1. Executive summary

The ultimate objective of this project is to explore the potential of non-food crops (oil, fibre, carbohydrate and other specialty crops) which can be domestically grown in EU27 context, for selected industrial applications (oils, fibres, resins and other specialty products) and outline and prioritise crops-to-products schemes, suitable for the different Member States, which will support sustainable, economic viable and competitive European bio-based industry and agriculture.

The crops

Extended reviews were made for a wide variety of crops. From the data collected it is evident that there is a variety of crops that are/could be grown in Europe at different scales and for different industrial exploitation. ***Rapeseed and sunflower*** are the feedstocks available in significant quantities to supply the biofuel and the oil industry, being well distributed throughout Europe, grown mechanically in commercial scale fields, while considerable research has been done to optimize yields and oil quality. Other candidate oilseed species are ***linseed, castor, safflower and crambe***. ***Fibrous flax, industrial hemp and nettle*** are the fibre crops to be produced throughout EU, due to the suitable climatic conditions and the long tradition of cultivation, processing and utilization. Other species of interest are ***kenaf, giant reed, fibre sorghum, reed canary grass and miscanthus***. ***Maize, potato (mainly for its peels) and sweet sorghum*** prevailed in the list of carbohydrate crops. Five medicinal and aromatic species showed high potential for the pharmaceutical industry, cosmetics and other specialty products: ***Calendula/pot marigold, coneflower, levanter, peppermint, plantago.***

The bio-based products

Within the oil market four industrial streams were identified i) biodiesel, ii) lubricants, iii) paint, ink coating and resins, and iv) polymers. Within the fibre market the streams of i) textiles, ii) non-woven, iii) paper and pulp, iv) timber boards and panels, v) biofuels and vi) resins were identified. Likewise, the main streams of the other specialties markets are pharmaceuticals, cosmetics, dyes, colorants, insecticides.

According to the project reviews, the global **biodiesel** industry has grown significantly over the past decade. Europe will continue as the major Biodiesel market for the next decade or so closely followed by the US market. The raw materials for biodiesel production are lipids of oil plants, mainly rapeseed and sunflower (EU countries), soya (United States, Brazil, and African countries), canola (Canada), palm oil (Indonesia, Malaysia), and jatropha (India, African countries). In the global EU1542 ***lubricant*** market EU15 is ranking the third after United States and China, with 15Mtons. However, at the European level the bio lubricant market is limited with only 13 products Ecolabeled. The market for ***solvents*** currently stands at around 5 million tonnes for Europe. These solvents are generally petrochemical products emitting volatile organic compounds (VOCs) causing photochemical pollution, depletion of the ozone layer and the greenhouse effect. This opens up perspectives for the development of products based on agricultural resources, such as bio-solvents, that offer safety and biodegradability.

Polymers: The bio-industry sector has significant input in the general economy as according to economic data, by 2010 as much as 10% of the chemicals produced in Europe could be bio based, increasing from a value of €77 billion in 2005 to €125 billion in 2010. In 2010, global annual production capacity of bio-based resins came to just 0.72 million tonnes, against 245 million tonnes for global “plastic” production. Cellulose, lignin, sugars and vegetable oils are the main bio-based raw materials. Sugars have been used to produce polyesters like polyhydroxyalkanoates (PHA) and polylactic acid (PLA). These bio-based raw materials have already found applications in sectors ranging from energy to industry, fine chemicals to pharmaceuticals, and cosmetics to the food industry.

Although for last two, three centuries ***bast fibrous raw materials*** faced a strong competition from cotton and especially for last couple tens of years from synthetic fibres, they are still utilized in many industries. Flax, hemp and kenaf can yield over 10 000 different products each. Yet, in practice, utilization focuses only on relevant very little portion of them that currently are produced by the industry or for the industry.

Pharma industry: In the past 20 years, 28% of new drug entities were either natural products or derived from them as semi-synthetic derivatives. It has been projected that, by 2020, 75% of worldwide deaths due to stroke and 70% of deaths due to diabetes will occur in developing countries. A new concept has developed – *cosmeceutics* -cosmetic products that include ingredients designed not only to enhance the appearance but to also have a positive physiological effect at the cellular level. A recent study shows that cosmetic industry based on natural products could be very profitable. There is an increasing development of new natural compounds able to substitute chemical additives (***dyes, colorants***) for food and beverage industry. These compounds are used as antioxidants or colorants. The most known ***natural insecticides*** are pyrethrins which come from certain species of chrysanthemums and limonene and linalool which are volatile molecules obtained from some vegetal species.

Plant breeding

Current molecular genetics technologies (genomic and biotechnological tools) were examined for each crop. Europe holds the largest collection of germplasm accessions stored in national gene banks (FAO, EURISKO). More than 250,000 accessions of maize and sorghum and 25,000-43,000 of rapeseed, sunflower and flax have been stored in FAO gene banks. Dominant markers such as RAPD, AFLPs, RFLP, SSRs have been reported as employed for rapeseed, sunflower, flax, hemp maize, potato, sweet sorghum coneflower and peppermint. Kenaf and pot marigold knowledge on genetic variation is limited. Specific breeding strategies and identification of new resources with valuable traits are also reported.

Costs and socio-economics

The most costly factor in the biomass production costs is cultivation practices while materials showed a very high share in the total cost of pot marigold & coneflower (very expensive propagation material). Land has occasionally high cost. In most cases for the oil, fibre & carbohydrate crops the cost of producing the crop exceeds its selling price and they can be made profitable only with financial support.

In terms of socio-economic impacts, sweet sorghum, maize, potato and kenaf scored the best. These crops shared several favourable characteristics: high yielding crops, efficient in terms of land, water and nutrient use and they also present high levels of resistance to pests and diseases. These various factors combine to make economic performance relatively good. From these crops only maize has wide geographical distribution while both kenaf & sweet sorghum are mostly considered for the South Europe.

Sustainability

In terms of sustainability, the highest bio-physical biomass production potentials on EU27 croplands are attained with hemp and perennial crops. Perennial biomass crops do environmentally better than annual biomass crops with respect to impacts on topsoil organic carbon and total nitrogen emissions. The long-run bio-physical impacts of perennial biomass crops outperform annual biomass crops; however, land use adjustments are less flexible for perennial crops. Carbohydrate and oil crops need careful evaluation. A key concept to improve the overall sustainability of biomass use is the "cascading" concept: material use first, then recovering the energy of used bio-based products.

Overall assessment

The majority of the studied crops show a net benefit in terms of yielding potential and quality of raw materials, being it oils, fibres, starch, sugars or other specialty products, which –up to a certain extent – could compensate for the limited geographic distribution, the small scale of cultivation, or the challenging crop management and logistics.

It is increasingly understood that bio-products - following the biofuels case – when produced from conventional food crops such as grains, sugar beet and oil seeds, are limited in their ability to achieve targets for greenhouse gas emission reduction. Their sustainable production is under review, because they could create strong competition for land and water used for food production.

However, the cultivation of conventional food crops for non-food uses is characterised by mature commercial yields, and well understood crop management and logistics therefore present lower risks for the farmers to grow and the industries to use. Most of the crops selected for the several product streams are used also for the food market. In such cases, breeding efforts have been initiated and new varieties are being produced with improved traits for the several industrial products but low food value.

It was noted that maize, potato and sweet sorghum were higher marked, because of their cultivation in commercial scale (except for sorghum), their high yielding potential, the largest total numbers of accessions and published genomics, their favourable economics because of the high yields, as well as high efficiency in terms of land, water and nutrient use and resistance to pests and diseases.

The rest of the crops have shown similar overall performances but for different parameters. For instance the commercial plantations of the oil crops which involves mechanized crop planting, management and harvesting techniques, accompanied with high yields and good quality of the raw material out yielded the highly sustainable performance of the fibre and other specialty crops. The market diversification of the oil crops was also much more significant than this of the other specialty crops.

2. Concept and main objectives of the project

Agricultural and forestry resources can provide renewable raw materials for a broad range of non-food products, such as chemicals, fibers, construction materials, lubricants, and fuels. Development and commercialization of such bio based and bioenergy products provide new and expanded markets for agricultural feedstocks, accelerate market penetration, reduce dependence on petroleum and other imports of critical materials, and diversify agriculture while fostering rural and sustainable development. Such products are friendlier to the environment than their petroleum-based counterparts.

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 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 (Schenkel, 2006).

Increased world oil prices, energy security concern and the drive for reduction of GHG emissions have increased lately the interest in biofuels and although only a small part of the EU's total primary energy consumption is met from biomass (around 4% that is equal to 69MtOE), the projections for the future are much higher. The new binding EU target of about 20% share of renewables in total energy consumption in 2020 (with a 10% contribution of biofuels) could require about 230-250 MTOE from primary biomass potential. According to the 'VISION' report for the 2030 and beyond, for the supply of the biomass feedstock, *sustainable land strategies must be created that are compatible with climatic, environmental and socio-economic conditions prevailing in each region and apart from residual biomass, dedicated energy crops should also be promoted.*

Interest in natural fibers is also increasing lately for a number of reasons, most particularly due to new environmental legislation and concerns, resulting in a growing market for biodegradable and recyclable materials (IENICA European Summary report 2000-2005). Total worldwide demand for fiber (cellulosic, cotton, wool, man-made, others) is predicted to increase from approximately 50 million tons/year (1999 figure) to 130 million tons/year by 2050 (in line with the predicted growth of the world's population). According to the European 'Plants for the Future Platform' Europe has already a bio-economy, with plants being the basis of European industries with an annual turnover of more than € 1 trillion (Plants for the Future Platform, 2005). But in order to rise to the challenges of a growing population, dwindling resources and the environment, the new bio-based economy will have to be knowledge-based.

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-bio based 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 (EEA, 2006).

As identified by the previously mentioned IENICA summary report, industrial raw materials can be sourced from a very wide range of plant species. In fact, all plants have the potential to provide non-food products in some form – whether it is their primary metabolites as bulk materials (e.g. oil, carbohydrates); their secondary metabolites for specialty products (e.g.

chemicals, pharmaceuticals) or the remaining biomass as a source of energy. The plant database on the IENICA website lists over 100 plant species with known or potential industrial applications. Some of the species are of interest/are cultivated solely for one non-food application (e.g. flax); some have a range of non-food applications or the by/co-products can be used to add further value to the primary use (e.g. hemp); some are grown for food purposes and their by-products have non-food applications (e.g. wheat, potatoes).

Based on the experience that has been collected in previous projects (such as IENICA) the non-food crops have been categorized into four categories, namely ***oil crops, fiber crops, carbohydrate crops and crops with other specialty uses***, according to their final uses.

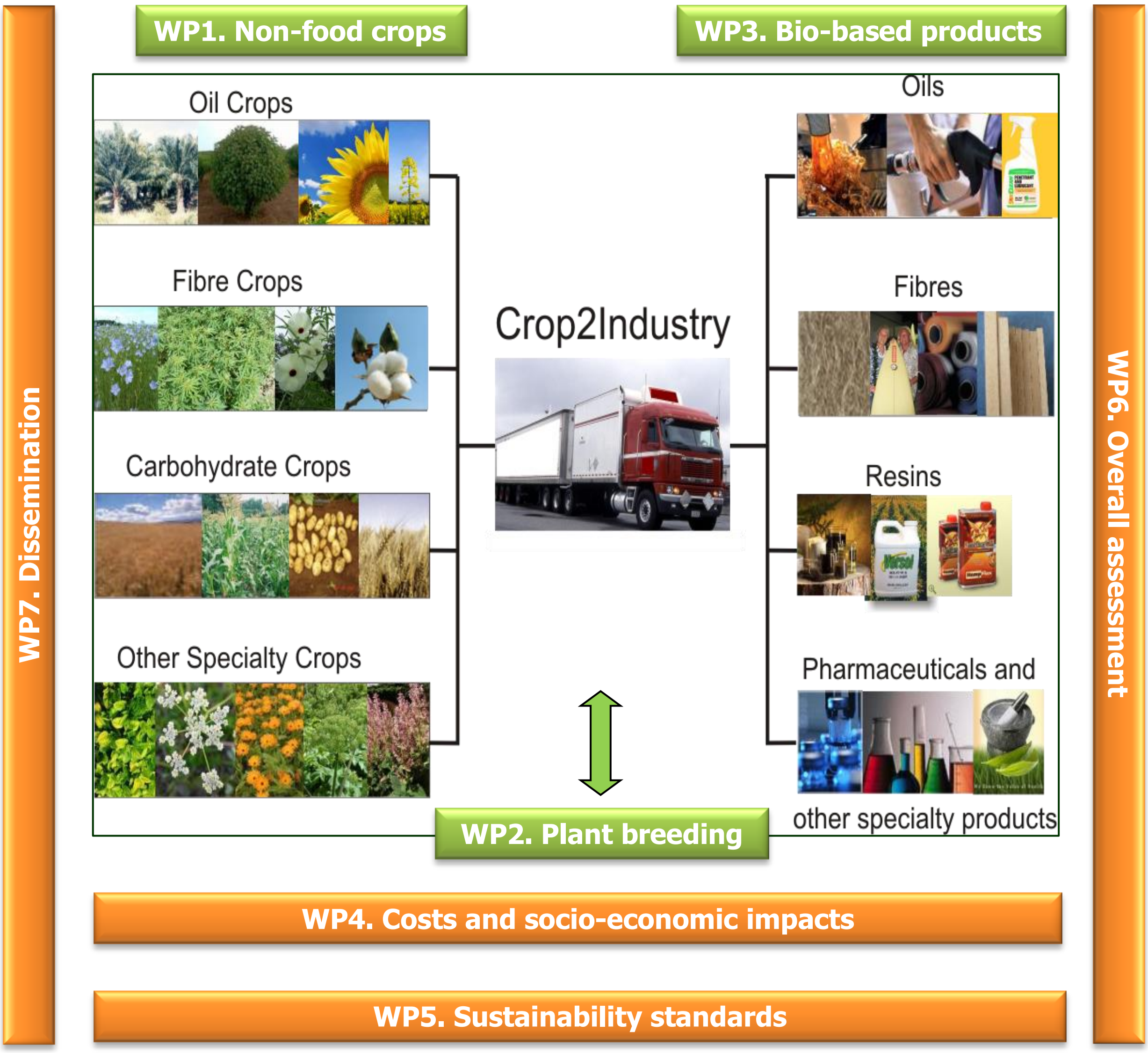
The ultimate objective of this project is to explore the potential of non-food crops, which can be domestically grown in EU27 context, for selected industrial applications, namely oils, fibers, resins, pharmaceuticals and other specialty products and outline and prioritize crops-to-products schemes, suitable for the different Member States, which will support sustainable, economic viable and competitive European bio-based industry and agriculture.

