# Green biotechnology applications for industrial development: opportunities and challenges for cooperation between the EU and the Mercosur

## 1. The bio-economy: the way forward to a sustainable agricultural and industrial development

The increasing world population and explosive growth of emerging economies create escalating demands for agricultural, industrial and health products. At the same time, more sustainable industrial and agricultural productivity will be required with the resilience to cope with future climate change impacts and enhanced resource use efficiency to deal with natural resource constraints and restricted fossil fuel reserves.

This rising need for a sustainable supply of food, raw materials and energy, together with tremendous progress in the life sciences has led to the concept of the Knowledge-Based Bio-economy (KBBE) (2007) or 'bio-economy' with emerging key technologies as major drivers of innovation. According to the OECD, biotechnology offers technological solutions for many of the health and resource-based problems facing the world. The application of biotechnology to primary production, health and industry could result in an emerging bio-economy where biotechnology contributes to a significant share of the economic input (OECD, 2009).

Innovations in biotechnology can expand the markets for agricultural producers worldwide, reduce environmental degradation, and provide alternatives to fossil carbon-derived products and energy. The cultivation of biotechnology crops has already contributed substantially to sustainable development and climate smart practices including a reduction of agricultural and industrial environmental footprints, and conservation of biodiversity (WWF 2010, James 2012, Brookes and Barfoot 2012). Farmers have benefitted both financially and health-wise with significantly higher

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incomes per hectare and reductions in chemical sprayings (JRC 2008, Carpenter 2010, Qaim 2010, Brookes and Barfoot 2012, James 2012, Lusser et al., 2012). The bio-economy especially offers new opportunities for farming, forestry and related agribusiness in the developing world, where a large fraction of the population, often over 50%, derives their livelihoods from agriculture and where the productivity levels of land are significantly below the technical and environmental potential. Moreover, subtropical and tropical regions have a rich biodiversity with a huge potential for value addition which remains largely underutilized.

## 2. Green biotechnology in Europe: the KKBE concept

In Europe, the KBBE concept has been translated in KBBE specific European Technology Platforms (ETP) and the implementation of several European Research Area (ERA) nets to reduce fragmentation and improve the coherence and coordination of national research programs. Along with this, several European Commission expert groups have been established. Research in the different areas of the KBBE has been promoted and financed through the Commission's Framework Programme 7 (FP7) and several Member State initiatives (The Knowledge Based Bio-Economy  KBBE in Europe: Achievements and Challenges, 2010).

In 2009, the European Commission developed a common strategy for the promotion of six key enabling technologies (KETs) as main drivers for the development of new goods and services for a low carbon, knowledge based economy. Industrial biotechnology was defined as a KET for the progressive replacement of non-renewable materials currently used in various industries with renewable resources. Six different research areas have been identified under the current framework programme (FP7) activity Biotechnologies, which are linked to a wide range of different European and international policies: (1) novel sources of biomass and bio-products, (2) marine and fresh-water biotechnology (blue biotech), (3) industrial biotechnology: novel high added-value bio-products and bioprocesses (white biotech), (4) bio refinery, (5) environmental biotechnology and (6) emerging trends in biotechnology (http://ec.europa.eu/research/bioeconomy/biotechnology/policy/index_en.htm).

With the adoption of the FP7 programme (2007-2013), the EU decided to invest in European knowledge by increasing growth and competitiveness and doubling the budget compared to the FP6 programme to a total of 67.8 billion euro. The FP7 is being organized through 4 main programmes: Cooperation, Ideas, People and Capacities. The Cooperation programme aims to promote collaborative research projects and networking activities between industry and public research in order to develop excellence in European science. Within this programme several thematic areas have been identified, with the Food, Agriculture and Fisheries and Biotechnology theme being of particular interest for biotech research. This theme, with 1.9 billion euro funding, specifically addresses 3 major activities: (1) sustainable production and management of biological resources from land, forest and aquatic environments, (2) fork to farm: food (including seafood), health and well-being, (3) life sciences, biotechnology and biochemistry for sustainable non-food products and processes (European Commission, 2005; Cordis, 2012). With FP7, international cooperation has been integrated into all 4 programmes. Recognized international cooperation partner countries or ICPs can receive funding by participating in collaborative projects under the cooperation programme, while international cooperation and science and technology policy dialogue is stimulated under the capacities programme. In addition, international cooperation opportunities can also be identified through the Marie Curie actions of the people programme or ERC grants under the ideas programme (research*eu focus, 2012a).

