVII Congress of the Federation of European Societies of Plant Biology – FESPB 2010 (http://www.geyseco.es/fespb/fespb.html)

- Margaritopoulou, T., Rigas, S., Hatzopoulos, P., Alexopoulou, E. and D. Millioni. 2010. 4FCROPS. In Proceedings of XVII Congress of the Federation of European Societies of Plant Biology – FESPB 2010, 4-9/7/10, Valencia, Spain

Presentations of the projects findings to journals

Biofuels, Bioproducts & Biorefinery

1. Critical review on energy balance of agricultural systems
Authors: Walter Zegada-Lizarazu (University of Bologna, Italy), **D. Matteucci** (University of Bologna, Italy) **and A. Monti** (University of Bologna, Italy)

Received May 3, 2010; revised June 22, 2010; accepted July 9, 2010, View online at Wiley Online Library (wileyonlinelibrary.com); DOI: 10.1002/bbb.242; *Biofuels, Bioprod. Bioref.* 4:423-446 (2010)

2. Agronomic aspects of future energy crops in Europe
Authors: Walter Zegada-Lizarazu (University of Bologna, Italy), **H. Wolter Elbersen,** (Wageningen UR Food & Biobased Research, the Netherlands), **Salvatore L. Cosentino** (DACPA, University of Catania, Italy), **Alessandro Zatta** (University of Bologna, Italy), **Efi Alexopoulou** (Center for Renewable Energy Sources, Pikerme, Attiki, Greece) and **Andrea Monti** (University of Bologna, Italy)

Received May 3, 2010; revised June 22, 2010; accepted July 9, 2010, View online at Wiley Online Library (wileyonlinelibrary.com); DOI: 10.1002/bbb.242; *Biofuels, Bioprod. Bioref.* 4:674–691 (2010)

3. Life cycle assessment of selected future energy crops for Europe
Authors: Nils Rettenmaier*, Susanne Köppen, Sven O. Gärtner and Guido A. Reinhardt, (IFEU, Heidelberg, Germany)

Received May 20, 2010; revised version received July 5, 2010; accepted July 27, 2010 View online at Wiley Online Library (wileyonlinelibrary.com); DOI: 10.1002/bbb.245; *Biofuels, Bioprod. Bioref* 4:620–636 (2010)

4. Environmental impact assessment of energy crops cultivation in Europe
Authors: **Ana L Fernando, Maria P Duarte, Joana Almeida, Sara Boléo** and **Benilde Mendes** (Universidade Nova de Lisboa, Caparica, Portugal)

Received April 30, 2010; revised version received July 9, 2010; accepted August 11, 2010 View online at Wiley Online Library (wileyonlinelibrary.com); DOI: 10.1002/bbb.249; *Biofuels, Bioprod. Bioref.* 4: 594–604 (2010)

5. Overview of the markets for energy crops in EU27
Authors: Myrsini Christou, Efthinia Alexopoulou (Center for Renewable Energy Sources - CRES, Attiki, Greece), **Calliope Panoutsou (**Imperial College London, UK), **Andrea Monti** (University of Bologna, Italy)

Received July 30, 2010; revised version received September 16, 2010; accepted September 17, 2010, View online at Wiley Online Library (wileyonlinelibrary.com); DOI: 10.1002/bbb.255; *Biofuels, Bioprod. Bioref.* 4:605–619 (2010)

6. Economic viability of energy crops in the EU: the farmer's point of view
Authors: Peter Soldatos (Agricultural University of Athens, Greece), **Vassilis Lychnaras (**Centre for Planning and Economic Research, Greece), **Calliope Panoutsou (**Imperial College London, UK) and Salvatore **L. Cosentino (**University of Catania, Italy)

Received May 18, 2010; revised version received September 20, 2010; accepted September 21, 2010 View online at Wiley Online Library (wileyonlinelibrary.com); DOI: 10.1002/bbb.257; *Biofuels, Bioprod. Bioref.* 4:637–657 (2010)