The expected output of this project will be to identify whether and under which terms Europe has the potential and the technical competence to develop a competitive bio-industry fed by a sustainable agriculture.

To achieve the objective of this project, the following ***specific objectives*** were set:

- Explore the potential of non-food crops, which can be domestically grown in EU27 countries, for selected industrial applications, namely oils, fibers, resins, pharmaceuticals and other specialty products (**WP1**)
- Identify current molecular genetics technologies (genomic and biotechnological tools) and suggest their potential applications in a crop-specific manner to address a wide range of breeding constraints regarding yields and tolerance to abiotic and biotic conditions (**WP2**).
- Explore the potential and feasibility of the European industry to make high-value bio based products from renewable agriculture and forestry feedstocks and biotechnological routes (**WP3**).
- Perform supply chain cost analysis, identify best business opportunities and assess the socio-economic impacts of selected crop-to-product schemes at EU-27, regional and country levels (**WP4**).
- Assess selected production and environmental impacts and identify a 'core' list of standards and criteria for the environmental and socio-economic sustainability of selected non-food crops-to-industrial-products systems (**WP5**).
- Perform an overall assessment aiming to select and prioritize crops-to-products schemes in technical, socio-economic and environmental terms (**WP6**).
- Develop a sound dissemination plan for distributing the information collected to targeted audience; provide a mechanism for bringing stakeholders together to force a coherent strategy for the promotion of bio-based products in Europe and link with other relevant projects (**WP7**).

Figure 1: Concept of the project



WP1. Non-food crops

This WP served to explore the potential of non-food crops, which can be domestically grown in EU27 countries, for selected industrial applications, namely oils, fibers, resins, pharmaceuticals and other specialty products. The work was divided in six tasks: Task 1.1 Oil crops, Task 1.2 Fiber crops, Task 1.3 Carbohydrate crops and Task 1.4 Other specialty crops. Information was collected referring to their main physical traits, cultivation areas, inputs, supply and logistics, yields, quality issues. Research gaps, prospects and recommendations to widen the range of potential feedstocks for the understudy industrial uses were tackled. In the horizontal Task 1.5 Multiple end use potentials and allocation factors the multiple use possibilities for the under study nonfood crops were recorded and the best range of end use allocation factors were defined. In Task 1.6 Available land area for the cultivation of non-food crops in EU27, the available lands for the cultivation of - food and - non-food crops were estimated for now, 2020 and 2030 based on spatial agro-climate data and performed in GIS software.

WP2. Plant breeding

The aim of this WP was to identify current molecular genetics technologies (genomic and biotechnological tools) and suggest their potential applications in a crop-specific manner to address a wide range of breeding constraints. Improvement of selected non-food crops entails breeding for agronomically important traits such as yield and tolerance to abiotic and biotic conditions. Generic tools currently available for the selected non-food crops/species research were surveyed, among others, and information was collected on progress in research aimed at identifying, understanding and possibly controlling mechanisms and/or the range of genes involved in complex processes- such as yield, quality and adaptation to biotic/abiotic stresses. The most relevant new technologies potentially useful for the selected non-food crops breeding production and processing were also identified. The Work was divided in four tasks: Task 2.1 Survey of the generic tools, Task 2.2 Identification of European Genetic Resource Centers, Task 2.3 Identification of the most relevant new technologies and Task 2.4 Review potential applications of molecular genetics technologies at pre-commercial scale.

WP3. Bio-based products

The main target of this WP was to explore the potential and feasibility of the European industry to manufacture high-value bio based products from renewable agriculture and forestry feedstocks and biotechnological routes. The work was divided in four tasks: Task 3.1 Oils, Task 3.2 Fibers, Task 3.3 Resins, Task 3.4 Pharmaceutical and other specialty products. In this WP, the bio-industry demands in oils, carbohydrates, resins, pharmaceutical and other specialty products will be reported and restricting factors that inhibit broader industrial use of the feedstocks were identified. Research gaps, prospects and recommendations to procure bio-based products were tackled.

WP4. Costs and socio-economic impacts

The main objective of this work package was to perform supply chain cost analysis, identify best business opportunities and assess the socio-economic impacts of selected crop-to-product schemes at EU-27, regional and country levels. The work was divided in four tasks: Task 4.1 Modeling framework, Task 4.2 Data collection, Task 4.3 Cost analysis and Task 4.4 Socio-economic impact.

WP5. Sustainability standards for European non-food cropping systems

The main objective of this WP was to assess selected production and environmental impacts and identify a 'core' list of standards and criteria for the environmental and socio-economic sustainability of selected non-food crops-to-industrial-products systems in a global and country-specific perspective. The work was divided in three tasks: Task 5.1 Geo-spatial bio-physical impact analysis, where maps on the spatial distribution of crop yields and biomass yields, and selected environmental indicators of the understudy non-food crops were produced to assess the production and environmental suitability of non-food crops in EU27 context. Task 5.2 Identification of challenges and conflict areas for non-food crop production systems and Task 5.3 Set-up of a core list of sustainability standards and criteria, for the environmental and socio-economic sustainability of selected non-food crops-to-industrial-products systems.

WP6. Overall assessment of crops-to-products schemes

The aim of this WP was to perform an integrated technical, environmental and economic assessment to help selecting and prioritizing non-food crops so as to enhance competitiveness of the European industry and improve rural development through diversification and provides new sustainable sources of income for the farming community. The assessment also included identification of major technical and non-technical bottlenecks and will try and tackle possible solutions and steps to go forward. The work was divided in three tasks: Task 6.1 Set up of criteria, Task 6.2 Identify bottlenecks and developments to define systems boundaries and Task 6.3 Identification and prioritization of the most important crops for the EU industry.

WP7. Dissemination

This WP aimed to develop a sound dissemination plan for distributing the information collected to a targeted audience; provide a mechanism for bringing stakeholders together to force a coherent strategy for the promotion of bio-based products in Europe and link with other relevant completed or on-going projects. The work was divided in three tasks: Task 7.1 Development of the web site, Task 7.2 Thematic workshops, Task 7.3 Other dissemination activities.

WP8. Management

It was a general work package aiming at the coordination, management and reporting of the project. It was divided in two tasks: Task 8.1 Coordination and management of the project and Task 8.2 Reporting of the projects actions and findings.

3. Description of the main S & T results/foregrounds

3.1 The crops (WP1)

Extended reviews for a wide variety of non-food crops were made containing information on their areas of origin and geographic distribution, main plant characteristics, as well as information on their growing techniques, logistics, yields and yield quality and potential applications. Specific attention is given to the restricting factors and research gaps concerning their cultivation, due to the fact that the vast majority of them are not grown for commercial uses.

Oil crops: Calendula/pot marigold (Calendula officinalis), Caper spurge (Euphorbia lagascae), Cardoon (Cynara cardunculus), Castor (Ricinus communis), Cotton seed (Gossypium annum), Crambe (Crambe abyssinica), cuphea (Cuphea spp.), Ethiopean mustard (Brassica carinata), Honesty (Lunaria annua), Jatropha (Jatropha curcas), Linseed/flax (Linum usitatissium), Rapeseed (Brassica napus), Safflower (Carthamus tinctorius), Sunflower (Helianthus annus)

Fibre crops: Banana (Musa sp), Cotton (Gosypium hirsutum), Fibre sorghum (Sorghum bicolour), Flax (Linum usitatissimum), Giant reed (Arundo donax), Hemp (Cannabis sativa), Kenaf (Hibiscus cannabinus), Loofah (Luffa cylindrica), Miscanthus (Miscanthus x giganteus), Nettle (Urtica dioica), Phoenix (Phoenix theophrastii), Reed canary grass (Phalaris arundinacea), Yucca (Yucca gloriosa)

Carbohydrate crops: Cassava (Manihot esculenta), Jerusalem artichoke (Helianthus tuberosus), Potato (Solanum sp), Sugar beet, Sweet sorghum (Sorghum bicolor), maize (Zea mays)

Other specialty crops: Calendula/pot marigold (Calendula officinalis), American coneflower (Echinacea angustifolia), Lavande (Lavandula angustifolia), Peppermint (Mentha piperata), Plantago (Plantago lanceolata).

From the data collected it is evident that there is a variety of crops that are/could be grown in Europe at different scales and for different industrial exploitation. Rapeseed and sunflower are the feedstocks available in significant quantities to supply the biofuel and the oil industry, being well distributed throughout Europe, grown mechanically in commercial scale fields, while considerable research has been done to optimize yields and oil quality. Other candidate oilseed species are linseed, castor, safflower and crambe.

Fibrous flax, industrial hemp and nettle are the fibre crops to be produced throughout EU, due to the suitable climatic conditions and the long tradition of cultivation, processing and utilization. Other species of interest are kenaf, giant reed, fibre sorghum, reed canary grass and miscanthus.

Maize, potato (mainly for its peels) and sweet sorghum prevailed in the list of carbohydrate crops, because they grow mechanically in commercial scale fields, considerable research has been done to optimize yields and oil quality.

Five medicinal and aromatic species showed high potential for the bio-industry: Calendula/pot marigold, coneflower, lavender, peppermint, plantago.

Three crops per crop category were selected for further studies: Rapeseed, sunflower linseed, from the oil crops, flax, hemp and kenaf from the fibre crops, maize, potato and sweet sorghum from the carbohydrate crops and pot marigold, coneflower, peppermint from the other specialty crops.

Key facts of the oil crops

Oil Crops	Origin	Area of EU cultivation	Plant nature	Yields	Products/ Markets	Pros (+)	Cons (-)	Needs (Research, policy, etc.	Perspectives
Calendula (*Calendula officinalis* L.)	Native in Mediterra-nean W.Asia	EU 10000 ha Trials in Morocco	Annual spring crop Sown in April Hardy	Seeds: 1-2.5 t/ha of seeds 14-22% oil content 55-60% calendic fatty acid 300 kg/ha of oil	Paints, alkyd resins, non-fogging polyurethane foam, varnish additives, cosmetics	Mechanical sowing with grain drills Mechanical harvesting with grain combining machines but no swathing. Several uses of the plant parts: essential oils and pigments from flowers, oils from seeds which contain calendic acid.	Potential problems with seed drilling because seeds are small and irregularly shaped. Optimum harvest date difficult to determine because of indeterminate flowering. Seed crushing difficulties (hook). Crude oil of bad quality and difficult to refine due to its very high oxidative sensitivity.	Need to improve cultivars, production systems and seed dehulling for oil extraction. This to be achieved through breeding, ecophysiology studies, and seed cleaning and processing investigations.	Good competitor of tung oil, which is currently imported in the EU, due to the calendic fatty acid content.
Cardoon (*Cynara cardunculus* L.)	Native in Mediterra-nean, America (California, Mexico, Argentina) Australia	1000 ha in Spain	Perennial crop Sown in March or October Drought tolerant	Seeds: 3.4 - 25 t/ha of dry matter 8% seeds 1.1 t/ha of seeds (mean) 25% oil content 60% linoleic fatty acid	Aerial biomass is used for heat and power, seeds for biodiesel production	Mechanical sowing with grain drills Mechanical harvesting in two steps in order to separate seeds from the aerial biomass	High variability of yields when grown in marginal lands	Mechanical harvesting still needs improvement to efficiently separate seeds from the whole plant	Best grown crop for arid conditions because it grows during winter and benefits of rainfalls and is harvested in August when it is naturally matured
Caper/Wild spurge (*Euphorbia lagascae* SPRENG)	Native in Mediterranean (Spain, Italy). Spread in N. America & N. Europe Adapted to cool temperate zones	Grown in arid SE Spain, Sardinia. Trials in the Netherlands and Germany	Annual spring crop Sown in April-May Drought tolerant	Seeds: 0.4-1.6 t/ha (experimental) 46-52% oil content 60-75% vernolic fatty acid	Seeds for biofuels, adhesives, varnishes, paints, industrial coatings Leaves, latex for pharma, medicinal nutrition	Mechanical sowing with grain drills Mechanical harvesting with pea harvesters equipped with a special cutter-bar table to avoid blockage. Low nutrient inputs and plant protection Oil rich in vernolic acid	Optimum harvest date difficult to determine due to indeterminate flowering. Foliage rich in latex that blocks the threshing drums during harvest. Seed shattering Highly toxic due to poisonous latex	Breeding programmes should limit seed shattering, improve resistance against herbicides, increase yields and eliminate the toxic traits	Oil composition close to diesel oil thus suitable for biofuels. Niche crop Many potential market applications but little industrial use so far.