With the Europe 2020 strategy, launched in 2010, Europe prioritizes on smart and sustainable growth by developing and promoting a knowledge and innovation based economy, which will be greener, more resource efficient and more competitive. Europe is concentrating its efforts on research and innovation by aiming to invest 3% of the EU's GDP in R&D. The "Innovation Union", one of the 7 flagship initiatives of the Commission, aims to improve funding conditions to ensure technology transfer and product and service development from innovative ideas and scientific research (European Commission, 2010). Under this flagship one single funding programme has been established. Horizon 2020 will run from 2014-2020 and the Commission has proposed to invest 80 billion euro into this framework to support multi-disciplinary and multi-actor projects developing solutions for specific challenges. It will focus on 3 major objectives: scientific world leadership (24.6 billion euro budget), industrial leadership (17.9 billion euro budget) and European societal challenges (31.7 billion euro budget). Under these societal challenges, six themes have been identified: (1) Health, demographic change and well-being, (2) food security, sustainable agriculture, marine and maritime research and the bio-economy, (3) secure, clean and efficient energy, (4) smart, green and integrated transport, (5) climate action, resource efficiency and raw materials and (6) inclusive, innovative and secure societies. As these challenges are global, international cooperation in science, technology and innovation will be stimulated as well as partnerships with industry, civil society and governments (European Commission, 2011; Research* EU focus, 2012b). With this program bio-economy research and innovation funding will increase as it has been proposed to allocate 4.7 billion euro to the "Food security, sustainable agriculture, marine and maritime research and the bio-economy" challenge. In addition, other funding opportunities will be present under the challenges "Health, demographic change and well-being", "Secure, clean and efficient energy" and "Climate action, resource efficiency and raw materials" to further stimulate the bio-economy (European Commission, 2012).

## 3. Optimization yield and quality traits for biomass production

International and national research addressing the availability of feedstock for a bio-economy focuses mainly on the optimization of yield as well as quality traits such as starch properties in potato or fatty acids composition in rapeseed, sunflower or crambe oils (Albrecht et al. 2010). Biorefineries are highlighted as sustainable production systems to use forestry and agricultural feedstock for the production of bio-based transportation fuels, chemicals, heat and power since they represent significant advantages in economies of scale and closed-loop structure. Several FP7 collaborative projects and networking actions such as Crops2Industry, the ERA-IB-2, GLOBAL-BIO-PACT and SAHYOG (Table 1), covering the whole value chain and/or investigating the technical competence and socio-economic impact of using non-food crops for industrial applications, have been launched recently. In the EU BIOCORE project (Table 1) the industrial feasibility of a bio-refinery concept to convert cereal by-products such as straws, forestry residues and short rotation woody crops into second generation biofuels, chemical intermediates, polymers and materials is being analyzed. In recent years, several bio-refinery pilot plants have been constructed in Europe amongst which the Bio-Base Europe which is a joint initiative of Flanders and the Netherlands and the first open innovation and education center for the bio-based economy (www.bbeu.org).

Linking up with white biotechnology, green biotechnology research efforts are being undertaken to optimize plant biomass as alternative renewable and carbon-neutral raw material for the production of bio-energy and biomaterials. In frame of the competitive agricultural market with producers of food, feed, fibers, and increasingly bio-energy, it is anticipated that the second generation biofuels will be derived from cellulosic biomass from fast growing perennial grasses, such as Miscanthus, and trees such as poplar and willow. At the Plant Systems Biology Department (PSB) of the Flanders Institute of Biotechnology (VIB, Belgium), research is being carried out on modification of lignin, a cell wall polymer that hinders saccharification. The aim is to design trees with altered cell wall properties in order to facilitate lignocellulosic biomass conversion to bio-ethanol and to reduce the chemical load required for industrial processing for paper and pulp applications. Currently, a field trial is being performed with poplar trees with down-regulated cinnamoyl-CoA reductase to serve as non-food feedstock for the production of bio-ethanol. The first results indicated a bio-ethanol yield up to 81% higher compared to non-modified poplar (Van Acker et al., 2011). The same principle can be extended to other crops through powerful gene discovery programs targeted to cell wall recalcitrance genes (Vanholme et al., 2010). Under the FP7 project RENEWALL (Table 1), a European consortium is investigating different plant genes involved in cell wall biosynthesis as well as microbial genes to develop new strategies for crop improvement, either through conventional breeding, or in combination with genetic modification (GM) to produce plants with modified cell wall properties that are easier to saccharify for biorefining.