7. Direct and indirect land-use competition issues for energy crops and their sustainable production – an overview
Authors: Uwe R. Fritsche (Oeko-Institut, Darmstadt, Germany), Ralph **E. H. Sims (**Centre for Energy Research, Massey University, New Zealand) and **Andrea Monti (**University of Bologna, Italy)

Received August 2, 2010; revised version received September 17, 2010; accepted September 27, 2010, View online at Wiley Online Library (wileyonlinelibrary.com); DOI: 10.1002/bbb.258, *Biofuels, Bioprod. Bioref.* 4:692–704 (2010)

8. Potential land availability for energy crops production in Europe
Authors: Ewa Krasuska (Institute for Fuels and Renewable Energy (IPiEO), Warsaw, Poland), **Carlos Cadórniga and José L Tenorio (**Spanish Institute of Agricultural and Food Research (INIA), Department of Environment, Madrid, Spain), **Giorgio Testa and Danilo Scordia (**University of Catania, Department of Agronomy, Agro chemistry

and Animal Husbandry, Catania, Italy)

Received April 30, 2010; revised version received September 28, 2010; accepted September 28, 2010, View online at Wiley Online Library (wileyonlinelibrary.com); DOI: 10.1002/bbb.259; *Biofuels, Bioprod, Bioref.* 4:658–673 (2010)

Biomass and Bioenergy

Zegada-Lizarazu W. and Monti A. 2010. Energy crops in rotation. A review. Biomass and Bioenergy. DOI:10.1016/j.biombioe.2010.08.001.

Bioprocessing Technologies in Integrated Biorefinery for Production of Biofuels, Biochemicals

Zegada-Lizarazu W. and Monti A. 2010. Energy crops. In: Bioprocessing Technologies in Integrated Biorefinery for Production of Biofuels, Biochemicals, and Biopolymers from Biomass. Wiley (in Press)

SCIENTIFIC BULLETIN OF ESCORENA

1. Kozłowski R[1], Heller K. [2], Mańkowski J.[2], Kołodziej J.[2], Kubacki A.[2], Grabowska L.[2], Mackiewicz-Talarczyk M.[1,2], P. Baraniecki[2], Praczyk.[2], Burczyk H.[2], Kołodziejczyk P.[2]. [1]ESCORENA Focal Point, [2]Institute of Natural Fibres and Medicinal Plants, Poznan, Poland. (2009): Yielding Potential of Bast Fibrous Plants in Europe. *SCIENTIFIC BULLETIN OF ESCORENA*, Vol.1, pp. 27 – 44, ISSN 2066-5687
2. Kozłowski R.[1], Mańkowski J.[2], Kołodziej J. [2], Mackiewicz-Talarczyk M.[1,2], Baraniecki P.[2.] [1]ESCORENA Focal Point, [2]Institute of Natural Fibres and Medicinal Plants, Poznan, Poland. (2009). Bast Fibrous Plants Raw Materials Characteristic and their Applications. *SCIENTIFIC BULLETIN OF ESCORENA*, Vol.1, pp. 53 – 63, ISSN 2066-5687

Dissemination of the project in European meetings

Presentation of the achievements of the 4FCROPS project during EUROPEAN MEETING ON INNOVATION IN RURAL DEVELOPMENT 2009, Valencia, Spain, Castellón de la Plana, 15-16 October 2009

Participation in twinning opportunities between EU-Canada and EU-Argentina/MERCOSUR

4FCROPS has been selected for twinning opportunities with Canada and Argentina/MERCOSUR projects. The selected European projects for both twinning opportunities are presented below:

The selected EU projects for EU-Argentina twinning:

4FCROPS (www.4fcrops.eu)
SWEETFUEL (www.sweetfuel.eu)
MycoRed (www.mycored.com)
TriticeaeGenome (www.triticeaegenome.eu),
VALORAM (http://valoram.ucc.ie),
ENDURE (www.endure-network.eu),
LEGUMES FUTURES (new project)
AgroCos (new project)