Oil Crops	Origin	Area of EU cultivation	Plant nature	Yields	Products/ Markets	Pros (+)	Cons (-)	Needs	Perspectives
Castor seed (*Ricinus communis* L.)	Ethiopia Well diffused in India, Australia, USA, South America Naturalized in tropical and warm temperate regions throughout the world	Eu27: 0 Brasil: 149803 ha China: 210000 ha India: 910000 ha Russia: 400 ha World: 1537773 ha	Annual spring crop Sown in March-April	EU : 0t World: 9985 t Seeds: 0.5 -4 t/ha 40-55% oil content Oil yields: 0.6-2 t/ha Rich in ricinoleic fatty acid: 85-95%	Biodiesel, Technical oil, Pharmaceutical Cosmetics Food Additive Inks and Paints Electronics Polymers	Good Rotation crop Dry land crop Traditional Mechanical Harvest Low nutrient inputs and plant protection	It is a tropical season crop and cannot tolerate temperatures as low as 15°C Irrigation is necessary It contains ricin that is a toxic protein	Yield Improvement Limitation of ricin content	Oil for technical products polymers (Nylon11) Researchers are trying to genetically modify the plant to prevent the synthesis of ricin but this would not solve the issue with the allergenic compound.
Crambe (*Crambe abyssinica* Hochst.ex. R.E. Fries)	Medditerranea n, Euro-Siberia and Turko-Iranian Tropical, subtropical Africa, Near East, C & W Asia USA and S. America, Canada	EU (Poland, Denmark, Germany, Lithuania, Sweden)	Annual spring crop Cool season but not frost tolerant	Seeds: 1.5-2 (up to 2.5) t/ha in EU, USSR. 35-60% oil content 35-65% erucic fatty acid 550kg oil/ha	Lubricants, plastics (via erucamide), chemicals	Mechanical sowing with grain drills Can grow on a variety of climate and soil types Tolerant to lodging Drought tolerant Mechanical harvesting with grain combining machines but no swathing.	Monitoring of harvest onset Susceptible to seed shatter if harvesting delays Low genetic variability Very low investments in research - some industrial production in USA Low seed germination Competition with high erucic rapeseed but lower oil yields	Selection programs for improving seed and oil yields	Industry is looking for erucic acid Crambe appears to be a better potential domestic crop than rapeseed. Many potential uses for pharma, cosmetics, detergents, ceramids, perfumes
Cuphea (*Cuphea spp* L.)	Central America and South America (adapted to North America and Europe)	0	Annual spring crop Sown in late April	Seeds: 0.5-1.5 t/ha (experimental USA) Oil content: 27 – 35% Oil yields: 240 – 300 kg/ha.	Lauric acid Chemicals Pharma Technical oil Inks and Paints	Commercial hybrid line PSR23 Mechanical Harvest Low nutrient inputs and plant protection	Seed shatter Indeterminate flowering making harvest difficult and less economic Long term maturation and high moisture content (>50%) at harvest Sticky petals can clog mechanical harvester	Yield Improvement Elimination of seed shatter trait Domestication in Europe	Need to be re-introduced and exploited in Europe

Oil Crops	Origin	Area of EU cultivation	Plant nature	Yields	Products/ Markets	Pros (+)	Cons (-)	Needs	Perspectives
Ethiopean mustard (*Brassica carinata* L)	Originated from Ethiopia, but also grown in East and South Africa. Well adapted in the Mediterranean climate	Europe: 0 ha Some trials in Greece.	Annual spring crop Vegetable and oil crop Sown in autumn in Mediterranean and spring in cooler areas	Seeds: 1.4 - 3 t/ha of seeds 14-22% oil content 55-60% calendic fatty acid 300 kg/ha of oil	At present oil is regarded as low quality; High erucic acid types suitable for biodiesel and for the production of plastics and additives	Heat and drought tolerant but not very resistant to frost Similar to rapeseed growing methods Much more vigorous and branched than rapeseed; therefore required plant densities are lower	Production likely to be limited to southern Mediterranean regions.	Seed breeding programmes must select cultivars to improve oil content, lower erucic acid and lower glucosinolate content.	Potential crop for biofuels, principally as a new crop for Southern EU countries but with potential also for use in Northern Europe.
Honesty (*Lunaria annua* L.)	Southern Europe and West Asia	0 Only in experimen-tation	Biennial crop Sown in May-June	Seeds: 1-3 t/ha 36% oil content 38-48% in erucic fatty acid 20-25% in nervonic fatty acid	Nervonic acid: Pharma, Medical nutrition, Neurological disorders Chemicals Technical oil Richest source in LCT	Low nutrient inputs and plant protection Non-food crop Resistant to seed shattering Oil that contains nervonic acid and erucic acid Natural source of lunarine for pharmaceuticals	Seed Indehiscence Limited domestication Uncertain yields Does not thrive in large open fields Poorly suitable to mechanical harvest Difficulty in seed cleaning	Yield improvement Cultivation improvement Hybrid rapeseed containing genetic elements from the nervonic pathway Need for vernalisation	Oil for food and medical nutrition Nervonic acid exploitation
Jatropha (*Jatropha curcas* L.)	Peru, Mexico and Central America	Not grown		Seeds: 0.1- 5 t/ha Realistic seeds yields: 1-2,5 t/ha Max oil content: 30-35 %	Biodiesel and other traditional uses : soaps	wild nature of the plant seeds are toxic for humans and animals : non-food uses	It likes high temperatures like in the tropics and subtropics		Results from EU R&D projects: JATROPT, ECODIESEL and EUROBIOREF) uncertain interest in EU

Oil Crops	Origin	Area of EU cultivation	Plant nature	Yields	Products/ Markets	Pros (+)	Cons (-)	Needs	Perspectives
Linseed (*Linum usitatissimum* L.)	N. USA Adapted to cool temperate zones	15,000 ha		1.2-2 t/ha	Food Chemicals Pharma Research towards new green products	Traditional Many varieties, Mechanical cultivation Low N inputs and plant protection Good in crop rotations Breeding efforts in France towards better yields and oil quality (>% in linolenic fatty acid)	Sensitive to seed bed conditions Timely harvest Oil content, fatty acid distribution affected by environments Canadian GMO	Several studies are carried out on the biological process leading to the filling of seeds in order to improve the quality of seed flax (oil content, improved fatty acid profile)	Seed industry is working to develop new uses for flaxseed in animal feed and human food, improve plant properties and select new breeds capable of producing high quality oil with optimal nutritional content
Rape-seed (+High erucic rape seed HEAR)	Asia, S EU, Med, Adapted to cool temperate zones	6,500 Mha (HEAR: 40,000 ha)		Seeds: 2.5 t/ha (EU mean)	Biodiesel Food	Traditional Many varieties (2-3 HEAR varieties available) Mechanical sowing with grain drills	Prone to shattering at harvest Small market for HEAR Narrow genetic variability - Only few HEAR varieties exist	Crop development studies involving the development of new types as well as visual markers for each crop type would contribute to achieve higher yields at lower production costs	Despite the fact that this crop is the most important oil crop for biodiesel production in Europe better adapted varieties should be developed for the Mediterranean region
Safflower (*Carthamus tinctorius* L.)	Asia (Turkey-Afghanistan)	EU27 133 Spain 60 Hungary 73 India 270600 China 22600 USA 67870	Annual spring crop	Seed: 2600-4000 21-22% oil content 0.5 -1 t/ha oils	Food Dye Textile Dye Technical oil Inks and Paints	Traditional Many varieties Mechanical Harvest Modest water needs Oleic and linoleic varieties	Weed Poor seed yield	Improvement of diserbant and weed resistance	Oil for food and medical nutrition. Dye more important product
Sunflower	USA, Med Adapted in wide range of soil and climate conditions)	3,300 Mha		Seeds: 1.9t/ha	Food Biodiesel	Traditional Many varieties, Mechanical sowing with grain drills Drought resistant Modest water needs BUT N is crucial factor	Self-incompatible varieties BUT hybrids are developed Oleic/linoleic varies depending on site, date, year	Crop development studies involving the development of new types (i.e. high oleic) would contribute to achieve higher yields at lower production costs	

Key facts of the fiber crops

Fiber Crops	Origin	Area of EU cultivation (ha)	Plant nature	Yields	Products/ Markets	Pros (+)	Cons (-)	Needs (Research, policy, etc	Perspectives
Banana (*Mussa spp* L.)	Canary Isle	EU27:1514 Greece:170 Italy:15 Spain: 9900 Portugal: 1200		EU27: 365399 Greece: 194118 Italy: 226667 Spain: 380505 Portugal: 286667 Yield Hg/Ha)	Fibers Food Feed Chemicals Biofuels	Exploitation of the waste stream from the food chain	High soil requirements (fertile, good structure, water) High water requirements All the European Market is for food EU cultivable area too small. Fertility	Resolve problems of fertility Extend the area of cultivation	Industrial applications should come only from cultivation residues (e.g. stalks)
Fiber flax (*Linum usitatissimum* L.)	Middle Asia, Mesopota-mia Etruria, Egypt	73 029 ha (2010/2011) 84 070 ha (2011/2012)	Annual spring crop	West – EU Straw – 6,5 Fibres – 1,67 East - EU Straw – 4,4 Fibres – 1,1	Clothing products, industrial (technical) materials, Bio composites insulation materials, building materials, geotextiles, pulp, agro-fine chemicals, feed industry, pharma	Traditional EU crop positive effect on environment, positive effect on crop rotation, low needs with fertilization and agrophags control, good effect on biodiversity, reducing unemployment on rural area (farmers sell fibre - processed crop yields)	Difficulty in flax breeding (lack information about genotypic markers) lack of cultivars resistant to drought and high temp., poor fidelity of yield and its quality, lack of technologies for organic growing, difficult to control dew retting, needs for special harvesting machines and primary processing	Breeding for resistance to biotic and abiotic stress and high good quality yield of fibre, methods for organic farming (weed control), modernization of processing technology, polices favoring good quality raw material /product	
Giant reed (*Arundo donax* L)	Native of Asia and Mediterranean China, S. Africa, Australia, America, Egypt		Perennial grass Adapted in warm EU regions	15-40 t/ha dry matter 50-55% moisture content	Fibre Paper and pulp Construction materials Insulation materials Energy	Low inputs Soil protection against erosion Drought resistant Can be grown in arid and marginal lands	Expensive establishment of rhizomes Ash content similar to straw High moisture content at harvest	Breeding efforts for improved yields More research on mechanical planting and harvesting	Used as solid biomass for CHP plants

Fibre Crops	Origin	Area of EU cultivation (ha)	Plant nature	Yields	Products/ Markets	Pros (+)	Cons (-)	Needs (Research, policy, etc.	Perspectives
Fibre hemp (*Cannabis sativa* L.)	Middle Asia	14 550 ha (2010/2011)	Annual spring crop	Straw: 7.3 t/ha Fibres : 2,43 t/ha	Clothing products, industrial (technical) materials, bio composites, insulation materials, building materials geotextiles, pulp, biofuel, feed industry, pharma, animal bedding.	Traditional European crops, highly productive, positive effect on environment, positive effect on biodiversity, no needs for plant protection, good effect on biodiversity, good crop for organic farming, small input requirements,	Marginal crop in Europe, competition from tropical fibres, difficulty in hemp breeding (allogamy, heterozigosity), poor fidelity of yield and its quality, difficult to control dew retting, Needs special machines primary processing, yield price very balanced	Modernization of processing technology, polices favoring good quality raw material /product	
Kenaf (*Hibiscus cannabinus L.)*	Middle Asia,	1.4 million ha (world), very small area in Europe	Annual spring crop	Fibre: 1-2 t/ha, Biomass: 12-18 t/ha	Paper, bio composites, industrial (technical) materials, pharmaceuticals, biofuel, feed	Positive effect on biodiversity, no needs for plant protection, high crop efficiency (biomass)	Marginal crop in EU, difficulty to grow for seed in the majority of EU countries, difficult to control the process of retting	Breeding of new cultivar for colder EU regions, modernization of processing technology, polices favoring good quality raw material /product.	In EU commercial cultivation area practically 0
Loofah (*Luffa cylindrica* L.)	Europe Africa	0		70000 gourds/ha (experimental)	Fibres Spounge Polymers Chemicals Biofuels Pharma	Tolerates drought Low input requirements	Trally system for cultivation Limited yield Non uniform harvest Handmade cultivation	Yield improvement Mechanical cultivation	Interesting for the extraction of chemicals Oil from seeds
Miscanthus (*Miscanthus giganteus*)	Native in South East Asia China, Japan Europe	4500 ha in Europe	Perennial grass Adapted in cold and warm EU regions	10-30 t/ha dry matter 30-45% of moisture content	Fibre Paper and pulp Construction materials Insulation materials Energy	Low inputs Soil protection against erosion Drought resistant Mechanical planting and harvesting	Needs irrigation	Breeding efforts for improved yields	Used as solid biomass for CHP plants

Fibre Crops	Origin	Area of EU cultivation (ha)	Plant nature	Yields	Products/ Markets	Pros (+)	Cons (-)	Needs (Research, policy, etc.	Perspectives
Nettle (Urtica dioica)	Tropic origin Europe, Asia, North America,	Practically not grown commercially in Europe	Annual Planted by rhizomes or clone seedlings	Stalk mean dry mass: 15.4 t/ha Mean fibre content: 11% of stalk dry mass Fibre yield: 1696 kg/ha	Fibre Clothing, Leaves used for cosmetics Leaves, roots and seed in medicine Young leaves and buds can be used as additive to salads, spinach and soups.	Well suited for cultivation in ecological farms. Textiles made of nettle fibres are a useful alternative hemp, linen and cotton The fibres are hollow which helps accumulating air inside thus creating a natural thermal insulation.	Yields are limited by natural conditions (plant growing in shade, susceptible to water deficiency, nitrophyllic). Vegetative multiplication is limited by genetic factors. Dioeciousness and high heterozygoticity make classical breeding difficult or even make it impossible. Narrow gene pool	Genetic research and breeding to improve content and yield of fibre, resistance of nettle against drought stress Research on wider application of fibre should be undertaken and other products (e.g. water extract as bio-stimulating product for crops). Necessary to improve social acceptance for nettle products	Novel solutions must be searched for in terms of physicochemical properties of nettle fibre. An interesting idea is using nettle fibre as the additive to water proof clothes.
Reed canary grass (*Phararis arundinaceae* L.)	Europe	EU: 27,000 ha Finland: 20000 ha Sweden: 7000 ha	Perennial grass Adapted in cold and wet EU regions	10-30 t/ha dry matter 30-45% moisture content	Fibre Paper and pulp Construction materials Insulation materials Energy	Low inputs Soil protection against erosion Drought resistant Mechanical planting and harvesting at very low costs		Breeding efforts for improved yields	Used as solid biomass for CHP plants
Yucca (*Yucca gloriosa* L.)	Central America, Introduced in Europe (XVI Century)	0	A tree	0	Fibres, Pharma Feed Beverages Food Chemicals Antioxidant Phenols Steroids Cosmetics	Highly competitive to weeds. Pests resistant Highly productive Low inputs Tolerates drought Saline resistant	Infestant No domestication	Domestication Mechanical cultivation Genetic seed bank	Extraction of saponins Extraction of resveratrol