Alongside agricultural feedstock yield optimization for better processing, there is also a focus on better crop yields to intensify biomass production in frame of limited available arable land and the continuing decrease per capita, biodiversity conservation and sustainability criteria. Apart from modern breeding techniques, computational approaches combined with high-throughput technologies (systems biology) are being applied to unravel the molecular basis underpinning plant growth in order to boost crop productivity. BASF Plant Science in Europe announced with Monsanto in 2010 to expand their joint efforts to develop higher-yielding and stress tolerant crops through inclusion of wheat into the existing program on corn, soy, cotton, and canola (www.yieldbooster.org/images/stories/PDF/final%20release.pdf). BASF Plant Science is working in close collaboration with PSB (VIB; www.psb.ugent.be/the-ipb-division/systems-biology-of-yield) where researchers are also looking into possibilities to enhance the yield performance of bioenergy crops such as poplar and maize, as model for grasses, under abiotic stress conditions. PSB (VIB) is also part of the FP7 funded ENERGYPOPLAR consortium (Table 1) that aims to develop energy poplar trees with both desirable cell-wall traits and high biomass yield under sustainable low-input conditions to be used as a source of cellulosic feedstock for bioethanol production. Other current European FP7 research projects in the field of yield optimization are the RECBREED project (Table 1) on new genetic and molecular breeding tools, and SPICY (Table 1) which aims to develop a suite of tools based on molecular breeding to help breeders in predicting phenotypic responses of genotypes for complex traits such as yield under a range of environmental conditions. The collaborative 3TO4 project (Table 1) with academic and industrial participation seeks to increase productivity and decrease the input per unit yield through the conversion of C3 crops to use C4 photosynthesis. Several FP7 projects aim at identifying new crops for the sustainable production of bio-based products. The objective of the collaborative OPTIMA project (Table 1) is to identify high yielding grasses for the Mediterranean region, within the optimization chain that will provide a stable source for both biomass and new plant derived bio-products using an interdisciplinary approach. The FP7 large scale integrating project ICON (Table 1) under the leadership of the Swedish University of Agricultural Sciences (SLU) is aiming at the biotechnological development of high yielding oil crops (Crambe abyssinca and Brassica carinata) for the sustainable production of oils and lubricants for the chemical industry. JATROPT (Table 1) is linking high quality research groups, including EMBRAPA and companies operating in different continents and disciplines on research and development of Jatropha curcas as a high oil, low competition with food crop, for the production of biofuel.

In addition to improving yield of the classical agricultural feedstock, several European projects are looking into taking advantage of alternative sources which do not compete with feedstock for arable land. Microalgae show great promise as small factories using sunlight, marginal water resources, waste nutrients and high levels of carbon dioxide to sustainably produce biomass and a wide variety of biomaterials. However, large-scale commercial cultivation of algae still faces some challenges, including high cultivation and harvesting costs, contamination and an inconsistent productivity level. The GIAVAP consortium (Table 1), running under the FP7, is aiming to adapt available engineering techniques and to develop cultivation, harvesting and extraction techniques to make algae strains of economic interest better suited for industrial applications. Likewise, the FP7 SUNBIOPATH project (Table 1) is looking into the genetic improvement of photochemistry and sunlight collecting processes in algae chloroplasts in order to increase biomass yield.

## 4. Molecular farming

Molecular farming for the production of nutraceuticals, medicinal products, cosmetics, agrochemical or pharmaceutical compounds in plants is another example of promising applications of green biotechnology for the renewable industrial sector. Recently, much progress has been made in the field of bio-pharmaceutical production, a process less costly than bacterial or mammalian cell-based production. The Pharma-Planta consortium, a mixture of academic partners, SMEs and large industry partners (www.pharma-planta.net), created under the EU Sixth Framework Program has successfully developed the production of a monoclonal antibody against HIV in transgenic tobacco plants. The product has already been tested in clinical trial phase I at the Surrey Clinical Research Centre (UK) and the first results are promising.

Other efforts have been undertaken for the production of plant-derived molecules using contained facilities. The COMOFARM project (Table 1), funded under the EU FP7 programme, aims to establish high-yielding production systems for pharmaceutical and industrial proteins based on plants, plant tissue and plant cells. The project includes a comparison of four alternative systems of hydroponic plants, root cultures, moss and suspension cells, and involves the evaluation of different species, strain and process optimization, scale-up, downstream processing, protein characterization and process evaluation in terms of regulatory compliance. The multidisciplinary team of the METAPRO project (Table 1) aims to optimize the production of several useful isoprenoid derived secondary metabolites to demonstrate the tools and strategies needed for the generic production of useful secondary metabolites in plants. As a proof of concept astataxanthin (ketocaretonoids) and the apocarotenoid crocin are being engineered into Solanaceaeous host platforms with tomato fruit and potato tubers as ideal cell factories. The TERPMED small collaborative project (Table 1) makes use of 'omics' technologies to detect, purify and characterize compounds bearing specific functional groups from the terpenes with high potential as novel human drugs for treating cancer and neurological disorders. Innovative production platforms using plant secretory organs such as trichomes are being tested to produce the most biologically active and interesting compounds as well as novel compounds by combinatorial biosynthesis. The objective of another FP7 project, SMARTCELL (Table 1), is to design plant systems for sustainable production of secondary plant metabolites and value-added industrial products. SMARTCELL focuses on metabolites of the terpenoid pathway and the production in periwinkle and tobacco derived plant systems. The PLAPROVA collaborative project (Table 1) between the EU and Russia with participation of South-Africa has developed a rapid plant-based system to produce vaccines and pharmaceutical products in plants. The project was launched with the development of vaccines against important diseases of livestock such as avian influenza and blue tongue and extended to other viruses such as the human and bovine papillomaviruses, hepatitis B virus, porcine respiratory and reproductive syndrome virus and foot and mouth disease virus.

