The Knowledge Based Bio-Economy (KBBE) in Europe: Achievements and Challenges

Full report

14 September 2010

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1 SUMMARY

The European Knowledge Based Bio-Economy (KBBE)

The increasing demand for a sustainable supply of food, raw materials and fuels, together with recent scientific progress, is the major economic driving force behind growth of the Knowledge Based Bio-economy (KBBE) in Europe over the last few decades. The bio-economy – the sustainable production and conversion of biomass, for a range of food, health, fibre and industrial products and energy, where renewable biomass encompasses any biological material to be used as raw material - can play an important role in both creating economic growth, and in formulating effective responses to pressing global challenges. In this way it contributes to a smarter, more sustainable and inclusive economy.

It is estimated that the European bio-economy currently has an approximate market size of over 2 trillion Euro, employing around 21.5 million people, with prospects for further growth looking more than promising. In addition to being economically favourable, the KBBE can help to meet the most urgent global challenges improving public well-being in general. Areas that it can benefit include social and demographic development and its impact on agriculture, the growing pressure on water, the threat of climate change, the limited resources of fossil fuel, the need for sustainable development, the impact of changes in lifestyles and eating habits, the demand for safer and healthier foods and the prevention of epizootic and zoonotic diseases.

Major achievements

When the European Commission developed the concept of the KBBE, it was with the aim of developing the European bio-economy so that it could compete on a global level and build on European strengths. These included excellence in science, technology and industry to deliver innovation, world leadership in food technologies and products and animal breeding technologies, and having a strong chemical and manufacturing industry base. Over the last five years, within the Commission, research and innovation have provided the main supporting policies for the KBBE. To support this initiative, 9 KBBE specific **European Technology Platforms** (ETP) were set up, and research in the area of the KBBE has been promoted and financed through the Commission's Framework Programme 7 and several Member State initiatives.

As these ETPs developed, they started to communicate and work together on issues of mutual interest, such as **identifying synergies** in their Strategic Research Agendas (SRAs). The European Commission set up regular meetings with representatives from the KBBE ETPs and invited experts to discuss policy-related issues together. Today the 9 ETPs active in the KBBE sector are joining forces in the BECOTEPS project, funded by the European Commission's Seventh Framework Programme. The objectives of the BECOTEPS project are to achieve closer and more coordinated collaboration between the KBBE ETPs and to develop recommendations for better interaction between the KBBE ETP stakeholders along the product chains. They also focus on the sustainability issue regarding multidisciplinary research, innovation and policy issues, and the goal to encourage dialogue between European and national, public and private and research and innovation initiatives.

At EU level, research in the KBBE area has also strengthened by the implementation of several **ERA-Nets**. The ERA-NETs aim to reduce the fragmentation of the European Research Area (ERA) by improving the coherence and coordination of national and regional research programmes.

In addition to ERA-NETs and ETPs, a third category of pan-European KBBE-related networks consists of European Commission **expert groups**. These include the Advisory Group on Food, Agriculture and Biotechnologies, the KBBE-Net, the KBBE National Contact Point, and the EU Standing Committee for Agriculture Research.

The current and future availability of **biomass feedstock for food, feed, energy and industrial material use** in Europe as well as the question of the available land for food and non-food crops still remains a contentious issue in need of in depth analysis. The impact on food security is one of the core social factors to be considered in the development of the use of renewable resources for biofuels and material use in biorefineries. The growing market (today largely focussed on the production of biofuels but in the future undoubtedly also for biorefineries) represents a new source of demand for agricultural commodities. This demand must be managed appropriately with respect to available land resources and without associated negative impacts on the food and feed sector.

Feedstocks are continually adapting to the needs of the modern (agricultural) industry. A key focus of national and international research concerning the availability of feedstocks for a bio-based economy is the **optimisation of the yields** and materials for different uses. This includes the technological optimisation of agricultural processes as well as the direct optimisation of crops (and wood for short rotation plantations) via conventional breeding, refinements of conventional breeding or biotechnological methods. Today, modern breeding methods offer a wide range of different approaches. In addition to traditional selection procedures and genetic engineering, (green) biotechnology for feedstock optimization receives increasing attention, though some industry sectors, politicians and the general public continue to regard this technology with suspicion. This appears to remain a Europe-specific problem whilst emerging economies such as China, Brazil and India are embracing these techniques as promising and important technology advances for their nations. The potential of this technology is also demonstrated by the fact that in 2009 more than 134 million ha of arable land were planted with transgenic crops by 14 million farmers worldwide.

A second focus is the **optimization of the plant ingredients** such as through a change of the starch molecule for technical uses of the potato or the change in composition of fatty acids in rapeseed, sunflower or crambe oils.

Nutritional improvements of a large range of food products and the development of novel food products and processes, including food packaging technologies are important drivers in realising ambitions for healthy food and healthy lifestyles. Additionally improvements in this area are necessary for minimising the environmental impacts of agriculture by reducing green house gas emissions and energy and water consumption whilst contributing to a more sustainable eco-friendly economy. These research topics tackle some of our key societal challenges such as how to feed almost 9 billon people by 2050 and how to manage the demands of a population that is shifting its food preferences towards a greater consumption of meat. Achievements in the **food sector** in terms of promoting research and market development include the launch of diversified research programmes (from basic to applied research, research infrastructures, training and support to SMEs), reinforcing cooperation and better exploiting research results. They have also involved boosting competitiveness through the active participation of relevant industrial partners in European technology platforms, and integrating strategically focused, trans-national research that will deliver innovative processes, products and tools in line with the needs and expectations of the consumer. Since 2006, 36 National Technology Platforms (NTPs) have been established under the umbrella of the **ETP Food for Life**. The National Food Platforms play a key role in conveying the programme of the ETP to the national industry, especially to SMEs and the research community.

In addition, actors within the food supply chain are united together under the **European Food Sustainable Consumption and Production (SCP) Round Table** initiative in order to face current and future sustainability challenges.

In the area of **bio-based products**, Europe has become the leading region for the development and production of enzymes. Because enzymes play a crucial role for applications in many other industrial sectors, this sector represents significant potential for the EU in terms of escalating global leadership in the area of biobased products and processes. On the other hand, the United States and Brazil are the world leaders in the production of biofuels (mainly bioethanol). Another established sector is the production of biochemicals which find applications in the pharmaceutical industry, the food and feed industry, the production of detergents and cosmetics, and many other sectors. In the chemical industry, an important step in increasing the share of biobased chemicals is the creation of biotechnological platform intermediates based on the use of renewable carbon sources. Furthermore, although the production of bio-based polymers and plastics are technologies still in their infancy, this industry has been characterised by an annual grow rate of almost 50% due to new synergies and collaborations.

In Europe, there is also a growing focus on **biorefineries**. These use biological matter (as opposed to petroleum or other fossil sources) to produce transportation fuels, chemicals, and heat and power. Because they combine and integrate the technologies necessary to convert renewable raw materials into industrial intermediates and final products, they can straddle the whole value chain. The European Commission has funded several projects under FP6 and FP7 analysing the biorefinery research situation in the European Union. At the beginning of 2010, they then launched three large collaborative projects addressing the entire value chain. Aspects included in these projects were the production of biomass, logistics, intermediary processing steps and conversion into end-products with the feasibility of techniques shown at pilot scale. Moving forward, the Commission will fund the programmes with 52 million Euro over a period of 4 years. 81 partners from universities, research institutes and industry in 20 countries will invest an additional €28 million. In addition, at member state level, we see an increasing number of biorefinery oriented research programmes. More than 300 research projects have been identified in Europe (at EU, national and regional levels), with a total budget of around 1.2 billion Euro, of which more than 808 million Euro comes from public funding.