Key facts of the carbohydrate crops

Carbo-hydrate crops	Origin	Area of EU cultivation (ha)	Plant nature	Yields	Products/ Markets	Pros (+)	Cons (-)	Needs (Research, policy, etc.	Perspectives
Cassava (*Manihot spp* L.)	Central Africa South East Asia	EU27 0 World 16240 Africa 8880 Nigeria 2940 Asia 3634 Thailand 1297 Indonesia 1266 S. America 2512 Brazil1981 (HA)		EU27 0 World 165.3 Africa 84.4 Nigeria 31.4 Asia 48.5 Thailand 18.2 Indonesia 15.4 S. America 31.4 Brazil 25.5 (Production Mton)	Food Chemicals Biofuels Laundry products Paper Textile sizing Glue Beverages	Traditional Many varieties, Mechanical cultivation Tolerates drought Low inputs Famine storage food	Food crop Rapid deterioration of fresh tubers (2-3 days of storage)	Improvement of waste stream from the main food chain to obtain industrial products.	In Europe Cassava production is not feasible. Cultivation limited to Africa and Asia.
Maize (*Zea mays* L.)	Central America (species of Indian origin)	World 16,2 MHa EU27 8,9 MHa Italy 0,9 MHa Poland 298700 Germany 463600 France 1,57 MHa Hungary 1,06 MHa		World 263724 EU27 60642 Italy 95336 Poland 57456 Germany 87854 France 88956 Hungary 65690 (Hg/Ha)	Biofuel Polymers Industrial starch Food Feed Pharmaceutical Food additives Cosmetics Laundry products	Many varieties Traditional Mechanical cultivation	Food crop Soil erosion High water demand High nutrient demand Soil leakage of nutrients Frost sensitive	Improvement of waste stream from the main food chain to obtain industrial products.	Industrial applications should come only from cultivation residues (e.g. stalks)
Potato (*Solanum tuberosum* L.)	South America	1,46 MHa		29,3 t/ha (mean)	Food Paper, building, polymers, Pharma Biofuels	Traditional Many varieties, Mechanical cultivation	Food crop Water demanding Susceptible to draught, pathogens and virus diseases. Seasonal character Restrictions geographical location Sensitive to skinning Careful storage of tubers	Improvement of waste stream from the main food chain to obtain industrial products.	Industrial applications should come only from cultivation residues (peels)

Carbo-hydrate crops	Origin	Area of EU cultivation (ha)	Plant nature	Yields	Products/ Markets	Pros (+)	Cons (-)	Needs (Research, policy, etc.	Perspectives
Sugar beet (*Beta vulgaris* L.)	Southern Britain, through Europe and Asia	World 4663610 EU27 1555901 Italy 62700 Poland 199900 Germany 367000 France 383479 (Ha)		World 4663610 EU27 669030 Italy 566204 Poland 491391 Germany 650093 France 832129 (Hg/ha)	Biofuel Paper Pharmaceutical Sugar industry Food Feed Polymers Chemicals	Traditional Many varieties, Mechanical cultivation Conversion of sugar plant in biofuel plant	High standard of management of land is needed Production of seeds and sugar must be done in different locations Non frost resistant.	Productivity improvement in southern Europe Incentive to convert a sugar plant in a biofuel plant in southern Europe	In Europe the cultivation has moved northern (more sugar content) and many Mediterranean countries should produce biofuels
Sweet sorghum (*Sorghum bicolor L.)*	Central eastern Africa, USA		Annual spring crop Adapted in dry climates and poor soils	100-140 t/ha of fresh stems Sugar content up to 12% in the stems 25-45 t/ha of dry matter	Grain for food Juice for bioethanol Bagasse for animal feed and power generation	Adapted in wide range of soils and climates Tolerates drought and high temperatures Input demands relatively low Water use efficient Mechanical cultivation like maize High salinity tolerance	Narrow harvesting window due to rapid decomposition of sugars Susceptible to lodging	Productivity improvement in southern Europe Improvement of harvesting an logistics	High potential for biofuels production due to its high sugar content and stem yields

Key facts of the other specialty crops

Other specialty Crops	**Origin**	**Area of EU cultivation**	**Yields**	**Products/ Markets**	**Pros (+)**	**Cons (-)**	**Needs (Research, policy, etc.**	**Perspectives**
Calendula	Central, Eastern and Southern Europe	Cultivated commercially in North America, the Balkans, Eastern Europe and Germany	1.5-3t / ha ligulate flowers and 4-9 t / ha fresh inflorescences. Drying efficiency is 8:1, resulting in production of dried ligulate flowers around 0.2-0.3 t / ha and the inflorescences of 1-1 t / ha	Pharmaceutical Cosmetics Painting Agriculture Dye Ornamental	Traditional Many varieties Vegetation period is quite long, being able to give good production Demands no special requirements from climatic factors Official in the British & European Pharmacopeia In US does have generally recognized as safe status	Harvest requires attention and manual labor	Early maturing genotypes appear to be most suitable for climatic conditions of NW Europe Grown as biennial	Improve genetic stocks for desirable agronomic characteristics Ecological cultures
Lavender	SE and SW Europe, naturalized elsewhere in Europe and Africa	Cultivated in southern Europe, Russian Federation, United States of America	Fresh inflorescence production in the first 2-3 years is 2-3 t / ha and in coming years can reach 5-6 t / ha. From a ton of fresh inflorescences result up to 10 kg volatile oil.	Pharmaceutical Cosmetics Insecticide Flavoring agent	Traditional Drought resistant Modest water needs Succeed on nutrient deficient soils Resistant to diseases and pests Mechanized harvesting Official in the British & European Pharmacopeia In US does have generally recognized as safe status	Volatile oil quality Depends on climatic and agronomical factors High altitude Lavender plants produce the finest, most expensive quality oil Needs to be near a distillery to minimize losses in oil quantity and quality	Improvement in oil quality (high content of linalool and linalyl acetate) Could be achieved by selection and breeding.	Ecological cultures
Ribwort plantain	Europe and northern and central Asia	Common weed Widely cultivated	10-12 t of fresh leaves and 1.5 to 2 t of dry leaves	Pharmaceutical Food Cosmetics Textiles	High ecological plasticity Resist well in drought and cold winters Moderate demands in soil and climatic factors No important diseases or pests Official in European Pharmacopoeia	Recommended to harvest manually	-breeding for improving the active principles content	Ecological cultures

Other specialty Crops	Origin	Area of EU cultivation	Yields	Products/ Markets	Pros (+)	Cons (-)	Needs (Research, policy, etc.	Perspectives
Coneflower	Atlantic drainage area of the United States of America and Canada	Commercially cultivated in Europe and US	Fresh production of herba about 5 t / ha in the second year of vegetation, and 10-12 t / ha in the coming years. 2-3 t/ha of dried root in the first year and up to 6 t/ha after two years.	Pharmaceuticals Cosmetics Ornamental	Traditional Resistant to drought Frost-resistant and winter-hardy perennials,	Aerial parts are harvested from the first year, the root could be harvested since the second year of culture, Aerial parts and root are covered by a negative Commission E monograph (due to lack of clinical trials for the specific plant parts). It is not recognized as safe (GRAS status) in US Natural variation of the species	Cultivar selection Chemotype Identification for prediction of phytochemical content in cultivar development.	Ecological cultures
Peppermint	Europe	Widely naturalized and widely cultivated	-10-20 t / ha fresh herba respectively 2.5 to 3 t / ha dry herba or 1-1.3 t / ha of dry leaves 35 to 44 kg of oil / ha	Pharmaceutical Cosmetics Food Insecticide	Traditional Valorize good organic fertilizer Official in European Pharmacopoeia generally recognized as safe (GRAS) status in US	Demanding for soil moisture, water is a limiting factor. Large numbers of pests & pathogens Season, soil and situation influence the yield of volatile oil, its flavor and color. Needs to be near a distillery to minimize losses in oil quantity and quality	Hybridization studies aimed at modifying the composition of the oil or at combining essential oil quality with disease resistance	Ecological cultures

a. The oil crops

While European oilseed production is dominated by ***rapeseed*** (Brassica napus) and ***sunflower*** (Helianthus annus) accounting for the 59% and 20% of the total vegetable oil production respectively, a number of other oilseed crops are produced, and this range has increased with the accession of the new European states. Oilseed rape dominates in most northern countries and sunflower in most central and southern countries. Although the largest proportion of the produced oil was used for food purposes, a significant proportion was used for non-food. Soya bean (Glycine max) cultivation was shown to be increasing in southern Europe, accounting for the 16% of the total vegetable oil production in 2009; the area of ***linseed*** (Linum usitatissimum) was shown to fluctuate, it was largely subsidy driven, and considerable quantities of, primarily tropical, oilseeds were imported to supplement European production. About 15,000ha are grown with linseed in Europe. ***Safflower*** (Carthamus tinctorius) production is commercialized with 0.10% of the total vegetable oils production. The main producers are India (54,000 tons), USA (39,256 tons) and Argentina (27,460 tons).

For certain crops like ***castor seed*** and ***safflower*** there is already an established market and considerable research going on in the Mediterranean area, thus it is highly likely that these crops could be candidate for larger-scale development in Europe. Castor requires irrigation while safflower is vulnerable to weeds. Both crops require seed and oil yield improvement with the use of biotechnology, among others. Castor seed, ***jatropha*** and safflower are commercialized for a number of industrial uses; castor oil is used mainly in industry for technical polymer (polyamide-11), fragrances, coating fabrics, high-grade lubricants, inks, textile dyeing, leather preservation, etc. as well as in medicine. Jatropha recently gained a lot of attention for biodiesel production, while safflower has been known since ancient times as a source of orange and yellow dyes and food colourings, and more recently has been grown for oil, meal, birdseed for the food and industrial product markets, such as paints and varnishes as well as for the oil food market. Researchers are trying to genetically modify the castor plant to prevent the synthesis of ricin but this would not solve the issue with the allergenic compound.

Crambe is closely related to rapeseed and mustard and thus can be cultivated with existing agricultural methods and machinery. Crambe production would not compete directly with domestic seed oils since it would provide a substitute for erucic acid extracted from imported rapeseed. However, there is no broad commercial outlet for crambe seed, therefore its commercial deployment depends on the market needs. In the cold climate of Central Europe only crambe seems to have a potential to grow as it shows similar performances to rapeseed.

Calendula, caper/wild spurge, cuphea and lunaria still need experimentation on agronomic methods and plant breeding to improve crop characteristics in order to allow their industrial exploitation. Calendula is a good competitor to tung oil, which is currently imported in the EU, due to the calendic fatty acid content. Its indeterminate flowering and seed crushing difficulties hinders its development in large scale. Thus, there is need to improve cultivars, production systems and seed dehulling for oil extraction and that is to be achieved through breeding, ecophysiology studies, and seed cleaning and processing investigations.

Indeterminate flowering and seed shattering is also occurring in caper/wild spurge and cuphea, which makes harvesting difficult and less economic. The major constraint to the development of Cuphea for industrial uses, apart from its frost sensitiveness, sequential maturation and release of seeds from seed pots, is the seed shattering, stickiness and dormancy, which is at present being studied by plant breeders. In the case of caper/wild spurge, the presence of poisonous latex in the foliage makes the crop highly toxic and also blocks the threshing drums during harvest. Thus the highest priority to assure maximum seed yields is genetic and plant breeding research to obtain determinate flowering and non-shattering cultivars.

Lunaria is also at the development stage. Its mechanical harvesting and cleaning of the seeds is a problem but the major limitation to progress is the biennial nature of the plant and its high vernalisation requirement. The production potential and agronomy of the crop requires further investigation as the crop often does not thrive in large open fields. Thus, at present commercial production of lunaria is limited to seed multiplication for ornamentals.

Linseed is widely grown also as a fibre crop in Europe. Harvesting can be a major problem with linseed, particularly if the crop is late, incompletely desiccated or lodged. Several studies are carried out on the biological process leading to the filling of seeds in order to improve the quality of seed flax (oil content, improved fatty acid profile).

In contrast to all oil crops studied in this work, ***cardoon*** is a perennial crop grown only in the Southern European climates. It is the best crop for arid conditions because it matures naturally on the field in summer time when crops usually need irrigation. Mechanical harvesting still needs improvement to efficiently separate seeds from the whole plant.

b. The fibre crops

Fibrous flax and oil flax (linseed), industrial hemp and nettle can be produced in all EU27 countries, due to the suitable climatic conditions and the long lasting tradition of cultivation, processing and utilization of the flax/hemp and derived linen products. Kenaf, is a new crop in Europe, originating from tropics. It can be grown mostly in southern Europe. Bast fibrous plants mentioned above should be favourable and strategic industrial crops in Europe, especially in EU 27 countries. Fibre content is around 32%.

The cultivation area of industrial hemp in EU 27 was 14 544 ha in 2009/2010, while in the campaign 2010/2011: 15 014 ha. The tendency of increasing the hemp cultivation area in EU countries is noticed. The average yield of the straw is 7.3 t/ha and 2.43 t/ha of the fibre. Fibre content is around 25%.

As mentioned above, kenaf is a plant native to tropical regions. To grow and develop normally, it requires the air temperature above 200C. In Europe the crop is thriving only in southern countries preferably south of 45° latitude (Greece, Spain, and Italy). Kenaf seeds are not harvested north of 35°. The dry mass yield is 20-40 t/ha in tropical countries and 12-20 t/ha in Europe. Yield of fibre could be on level 1-3 t/ha (fibre content: 18-22%).

Nettle is the plant of the lowest significance among the fibrous crops discussed in the project. It is not grown commercially in Europe and it is the least domesticated crop among all discussed in the report. In fact it used to became of importance only in critical times when the supply of other fibre stock was in shortage, e.g. in Germany during the Second World War. Although some, mainly national research were conducted on nettle, it is not commercially used mainly because a small content of fibre in stalks of plants (11-16%) and consequently, the yields. Yields of a total dry matter are also low (3-10 t/ha).

Several European research projects, co-financed by the EC and domestic ones, prove and confirm the multifunctional and diversified textile and non-textile applications of bast fibrous plants as well as the potential role to play as the strategic industrial crops in Europe e.g. projects BASTEURES, FLEXIFUNBAR, CORONA, NATEX, IENICA, EUROCROP, COST ACTION 847, COST Action 862 etc.

All discussed fibre crops have very different and versatile applications however, majority of them focus in the same areas/industries. Bast fibrous plants cultivation, processing and utilization are advantageous, because they are traditionally grown EU crops (except kenaf and nettle), have positive effect on environment, can be grown in many regions in EU 27 (except kenaf), have positive effect on crop rotation, have low needs for fertilization and agrophags control (especially hemp and kenaf), have good effect on biodiversity, contribute to reducing unemployment on rural area (farmers sell fibre – processed crop yields), are good crop for organic farming (especially hemp), offer renewable, biodegradable raw materials for different industries, have possible applications in not fibre related areas (food, cosmetics, pharmacy, medicine), have high biomass yields with still not fully used high potential (especially hemp and kenaf) and have high content of fibre (except nettle).