## Small or medium-scale focused research projects

| Project | Project title | Subject(s) | Period | Website |
|---|---|---|---|---|
| **AGROCOS** | *From biodiversity to chemodiversity: novel plant produced compounds with agrochemical and cosmetic interest* | *Agricultural biotechnology - Biotechnology* | 2010-2014 | www.agrocos.eu |
| **COMOFARM** | *Contained molecular farming controllable contained systems for high yield and consistency* | *Agricultural biotechnology - Biotechnology* | 2009-2012 | www.comofarm.org |
| **ENERGYPOPLAR** | *Enhancing poplar traits for energy applications* | *Agricultural biotechnology – Agriculture – Biofuels – Renewable sources of energy* | 2008-2012 | www.energypoplar.eu |
| **METAPRO** | *The development of tools and effective strategies for the optimization of useful secondary metabolite production in plants* | *Agricultural biotechnology - Agriculture* | 2009-2013 | www.isoprenoid.com |
| **RECBREED** | *Recombination: an old and new tool for plant breeding* | *Agricultural biotechnology - Agriculture* | 2009-2013 | recbreed.eu/ |
| **SPICY** | *Smart tools for prediction and improvement of crop yield* | *Agricultural biotechnology* | 2008-2012 | www.spicyweb.eu |
| **SUNBIOPATH** | *Towards a better sunlight to biomass conversion efficiency in microalgae* | *Industrial manufacture - Sustainable development -Resources of the sea, Fisheries* | 2010-2012 | www2.ulg.ac.be/genemic/sunbiopath |
| **TERPMED** | *Plant terpenoids for human health: a chemical and genomic approach to identify and produce bioactive compounds* | *Agricultural biotechnology* | 2009-2013 | www.terpmed.eu |

## Collaborative projects

| Project | Project title | Subject(s) | Period | Website |
|---|---|---|---|---|
| **3TO4** | *Converting C3 to C4 photosynthesis for sustainable agriculture* | *Scientific research* | 2012-2016 | www.3to4.org |
| **BIOCORE** | *Biocommodity refinery* | *Agricultural biotechnology – Sustainable development* | 2010-2014 | www.biocore-europe.org |
| **OPTIMA** | *Optimization of perennial grasses for biomass production* | *Biotechnology* | 2011-2015 | www.optimafp7.eu |

## Support actions

| Project | Project title | Subject(s) | Period | Website |
|---|---|---|---|---|
| **ALCUE-KBBE** | *Towards a Latin America & Caribbean Knowledge Based Bio-Economy (KBBE) in partnership with Europe* | *Coordination, cooperation – Economic aspects* | 2011-2013 | bioeconomy-alcue.org |

Table 1: Overview on green biotech related projects currently running or ending in 2012 under the FP7-KBBE programme (CORDIS, 2012)

## Large-scale integrating projects

| Project | Project title | Subject(s) | Period | Website |
|---|---|---|---|---|
| **EU-PEARLS** | *EU-based production and exploitation of alternative rubber and latex sources* | *Agricultural biotechnology -Biotechnology - Coordination, Cooperation - Food - Life sciences - Policies - Scientific research* | 2008-2012 | www.eu-pearls.eu/UK/ |
| **GIAVAP** | *Genetic improvement of algae for value added products* | *Scientific Research – Resources of the sea, Fisheries* | 2011-2013 | giavap.eu |
| **ICON** | *Industrial crops producing added value oils for novel chemicals* | *Biofuels – Sustainable development* | 2008-2013 | icon.slu.se/ICON/ |
| **RENEWALL** | *Improving plant cell walls for use as a renewable industrial feedstock* | *Agricultural biotechnology- Agriculture – Biofuels – Renewable sources of energy* | 2008-2012 | www.renewall.eu |
| **SMARTCELL** | *Rational design of plant systems for sustainable generation of value-added industrial products* | *Agricultural biotechnology - Agriculture* | 2009-2012 | www.smart-cell.org |

## Small/medium-scale focused research project for specific cooperation actions dedicated to international cooperation partner countries (SICA)

| Project | Project title | Subject(s) | Period | Website |
|---|---|---|---|---|
| **JATROPT** | *Jatropha curcas applied and technological research on plant traits* | *Agricultural biotechnology – Biofuels* | 2010-2013 | www.jatropt.eu |

## Collaborative project for specific cooperation actions dedicated to international cooperation partner countries (SICA)

| Project | Project title | Subject(s) | Period | Website |
|---|---|---|---|---|
| **PLAPROVA** | *Plant production of vaccines* | *Agricultural biotechnology – Biotechnology - Medicine, Health* | 2009-2012 | www.plaprova.eu |

## Large-scale integrating projects

| Project | Project title | Subject(s) | Period | Website |
|---|---|---|---|---|
| **CROPS2 INDUSTRY** | *Non-food crops-to-industry schemes in EU27* | *Biotechnology - Coordination, Cooperation - Food - Life sciences - Policies - Scientific research* | 2009-2012 | www.crops2industry.eu |
| **ERACAPS** | *ERA-Net for coordinating action in plant sciences* | *Coordination, cooperation – Earth sciences* | 2011-2014 | www.eracaps.org |
| **ERA-IB-2** | *ERA-Net for industrial biotechnology 2* | *Biotechnology - Coordination, Cooperation* | 2011-2015 | www.era-ib.net |
| **GLOBAL-BIO-PACT** | *Global assessment of biomass and bioproduct impacts on socio-economics and sustainability* | *Agricultural biotechnology* | 2010-2013 | www.globalbiopact.eu |
| **SAHYOG** | *Strengthening networking on biomass research and biowaste conversion biotechnology for Europe India integration* | *Biotechnology* | 2011-2014 | www.sahyog-europe-india.eu |

Table 1: continued

# 5. Mercosur emerging economies at the frontier of technology adoption and development

Following Canada and the US, emerging economies such as China, India and Brazil have been embracing green biotechnology and in particular genetic engineering as one of the frontier technologies to advance sustainable agriculture and crop productivity.