There is a clear need for a coordinated technology development covering different technologies and parts of the value chain including feedstock development, product development, production optimization and innovative application development. **Cooperation in cluster structures** rather than in single-company partnerships is significantly accelerating the development of processes and their penetration into the industry. Towards the end of 2009, the European Commission published an action plan on **Key Enabling Technologies (KET**), which included industrial biotechnology. The purpose is to develop an action plan with measures to remove obstacles hindering further development and to fully exploit the results of research. These measures include a focus on demo projects and better coordination of the activities between EU and Member States for example through joint calls or joint programming.

SusChem's European Innovation project - **BIOCHEM** - was selected at the beginning of 2010 for funding by the European Commission under its INNOVA scheme. BIOCHEM will define and promote bio-based product opportunities in the chemical sector, and will also facilitate and help finance new bio-based business ideas to proof-of-concept, including facilitating access for organizations to European test facilities.
Specific policies for the development of biobased products are more extensive for bioenergy, including for liquid biofuel use and solid biomass applications, than for biochemicals or biomaterials. Worldwide, many governments support their emerging biofuel industries far more than other KBBE sectors through subsidies, mandates, adjustments to fuel taxes and incentives for the use of flexi-fuel vehicles. In Europe, the **Renewable Energy Directive** of 2009 is calling for a mandatory target of a 20% share of renewable energies in the EU's energy mix by 2020. In addition, by the same date, each Member State must ensure that 10% of total terrestrial transport, such as road transport and train fuel, comes from 'renewable energy', defined to include biofuels and biogas, as well as hydrogen and electricity. Furthermore, in order to stimulate the use of so-called second generation energy sources, biofuels from waste, residues, non food cellulosic material, and lignocellulosic material will count twice towards achieving the renewable energy transport target.

Although Europe plays a leading role in research and science, it is less successful in converting the science-based findings into commercially valuable products. This is why the Commission has developed a so-called demand-based innovation policy, the **Lead Market Initiative** (LMI). One of the areas that this policy focuses on is that of bio-based products. An Ad-hoc Advisory group has developed a series of concrete recommendations and actions, ranging from improving the implementation of the present targets for bio-based products to standardisation, labelling and certification in order to ensure the quality and consumer information on the new products.

In Europe, sustainability it is an important driver for many of our policies, and several of the demand-side regulations include **sustainability aspects** such as 'green' public procurement. But sustainability is not solely about greenhouse gas emissions reductions or climate change, it also concerns waste reduction, minimizing energy consumption and efficient use of resources. Because of the interdependencies between processes involved in growing, harvesting, manufacturing, distributing and disposing of a product, sustainability requires a life cycle analysis encompassing the whole value chain. This includes the production of biomass, evaluating land use, consumption of water, energy, pesticides and fertilizers and the production and use of the final products. Currently, national and international efforts to develop more comprehensive, systems-oriented sustainability frameworks for bio-based products are under development.

Main challenges

Over the next 10 years we can expect a shift in practice from a sectoral approach towards a more **integrated approach** of the KBBE.

In the case of a **sustainable feedstock production,** for food and non-food applications, significant challenges remain to be solved for the future. In Europe, in particular, there needs to be a concise strategy to satisfy the demands of a range of stakeholders for the use for food, feed, fuel and materials. On this basis, "food versus non-food" debates and the biomass competition between energy and material still needs to be resolved. Other challenges concerning the feedstock needed for different applications include the growing demands for food, fuels and materials in the context of an expanding worldwide human population. In addition, the adaptation and optimisation of existing feedstocks for the given land that can be used for agriculture are a key focus. In this field, in particular, the use of advanced breeding technologies and green biotechnology should be discussed and evaluated in the context of new challenges concerning global warming, pressure on natural resources and sustainable agriculture.

Gene transfer between species has now been a reality in plant breeding and selection for two decades. In addition, it has been achieved technically in animal species as diverse as goats, pigs and fish. The debate on the public acceptability of these techniques in **food animals** has already begun in the United States, and is likely to be even more contentious in Europe. In parallel, the cloning of animals is also now technically feasible, though it is still far from becoming commercially viable. Genetic modification (GM) technologies, already applied in over 130 million ha of crops worldwide, have met strong opposition from European consumers. Issues of **public acceptability** are therefore likely to be increasingly important as GM and related technologies, such as (animal) cloning, continue to develop.
Changes in both population demographics and life span demand that European public health policies focus on healthy ageing, which not only includes the prevention of diseases but also on delaying the deterioration of health status. However, the area of **research in health, food and diet-related diseases** is both complex and fragmented. At the same time, there are a number of pressing challenges on a European-scale that can only be tackled through a combination of public policy development, academic research and industry developments in European Member States and Associated Countries. Future efforts should include prevention of chronic diseases through promoting collaborative research and sharing data and results on health impacts of nutrition and lifestyle. They should also incorporate effective interventions, and the creation of a coherent long term, public health research programme on diet related diseases from molecular to population levels by integrating systems including biology, genetics, nutrition, epidemiology and social sciences.

In addition, industry finds it difficult to seek **authorisation for novel food products**, because of the lengthy procedures and the uncertainty of the outcome. The cost factor discourages many from patenting food products or new processing techniques, in particular SMEs.

Although the total amount of agricultural output will have to increase over the coming decades, climate change is expected to have a profound and increasing impact on food production through factors such as rising temperatures, altered rainfall patterns and more frequent extreme events. Moreover, this challenge of delivering **food security in the**

context of climate change also means that it is necessary to find innovative ways of increasing efficiency and reducing waste throughout the food chain in order to make the most of the resources and raw materials available. Another important contribution of the food sector could be the reduction of food losses by introducing modern collection, processing, storage and transportation methods.

The **development of innovative bio-based products is R&D intensive**, and increasing investments in certain technologies will be a major challenge. Although industrial biotechnology has been identified as a key enabling technology, only 2% of biotech R&D went towards developing industrial biotechnology in 2003. This is incongruous with OECD predictions that industrial biotechnology will contribute up to 39% of the biotech industry's gross value added (GVA) by 2030. In addition, member states of the International Energy Agency (IEA) spent 13 times less on R&D in bioenergy (including biofuels) than the amount spent on nuclear fission and fusion R&D and 4 times less than was spent on R&D into fossil fuels. Furthermore, research activities in the EU concerning lignocellulosic bio-ethanol and second generation biofuels in general, are modest when compared with the massive efforts of the U.S. and Brazilian governments.

The initial construction of **bio-refinery pilot and demonstration plants** is not only a costly undertaking but it also involves bringing together market actors along a new and highly complex value chain. Countries like the US, Brazil, China and others are increasing investment into research, technology development and innovation, and are supporting large scale demonstrators in which many European companies already participate. In addition, producing chemicals through bio-chemical routes is currently still more expensive when compared with traditional production routes. It should also be taken into account that existing production facilities for chemical syntheses cannot be converted to biotechnological production without massive new investments.