Among the disadvantages, constrains and problems in breeding, processing and utilization of fibrous crops are their difficult breeding (lack information about genotypic markers, high heterozygoticity – hemp, allogamy and wind pollination – hemp), effect by global warming, lack of cultivars resistant to drought and high temperature (especially flax), poor credibility of yields and yield quality, lack of technologies for organic growing (especially flax – lack of suitable certified pest control products), difficulty to control dew retting, needs for special harvesting machines and primary processing, lack of efficient, cost effective processing machinery, lack polices favouring good quality raw material /product, reputation of a narcotic crop (hemp), low supply of EU grown feedstock, strong competition from natural fibres grown outside Europe and strong competition from fossil-based feedstock

The major products on the EU markets made of bast fibrous crops include clothing products, bio composites, insulation materials, construction materials, geotextiles, pulp, agro-fine chemicals, feed industry, and pharmaceuticals.

The major needs of the improvement in the scope of research, policy, etc.:

- genetic determination of yield and its quality,
- breeding for resistance to abiotic stress (drought) and high good quality yield of fibre (especially flax),
- methods for organic farming (weed control in flax),
- cost efficient and controllable methods of fibre extraction,
- modernization of harvesting and processing technology,
- polices favouring good quality raw material/product
- increasing the knowledge about advantages of fibrous crops in European society

c. The carbohydrate crops

Cassava, sugar beets, potatoes, sweet Sorghum and Maize as a carbohydrate crops for industrial uses were reviewed. In general all these plants are suitable to be cultivated in the EU27 area, with the only exception of cassava which seems much more adapted to the tropic environments.

Of the abovementioned crops, sweet sorghum, though not being yet in the European marketplace, exhibits remarkable potentialities as inland industrial feedstock due to its wide adaptability and interesting yields across Europe. Noteworthy, maize, potato, cassava, and sugar beet are broadly known as food crops, sometimes corresponding to the sole source for human nutrition (e.g. cassava is defined a "storage famine food" in countries of Central Africa), which may appear contrasting with the rationale of the present project which addresses "non-food crops" for the European industrial market.

Nonetheless, seeking for new industrial crops does not necessary means that new selected and tailored varieties of former food crops could not be used for emerging green applications. These crops may serve as new and sustainable compounds feeding the green industry, not necessarily rising ethical concerns (a food crop grown for non-food applications is not affecting the existing food market, nor limiting lands for food, but simply going in parallel to it).

Adding to that, the new challenge for sustainability and profitability seems to lie in the exploitation of waste streams of the carbohydrate crops production chains. For example, the utilization of wasted peel of potatoes, either for the production of biofuel (e.g. ethanol) or for polymers for packaging (e.g. chips bag), was seen as an interesting option; also, the use of maize stalks after the harvest or other un-marketable products for the production of lingo-cellulosic biofuels or for the production of cosmetics and pharmaceuticals.

From the environmental point of view, it should be recognized, however, that some of these crops may require intensive and laborious soil tillage for their cultivation, with associated soil erosion risks. High-demanding crops may lead to eutrophication of fresh waters due to the leakage of remaining synthetic nutrients, especially in the case of maize. Maize displacement by growing sweet sorghum could significantly reduce the overall environmental impacts in that sense. In line with the above concerns, it should be emphasized that major challenged for biomass crops in the near future will likely derive by the biorefinery concept, meaning that a spectrum of high-value low volume products can be extracted from biomass before utilizing it as biofuel and bioenergy. Bio refineries are expected to increase competitiveness while responding to the need to supply a wide range of bio-based products, and bio-energy at the same time, in a socially, economically and environmentally sustainable manner.

d. The other specialty crops

In Europe as a whole, only 130–140 MAP species are cultivated and the number of MAP species currently in formal cultivation for commercial production does not exceed a few hundred worldwide – less than 1% of the total number of medicinal plants used.

There are countries with a very long tradition in medicinal and aromatic plants cultivation which develop this sector on large areas. In Bulgaria about 30-40 medicinal and aromatic plants are cultivated on an area of about 43200 ha; in France acreage planted with medicinal, aromatic and perfume plants exceeds 30000 ha; in Poland 70 species are cultivated on 20000-25000 ha/year by almost 20000 farms; in Hungary the area covered by medicinal plants is around 37000-42000 ha/year and in Romania cultivated area with medicinal and aromatic plants varied between 26500 ha/1995 and 10680 ha/2009.

In other countries, medicinal plants are cultivated on smaller areas (in some cases, despite to some non-favourable climatic or geographic conditions): In Finland, more than 100 medicinal and culinary herbs grow wild and some are cultivated; there are currently approx. 70 different medicinal and spice plant species grown on a surface of 5600 hectares in Germany; the total area occupied by MAPs: 3342 ha/2002, with over a hundred species grown in Italy; the total area cultivated with MAPs in Latvia is estimated to be about 300 ha; in UK, current production of herbs occupies a relatively small area (ca. 4000 ha), most of culinary herbs; in Netherlands, 450 ha of medicinal herbs are grown (0,05% from total area of arable land); in Slovenia the total surface cultivated with medicinal and aromatic plants is smaller than 20 ha; in Spain, estimated area cultivated with MAPs is about 6000 ha;in Sweden, the production of medicinal and aromatic plants is small - the production of herbs grown in the field covered an area of 236 ha.

In all countries, a high quantity of vegetal raw material is still wild harvested. A limiting factor for starting new crops is represented by climate changes. Scientists widely agree that global climate change is already causing major environmental effects, such as changes in the frequency and intensity of precipitation, droughts, heat waves and wildfires; rising sea level; water shortages in arid regions; new and larger pest outbreaks afflicting crops and forests.

Quality control systems are important for the production of high-quality herbal products. The European Herb Growers Association (EUROPAM) has developed Good Agricultural Practice (GAP) guidelines which were further developed into Good Agricultural and Collection Practice for starting materials of herbal origin (GACP) by the European Agency for the Evaluation of Medicinal Product (EMEA). Also the WHO has developed similar guidelines.

Based on statistical survey of existing European medicinal crops, on forecast of climate change and on data received from the most important Romanian manufacturers of phyto-pharmaceutically products, 5 medicinal and aromatic species showed high potential for cultivation in order to provide a steady source of raw material for bio-industry: Lavandula angustifolia, Calendula officinalis, Mentha piperita, Plantago lanceolata, Echinacea angustifolia. Although these species are widely cultivated in Europe, the selection is justified by the multi-purpose potential of the plant - a variety of products based on current uses and future projections, various types (herb, seeds, fruits, leaves, flowers, roots) of raw material for industrial use and an important market demand.

Calendula officinalis - Annual herb, demands no special requirements from climatic factors, Plant material of interest: dried ligulate florets and composite flowers, seeds; applications: pharmaceutical (antimicrobial activity, antiviral activity; anti-inflammatory activity; wound-healing activity), insecticide, cosmetics, and tinctorial, strong allelophatic properties.

Echinacea angustifolia – Perennial herb with high ecological plasticity, grows best in an alkaline soil and is frost-resistant and well adapted to dry growing conditions in Europe, weed control is very important; E. angustifolia herba could be harvested since the second year of culture and in the third, fourth years of culture, harvested both aerial parts and root; plant material of interest: fresh or dried roots, herba; applications: pharmaceutical (stimulator of the immune system both in human and veterinary medicine), cosmetics, ornamental value.

Lavandula angustifolia – aromatic plant, long-lived perennial, requires high temperatures on germination, it grows very well on different soils even on nutrient deficient ones, supports drought well and is a light-loving plant, smaller yield in first 2-3 years; plant material of interest: dried flowers; applications: pharmaceutical (antimicrobial, antioxidant, antiulcer, anticonvulsant and sedative activities), cosmetics, perfumery, insecticide, ornamental value.

Mentha piperita – perennial herb, demanding from soil moisture, water is a limiting factor, pretentious and towards light, grows very well on loose soil, permeable and well-supplied nutrients, associated with large numbers of pests and pathogens; plant material of interest: dried leaves; applications: pharmacology (antimicrobial activity; smooth muscle contraction, choleric activity, angioedema activity, analgesic activity); cosmetics, perfumery, insecticide.

Plantago lanceolata – perennial herb, shows high ecological plasticity, moderate demands regarding soil and climatic factors, resist well in drought and cold winters; plant material of interest: dried leaves, seeds; applications: pharmacology (anti-inflammatory, antibacterial, laxative, spasmolytic and immunostimulatory effects), cosmetics, fibres for textiles, dye, gelling agent, stop smoking aid, fodder crop, antiparasitic.

Key facts of the selected crops

Crop type	EU regions	Agronomic issues	Common Uses
Oil crops			
Rapeseed (Brassica napus L.)	Central, Eastern, Mediterranean 6.500 million ha	Yields: 1.4-5 t/ha seeds (3.3 t/ha in Germany) Traditional crop, commercially grown. Winter and spring types. High erucic acid (HEAR), low erucic acid (canola), high oleic (HOLL) and classic varieties	Edible oil; biodiesel, animal feed. Rapeseed is the third largest source of vegetable oil in the world.
Sunflower (Helianthus annus L.*)*	South	Yields: 3-4,5 t/ha seeds Traditional crop, commercially grown. Spring crop. Moderate inputs. Classic, high oleic (HOSO), high oleic varieties.	Edible oil; biodiesel, animal feed. The leaves can be used as cattle feed, while the stems may be used in paper production.
Linseed/flax (Linum usitatissium L.*)*	Central, Eastern, Mediterranean 15,000 ha	Yields: 1- 2 t/ha seeds Traditional crop, commercially grown. Winter and spring types. Moderate inputs needs, carbon impact. But low and variable yields and logistic and storage difficulties	Linseed oil is used as edible oil, nutritional supplement; ingredient in many wood finishing products.
Fibre Crops			
Fibre Flax (*Linum usitatisimum* L.*)*	Central, Eastern, Mediterranean 15 014 ha	Yields: 3- 6 t/ha Traditional crop, commercially grown. Poor credibility of yields and quality. Difficulty in breeding. Needs specific harvesting machines.	Flax is grown both for its seeds and for its fiber. Uses include fabric, dye, paper, medicines, fishing nets, hair gels, soap and ornamental.
Hemp (*Cannabis sativa* L.*)*	Central, Eastern, Mediterranean	Yields: 6-10 t/ha Traditional crop, commercially grown. Approximately 40 varieties certified in Europe. Difficulty in breeding. Needs specific harvesting machines.	Clothing, nutritional products, manufacture of oil-based paints, in creams as a moisturizing agent, for cooking, and in plastics.
Kenaf (*Hibiscus cannabinus* L.*)*	South	Yields: 10- 18 t/ha Marginal crop in EU, difficulty to grow for seed in the majority of EU countries.	Paper and pulp, insulation material and can be used for energy and second generation bioethanol.
Carbohydrate crops			
Maize (*Zea mais L.*)	Central, Eastern, Mediterranean	Yields: 2- 10 t/ha seeds Recently the crop is also used as a bioethanol feedstock with specifically bred varieties.	Widely grown crop for edible uses (starch & oil products); plastics, chemicals and bioethanol.
Potato (*Solanum spp* L.)	Central, Eastern, Mediterranean	Yields: 20- 50 t/ha High water demands. The seasonal character and geographical location restrict the prospects of growth of the potato starch industry.	Edible uses (starch), plastics, animal food
Sweet sorghum (*Sorghum bicolor L.*)	South	Yields: 50- 100 t/ha (fresh stems biomass) Does not store well & has to be process on site within a short period after harvesting.	Edible syrup; bioethanol
Other specialty crops			
Coneflower *(Echinacea angustifolia DC)*	Central, Eastern, Mediterranean	Yields: 2- 4 t/ha Perennial herb with high ecological plasticity, frost-resistant and well adapted to dry growing conditions in Europe, weed control is very important.	Medicinal, ornamental
Peppermint *(Mentha piperita L.)*		Yields: 2-4 t/ha Perennial herb, demanding for soil moisture, water is a limiting factor, pretentious and towards light, grows very well on loose and fertile soils, attacked by pests and pathogens	Medicinal, food, ornamental
Pot marigold (*Calendula officinalis L.)*		Yields: 4-8 t/ha Although perennial, it is commonly treated as an annual plant. No special requirements from climatic factors.	Medicinal, food, ornamental

e. Matrix with crops and their multiple end use potentials and allocation factors

A matrix of crops and their multiple use possibilities is designed, that showed the best candidate streams for crops and products:

For the ***Oil market,*** the best candidate streams are:

- Rapeseed, sunflower for biodiesel
- Sunflower (classic, HOSO-high oleic sunflower oil), rapeseed (classic, HEAR-high erucic acid rapeseed, HOLL-high oleic) for lubricants
- Sunflower (classic, high linoleic variety), linseed/flax for paints and inks
- Sunflower (HOSO), rapeseed (HEAR), linseed/flax for polymers

For the ***Fiber market and resins,*** the best candidate streams are:

- Fiber flax and fibre hemp and kenaf for almost all applications: textiles, non-woven, paper and pulp, composites and energy
- Maize, sweet sorghum for biofuels and potato for energy purposes (using the residues from peeling off the potatoes)
- Potato for composite and construction materials

For the ***Pharmaceutical and other specialty product markets*** the best candidate streams are:

- All crops are suitable for pharmaceutical uses.
- Calendula/Pot marigold and menthe are best suited for cosmetics
- Calendula/Pot marigold, coneflower and menthe have a number of intermediary products

f. Maps of available lands for the cultivation of non-food crops

The aim of this task was to present the available land in EU27 for the cultivation of non-food crops (crops for fibre and fuel production). The main source for this task was the project 4FCROPS (www.4fcrops.eu) entitled "Future crops for Food, Feed, Fibre and Fuel" that ended at the end of November 2010 and was coordinated by CRES. In this project the available lands were estimated at three time frames: now, in 2020 and in 2030.

This work was carried out by EC BREC (PL), WP leader in 4FCROPS. The assessment of land availability for non-food systems was performed with the use of a land allocation model elaborated by ECBREC team (IPiEO) for the RENEW project (www.renew-fuel.com). The core of the model was kept unchanged; however, the input data and assumptions on scenarios were updated for the 4F CROPS project. The key assumption in this model is that the non-food crops can be cultivated only on a surplus land that is left after satisfying food and fodder production.

The land allocation for 2020 and 2030 in 4F CROPS was based on a Base Case situation, which reflects the average situation for land use within the period 2003-2007 in the EU-27. The data for the Base Case are derived from EUROSTAT database and include statistical data on land use, crop production volumes and yields. The calculations performed on NUTS-2 level regional level (with the exception of Germany, which is NUTS-1 level) and the results were aggregated into national (NUTS-0) level.