Not only is Brazil ranking first for biofuel production but it is also emerging as global leader for the cultivation of biotech crops with an impressive growth of biotech crop hectarage of 19% in 2011 and as such rapidly closing the gap with the US. To date 3 biotech crops are being cultivated in Brazil covering 30.3 million hectares or 75% of their total hectarage in Brazil in 2011. Herbicide tolerant (HT) soybean is the most important cultivated biotech crop in Brazil (20.6 million ha), followed by insect-resistant Bt maize, HT maize and maize combining the Bt and HT traits (9.1 million ha) and insect-resistant Bt cotton (0.606 million ha). Trends show an increasing preference for the use of stacks which will further increase with soybean with stacked traits becoming commercially available in Brazil in 2012 (James, 2012). Moreover, the recent approval for commercialization of virus resistant bean by EMBRAPA demonstrates the impressive technical capacity to develop, deliver and approve a new state-of the art biotech crop by the public sector. This bean variety is expected to be commercially available within the next two years (James, 2012). Argentina is following in third position with 23.7 million hectares biotech crops by cultivating HT soybean (19.1 million ha, HT/Bt/Bt-HT maize (3.9 million maize) and HT/Bt/Bt-HT cotton (0.7 million ha), followed by Paraguay (7) with 2.8 million hectares of herbicide resistant soybean and Uruguay (10) with 1.3 million hectares of herbicide resistant soybean and Bt maize. Europe in contrast grew only 114,507 ha biotech crops in 2011 consisting of 114,490 ha Bt maize and 17 ha Amflora potato with modified starch content (James, 2012).

Notwithstanding Brazil's performance as the second in cultivating GM crops, just behind the US, the biotech industry in Brazil is jeopardized by the lack of strategy to find new genes needed to improve plants for agriculture and industry. One of the reasons is the still deficient scientific body. Although the Brazilian science output increased expressively during the last 20 years, the density of scientists is still unsatisfactory especially in the Northeast and North of the country. Internal efforts have recently been made to minimize this drawback, notably the Brazilian government program 'Science without Frontiers' with the main goal of promoting the consolidation and expansion of science, technology and innovation in Brazil by means of international exchange and mobility (http://www.cienciasemfronteiras.gov.br/web/csf-eng/).

The challenge of moving from science to industry in biotechnology bears another important lagging factor: the excessively restrictive regulatory framework for the use of biodiversity is preventing Brazilian scientists from exploring the potential of the extremely rich Brazilian natural resources. The actual provisional measure for the use of Brazilian biodiversity is considered to be disastrous to the Brazilian biotech industry and also the Brazilian Patent Law is quite restrictive. Law 9279 prevents patenting of cells, genes or molecules (Barreto de Castro, 2011). As a result there is not a single molecule from Brazilian biodiversity patented.

## Trade

The EU is ranked first as export market for the agricultural products of the Mercosur region accounting for 19.8 % of total agricultural imports in 2009. Protein-rich livestock feed materials can only be grown to a small extent in Europe because of agricultural and climate limitations. In order to maintain meat and dairy production, Europe currently imports approximately 30 million tons or about 72% of its need for feed materials, mainly soy, from the US, Brazil and Argentina (Europabio, 2011). In the past some problems arose as the majority of soy grown in these countries is GM soy and Europe approved only few varieties for import and in addition applied a zero-tolerance policy towards traces of non-approved GM in imports. As a result, in 2009, approximately 180,000 tons of US GM soy, which was approved for import into the EU, were rejected because trace amounts of unapproved GM maize had been detected (Wager and McHughen, 2010). As the majority of soy grown in these countries is GM soy (94% in US, 83% in Brazil and 100% in Argentina) and the number of new events in these countries further increases while the rate of approval in Europe is much slower, it was not unlikely these situations would occur again in the future (Wager and McHughen, 2010; James, 2012). To address this situation of asynchronous approvals, the EU adopted new legislation in 2011 allowing 0.1% of unauthorized GM events in animal feed when meeting certain criteria. The event must have been approved by at least one non-EU food safety authority and must have been submitted to the European Food Safety Authority (EFSA) for review. With this 'technical solution' Europe aims to lift this trade obstacle and assure feed supply. However, zero-tolerance remains in place when it concerns food imports (EuropaBio, 2011).