The selected EU projects for EU-Canada twinning:

4FCROPS (www.4fcrops.eu)
AQUATERRE (www.aquaterre.info),
Global bio-pact (www.globalbiopact.eu),
Novel Tree (www.noveltree.eu)
FORBIOPLAST (www.forbioplast.eu),
ENERGYPOPLAR (www.energypoplar.eu),
AgFood Trade (www.agfoodtrade.eu),
EU-Pearls (www.eu-pearls.eu),
ICON (www.slu.se),
DISCO (www.disco-project.eu),
RENEWALL (www.renewall.eu),
Lipoyeasts (www.lipoyeasts.ugent.be),
Oxygreen (www.rug.nl/oxygreen),
Crops2Industry (www.crops2industry.eu)
AgroCos (new project)

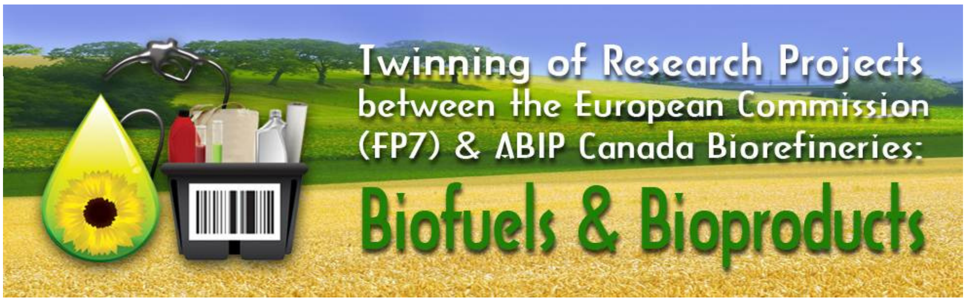
In the EC-Canada twinning three workshops had been taken place; the first in Montréal (February 2008), the second in Pisa (June 2009) and the third in Saskatoon (October 2010). In the EC-Argentina/MERCOSUR twinning two workshops had been carried out; the first in Buenos Aires (May 2009) and the second one on 30/6 &1/7/10 in Athens (hosted by CRES and funded by the project 4fcrops).

Photos from second workshop for EU-Argentina and MERCOSUR twinning (Athens, 30/6 and 1/7/10)

4FCROPS was actively participate in both twinning, established and maintain the web sites for both bilateral agreements (www.ec-canada.eu for EU-Canada twinning and www.ec-argentina.eu for EU-Argentina twinning). In the last workshop of the EU-Canada in Saskatoon the twinning was extended and including also Australia and New Zealand. CRES proposed to create a website for this action that was done at the end of December 2010 (www.ec-ca-au-nz.net). The banners of the websites are presenting below.

www.ec-argentina.eu

www.ec-canada.eu



www.ec-ca-au-nz.net

It should be noted that for the Athens workshop of the twinning with Argentina and MERCOSUR project, CRES prepared also the minutes of the workshop and actively participated in the discussion about the future of this twinning on Soil, Plant and Food. CRES developed a proposal and sent it to all workshop participants for comments.

4.1.5 Address of the project public website and project contact details

The website address of the 4FCROPS projects is www.4fcrops.eu

The contents of the website are: ***home page, concept, beneficiaries, events, deliverables, links, EU-Canada twinning, contact us and intranet***. In the first page can be uploaded the project leaflet.
The project beneficiaries are listed below:

Coordinator		
CRES	Center for Renewable Energy Sources *Biomass Department*	Dr. Efi Alexopoulou Tel:+30 210 6603382, Fax:+30 210 6603301 ealex@cres.gr, www.cres.gr
Partners		
UNI.CT	University of Catania *Department of Agronomy*	Prof. Salvatore. Luciano Cosentino Tel: +39 095 234480, Fax: +39 095 234449 cosentin@unict.it, www.unict.it
AUA.eco	Agricultural University of Athens *Department of Agricultural Economics & Rural development*	Prof. Peter Soldatos Tel: +30 210 529 4762, Fax: +30 210 5294767 p.soldatos@aua.gr, www.aua.gr
IFEU	Institute for Energy and Environmental Research	Dr. Guido Reingardt Tel: 49 6221 47670, Fax:49 6221 47619 guido.reinhardt@ifeu.de, www.ifeu.de
A&F	Agrotechnology & Food Innovations B V	Dr. Wolter Elbersen Wolter.Elbersen@wur.nl, www.wur.nl
UNIBO	University of Bologna *Department of Agroenrironmental Science and Technologies (DiSTA)*	Prof. Gianpietro Venturi Dr. Andrea Monti Tel: +39 51 2096652, Fax: +39 51 2096241 a.monti@unibo.it, www.unibo.it
INIA	National Institute for Agricultural Research	Dr. Jose Luis Tenorio Tel: +34 91 8892943, Fax: +34 91 8828124 tenorio@inia.es, www.inia.es
UniNOVA	University of Lisbon Grupo de Disciplinas de Ecologia da Hydrosfera	Prof. Benilde Mendes Dr. Ana Luisa Fernando Tel: +351 21 294 85 43 ala@fct.unl.pt , http://campus.fct.unl.pt
INF	Institute of Natural Fibres and Medicinal Plants	Prof. Ryszard M. Kolzlowski Tel: +48 61 8455 823, Fax: +48 61 8417 830 www.inf.poznan.pl
UASB	University of Agricultural Science in Bucharest	Dr. Cimpeanu Tel: +40 21 3184718 dzvorasteanu@gmail.com, www.ecoland.ro
AUA.bio	Agricultural University of Athens *Department of Agrictural Biotechnology*	Prof. Dimitra Millioni Tel: +30 210 5294329, Fax: +30 210 5294321 dmilioni@aua.gr, www.aua.gr
NAGREF	National Agricultural Research Foundation	Dr. Evripides Kipriotis Tel: +30 2531 0 81920, Fax: +30 2531 0 33556 nagrefk@otenet.gr , www.nagref.gr
EC BREC	Baltic Renewable Energy Centre	Dr. Ewa Ganko Tel: +48 22 5100 231, Fax: +48 22 5100 220 eganko@ipieo.pl, www.ecbrec.pl

4.2 Use and dissemination of foreground

4FCROPS according to its dissemination plan had to disseminate its results on national or European conferences and workshops as well as on scientific articles. In templates A1 and A2 all the articles as well as the most important presentations that were carried out are listed. It should be noted that all dissemination activities of the project were available to public.

Links with several projects were established and the most important ones were: a) the participation of 4FCROPS in EU-Canada twinning as well as of several European and Canadian projects on biofuels and bio-products (www.ec-canada.eu) and b) the participation of 4FCROPS in EU-Argentina twinning on soil, plant and food (www.ec-argentina.eu).

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication?
1	*Critical review on energy balance of agricultural systems*	*Walter Zegada-Lizarazu*	*Biofuels, Bioproducts& Biorefinery*	*Vol. 4, Issue 6 Special Issue "Biofuels for Europe"*	*Wiley Online Library*	*UK*	*2010*	*pp. 432 - 446*		no
2	*Agronomic aspects of future energy crops in Europe*	*Walter Zegada-Lizarazu*	*Biofuels, Bioproducts& Biorefinery*	*Vol. 4, Issue 6 Special Issue "Biofuels for Europe"*	*Wiley Online Library*	*UK*	*2010*	*pp. 674 - 691*		no
3	*Life cycle assessment of selected future energy crops for Europe*	*Nils Rettenmaier*	*Biofuels, Bioproducts& Biorefinery*	*Vol. 4, Issue 6 Special Issue "Biofuels for Europe"*	*Wiley Online Library*	*UK*	*2010*	*pp. 620 - 636*		no

[2] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[3] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