The current available area for the cultivation of non-food crops was the sum of the current fallow land and the area that is being cultivated with energy crops. In order to estimate the available land in 2020 and 2030 three parameters were taken under consideration: a) current fallow land, b) current land area that is being cultivated with energy crops and c) the surplus land released from food and fodder crops.

It was found that now the total available land 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%.

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 another approach for 2020. The general overview is that countries with large agricultural land areas were found to be the major suppliers of lands 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.

3.2 Plant breeding (WP2)

Genetic technologies

An overview of several representative genomics resources available for use in plant research, with particular emphasis on selected crop species was implemented. The selected crops were divided in four groups: oil crops (rapeseed, sunflower, linseed), fibre crops (linseed, flax, hemp), carbohydrate crops (maize, potato, sorghum) and specialty crops (coneflower, peppermint, pot marigold).

Sequence-related resources such as whole genome and protein coding transcripts were described, and sequencing updates were provided. Resources for genetic map based approaches such as QTL analyses were reviewed. The status of resources and technologies for transcriptome, proteome and metabolome analysis was also described, and examples of their combinatorial uses in the investigation of particular biological systems were reviewed. The current perspective on using loss-of-function and gain-of-function mutants in phenome research was also discussed. Finally, the progress of comparative genomics was reviewed and examples of applications of such resources to selected crop species were provided.

Biodiversity is increasingly being recognised as a vital resource for economic, social and environmental development. Plant germplasm provides the raw materials we rely upon for food, fibre, energy, medicinal and industrial products. Plant genetic diversity increases options, may provide innovative, plant-based solutions to the major environmental challenges that we all face - food security, water scarcity, deforestation, energy and climate change and broaden the scope of plant breeding.

The work was also focused on the identification of European Genetic Resource Centres. The European Internet Search Catalogue (EURISCO) is a searchable web-based germplasm information database, maintained on behalf of ECPGR. EURISCO provides information about European ex situ collections and links national inventories on plant genetic resources. The study also identified a number of genetic resources, which focused on selected crops by the Crops2Industry consortium.

However, crop biodiversity is under threat. Recognizing this danger, methods of biodiversity conservation need to be even more dynamic. Priority should be given on securing and providing financial support to already existing collections and to expansion of species collection in the centres of diversity. Adequate information about the genetic material that is conserved, whether ex situ or in situ, should allow the most efficient use of resources. The application of molecular and genetic engineering technologies enhances the characterization, conservation and utilization of genetic resources.

The recent trends and potential of plant biotechnology and genomics towards the creation, analysis, and manipulation of genetic variation and the development of improved cultivars was also investigated. Agriculture faces demands to sustainably produce enough food for an expanding world population and to improve the nutritional quality of food crops, as well as to provide non-food crops, e.g. for the pharmaceutical industry. The progress in molecular plant breeding can help meet these demands by shortening the time it takes to domesticate new crops from semi-wild plants, tailoring existing crops to meet new requirements, such as nutritional enhancement or climate change, rapidly incorporating valuable traits from wild relatives into established crops, allowing plant breeders to work with highly complex traits, such as hybrid vigour and flowering.

It was briefly summarized how molecular information and genetic engineering positively impacts the breeding paradigm of the selected crops. Molecular markers can facilitate the selection of agronomically important traits. Review papers on Marker-Assisted Selection (MAS) for the selected crops were a key source of information. Based on the information presented in these papers not only validated markers, but also potential markers were identified for nine of the selected crops. That is, marker assisted selection is not yet used for coneflower, peppermint and pot marigold. Wild relatives of crop species are a rich source of valuable traits from which currently only a small fraction have been exploited for crop improvement. We reviewed the continuing increase in the use of crops wild relatives (CWR) as sources of pest and disease resistance, drought and salt tolerance, improved quality, yield and cytoplasmic male sterility.

Historically, breeders develop new plant varieties by repeatedly crossing, growing and selecting the best performers within their germplasm collection. While conventional breeding methods continue to play an important role in developing new crops and cultivars, modern biotechnological tools are rapid and precise. The arrival of affordable, high throughput DNA sequencing, coupled with improved bioinformatics and statistical analyses is bringing about major advances in the field of molecular plant breeding. Multidisciplinary breeding programs on the world's major crop plants are able to investigate genome-wide variations in DNA sequences and link them to the inheritance of highly complex traits controlled by many genes, such as hybrid vigour. Furthermore, there has been a step-change in speed and cost-effectiveness. What previously took six generations to achieve can now be done in two, delivering massive time and resource savings. This has made molecular plant breeding feasible on marginal crops including medicinal plants and crops of the developing world. Finally, we need to recognize that the path to improve important crops traits may be realized through genetic modification (GM) of crops. GM technologies permit the generation of novel variation beyond that is available in naturally occurring (or purposely mutated) populations. Although, it is most likely that most the most noteworthy contributions to crop improvement in the next 5-10 years will continue to be from non-GM approaches, we contemplate that transgenic technologies will be deployed for most of the major crops in the future.

The conclusions from the breeding assessment were that plant genetic resources are the most important components of agro-biodiversity. Germplasm is a fundamental objective for effective conservation and use of crop genetic resources. The largest total numbers of ex situ accessions are of maize (327932 accessions), sorghum (about 235000 accessions) and potato (more than 98000 accessions). Among oilseed crops, sunflower accounts for almost 40000 accessions globally and rapeseed for more than 25000 accessions. Flax is the most important fibre crop in terms of the total number of accessions held, with almost 41000 accessions being maintained worldwide. In recent decades serious attention shifted towards a wide range of "underutilized" species to rescue, conserve and produce raw materials for a variety of applications. Examples have included kenaf (860 accessions) and hemp (almost 1450 accessions) for fibres; linseed (2730 accessions) for oils; coneflower (109 accessions), peppermint (954 accessions) and pot marigold (328 accessions), for medicinal uses.

Potential applications of molecular genetics at pre-commercial scale

Before releasing a hybrid in the market the research company has to select from a wide range of hybrids (5-7 out of 100-200) whose genome carries the desirable characteristics. After this first screening and before placement in the market, the distribution companies have to conduct many trials locally in order to verify in practice the performance of each hybrid in certain traits.

The selection of adaptable hybrids is the first important step in order all molecular genetics technologies to be applied at growing conditions and local production practices. Correct hybrid selection is extremely important for top yields. It is advisable to grow more than one hybrid to spread risks, as no hybrid excels in all characteristics.

Before a company-distributor announced its disposable portfolio of hybrids, must organize and carry out small scale trials under two important preconditions: a) many locations and b) under many cultivation techniques such as planting time, irrigation, fertilization etc. After a testing period of 2-3 crop cycles, it is almost certain that the desirable characteristics will be attributed also under common agricultural practice.

Companies should use several criteria in hybrid selection. Seed yield potential is an important trait to consider when looking at an available hybrid list. Results from strip tests or demonstration plots on or near growers' farms pre-commercially, should be evaluated.

An important trait to consider is pest resistance or tolerance. Pest resistance is becoming more common in current sunflower hybrids. Many hybrids are available with tolerance to most known races of Downy mildew, Phoma black stem, Rust, Sclerotinia head & stem rot and Verticillium wilt. The stalk quality is an equally important trait that must be considered. Hybrids with strong stalk characteristics reduce lodging, allow easier harvesting and reduce field losses due to high winds. Where lodging is a problem due to climate or environmental conditions, a selection within dwarf or semidwarf hybrids could potentially reduce lodging and tendency for early maturity.

Oil percentage should be another trait to be considered by breeders and companies in <u>oil crops hybrid selection</u>. Several environmental factors influence oil percentage, but the hybrid's genetic potential for oil percentage is the most important. Usually the market price influenced by oil percentage. All available hybrids have oil percentages ranging from 38 to over 50 per cent. Hybrids with oil percentages in the 40-45 range, on a 10 per cent moisture basis, should be selected. When deciding to grow oil-type sunflowers, hybrids producing satisfactory seed yields and oil percentages should be selected. Growers generally have signed contracts for marketing of non-oilseed or high oleic sunflower prior to planting since they are considered specialty crops. Test weight is also an important trait for consideration, especially for hybrids selected for late planting or replanting. For evaluating this trait, companies must experiment on different planting times.

As far as fibre crops are concerned, at pre-commercial scale breeders and distribution have to select from a wide range of varieties in order to achieve the goals that market requires. After the breeder's first screening, the distributing companies are conducting the pre-commercial trials in order to verify the presence of all desirable characteristics in new varieties, before their release in market. Fibre flax varieties are taller than oilseed types and have much lower seed yields. There are also varieties which are considered "dual purpose" for both fibre and seed, being intermediate in production of both products. Before releasing a new variety in the market, it is very important to be defined its certain use.

The most important, from the breeding point of view parameters of fibrous flax is the quality and content of fibre which is characterized by the low inheritability and high effect of environmental factors which makes breeding difficult, especially in countries with less favourable climate. Therefore breeders and companies must test the new varieties in a wide range of climate and environmental conditions that they are having an indirect effect on quality and content of fibre.

An important trait that must be taken in account when we are selecting a new variety is the resistance to different races of Fusarium fungi. Consequently, breeders need to pay particular attention to ensuring that any new variety released to companies pre-commercially and to growers in commercial scale, is genetically resistant to all races of the rust in the geographical area that it is intended to be grown (Lawrence et al., 2007). An interesting direction of breeding is also new cultivars resistant to low air temperatures.

During the past 50 years there has been a continuous improvement in the genetics of corn hybrids. Breeders and companies developed and selected hybrids best suited to the farmers needs. Size of corn acreage, soil type, tillage practices, pest problems and desired harvest moisture determined needs for such traits as dry down, disease resistance, insect tolerance, early plant vigour, plant height and relative maturity.

The key factors that can be supported by modern genomic technologies for selecting corn hybrids are yields, root & stalk lodging, maturity and other characteristics e.g., herbicide tolerance, insect and disease tolerance, drought tolerance, quick-drying ears, synchronized flowering, cob height outgrowth, number of rows per cob, number of kernels per row, or have more than one ear per stalk. At pre-commercial scale, hybrids should be selected with consistently high yields across a number of locations or for two years, with tolerance to stalk rots and green snap. Before releasing new hybrids in the market, local trials are a good source of information on relative maturity by reporting silking dates and harvest moisture for all hybrids in a given test. Seed company representatives can usually provide accurate information on most characteristics after evaluating new hybrids for these characteristics.

Finally, for getting credible results at pre-commercial evaluation regarding the tolerance in drought stress, it is critical during germination, emergence, tasseling and silking to control the soil moisture and provide the needed quantities of water through irrigation. While evaluating new hybrids in pre-commercial scale it is strongly recommended to balance the fertility management.

3.3 The bio-based products (WP3)

The main target of this WP is to explore the potential and feasibility of the European industry to make high-value bio based products from renewable agriculture and forestry feedstocks and biotechnological routes. WP3 activities were structured around the following guidelines:

- Review on the product yielding capacity from various industrial crops streams
- Identify desirable quality characteristics that feedstock has to meet for mature industrial processes
- Report on current alternative resources (including petroleum-based or chemical counterparts) for each industrial use.
- Set prospects to widen the range of potential feedstocks for the understudy industrial uses, based on the technology improvements
- Identify restricting factors that inhibit broader industrial use of the biomass feedstocks (supply, costs, physical traits, consistency in quality, technical performance, research gaps, etc.)
- Set forth research gaps, prospects and recommendations to procure bio-based products will be tackled.

Markets for non-food crops serve multiple end users, food, feed, fibre and fuel (4F) applications. As policy demand grows and industrial sectors seek alternative feedstocks to substitute fossil-derived substrates, the competition becomes high and risks arise for commodity price rises, land use, etc. The non-food markets dealt in this project are oils, fibres, resins and pharmaceutical and other niche markets. Within the oil market four industrial streams were identified i) biodiesel, ii) lubricants, iii) paint, ink coating and resins, and iv) polymers. Within the fibre market the streams of i) textiles, ii) non-woven, iii) paper and pulp, iv) composites v) biofuels and vi) resins were identified. Likewise, the main streams of the other specialties markets are pharmaceuticals, cosmetics, dyes, colorants, insecticides.

Extended reviews containing yielding capacities from various industrial crops streams, desirable quality characteristics that feedstock has to meet for mature industrial processes, current alternative resources for each industrial use, restricting factors that burden broader industrial use of the biomass feedstocks (supply, costs, physical traits, consistency in quality, technical performance, research gaps, etc.) as well as research gaps, prospects and recommendations to procure bio-based products were identified and reported.

a. Oils

Four industrial oil markets have been studied in the project :

- Field 1: Biodiesel production
- Field 2: Lubricant
- Field 3: Paint, ink coating & resin
- Field 4: Polymer

The Global Biodiesel industry has grown significantly over the past decade. Some of the main drivers behind this tremendous growth are reducing dependence on imported oil, environmentally friendly alternative to diesel, reducing greenhouse gas emission, able to be used in the existing diesel engines without (or little) modifications, and compatible with existing fuel distribution infrastructure. A rapid expansion in production capacity is being observed not only in developed countries such as Germany, Italy, France, and the United States but also in developing countries such as China, Brazil, Argentina, Indonesia, and Malaysia. The Global Biodiesel market is estimated to reach 37 billion gal by 2016 growing at an average annual growth of 42%. Europe will continue as the major Biodiesel market for the next decade or so closely followed by the US market.

The raw materials for biodiesel production are lipids of oil plants. The main cultivated crops are rape (EU countries), sunflower (France, Italy), soya (United States, Brazil, and African countries), canola—a kind of rape (Canada)—palm oil (Indonesia, Malaysia), and jatropha (India, African countries). The main fatty acids that are in lipids of oil cultures are palmic (C16 : 0), oleic acid (C18:1), and linoleic (C18 : 2) acid. A lot of oils can be used for producing biofuel; an important factor is to fit the European specifications for biodiesel. The European standards for biodiesel (e.g., EN 14214 or EN 14213) have strict limitations on the content of unsaturated acids and on such values that indicate the level of unsaturated lipids as iodine number.

Sunflower and rapeseed oils can be used directly as raw materials; other oils (palm, soybean oil) have to be used in mixture. An important parameter is to use raw material with good oxidative stability; unsaturated oils rich in linolenic acid (linseed oils , calendula) are difficult to use and are poor candidates for biodiesel production.