Next to being a prominent trading partner for export, the EU is also the leading investor in the Mercosur region. European green biotech companies and technology providers may represent a new wave of potential investors to invest in the Mercosur region in order to bring their products to the market. Europe may have a strong base in R&D in green biotechnology but is, in comparison with emerging economies, lagging behind when it comes to commercialization. The main reason for that is two-fold. First of all, the policy and regulatory climate is not attractive for companies and investors. The EU regulatory framework for GM plants, rooted in public reluctance and misconception, is by far the most stringent and complex with several discrepancies at the EU and national level. Some countries allow growing GM crops on their territories and others not despite the authorization by the European Commission and positive advice of the European Food Safety Authority (EFSA). Moreover, the average time required to obtain authorizations is 1.5 to 2 years longer than in Canada, Brazil and the US (Europabio 2011). Additionally, many debates at several levels have been ongoing on genetically modified crops as well as on the competition between the use of arable land for food production or the production of industrial compounds or bio-energy (Doran, 2009). Due to these difficult circumstances, one of the major leading plant science companies in Europe, BASF Plant Science, has recently decided to focus on the main markets in North and South America, as well as the growing markets in Asia and to move its headquarters to North Carolina, US. Despite the fact that several sites in Europe will be closed, a reinforcement will be made at the sites in Ghent (Crop Design, Belgium) and Berlin (Germany) where the industry-leading research is being performed in close partnership and collaboration with top scientists (www.basf.com/group/corporate/en/products-and-industries/biotechnology/plant-biotechnology/index).

Mercosur countries belong to the top ten countries growing biotech crops with a total acreage of 58.1 million hectares (ha) representing more than one third of the global biotech crop acreage. By contrast, Europe is only growing 114,490 ha of mainly one crop (Bt maize) in only seven countries: Spain, Portugal, Poland, Slovakia, Romania, the Czech Republic and Sweden (James 2012). Another commercial release is planned in 2014 with the Fortuna potato which is more resistant to *Phytophthora infestans* or late blight. But very few new biotech crops are to be expected on the market as the number of release experiments in Europe, with the exception of Spain, is decreasing all the time (www.gmo-safety.eu). Additionally, more than half of the Net Land Balance (NLB) corresponding to the additional available area for crop production is located in Africa and Latin-America. This is in contrast with Europe where the NLB has continuously declined. The limitation of arable land and available land resources may be a major bottleneck for the production of agro-industrial crops for Europe. Due to its restricted agricultural area Europe's industry will greatly depend on imports from countries and regions such as the US, Brazil, South-East Asia and Russia (King and Hagan, 2010). The rising need for a continuous agricultural feedstock for the chemical industry for sustainable bio-based products may therefore open up new opportunities for the export of high yielding agro-industrial crops including crops obtained through genetic engineering.

## Plant genetic resources and benefit sharing

In a recent study of the European Academies, Science Advisory Council (EASAC, 2011), the crucial contribution that plant genetic resources can make to address the societal challenges in Europe is depicted. Pursuing scientific priorities for plant genetic resources and wider international collaborations can help EU countries to tackle food security, sustainability, crop diversification and nutritional value, and other opportunities for restoration of neglected and underused land and for the deployment of new crop uses, such as biofuels, biomaterials and chemical feedstock.

Climate change will increasingly become an influencing factor on crop production in Europe. It is expected that in Southern Europe crop-specific high temperature thresholds may be exceeded which may result in significantly higher risk of crop failure in Southern Europe, while Northern Europe may be able to grow a wider range of crops than is currently possible (EASAC, 2011).

Access to plant genetic resources can crucially contribute to the development of novel smart crops not only to produce higher yields but also for the production of industrial, chemical and pharmaceutical compounds as biobased products or biofuels. Mercosur countries harbor a wealth of biodiversity and the advent of 'omics' technologies such as plant genomics and metabolomics, and other recent technological advances in the plants science field, allow to define, capture, and create value from this biodiversity while conserving and protecting it at the same time.

The objective of the running FP7 AGROCOS project (Table 1) is to discover and carry to the stage of development plant derived small molecules with potential as new cosmetic and agrochemical agents. Compounds are searched for a diversity-oriented natural product library of compounds derived from plants originating from biodiversity hot-spots in Europe, Africa, Latin-America, and the Asia-Pacific region. The consortium gathers industrial and academic partners amongst which BASF, KORRES S.A. (Greece) and the University of Panama. Another current FP7 project aiming at bio-prospection, development, exploitation and sustainable use of plant derived products with industrial value is EU-Pearls. The project seeks to establish new value creation chains for natural rubber and latex from guayule and Russian dandelion.

## Strengthening strategic networking

European technology platforms (ETPs) have been set up with the aim to develop strategic research agendas for a particular area by bringing together industry-led stakeholders and facilitating public-private partnerships. Amongst these, the European Biofuels Technology Platform (www.biofuelstp.eu) and the European Technology Platforms Plants (Plants for the Future; ) can deliver valuable input on research priorities and action plans in green biotechnology to be considered for contributing to the establishment of the KBBE.