In contrast to biofuels, there is currently no European **policy framework to support bio-based materials**. As a result, these products suffer from a lack of tax incentives or other supporting regulations. Other demand-driven policies focus on the sustainability agenda (including green public procurement) and are often implemented as a mix of public procurement procedures, legislation and direct financial incentives which is a complex matter in Europe. However, such policy frameworks have been successfully developed in other parts of the world.

Addressing sustainability issues through all segments of the value chain of bio-based products (from biomass production to end-use) in a fair, evidence-based regulatory framework, is a major challenge for biofuels and other bio-based products. In doing so, the sector has to demonstrate that it possesses sustainability credentials in order to gain a strong "license to operate" from governments and consumers, especially if supporting policies have to be developed. Unfortunately the lack of widely-accepted schemes to assess and confirm sustainability is a significant barrier to consumer and government confidence.

Main recommendations

1. Need for an integrated policy for the KBBE

To achieve a competitive KBBE, broad approaches, such as creating and maintaining markets for environmentally sustainable products, funding basic and applied research, and investing in multi-purpose infrastructure and education, will need to be combined with shorter term policies. These include measures such as the application of biotechnology to improve plant and animal varieties, improving access to technologies for use in a wider range of plants, fostering public dialogue, increasing support for the adoption and use of internationally accepted standards for life cycle analysis together with other incentives designed to reward environmentally sustainable technologies.

2. Research and innovation

In order to make a swifter more efficient shift towards more integrated and sustainable production and processing systems, the level of R&D funding in the bio-economy should be increased through multidisciplinary research programmes at both national and European level. In addition, cooperation between private and public sectors should be a focus for further improvement. Building competence networks between industry and academia could also help to overcome the competence hurdle and knowledge gap that currently exist between these two stakeholder groups. In addition, better interdisciplinary and collaborative research would lead to valuable new business activities.

Special attention should also be placed on specific key areas, such as the development of efficient and robust enzymes particularly for the conversion of lignocellulosic material. This should enable conversion from a variety of feedstock, synthetic biology and metabolic pathway engineering and the combination of technologies such as biochemical and chemical processes as well as applications derived from agricultural and industrial biotechnology. In addition, specific research is needed to improve feedstock yield and/or the composition of biomass involving both plant genomics and new breeding programmes, also incorporating further research into efficient crop rotation, land management and land-use change issues.

Integration of the individual KBBE sectors should support pre-competitive research covering the entire value chain – from feedstock to end-product – as this will help to stimulate innovation and encourage the uptake of its results by the industrial partners involved. In the longer term, we expect not only closer integration of the different sectors of the KBBE, but also between different research areas across food as well as non-food commercial applications.

One of industry's remaining major challenges is to translate research to products, including the development of new product applications. Setting up public-private partnerships would result in a pooling of resources, thus allowing more ambitious goals to be set in terms of reducing the time-to-market. This would also enable industry to adopt longer-term investment plans in the field of the bio-economy, taking into account the market perspective.

Stimulating the construction of demonstrators via public-private partnerships is one of the most important measures that can be taken in the development of the bio-economy, as they are able to close a critical gap between scientific feasibility and industrial application. They dramatically reduce the risk of introducing new technology on an industrial scale and therefore make a biorefinery venture much less risky for investors.

3. Towards economic-sustainable and innovative SMEs

Spin-offs and high-tech SMEs are key for technology and knowledge development, and investing in research and innovation is the only way for these enterprises to survive. It is of critical importance to the success of these SMEs, and hence to the innovation potential of the sector as a whole, to improve their access to finance. However, without larger scale validation, it remains very hard for SMEs to attract the large industrial partners or other private investors that they need to become sustainable. Developing grants for "Proof of Concept" studies could help partially overcome this problem.
One of the weaknesses of the many SMEs in the more "traditional" sectors (such as agriculture, forestry, aquaculture, food sector) is that many of them do not have the in-house technical skills to take up the results of innovation. Supporting tech transfer or stimulating SMEs to participate in "open innovation" programmes could therefore be a way to overcome this problem.

4. Communication and education

To facilitate smooth long-term development and implementation of the different technologies of the KBBE, a strategy for communication and stakeholder involvement is necessary. This would not only help to raise awareness of the technologies but would help ensure that longer term objectives are fixed to provide solutions that reflect societies real needs.

It is of critical importance for the bio-economy to have a multi- and interdisciplinary work force, in order to ensure that it keeps up-to-date with new knowledge and techniques. There is therefore a need for multidisciplinary education, good international training programmes and efficient lifelong learning. In addition, due to a gap in education, biotechnology and chemistry are still too often perceived as "competing technologies" instead of as being complementary.

5. A strong EU common policy for agriculture: the new CAP (post 2013)

It is essential that the new CAP promotes sustainable and competitive agricultural production, and ensures balanced access to raw materials for the food and feed sectors, as well as for industrial applications, without disrupting food supply. The new CAP should ensure the possibility to maintain a competitive supply of raw materials that meets EU standards, notably in the areas of safety, environmental sustainability, and animal welfare. The CAP should also address situations of extreme price volatility, acting as a safety net in order to secure supply by preventing crisis situations and remedying temporary market imbalances. Absolute coherence is needed across all the policy areas driving supply, including food safety, innovation and new technologies, trade, development, the environment, animal welfare, and consumer and public policies. Horizontal policy coherence should result in reduced raw material market disruptions and should also contribute to ensuring competitive EU agriculture.

In order to stimulate the development of local biorefineries and to support rural development, it is important to develop and maintain a reliable upstream supply chain. This should be capable of mobilising a sufficient level of feedstock for conversion without being achieved at the expense of food and land use. For this reason, it is also important to invest in local and regional infrastructures and in logistical capabilities to allow all biomass, including agricultural, forestry and waste-based raw material, to be utilized.

6. Support reconversion towards low-carbon renewable-based production systems

Investments required for building a new bio-industrial facility - especially if it competes with the conventional one - might be a significant barrier to the development of the KBBE. For SMEs, such an investment might represent an even more difficult hurdle to overcome. Governments aiming to support biorefineries for reasons of environmental sustainability, energy security and innovation leadership will therefore need to support market growth, and carefully regulate the industrialization process in order to stimulate and encourage private sector investments.

7. Policies stimulating the market for KBBE products

Decision makers can help provide the necessary motivation by implementing a regulatory framework of incentive based and demand stimulating policies. Mandates, subsidies and incentives are provided by governments all over the world to stimulate the demand of sustainable bio-based products. The European Commission's Lead Market Initiative for bio-based products represents a good example of such a scheme and moving forward, this should be further developed and build upon. In the future, a similar initiative could be developed for the food sector or for the KBBE as a whole.

8. Science based sustainability criteria

Sustainability criteria addressing the different KBBE sectors should aim to measurably reduce the key impacts associated with feedstock production, consumption and use. In addition, implementation of measures involve the active participation of all stakeholders involved in the supply chain. Recent developments in the biofuel sector in the EU will make it possible to use private standards to prove compliance with sustainability requirements. While some schemes have ambitious sustainability criteria going beyond the minimum EU requirements, most of these only address a fraction of the overall concerns. Wider sustainability concerns will need to be addressed by governments in partnership with the private sectors. In addition, feedstock producing countries - especially in the global South - will need significant technical and financial support to implement adequate safeguards.