4	*Environmental impact assessment of energy crops cultivation in Europe*	*Ana L. Fernando*	*Biofuels, Bioproducts& Biorefinery*	*Vol. 4, Issue 6 Special Issue "Biofuels for Europe"*	*Wiley Online Library*	*UK*	*2010*	*pp. 594-604*		no
5	*Overview of the markets for energy crops in EU27*	*Myrsini Christou*	*Biofuels, Bioproducts& Biorefinery*	*Vol. 4, Issue 6 Special Issue "Biofuels for Europe"*	*Wiley Online Library*	*UK*	*2010*	*pp. 605-619*		no
6	*Economic viability of energy crops in the EU: the farmer's point of view*	*Peter Soldatos*	*Biofuels, Bioproducts& Biorefinery*	*Vol. 4, Issue 6 Special Issue "Biofuels for Europe"*	*Wiley Online Library*	*UK*	*2010*	*pp. 637-657*		no
7	*Direct and indirect land-use competition issues for energy crops and their sustainable production – an overview*	*Uwe R. Fritsche*	*Biofuels, Bioproducts& Biorefinery*	*Vol. 4, Issue 6 Special Issue "Biofuels for Europe"*	*Wiley Online Library*	*UK*	*2010*	*pp. 692-704*		no
8	*Potential land availability for energy crops production in Europe*	*Ewa Krasuska*	*Biofuels, Bioproducts& Biorefinery*	*Vol. 4, Issue 6 Special Issue "Biofuels for Europe"*	*Wiley Online Library*	*UK*	*2010*	*pp. 658-673*		no
9	*Energy crops in rotation*	*Andrea Monti*	*Biomass & Bioenergy*	*Vol. 35, Issue 1*	*ELSEVIER*	*NL*	*2010*	*pp.12-25*		no
10	*Energy crops*	*Walter Zegada-Lizarazu*	*Bioprocessing Technologies in Integrated Biorefinery for Production of Biofuels, Biochemicals, and Biopolymers from Biomass"*	Chapter in a book that will be published in 2011	*Wiley Online Library*	*UK*	*2011*	*In press*		no
11	*Future Crops for Food, Feed, Fiber and Fuel*	*E. Alexopoulou*	*Italian Journal of Agronomy*	Vol. 3, No. 3	*PAGEPress®*	*IT*	*2008*	*pp. 473-474*		no
12	*Yielding Potential of Bast Fibrous Plants in Europe*	*R Kozłowski*	*Scientific Bulletin of*	*Vol. 1*	*University of Aurel Vlaicu,*	*RO*	*2009*	*pp. 27-44*		*yes*

			ESCORENA		*ARAD*					
13	*Bast Fibrous Plants Raw Materials Characteristic and their Applications*	*R Kozłowski*	*Scientific Bulletin of ESCORENA*	*Vol. 1*	*University of Aurel Vlaicu, ARAD*	*RO*	*2009*	*pp. 53-63*		*yes*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities[4]	Main leader	Title	Date	Place	Type of audience[5]	Size of audience	Countries addressed
1	*Conference 16th European Biomass Conference "From Research to Industry and Markets"*	*E. Alexopoulou*	*16th European Biomass Conference*	*2-6 June 2008*	*Valencia*	*Scientific Community, Industry, Policy makers, media*	*1500*	72 countries
2	*Conference 17th European Biomass Conference "From Research to Industry and Markets"*	*E. Alexopoulou*	*17th European Biomass Conference*	*29 June to 3 July 2009*	*Hamburg*	*Scientific Community, Industry, Policy makers, media*	*1312*	7 countries
3	*Conference 18th European Biomass Conference "From Research to Industry and Markets"*	*E. Alexopoulou*	*18th European Biomass Conference*	*3-7 May 2010*	*Lyon*	*Scientific Community, Industry, Policy makers, media*	*1505*	72 countries
4	*Conference 19th European Biomass Conference "From*	*E. Alexopoulou*	*19th European Biomass Conference*	*6-10 June 2011*	*Berlin*	*Scientific Community, Industry,*	*Around 1500*	Expected to be from at least 70 countries

[4] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[5] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias ('multiple choices' is possible.