The creation of multidisciplinary platforms covering the whole value chain from R&D to bringing on the market is key in the process of establishing efficient cooperation mechanisms. Benchmarking the Mercosur and EU partners in the field of (green) industrial biotechnology is the first step to the creation of a workable platform. Such strategic networks facilitate the identification of common needs, gaps and synergies in order to define the potential areas for cooperation and funding opportunities ultimately leading to the implementation of demonstration projects. Recently, several initiatives have been launched to strengthen networking in order to identify opportunities and foster international collaborations in the field of industrial and green biotechnology.

## The Mercosur-EU Biotech Program

Following an agreement between the EC and the Mercosur in 2005 the BIOTECSUR institutional platform has been launched with its management unit at the National Directorate of International Relations of the Argentine Ministry of Science, Technology and Productive Innovation. The aim of this regional biotechnology platform is to promote development and use of biotechnology applications in the Mercosur aimed at increasing the added value and competiveness of the region's products in international markets. The strategic lines are building business and productive capabilities, capacity building, supporting public policy formulation (including harmonization of standards and regional fiscal incentives), improving the funding system, and improving the positioning of biotechnology. In the meantime the platform has launched five regional projects of which two are related to green biotechnology, the forestry and oilseed production chain respectively: an integrated genotyping platform chain aiming at the bio-prospection of candidate genes for germoplasm of eucalyptus in the Mercosur and a platform for the comprehensive genomic approach in the Mercosur for prospection of genes that are appropriate for soybean improvement under biotic and abiotic stress conditions.

## The ALCUE-KBBE project

The ALCUE-KBBE project (see Table 1) was initiated under FP7 in 2011. ALCUE-KBBE stands for 'Towards a Latin America and Caribbean Knowledge Based Bio-Economy in Partnership with Europe' and the consortium consists of 12 organizations, seven of which are from Latin-America and the Caribbean, and five from Europe. The objective is to establish a platform of Latin-American Caribbean (LAC) and EU regional and continental organizations involved in research funding and implementation, as well as other stakeholders form the public and private sector and civil society, in order to generate relevant information to build a strategic roadmap for R&D, the establishment of enabling policy and institutional environment and the development of the KKBE in both the EU and LAC regions. To achieve these goals a database of experiences, resources, policies and actors is being pooled together. Key actors are being identified and an analysis of the LAC bio-economy opportunities and limitations to identify policy and R&D needs will be performed. To that extent e-consultations and workshops with multi-stakeholders to discuss and propose bio-economy policy roadmaps, scenarios for bio-economy development in LAC and R&D collaboration agenda for specific topics are being organized. ALCUE is represented in international summits and is mainstreaming the bio-economy concept in LAC via an electronic communication instrument. The project will also target bi-regional RTD projects in research areas subject to funding by FP7 or Horizon 2020 and successful consortia constructions and investments in common priority RDT themes will be identified.

### The International Industrial Biotechnology Network (IIBN)

The IIBN was established in 2010 by the Institute of Plant Biotechnology Outreach (IPBO) and the United Nations Industrial Development Organization (UNIDO) to assist developing and emerging economies to access, develop, or implement agricultural and industrial biotechnology for their sustainable agro-industrial development in a demand driven and socially responsible manner. IIBN stimulates the application of biotechnology for the socio-economic development of transition economies through the implementation of demand-driven demonstration projects intended to serve as "proof of concept" for further up-scaling and technology transfer, public outreach on the opportunities and challenges posed by the bio-economy and capacity building through strategic networking. Demonstration projects are developed through a consultation process involving stakeholders from the government, public and private sector institutions and other relevant groups such as farmers. In search for the identification of implementation projects, IIBN has organized an expert group meeting on the KBBE as a driver of economic development and industrial sustainability in Concepción, Chile (2009). At this meeting bio-prospection of plants for the improvement of the competitive position of plant-derived high-added-value botanical drugs and phytochemicals was critically evaluated by weighing the advantages and disadvantages of novel technologies vis-à-vis technologies currently in use. Another high level stakeholder meeting was held in Nanning, Guangxi Province, China (2010) on the valorization of underutilized tropical and subtropical plants. Areas and opportunities for intervention and cooperation in the field were identified in order to enhance the resource efficiency of existing agro-industries in the Guangxi Province. In 2011 a first demonstration project "Regional Potential Assessment of Novel Bio-Energy Crops in fifteen ECOWAS countries" was initiated together with the company "Quinvita" (Belgium) and the ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE, Cape Verde). The project aims at mapping the suitability of novel bio-energy crops for sustainable development across fifteen West-African countries.

## 7. Outlook

The rise of the KBBE in Europe, the emerging economies of the Mercosur countries and the pressing need for global sustainable development create new challenges and novel opportunities for cooperation between the Mercosur and the EU. Europe can capitalize on a strong research base and major tradition of leading scientific excellence in green biotechnology. The EU has currently a strong policy oriented to the development of bio-based products with the recently adopted Lead Market Initiative (EC 2009, 2011) and renewable energy with the Renewable Energy Directive (Directive 2009/28/EC) translated into several programmes and renewable energy will become a major player in the European energy market.