2 INTRODUCTION

2.1 The Knowledge Based Bio-Economy (KBBE)

The ability to innovate has increasingly determined the success and competitive strength of our industry. But even in a global economy where mainly high technological industries have been thriving, a large part of our prosperity is still directly derived from basic natural, biological resources, as they are the raw materials for the majority of the products on which we depend on a day to day basis. Although they are the basis of the oldest economic activities, new technologies such as and *life sciences and biotechnology* are now transforming them into one of the newest, at the frontier of the emerging knowledge-based economy.

The recent scientific and technological progress has opened up a vast array of new possible applications and products in a wide range of fields, and will soon yield immense health, societal and economic rewards. Scientists have mapped the entire human genome and those of a rapidly increasing number of animals, plants and micro-organisms. The growing knowledge of the molecular mechanics of organisms is paving the way for new agricultural products and practices, biodegradable materials as well as emission-reducing biofuels. Advanced biotechnology is creating new possibilities in terms of tailor-made foods targeted at specific consumer needs and tastes. In addition, industrial biotechnology is breaking new ground in understanding microbial biodiversity and bio-processes that could lead to valuable bio-products and bio-materials. All this has cleared the way for the emergence of a successful so-called Knowledge-Based Bioeconomy (KBBE) in Europe. The KBBE can be concisely defined[1] as "life sciences and biotechnology knowledge converging with other technologies to transform into new, sustainable, eco-efficient and competitive products". The 'bioeconomy' encompasses all industries and economic sectors that produce, manage, or otherwise exploit biological resources (e.g. agriculture, food, forestry, fisheries and the industries based upon).

Recently the 9 European Technology Platforms involved in the Becoteps[2] project developed a common definition for the KBBE:

The bio-economy is the sustainable production and conversion of biomass, for a range of food, health, fibre and industrial products and energy. Renewable biomass encompasses any biological material to be used as raw material.

2.2 The economic importance of the KBBE

The increasing demand for a sustainable supply of food, raw materials and fuels, together with the scientific progress, is the major economic driving force behind growth of the KBBE, which has been significant over the last few decades. Innovation is believed to be the best way to increase productivity and competitiveness, and at the same time to improve our quality of life, secure sustainable food production and protect the environment. The KBBE is basically occupied with both aspects, as life sciences and biotechnology help us to live in a healthier and more sustainable fashion by finding more environmentally friendly production methods. The sector can thus play an important role in both creating economic growth, and in formulating effective responses to pressing global challenges. In this way it contributes to a more competitive and sustainable economy - for the benefit of all.

It is estimated that the European bio-economy has currently an approximate market size of over 2 trillion Euro, employing around 21.5 million people, and the prospects for further growth are more than promising. For a variety of reasons it is expected that in the next decade significant changes will take place in this field. There is growing pressure on

[1] Cologne paper (2007) - En route to the knowledge-based bio-economy.
[2] http://www.becoteps.org/

European companies to diversify their portfolio of products. As an example, some of the largest pulp and paper producers, mainly in Northern-Europe, are conducting cutting-edge research in the field of biofuels and biomaterials.

Table 1: Turn over and employment KBBE sectors in Europe (2009)

Sector	Annual turnover (billion Euro)	Employment (thousand)	Data source
Food	965	4400	CIAA
Agriculture	381	12000	COPA-COGECA Eurostat
Paper/Pulp	375	1800	CEPI
Forestry/Wood ind.	269	3000	CEI-BOIS
Biobased products			
▪ **Chemicals and plastics**	50 (estimation*)	150 (estimation*)	USDA[3] Arthur D Little[4] Festel[5] McKinsey[6] CEFIC
▪ **Enzymes**	0.8 (estimation*)	5 (estimation*)	Amfep Novozymes, Danisco/Genencor, DSM
▪ **Biofuels**	6**	150	EBB eBio
Total	**2046**	**21505**	

* estimation for Europe for 2009
** estimation based on a production of 2.2 million tonnes bioethanol and 7.7 million tonnes biodiesel at average market price in Europe

2.3 The main global challenges

Apart from being interesting in the economic sense, the KBBE can help to meet the most urgent global challenges and to improve public well-being in general. As mentioned in a recent report of the Food and Agriculture Organization of the United Nations (FAO)[7], "Agriculture in the 21st century faces multiple challenges: it has to produce more food and fibre to feed a growing population with a smaller rural labour force, more feedstocks for a potentially huge bio-energy market, contribute to overall development in the many agriculture-dependent developing countries, adopt more efficient and sustainable production methods and adapt to climate change."

- **The social and demographic development and its impact on agriculture**
  Innovation will be an indispensable tool in the effort to feed the world's growing demand for food even as we endeavour to reduce the impact of agriculture on our climate. The FAO has estimated that we will have to produce 70% more food for an additional 2.3 billion people by 2050. This larger population will not only increase the world demand for food, but also for animal feed, fibre for clothing

[3] USDA (2008) – US Biobased Products Market Potential and Projections through 2025. See: http://www.usda.gov/oce/reports/energy/BiobasedReport2008.pdf
[4] Peter J. Nieuwenhuizen, David Lyon, Julia Laukkonen and Murray Hartley (2009) - A rose in the bud? Anticipating opportunities in industrial biotechnology. Prism/2/2009
[5] G. Festel (2010) - Industry Structure and Business Models for Industrial Biotechnology. Discussion paper at the OECD workshop: Outlook for Industrial Biotechnology (Vienna 13-15 January 2010)
[6] McKinsey (2009) – Presentation of J. Riese at DSM. See http://www.dsm.com/en_US/downloads/sustainability/white_biotech_mckinsey_feb_2009.pdf
[7] FAO (2009) - Global agriculture towards 2050

and housing, clean water and energy. Due to growing world demand for meat, grains and fuels, the average prices of food, feed and energy commodities are likely to remain volatile or could even rise significantly[8]. An important increase in agricultural production is needed to fulfill the growing demand for food and raw material for industrial use. In addition this should be achieved in a sustainable way, e.g. by avoiding losses, recycling where possible, maximising use of agricultural waste, conserving biodiversity, etc.

Management practices in forestry and agriculture will have to be continuously aligned with biodiversity and climate change mitigation targets. The challenge is undoubtedly significant, especially if we consider some of the key limitations. For example, at the moment approximately 30% of the Earth's area is used for agriculture and grazing. But this represents 55% of the habitable area[9]. So a growing population will not only increase demand for food, fuel and fibre but will also reduce the area where the production of these can take place.

- **The pressure on water**

  Agriculture is the largest consumer of freshwater by far – about 70% of all freshwater withdrawals go to irrigated agriculture[10] and nearly 60% is wasted. Water scarcity will limit food production and supply, putting pressure on food prices and increasing countries' dependence on food imports. Combining this with the potential for droughts caused by climate change, we may see many more people located on land under water stress in the future. Water shortage could drive the development of a KBBE that reduces water consumption.

- **Need to reverse current trends**

  Growing demand for food, fibre and fuel has contributed to the conversion of approximately 2.2 million hectares / year of new agricultural land. A significant share of this comes from converting natural forests and grasslands. Agriculture is responsible for at least 55% of habitat loss in the last few decades. Improving management practices and increasing the efficiency, both in the production but also in the processing and consumption of the commodities will have a significant influence on how we will satisfy the forecasted growth in demand. The potential to improve management practices and reduce impacts are significant. For example 70-90% of farmers loose more carbon/year than put back and 25-40% of greenhouse gases that contribute to climate change are related to agriculture[11]. Forestry management practices are equally important. Demand for one of the most versatile renewable material continues to grow. This can lead to unsustainable intensification of forest management in currently managed forests and expansion of harvesting into areas with natural forests. Responsible forest management can however have positive impacts on biodiversity, livelihoods and contribute to climate change mitigation.