The global EU1542 lubricant market is estimated around 15 Mt. As a result EU15 ranks third after United States (8.4Mt) and China (estimated 5.4Mt). Unlike for the lubricant market, for which national statistics (ex: C.P.L.44 statistics for France) and a harmonised statistical system at the European level exist (thanks to the existence of an association like EUROPALUB), there are no figures collected centrally at the national or at the European level for bio lubricants. Therefore, it is very difficult to find relevant and recent figures on this market.

Most of the lubricant markets could be open up to bio lubricants to a more or less extent. At the moment, high-risk and loss applications make up the biggest part. The EU Ecolabel for lubricants (EEL 2005/360/CE) was implemented in 2005. Up to now, only 13 products are Ecolabeled. It is evidence that the EU Ecolabel in isolation will not be sufficient to fundamentally "boost" the bio lubricant market. But if the environment become more focused on environmental issue (with policies and regulations), it is clear that the Ecolabeled products will gain significant market share. The actual market for vegetable oil based lubricants is 75MT and the long term market is estimated as a 1000 MT market.

The market for solvents currently stands at around five million tonnes for Europe (600 000 tonnes for France). These solvents are generally petrochemical products. They emit volatile organic compounds (VOCs) which are suspected of being a human health hazard, are a factor in photochemical pollution, and are implicated in depletion of the ozone layer and the greenhouse effect. These solvents are increasingly replaced with water-phase or oxygenated solvents or non-solvents processes in the main applications (paints, resins, inks and degreasing operations).

This trend opens up perspectives for the development of products based on agricultural resources, such as bio-solvents, that offer safety and biodegradability. Many regulations have been adopted to combat the environmental impact of VOCs, nationally and at the European level. These regulations target chlorinated and fluorinated solvents, and in some cases hydro carbonated and oxygenated solvents as well.

Polymers: The French chemical industry is a major driver of the nation's economy, generating around €18 billion in GDP and €1.3 billion in R&D investment. However, the chemicals sector also has its share of issues to contend with, much of which stem from downturn across the petrochemicals business and allied industries, and the effects of offshoring and clustered sourcing processes. Developing new bio-based materials therefore represents a major strategic challenge for the French chemicals industry. In 2010, global annual production capacity of bio-based resins came to just 0.72 million tonnes, against 245 million tonnes for global "plastic" production (see Figure 7). Although this underlines the minor position of plant-based chemistry today, it also highlights the sheer scale of the potential market.

Cellulose, lignin, sugars and vegetable oils are the main bio-based raw materials. Sugars have been used to produce polyesters like polyhydroxyalkanoates (PHA) and polylactic acid (PLA). These bio-based raw materials have already found applications in sectors ranging from energy to industry, fine chemicals to pharmaceuticals, cosmetics to the food industry.

Fibres

Although for last two, three centuries it has the bast fibrous raw materials faced a strong competition from cotton and especially for last couple tens of years from synthetic fibres, they are still utilized in many industries.

For the purpose of this project we will not consider all possible products that can be obtained from these crops but focus on currently most important products. Fibrous crop chains are generally quite similar. Flax, hemp and kenaf can yield over 10 000 different products each. Yet, in practice, utilization focuses only on relevant very little portion of them that currently are produced by the industry or for the industry. Despite numerous advantages resulting from their green character but also from the properties these products offer, the competition with similar fossil raw materials-based products is very difficult. Partially responsible for this situation is the technological level of processing industry which is often considerably less advanced compared to technologies used in processing fossil raw materials. This in turn is the result of incomparable investment discrepancies in renewable raw material-based industry versus fossil-based one, in favor of the latter. This also hinders the competition with alternative natural fibres imported from the countries where costs of labour are much lower.

The quality of fibrous feedstock determines their technological value. Quality parameters of lignocellulosic materials depend on a number of factors e.g. selection of cultivars, agricultural techniques, retting processes and processing methods. Retting process is labour intensive and totally dependent on atmospheric conditions. Without retting, fibre of lower quality may be produced, suitable only for non-textile technical applications. Existing methods of mechanical processing rely on crushing and breaking operations for separating fibre from the woody part. The technology of extraction, processing and application of bast fibres and other raw materials need improvement.

The ability to improve technology on all levels of production is presented, beginning with methods of harvesting and retting, and ending on bio-product technology production is also tackled. The factor determining progress in this area is the application of new generation fibres such as bio silk, fibres on the base of polyactic acid, fibroin, natural nano-fibres and others. However, out of three fibrous crops discussed here only flax is currently studied in this aspect.

Resins

A literature research about the ingredients of crops which are useful for industrial use was made by CHIMAR. It was found that although traditionally the adhesives used in the industrial sector of wood-based panels were products synthesized from petrochemical raw materials, in the last few years, intense efforts have been exerted for their replacement by materials of natural resources. Today, the majority of the basic components of plants are used as building blocks for the synthesis of various products. In particular, cellulose, starch, tannin, lignin, protein, natural oils and glycerol are already used by the industry for the synthesis of polymers. Moreover, plant biomass is liquefied by various methods (e.g. pyrolysis) and used as substitute of phenol in phenol-formaldehyde resins.

The bio-industry sector has significant input in the general economy as according to economical data, by 2010 as much as 10% of the chemicals produced in Europe could be bio based, increasing from a value of €77 billion in 2005 to €125 billion in 2010. This represents a 62% increase within 5 years.

Pharmaceutical and other specialty products

Pharmaceutical and other specialty crops are the starting point for a wide range of products: essential oils, human and veterinary drugs, herbal health products, inks, colorants and dyes, perfumes, beauty products, novel plant protection products and also a range of intermediate products from which the above are manufactured.

Pharma industry: The importance of plants as a source of new drug molecules is illustrated by the fact that, in the past 20 years, 28% of new drug entities were either natural products or derived from them as semi-synthetic derivatives. It has been projected that, by 2020, 75% of worldwide deaths due to stroke and 70% of deaths due to diabetes will occur in developing countries. It is advisable to look for new therapeutic strategies based on natural compounds for cardiovascular diseases, infectious diseases, diabetes, obesity, cancer and allergy. There are a wide range of medicinal preparations: tea (infusions or decoction), tinctures, glycerolates, medicinal oils, essential oils, compresses or plasters, eye washes, balsams, cataplasms, as well as a great number of pharmaceutical forms: tablets, capsules, syrups, ointments, hydrophilic gels, eye drops (colliriums), nasal sprays and drops. Over 75 years from its foundation, Fares is a private company with Romanian capital, leading on herbal tea (medicinal and aromatic) market in Romania.

Cosmetics: In the last years a new concept has developed – cosmeceutics -cosmetic products that include ingredients designed not only to enhance the appearance but to also have a positive physiological effect at the cellular level. The use of new products is increasing: men grooming products, anti-aging products, spa-at-home, detoxification products. A recent study shows that cosmetic industry based on natural products could be very profitable. There are success companies, like the Greek 'Korres SA Natural Products', set up in 196, aiming to use its extensive scientific resources for the creation of beneficial and safe products, which offers today a complete skin and hair care range, make-up, sun care products and herbal preparations. Another Greek company, Apivita Cosmetic Medicine Dietary SA, uses ingredients which fulfil the EU requirements (quality and technical) and are all developed and prepared in accordance with the European Union's Good Manufacturing Practices (GMP) for cosmetics, with strictly select natural ingredients whose proven effectiveness and safety have been supported by laboratory and clinical studies.

Dyes, colorants: There is an increasing development of new natural compounds able to substitute chemical additives for food and beverage industry. These compounds are used as antioxidants or colorants. For example, Naturex France has developed an extensive range of extracts which naturally protect food products against oxidation and therefore extend their shelf life as well as a wide range of special colouring formulations made by natural pigments like carotenoids, curcuminoids, chlorophylls and anthocyanins. Natural dyes are rarely used in modern dyeing, except by specialist companies and craft dyers. It has become a common misconception that natural dyes only produce beiges and browns and washed-out shades. In reality, vibrant, fast, natural colours can be produced which are comparable with, and often surpass the colours of synthetics.

Insecticides: Alternative insecticides normally mean the insecticides are less toxic to humans and breakdown more rapidly in the environment than conventional insecticides. They are often called "environmentally friendly". The most known natural insecticides are pyrethrins which come from certain species of chrysanthemums and limonene and linalool which are volatile molecules obtained from some vegetal species.

Information on the specialty crops and crop products sector is difficult to analyse, because of its extreme diversity and variability and is limited by the reluctance of certain parts of the industry to document for commercial reasons.

3.4 Costs and socio-economics (WP4)

a. Cost analysis

Cost analysis for the selected crop-to-product schemes at EU-27, regional and participating country levels were performed.

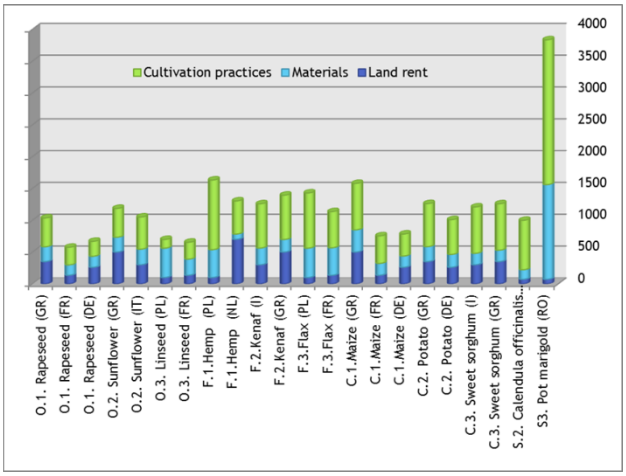
The costs of the under study crops have been evaluated with the model developed during the first period of the project & used data from the respective database created at the first reporting period.

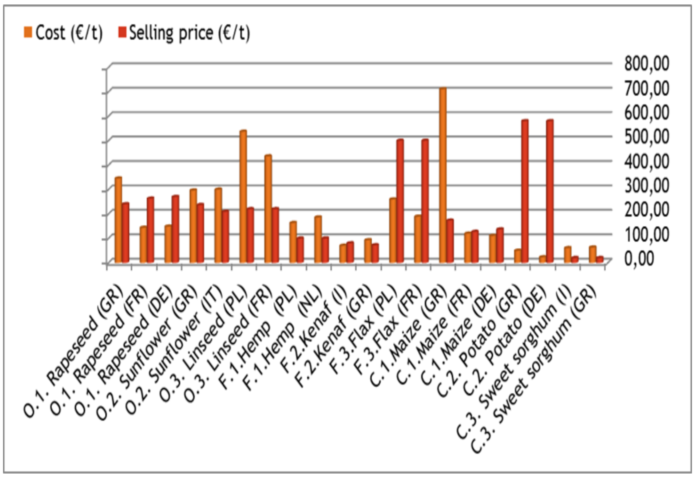
The crop production costs are divided into costs of land, labour, materials and time required for the respective cultivation practices. By this approach up to date market prices of these factors are taken into account. Cost analysis was performed for the selected crop-to-product schemes at EU-27, regional and participating country levels

Economically viable schemes were identified, and the effect of support mechanisms in each participating region (country level analyses were based on data from respective project participants), such as energy crop subsidies, capital grants, etc., on the techno-economic viability of selected crop-to-product chains was evaluated.

Accordingly, the profitability of the different crop-to-product chains and their prioritisation of crops for different markets was implemented. With given feedstock and 'main' product selling prices, the model calculated both the Internal Rate of Return (IRR) and Net Present Value (NPV) for both the industrial producer and the farmer, and the Net Margin (NM) for the farmer. The IRR and NPV give an indication of the economic viability of the investment in the conversion-to- product plant and in crop production. In addition, the level of net margin generated by the selected industrial crops was compared with the net margin generated by existing land uses. This provided the basis for a quick assessment of whether the selected industrial crops can be considered as a realistic alternative farm income source.

Pot marigold is the most expensive crop, with hemp (PL & NL), kenaf (I & GR), flax (PL) and maize (GR) following. Rapeseed (FR & DE), linseed (PL& FR) as well as maize (FR & DE) show the lowest production costs, which can be attributed to the higher efficiency of the agricultural prices and the lack of need for irrigation. The most costly factor is cultivation practices while materials show a very high share in the total cost of pot marigold & coneflower (very expensive propagation material) and land has exceptionally high cost in the cultivation of hemp in the Netherlands. In most cases for the oil, fibre & carbohydrate crops the cost of producing the crop exceeds its selling price, and they can be made profitable only with financial support (subsidies, etc.).





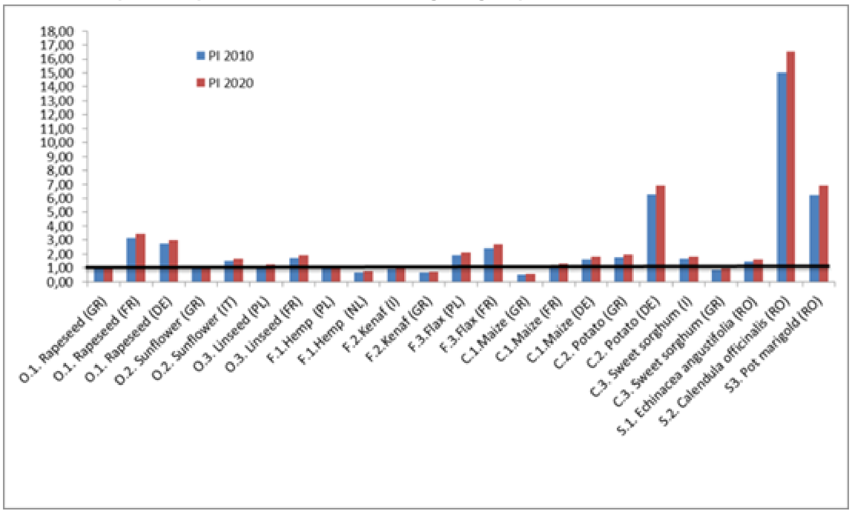
Production costs (€/ha) for the under study crops grouped by land rent, materials & cultivation practices and selling prices for the under study crops

b. Socio-economic assessment

A socioeconomic assessment for the selected crop-to-product schemes was performed based on the prioritisation and inputs from selected individuals/ related industry representatives.

A module (linked with the cost analysis model) was developed to assess the socio-economic impacts (income & jobs). A set of qualitative key factors was used in the analysis to assess the socioeconomic impacts of the selected crops plus wheat which has been used in the analysis as a reference crop as it is one of the most widely cultivated across European agricultural lands. The methodological approach was based on the evaluation of the economic viability of the crop-to- product scheme and then proceeded to the evaluation of the wider socio-economic benefits (income and jobs). A number of representative case studies (during the third workshop) were selected based on data availability, product and market focus (covering the range of markets addressed within this project namely energy, fuels, fibres, chemicals, boarding materials, etc.). The generated income and number of jobs for each of the selected cases was evaluated.