The work programme 2013 (WP2013) in the area of food, agriculture and fisheries, and biotechnology research aims to transform the society into a bio-based community relying on sustainable biological resources not only delivering food and feed, but also bio-based materials and bio-energy by supporting research activities as well as bio-economy market development and EU competitiveness. The specific topics were identified according to the four pillars under the “Food security, sustainable agriculture, marine and maritime research and the bio-economy” challenge of the horizon 2020 programme: (1) sustainable agriculture and forestry, (2) sustainable and competitive agri-food sector for a safe and healthy diet, (3) unlocking the potential of aquatic living resources and (4) sustainable and competitive bio-based industries. This fourth pillar will emphasize on further developing the biorefinery concept and on exploiting the chemical diversity of plants and the potential of algae as biochemical factories (FAFB 2013 orientation paper, 2012). The WP2013 energy theme will continue to support renewable energy technologies, including bio-energy (FP7 Energy theme orientation paper, 2012).

The Mercosur and the EU may seek collaboration opportunities in translating new R&D developments in the innovation cycle of the biotech industry and into business. The rising need for agricultural and woody feedstocks will expand the external agricultural market and with the application of recent biotechnologies, Mercosur countries can become amongst the main sustainable producers of biomass for the renewable chemical industry including the production of biofuels and bio-based products. Moreover, the Mercosur harbors a wealth of yet unexploited biodiversity with potentially interesting compounds that can be used to create value-added products for the pharmaceutical, cosmetic, agrochemical and fine chemical industry through the application of new biotechnological methods that allow rapid bioprospection, development and sustainable use. Access to existing germplasm collections of industrially relevant crops such as sugarcane, cassava, castor bean, eucalyptus and palm may very useful for the production of bio-based products and bio-energy and lead to benefit sharing and mutual exploitation together with technology and science providers.

WP2013 will also pinpoint translating research and innovation knowledge into bio-based market products and processes not only by including demonstration and dissemination actions, but also by targeting small medium enterprises and supporting market development. More specifically, the participation of small and medium enterprises is mandatory required for approximately half of the topics and highlighted as beneficial to several others. In addition to focusing on applications to address the posed challenges, international cooperation is seen as crucial to succeed. Therefore all topics are open to the participation of third countries. For Latin America specifically, new cooperation opportunities will be pursued on biodiversity in agriculture. WP2013 will continue to link up European R&D activities with related research programmes for counterpart projects in third countries (also known as twinning). Currently, twinning is ongoing with Argentina and the Mercosur on plants, soil and food research (FAFB 2013 orientation paper, 2012).

Multi-partner cooperation initiatives between the EU and the Mercosur including the public and private sector will be vital in defining common strategies and action plans in order to build synergies and critical mass in mutually characterizing and catalyzing the sustainable development of the bio-economy in both regions. In these technology platforms or clusters innovative SMEs will play a crucial role in transforming the technology into value-adding processes and value-added products. Partnerships between green biotechnology science and technology providers and producers bringing biotechnology applications to the market are currently amongst the major challenges to create opportunities for win-win situations and rendering the innovation cycle more efficient. Although several promising initiatives have already been taken additional government incentives will be needed to implement demonstration projects as proof of concept for the creation of value added products. Mapping key actors and technologies with crops and traits of shared interest for the innovation cycle in industrial biotechnology and the production of bio-based products will be essential in the process of building co-operations that will lead to trade and investment opportunities in the knowledge bio-based economy for the development of both the Mercosur and EU region. To achieve that ambitious goal however a policy towards equal sustainability criteria and a workable intellectual ownership environment will be essential.

## 8. Recommendations

1) Recent progress in crop biotechnologies represent new opportunities for high-yielding and land-saving agriculture as well as for the sustainable production of added value bio-based products and bio-energy, cooperation, and hence job creation in the agribusiness sector**. Harmonization of the regulatory frameworks both within and between the EU and the Mercosur regions is urgently needed to create an enabling environment for the implementation of agricultural biotechnology applications, market authorizations, and international trade.**

2) **Objectively verifiable criteria for the sustainable production of bio-based products and bio-energy should be defined considering the 3P standard 'People, Profit, and Planet' of both the EU and the Mercosur region in a global context**. An extensive set of sustainability indicators and metrics should be put in place to track and monitor continuous improvement along the 3P standards of sustainability pathways. Indicators may be amongst others, the efficient use of resources such as land, water and energy, greenhouse gas emissions, natural resource conservation, labor conditions, employment and income generation. In this context it is important to bear in mind that economic profit using a country's natural richness without socio-economic development is the antithesis of the concept of sustainability.

3**) Implementation of bilateral demonstration projects for the production of value added bio-based products built on complementary strengths and mutual needs of both regions should be strongly encouraged as proof of concept.** The identification of key actors in the EU and Mercosur region representing the whole value chain and multidisciplinary strategic networking in specific thematic areas linking industrial biotechnology with the agribusiness sector is a crucial step towards establishing successful demonstration projects. Government policies towards incentives are strongly needed to strengthen initiatives taken by public and private sector organizations to build such strategic networks.

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