- **The threat of climate change**

  Climate change could adversely affect water supplies and agricultural productivity. The need to cut CO_2 emissions to avoid dangerous climate change has made the transition from conventional fossil fuels to alternative and renewable resources a priority for everyone. UNEP (2010)[12] notes that "doubling of wealth leads to 80% higher CO_2 emissions". The KBBE can encourage the development of new biological processes and the use of agricultural waste streams and renewable raw materials derived from plants, crops and trees to produce biobased fuel, materials and chemicals that have the potential to enhance quality of life while reducing negative environmental impact and thus reducing our ecological footprint. While climate change mitigation is one of the main drivers, we should not forget that climate change will also have a

[8] OECD (2009) – The bioeconomy to 2030: designing a policy agenda
OECD-FAO (2010) - Agricultural Outlook 2010-2019
[9] Clay (2004) – World Agriculture and the Environment: A Commodity-By-Commodity Guide To Impacts And Practices
[10] Third United Nations World Water Development Report (2009) - Water in a changing world
[11] Clay (2004) – World Agriculture and the Environment: A Commodity-By-Commodity Guide To Impacts And Practices
[12] UNEP (2010) - Environmental Impacts of Consumption and Production

significant impact on productivity, yields, water and land availability. The development of the KBBE will likely mean the need for significant amounts of biomass. While yields in forest for example might increase in parts of the world such as Northern-Europe, the factors destabilizing forest ecosystems (insect attacks, changing weather conditions) will have growing impacts. In agriculture, IFPRI [13] notes that yields especially in the developing countries will likely decrease, and South-Asia will be especially hard hit.

- **Limited resources of fossil fuel and energy security**
  A challenge of equal order is the anticipated increased demand for services delivered through fossil fuels and energy in the next decades while fossil fuel reserves, particularly oil and gas, will continue to decline. The global demand for fossil fuels is expected to increase by over 44% from 2006 to 2030[14], and this will not only lead to a further increase in GHG emissions but also to higher energy prices. Expert analysis[15] shows that it is possible to decarbonize the energy sector by 2050 by massively investing in renewable energy and energy efficiency.

- **The need for sustainable development**
  All major facets of European society and economic activity are being challenged to demonstrate their sustainability. Consumers are more and more conscious about the impacts of their consumption and companies want to show the progress they make. In most countries, household consumption, over the life cycle of the products and services, accounts for more than 60% of all impacts of consumption[16]. The KBBE can contribute to a more sustainable society, not only because it leads to an economy no longer wholly dependent on fossil fuels for energy and industrial raw materials with the potential to reduce greenhouse gas emissions, but also by generating less waste, by a lower energy consumption and by using less water[17]. In addition, the KBBE provides also for the established industries the opportunity for further growth in a sustainable way.

- **Fast technological development**
  Technological development has progressed rapidly and will further boost the applications of the KBBE. Growing knowledge, bioinformatics, and the strong interaction of engineering sciences with life sciences will open avenues to new products and applications. Biotransformation will be a key technology in several industrial sectors, and the genetically engineered modification of microorganisms results in new sustainable processes.

- **Changes in lifestyles and eating habits**
  Economic development and the movement from an industrial economy to a service-based economy has brought new employment patterns and has changed consumer eating habits impacting on food consumption. While a quarter of the world's population does not have enough food, over 40% of the world's grain harvest is fed to livestock. Predominantly meat-based diets, characteristic to most OECD countries, are very inefficient. Farming animals for meat and dairy requires huge inputs of land and water for growing animal feed - on average, 6kg of plant protein is required to produce just 1kg of meat protein[18]. Transition to a lower meat rich diet will potentially reduce climate change mitigation costs by 50%[19]. Consumers demand "easy" food choice, "ready to eat" and "heat to eat" as meals are increasingly consumed away from home switching habits from domestic to out-of-home lifestyle and diets[20]. These changes require the

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[13] IPFRI (2009) - Climate change: Impact on agriculture and costs of adaptation. See: http://www.ifpri.org/publication/climate-change-impact-agriculture-and-costs-adaptation
[14] OECD (2009) – The bioeconomy to 2030: designing a policy agenda
[15] Ecofys (2010) - Energy Unlimited (to be published).
[16] UNEP (2010) - Environmental Impacts of Consumption and Production
[17] JRC (2007) - Consequences, Opportunities and Challenges of Modern Biotechnology for Europe
[18] WWF-UK (2010) - http://www.wwf.org.uk/what_we_do/changing_the_way_we_live/food/
[19] Stehfest et al. (2009) – Climate benefits of changing diet. Climatic Change 95, pp 83–102. See http://tier-im-fokus.ch/wp-content/uploads/2009/06/stehfest09.pdf
[20] ETP Food for Life (2007) - Strategic Research Agenda 2007-2020. See: http://etp.ciaa.be/asp/documents/docs.asp?cat=Documents

continuous development of innovative packaging able to guarantee that food remains healthy, tasty and convenient which still remain crucial factors for consumers, but also to satisfy the enjoyment of food and its accessibility (i.e. ease of container-opening for children and the elderly).

- **The demand for safer, healthier and higher quality foods**
  Although manufactured foods are safer than ever, excessive food intake, in conjunction with a decrease in physical activity has led to an increase of life style-related diseases such as obesity, diabetes, coronary and heart-related diseases in European society meaning that health and well being issues represent an increasingly significant concern for consumers. Food and drinks are necessary for the development, wellbeing and health of European citizens[21]. Therefore there is a need to provide not only quality, tasty and safe food but also varied, wholesome, functional, nutritious diets focusing on healthy ageing, prevention of diseases and delaying the deterioration of health status.

- **Control and prevention of epizootic and zoonotic diseases[22]**
  In the last fifty years, the situation in animal disease in Europe has been transformed. First, major diseases which were formerly of great importance (such as Foot & Mouth Disease or Classical Swine Fever) have been eradicated. Secondly, the major zoonoses (tuberculosis, brucellosis) are in the final stages of eradication. These eradication programmes, which required decades of dedicated and coordinated effort, have been very expensive, but have brought major economic benefits. At the same time, their very absence leaves the populations very vulnerable to major consequences of accidental reintroduction. This was illustrated in the case of the Foot & Mouth disease outbreak in the UK in 2001 which was brought under control at a cost estimated at 13 billion Euro. Continued controls and vigilance are therefore necessary.

  Changes in husbandry practices, generally involving intensification, together with development of effective drugs has eliminated much of the losses formerly due to various species of parasites in the different animal species. Increasingly intensive production systems, and stresses related to higher animal performance, require higher levels of management. In some cases a combination of these factors has facilitated the spread of the diseases BVD (Bovine Viral Diarrhea) and IVR in cattle, and influenza in pigs. Finally, the experience of BSE (Mad Cow Disease) has shown how unprepared Europe was for a devastating and totally new disease. The BSE experience is estimated to have imposed a permanent additional cost of 3 billion Euro per annum on the European beef production industry. Because of its demonstrated link to nvCJD (new variant Creutzfeldt-Jakob Disease) in humans, it has led to the creation of new food safety authorities on a permanent basis for the EU and in each European country. Finally, the extensive actions required in the face of potential threat from avian and swine virus sources illustrates the scale of the potential dangers faced in an increasingly integrated global food chain. These emerging threats are likely to continue. Experience has shown that, overall, new diseases have been detected at the rate of about one per year for the past thirty years.