The crops scoring the highest are by descending order of scoring: Sweet sorghum, maize, kenaf, and potato. They are all high yielding crops, efficient in terms of land, water and nutrient use and they also present high levels of resistance to pests and diseases. From these crops only maize has wide geographical distribution while both kenaf & sweet sorghum are mostly considered as options for the Mediterranean countries. The three conventional crops wheat, rapeseed and sunflower present low scores. These species use a less efficient photosynthetic pathway and normally require high land and nutrient input (fertilisers, pesticides, etc.)



Profitability index for the under study crops for the 2010 and 2020 timeframes

Without subsidies, most of the under study crops (with the exception of potato & flax) are almost breakeven or slightly negative in terms of profitability. This can be attributed mainly to two issues, i.e. low yields for some of the crops or high costs in the cultivation practices, especially when irrigation is required- as in the case of Greece.

Profitable options are rapeseed in France and Germany, due to both good yields and efficient crop management practices but also due to consistent biodiesel markets for the oilseeds, linseed in France and Poland, due to rising demand and good prices, as well as sunflower in Italy & Greece.

Within the fibre crops studied cases, the profitable options are hemp in Poland due to high reported yields and low land rent cost, flax in both Poland and France due to good yields and high market price, and kenaf in Italy in some regions with irrigation and appropriate crop management practices.

Within the carbohydrate crops studied cases, the profitable options are: maize in France and Germany due to both good yields and efficient crop management practices, potato in both Greece and Germany and sweet sorghum in Italy and Greece, due to its high yielding potential. All specialty crops are profitable options with calendula and pot marigold presenting the highest values.

3.5 Sustainability (WP5)

a. Geo-spatial bio-physical impact analysis

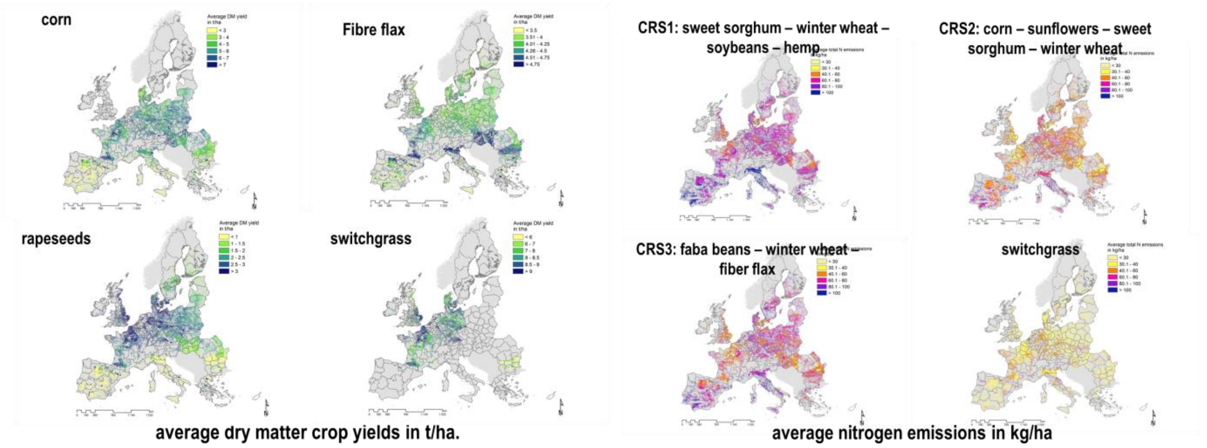
The objective is to simulate production and environmental impacts of selected non-food crop production systems in the EU.

A bio-physical data-model framework was applied to simulate the production and environmental impacts (i.e. biomass yields, topsoil organic carbon stocks (SOC), and total nitrogen emissions) of selected non-food crop production systems on croplands of the EU27. The specialty crops such as coneflower, peppermint, and pot marigold are not simulated, because of two main reasons: (i) there are no crop parameters available for these crops which make simulations with EPIC impossible, and (ii) these crops are often grown in the wilderness such that sustainability assessments are not relevant.

The bio-physical process model EPIC (Environmental Policy Integrated Climate) was applied to simulate production and environmental impacts of derived crop rotations and selected non-food crops. In this analysis, the EPIC model is run for a 20-year simulation period (1991-2010) using REMO daily climate data.

The simulations results indicate that the highest bio-physical biomass production potentials on EU27 croplands are attained with hemp and perennial biomass crops such as switchgrass and miscanthus. The frequency distributions reveal rather large yield variability for all crops, which are geo-referenced with maps. The maps also reveal the impact of irrigation on biomass yield particularly in Southern Europe.

Perennial biomass crops do environmentally better than annual biomass crops with respect to impacts on topsoil organic carbon and total nitrogen emissions. In the long-run, miscanthus yields the highest topsoil organic carbon stocks on average followed by switchgrass and the other biomass crops. On average, the total nitrogen emissions are lowest for miscanthus and switchgrass. Miscanthus has also the lowest nitrogen emission rate on average as well as the lowest frequency of total nitrogen emission rates above 200 kg/ha. The shares of water related nitrogen emissions are for crop rotations higher than for miscanthus and switchgrass. Consequently, the long-run bio-physical impacts of perennial biomass crops outperform annual biomass crops, however, land use adjustments are less flexible for perennial crops.



b. Challenges and conflict areas for non-food crop production systems

The C2I project defined "challenges" as both barriers to be overcome, and opportunities to be used in order to further the sustainable use of non-food crops in the EU27. The environmental conflict areas included land use, biodiversity, greenhouse gas emissions (GHG), environmental risks from GMO, water availability and quality, social conflict areas and competition for land and water.

Non-food crops cultivated on non-arable land or land not in competition with food and feed production, and not interfering with nature protection and using land with low carbon soils are favourable options, but social safeguards against land-tenure and land access related risks need consideration.

In general, edible crops such as maize and potato, and crops delivering edible oils do not qualify as sustainable options due to competition with food uses. Perennial crops seem more favourable than annual cultivation schemes, but biodiversity-related issues concern siting, and management practices. In that regard, fibre and specialty crops seem most favourable, while carbohydrate and oil crops need careful evaluation. A key concept to improve the overall sustainability of biomass use is the "cascading" concept: material use first, then recovering the energy content of used bio-based products.

As barriers to overcome in order to further develop the sustainable use of non-food crops in the EU27, the competition with fossil-based products and value chains, regulatory aspects of non-food value chain, and imports versus domestic supply were tackled and studied. Regarding opportunities of non-food crops, the domestic production and innovative technologies, environmental opportunities and social opportunities were evaluated for the selected crops-to-industry schemes.

The environmental impacts of biomass feedstock production for material use can be – similar to bioenergy – either positive or negative, depending on the cultivation system, its location and previous land-use, and the management practices with their effects on biodiversity, soil and water. Furthermore, the overall balance depends on the downstream processing of RRM into useful products, the use phase of such products, and their end-of-life management. The environmental conflict areas included land use, biodiversity, greenhouse gas emissions (GHG), environmental risks from GMO, water availability and quality, social conflict areas and competition for land and water.

c. Set-up of a core list of sustainability standards and criteria

After introducing the potential problems and conflicts, standards were developed to safeguard against the respective risks. In order to design a core set of sustainability standards, this task initially drew on other work that has been carried out on the sustainability of energy systems, especially those using bio energy and it will focus on annual and perennial energy crops.

The work for this report was able to take into account preliminary results from the WP1 and 6, and also results from WP 5.1 through 5.3. Furthermore, the authors were fortunate to make use of internal results from other projects on the national and international levels.

The standards that were derived here are based on evaluation of various studies, as well as the following standards and certification schemes: American Tree Farm System; European Green Electricity Network (EUGENE), EUREPGAP Protocol for Fresh Fruit and Vegetables; Fair-trade Labelling Organizations International (FLO); Flower Label Program (FLP); Forest Stewardship Council (FSC); Green Gold Label Program; Impact Basel Criteria for Responsible Soy Production; RSPO Principles and Criteria for Sustainable Palm Oil Production; Sustainable Agricultural Standards; Sustainable Forestry Initiative Standard (SFIS) 2005 - 2009 Standard; Utz Kapeh - Codes of Conduct.

Environmental standards and criteria included land use, biodiversity, emissions of greenhouse gases (GHG), environmental risks from GMO, soil erosion and productivity, water availability and quality. Social standards and criteria involved food security, competition for land and water, land tenure and land access, healthy livelihoods and labour conditions.

It is not yet possible to derive overall resource efficiency indicators for non-food crops without implying their use as either feedstock for biomaterials, bioenergy in general, or biofuels.

Thus, it is recommended to develop a comprehensive scheme for the sustainability of biomass in general which integrates the different markets, and allows for cross-sectorial application. This could foster the implementation of concepts such as cascading use if coupled to an incentive system.

3.6 Overall assessment of crops-to-industry schemes (WP6)

A collection of relevant strategies and papers in the field on non-food use of plant biomass was elaborated, based on which an initial list of topics to be prioritized in the further process is prepared to serve the overall assessment of crops-to-industry schemes, in cooperation with project partners and stakeholders.

The criteria list is set up to develop ideas and finally frameworks to enhance the utilisation of non-food plant based products in Europe. For the implementation of plant-based non-food bio products it is important to realize the special situation of non-food bio products with respect to **competition and economic situation**.

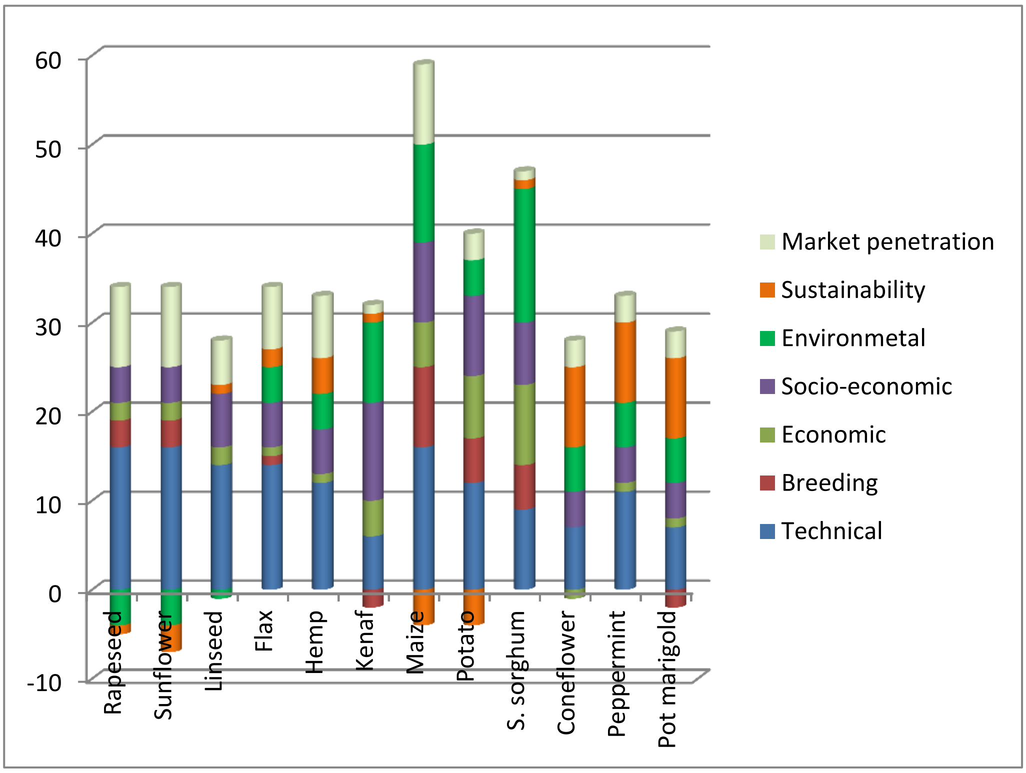
The majority of the crops showed a net benefit in terms of yielding potential and quality of raw materials, being it oils, fibres, starch, sugars or other specialty products, which –up to a certain extent – could compensate for the limited geographic distribution, the small scale of cultivation, or the challenging crop management and logistics.

It is increasingly understood that bio-products - following the biofuels case – when produced from conventional food crops such as grains, sugar beet and oil seeds, are limited in their ability to achieve targets for greenhouse gas emission reduction. Their sustainable production is under review, because they could create strong competition for land and water used for food production.

However, the cultivation of conventional food crops for non-food uses is characterised by mature commercial yields, and well understood crop management and logistics therefore present lower risks for the farmers to grow and the industries to use. Most of the crops selected for the several product streams are used also for the food market. In such cases, breeding efforts have been initiated and new varieties are being produced with improved traits for the several industrial products but low food value.

It was noted that maize, potato and sweet sorghum were higher marked, because of their cultivation in commercial scale (except for sorghum), their high yielding potential, the largest total numbers of accessions and published genomics, their favourable economics because of the high yields, as well as high efficiency in terms of land, water and nutrient use and resistance to pests and diseases.

The rest of the crops have shown similar performances but for different parameters. For instance the commercial plantations of the oil crops which involves mechanized crop planting, management and harvesting techniques, accompanied with high yields and good quality of the raw material out yielded the high sustainable performance of the fibre and other specialty crops. The market diversification of the oil crops was also much more significant than this of the other specialty crops.



Aggregated results from the technical, breeding, economic, socio-economic, environmental, sustainable and market assessments

Referring to the markets, the best candidate crops for the lubricants market are rapeseed and sunflower, for the paint market it is only linseed, for polymers all selected crops are suitable, while for the biodiesel market rapeseed and sunflower dominate.

All selected crops, hemp, flax, kenaf are suitable for the textiles, non-woven, paper and pulp and composites markets, including the resins, whereas when it comes to biofuels, they could be destined only for second generation biofuels, on the condition they pass the sustainability criteria, including LUC and ILUC factors.

The selected carbohydrate crops, maize, potato and sweet sorghum can be successfully used only in the biofuels market, where the market share, availability of product/ market demand as well as business models are well established. For the rest of the products, like polymers and resins, fibre crops constitute better raw materials

All selected crops, coneflower, peppermint and pot marigold are suitable for the several pharmaceutical uses and the cosmetics market. Peppermint is the only crop that can be used for repellents and pot marigold for paints and dyes.

4. List of project beneficiaries

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