	Research to Industry and Markets"					*Policy makers, media*		
5	*Conference* *11th ESA Conferece*	*E. Alexopoulou*	*Agro2010*	*29/8 to 3/9/10*	*Montpellier*	*Scientific Community, Industry, Policy makers, media*	*607*	56 countries
6	*International Conference entitled "Bioenergy: Challences and Opportunities"*	*E. Alexopoulou*		*6 to 9/4 2008*	*Guimaraes, Portugal*			

4.3 Report on societal implications

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	212811
Title of Project:	Future Crops for Food, Feed, Fiber and Fuel
Name and Title of Coordinator:	Efthimia Alexopoulou

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***NO***
2. Please indicate whether your project involved any of the following issues (tick box) :	
RESEARCH ON HUMANS	
• Did the project involve children?	***NO***
• Did the project involve patients?	***NO***
• Did the project involve persons not able to give consent?	***NO***
• Did the project involve adult healthy volunteers?	***NO***
• Did the project involve Human genetic material?	***NO***
• Did the project involve Human biological samples?	***NO***
• Did the project involve Human data collection?	***NO***
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	***NO***
• Did the project involve Human Foetal Tissue / Cells?	***NO***
• Did the project involve Human Embryonic Stem Cells (hESCs)?	***NO***
• Did the project on human Embryonic Stem Cells involve cells in culture?	***NO***
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	***NO***
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	***NO***
• Did the project involve tracking the location or observation of people?	***NO***
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	***NO***
• Were those animals transgenic small laboratory animals?	***NO***
• Were those animals transgenic farm animals?	***NO***
• Were those animals cloned farm animals?	***NO***
• Were those animals non-human primates?	***NO***
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	***NO***
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	***NO***
DUAL USE	
• Research having direct military use	***NO***

• Research having the potential for terrorist abuse	*NO*

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	2	3
Work package leaders	2	4
Experienced researchers (i.e. PhD holders)	22	30
PhD Students	0	0
Other	0	0

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	
Of which, indicate the number of men: ***22 in total that participate in the scientific committee and 18 of them were men***	

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	X	No

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
❑	Design and implement an equal opportunity policy	X	○	○	○	○
❑	Set targets to achieve a gender balance in the workforce	X	○	○	○	○
❑	Organise conferences and workshops on gender	X	○	○	○	○
❑	Actions to improve work-life balance	X	○	○	○	○
○	Other:	NONE				

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

X No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

X No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

○ Yes- please specify

X No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

○ Main discipline[6]: 4.1

○ Associated discipline[6]:1.5 | ○ Associated discipline[6]:1.4

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	X ○	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

X No

○ Yes- in determining what research should be performed

○ Yes - in implementing the research

○ Yes, in communicating /disseminating / using the results of the project

[6] Insert number from list below (Frascati Manual).

11c	**In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?**	○ ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- X Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- X Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture		Energy Environment Food Safety		Internal Market Regional Policy	

13c If Yes, at which level? ○ Local / regional levels ○ National level X European level ○ International level	

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**12**
To how many of these is open access[7] provided?	**2**
How many of these are published in open access journals?	**2**
How many of these are published in open repositories?	**2**
To how many of these is open access not provided?	**10**
Please check all applicable reasons for not providing open access:	
X publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[8]: ……………	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		**0**
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	**0**
17. How many spin-off companies were created / are planned as a direct result of the project?		**0**
Indicate the approximate number of additional jobs in these companies:		**0**

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑	Increase in employment, or	X	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
X	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*

[7] Open Access is defined as free of charge access for anyone via Internet.
[8] For instance: classification for security project.

Difficult to estimate / not possible to quantify	❑

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes X No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes X No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

X	Press Release	❑	Coverage in specialist press
❑	Media briefing	X	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
X	Brochures /posters / flyers	X	Website for the general public / internet
❑	DVD /Film /Multimedia	X	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

X	Language of the coordinator	X	English
X	Other language(s)		