  For the future, much of the emphasis will need to be on improved surveillance, detection, anticipation of diseases and practices in the animal sector which can have an impact on human health. Production and processing methods can adversely affect the incidence of food borne illness attributable to Salmonella, Listeria or E-coli. The development of antibiotic resistance as a result of widespread use of antibiotics in production systems is a problem which is not yet fully under control.

[21] Commission White Paper on nutrition, overweight and obesity-related health issues (2007). See: http://register.consilium.europa.eu/pdf/en/07/st15/st15612.en07.pdf
[22] Based on: P. Cunningham (2003) – "After BSE – A Future for the European Livestock Sector". European Association for Animal Production, Publication No. 108, 2003

3 THE KBBE FROM 2005 TO 2010: MAJOR ACHIEVEMENTS

3.1 The KBBE in EU research: building on European strengths and knowledge

3.1.1 Introduction

In 2004, the European Commission (DG Research) developed the concept of the Knowledge-Based Bio-Economy or KBBE. The idea behind it was that the European bioeconomy cannot compete on a global level by delivering only basic agricultural commodities, but needs to build on European strengths such as excellence in science, technology and industry to deliver innovation, world leadership in food technologies and products and animal breeding technologies, and having a strong chemical and manufacturing industry base. Several European Technology Platforms (ETP) were set up, and research in the area of the KBBE has been promoted and financed via the Commission's Framework Programme 7 and several Member State initiatives. In September 2005, the Commission also organised the first KBBE stakeholder conference in Brussels[23].

3.1.2 The EU Framework Programmes

3.1.2.1 Sixth Framework Programme (FP6)

Under FP6 (2002-2006), KBBE-related research was covered mainly through the Specific Programme "Integrating and Strengthening the European Research Area", Thematic Priority 5 ('Food Quality and Safety'). This thematic priority accounted for 6.1% of the FP6 budget allocated to thematic research and for 4.2% of the overall FP6 budget (excluding EURATOM). It addressed the complete food chain, from farmer to consumer, and consisted of eight scientific areas (Epidemiology of food-related diseases and allergies; Impact of food on health; Traceability' processes all along the production chain; Methods of analysis, detection and control; Safer and more environmentally friendly production methods and technologies and healthier foodstuffs; Impact of animal feed on health; Environmental health risks; The total food chain). Over the four years of the programme, the Food Quality and Safety priority spent 751 million Euro across 181 projects involving 3034 participants.

3.1.2.2 Seventh Framework Programme (FP7)

Under FP7 (2007-2013), KBBE-related issues are covered through the Specific Programme 'Cooperation', which constitutes the core of FP7, representing two thirds of the overall budget. It fosters collaborative research across Europe and other partner countries through projects by transnational consortia of industry and academia. Research is carried out in ten key thematic areas. The second key thematic area is 'Food, agriculture and fisheries, and biotechnology[24]', to which 1.9 billion Euro of funding has been allocated. This thematic area is built around three major activities:

- Sustainable production and management of biological resources from land, forest and aquatic environments
- Fork to farm: food (including seafood), health and well-being
- Life sciences, biotechnology and biochemistry for sustainable non-food products and processes

[23] EU Conference report (2005) – New perspectives on the Knowledge-based Bio-economy
[24] http://cordis.europa.eu/fp7/kbbe/

3.1.3 ERA-NETs

At EU level, research in the KBBE area is strengthened by the implementation of several ERA-Nets. The objective of the ERA-NET scheme is to develop and strengthen the coordination of public research programmes conducted at national or regional level. It provides a framework to network and mutually open national or regional research programmes, leading to concrete cooperation such as the development and implementation of joint programmes or activities. The ERA-NET scheme is expected to reduce the fragmentation of the European Research Area (ERA) by improving the coherence and coordination of national and regional research programmes. Some of the ERA-Nets with a clear link to the KBBE are: ERA-PG[25] (Plant Genomics), ERASysBio[26] (Systems Biology), EuroTrans-Bio[27] (European Network of Transnational Collaborative RTD for SME Projects in the Field of Biotechnology), ERA-IB[28] (Industrial Biotechnology), WoodWisdom-Net[29] (wood material science and engineering), SAFEFOODERA[30] (food safety research programming), Marifish[31] (marine fisheries science and fisheries management), EMIDA[32] (Emerging and Major Infectious Diseases of Livestock).

3.1.4 European Technology Platforms (ETPs)

The concept of European Technology Platforms (ETPs) was developed by the European Commission starting in 2003, with the first ETPs emerging in 2004. The aim of ETPs is to contribute to European competitiveness, boost research performance, concentrate efforts and address fragmentation across Europe. ETPs are characterised by addressing challenging issues for growth, embodying major technological advances in the medium to long term, creating community added-value, involving high research intensity and requiring a European approach.

In the KBBE area, nine ETPs have emerged since then: Plants for the Future[33], Food for Life[34], Sustainable Chemistry[35], Sustainable Farm Animal Breeding and Reproduction[36], Forest-based Sector[37], Biofuels[38], Agricultural Engineering[39], Aquaculture Technology and Innovation[40], and Global Animal Health[41].

As these ETPs developed, they started to communicate and work together on issues of mutual interest, such as identifying synergies in their Strategic Research Agendas (SRAs). The European Commission started regular meetings with representatives from the KBBE ETPs and invited experts to discuss policy-related issues together. Today the 9 ETPs active in the KBBE sector are joining forces in BECOTEPS[42], a Coordination and Support Action (CSA) funded by the European Commission's Seventh Framework Programme. The main objectives of the BECOTEPS project are:

- To achieve closer and more coordinated collaboration between the KBBE ETPs
- To develop recommendations for better interaction between the KBBE ETP stakeholders along the product chains and the sustainability issue regarding multidisciplinary research, innovation and policy issues

[25] http://www.erapg.org
[26] http://www.erasysbio.net
[27] http://www.eurotransbio.eu
[28] http://www.era-ib.net
[29] http://www.woodwisdom.net
[30] http://www.safefoodera.net
[31] http://www.marifish.net
[32] http://www.emida-era.net
[33] http://www.plantetp.org
[34] http://etp.ciaa.be
[35] http://www.suschem.org
[36] http://www.fabretp.org
[37] http://www.forestplatform.org
[38] http://www.biofuelstp.eu
[39] http://www.manufuture.org
[40] http://www.eatip.eu
[41] http://www.ifahsec.org
[42] http://www.becoteps.org

- To encourage discussions between European and national, public and private, research and innovation initiatives.

3.1.5 EU Expert Groups

In addition to ERA-NETs and ETPs, a third category of pan-European KBBE-related networks consists of European Commission expert groups. The expert groups the most related to the KBBE are:

- The **Advisory Group on Food, Agriculture and Biotechnologies**: it's mission is to give advice to the Commission services in the field of food, agriculture and biotechnology research and help to stimulate, if possible, the corresponding European research communities.

- The **KBBE-Net**: an expert Group of officials from Member States on the Knowledge Based Bio-Economy, coordinated by DG Research, supporting the Commission and the Member States to achieve a coordinated effort in the development and implementation of a research policy for a KBBE.
- The **KBBE National Contact Point**: the mission of this expert Group is to assist potential applicants for EC funding, to disseminate information on calls and policy initiatives, to raise awareness, to give feedback to the EC, etc.
- The **EU Standing Committee for Agriculture Research**: the Standing Committee on Agricultural Research (SCAR)[43] was initially managed by DG AGRI and advised the Commission in the field of the coordination of research in agriculture. Since 2005 the "renewed" SCAR is managed by DG RTD, and looks beyond the narrow aspects of research relating to production. Today SCAR addresses the major sectors within the concept of a 'Knowledge Based Bio-Economy' (e.g. animal health and welfare; consumer issues relating to the quality, safety and security of food production and supply; issues of consumer behaviour towards food, nutrition, retailing and market; issues related to developments in non-traditional and non-food areas of agriculture activity including forestry).

3.2 Feedstock for food, feed, fuel and products

The aim of this section is to analyse how the productivity of biomass from agriculture, forestry and organic waste streams has increased over recent years and how research and innovation has also improved the performance of crops especially those with higher yields using lower amounts of fertilisers and water. In addition to this the European feedstock situation should be compared to the rest of the world and there is a need to analyse what has been done to make agriculture more sustainable.

In this part of study we use the term feedstock to mean "biomass" according to the definition of the FAO from 2004:

> *"Biomass means material of biological origin excluding material embedded in geological formations and transformed to fossil.[44]"*

The use of biomass (Renewable Raw Materials or RRM) as a feedstock for the production of fuels, materials, chemicals and other biobased products can save fossil resources and reduce negative impacts on the environment. In particular, green house gas emissions could be reduced by bio-based products providing substitutes for products based on crude oil. It can also support the agricultural and forestry sectors and lead to innovations in, for example, biomaterials or biobased chemicals. For the chemical industry – other than for

[43] http://ec.europa.eu/research/agriculture/scar/index_en.html
[44] FAO (2004) – UBET: Unified Bioenergy Terminology. See http://www.fao.org/docrep/007/j4504e/j4504e00.htm

fuels and energy - RRM are the only current alternative source of carbon to crude oil for the production of chemical products[45].

In view of these opportunities a KBBE is widely needed and wanted in Europe. This leads to several needs especially with regards to the need for feedstock because if the bio-based industry is to achieve its potential the supply of feedstock is a key issue to be addressed (see 4.2).

3.2.1 The feedstock situation in Europe

The current and future amount of biomass feedstock for food, feed, energy and industrial material use in Europe as well as the question of the available land for food and non-food crops is a contentious issue and remains an area in need of in depth analysis. Although many studies, assessments and scenarios on biomass potentials in Europe as a whole and for different countries already exist their conclusions differ widely.

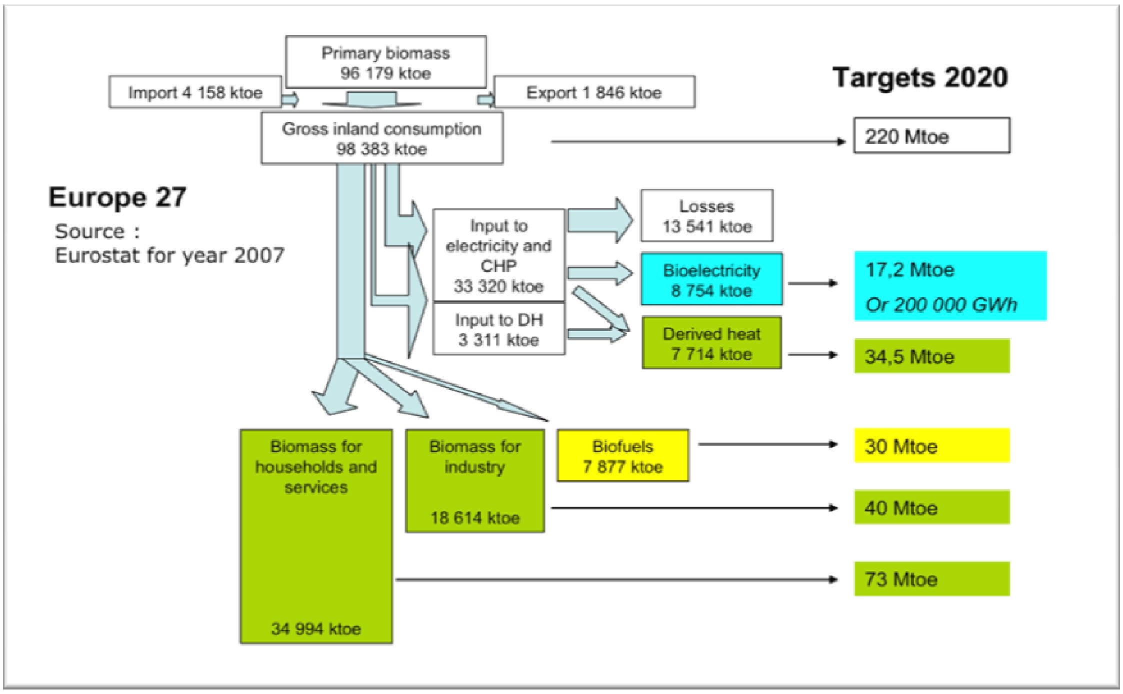

Figure 1: Assessment for recent biomass supply, use and future demand in Europe[46]

The FP7 project "Biomass Energy Europe" (BEE), focusing on the energy use and future demands of bioenergy, analyses several recent studies on biomass resources in a meta analysis for their "Status of Biomass Resource Assessments"[47]. The aim of this project is to harmonize the existing biomass resource availability assessments for Europe to improve the consistency, accuracy and reliability of the assessments. The project analyzed the results of 57 different data sources including 30 key studies and 9 further studies on three different types of biomass for the bio-based industry:

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[45] Jering A., Günther J., Raschka A., Carus M., Piotrowski S., Scholz L. (2010) - Use of renewable raw materials with special emphasis on chemical industry. ETC/SCP report 1/2010, European Environmental Agency.

[46] Jossart J.-M. (2009) - Development of the bioenergy sector. Presentation at the JRC Workshop "Biomass resource assessment", Eberswalde 8-9 December 2009.

[47] First results are published in: Rettenmaier N., Reinhardt G., Schorb A., Köppen S., von Falkenstein E. et al. (2008) - Status of Biomass Resource Assessments, Version 1. IFEU and BEE project, Heidelberg.
Despite this there are different presentations available on the topic, e.g. Dees M., Rettenmaier N. (2009) - Overview of European studies of biomass resource assessment. Presentation at the JRC Workshop "Biomass resource assessment", Eberswalde 8-9 December 2009.

- The forestry and forestry residues,
- The energy crops and
- The agricultural residues and organic waste.

The review showed significant differences between the analyzed assessments. It came to the conclusion that, especially with regards to wood biomass, agricultural residues and organic wastes, the difference between the reported biomass potentials in some cases is multiple for the same geographic area and time. The reviewed assessments are highly diverse in their approaches, methodology and assumptions and many authors highlighted an insufficient quality of available input data. Their results on wood biomass assessments, agricultural residues and organic wastes are shown in the images below.

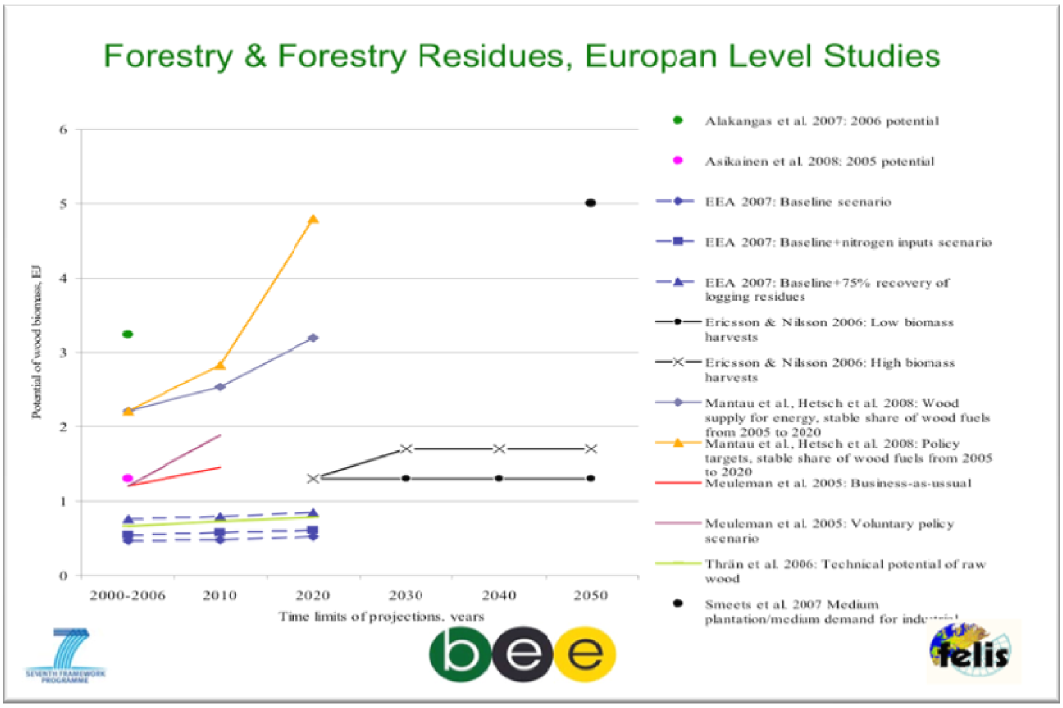

Figure 2: Biomass from Forestry and Forestry Residues, results from a meta-analysis of different European Level Studies[48]

48 Rettenmaier N., Reinhardt G., Schorb A., Köppen S., von Falkenstein E. et al. (2008) - Status of Biomass Resource Assessments, Version 1. IFEU and BEE project, Heidelberg.
Used sources for this meta-study are:
- Alakangas E., Heikkinen A., Lensu T., Vesterinen P. (2007) - Biomass fuel trade in Europe. Summary Report VTTR0350807. Jyväskylä, Finland.
- Asikainen A., Liiri H., Peltola S., Karjalainen T., Laitila J. (2008) - Forest Energy Potential in Europe (EU 27). Working Papers of the Finnish Forest Research Institute. Joensuu, Finland.
- European Enironmental Agency EEA (2007) - Environmentally compatible bio-energy potential from European forests. Copenhagen, Denmark.
- Ericsson K., Nilsson L. (2006) - Assessment of the potential biomass supply in Europe using a resource-focused approach. Biomass and Bioenergy 30 (1), p. 1-15.
- Mantau U., Steierer F., Hetsch S., Prinsc. (2008) - Wood resources availability and demands – Part I National and regional wood resource balances 2005. Background paper to the UNECE/FAO Workshop on Wood balances. Geneva, Italy.
- Meuleman B., Kuiper L., Nabuurs G. (2005) - Effect: EU forest for renewable energy to mitigate climate. Utrecht: Ecofys.
- Thrän D., Weber M., Scheuermann A., Fröhlich N., Zeddies J., Henze A., Thoroe C., Schweinle J., Fritsche U., Jenseit W., Rausch L., Schmidt K. (2006) - Sustainable Strategies for Biomass Use in the European Context. Institute for Energy and Environment, Leipzig, Germany.
- Smeets E.M., Faaji A.P.C., Lewandowski I.M., Turkenburg W.C. (2007) - A bottom-up-assessment and review of global bio-energy potentials to 2050. Progress in Energy and Combustion Science 33 (1), p 56-106.

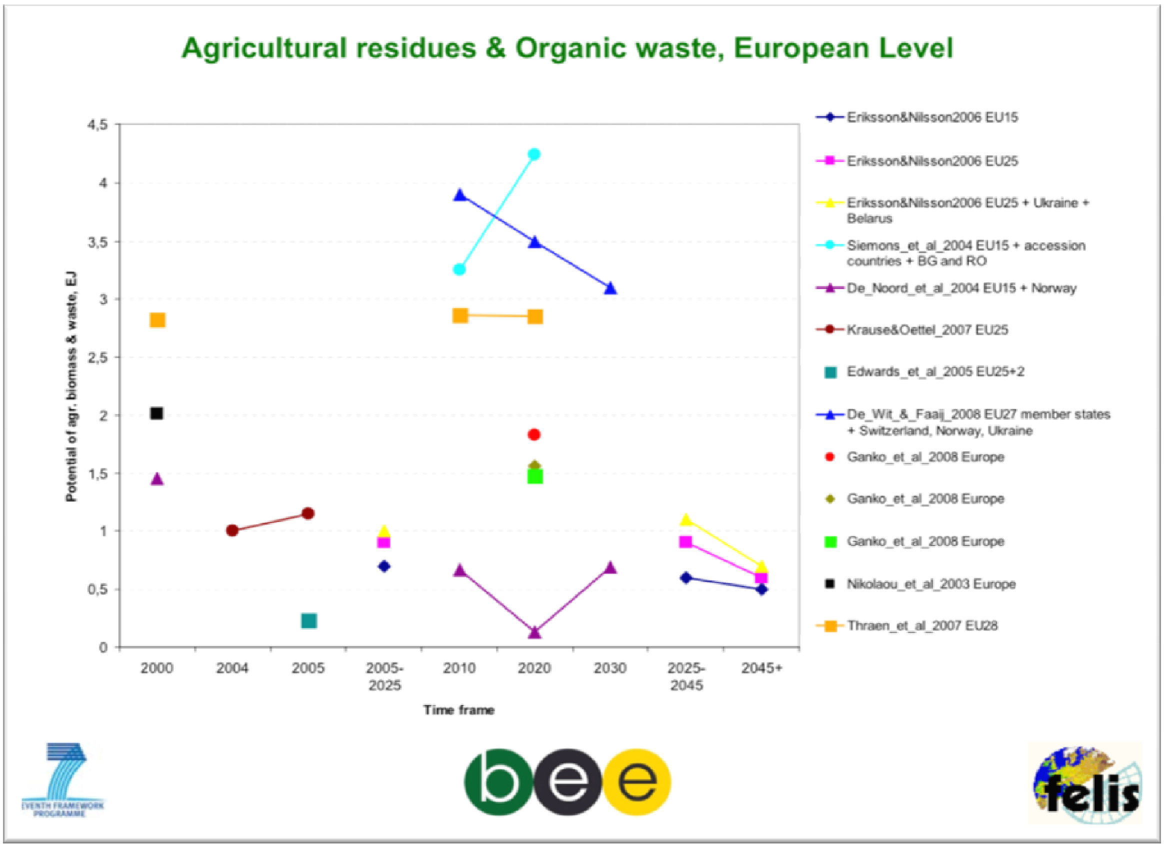

Figure 3: Biomass from agricultural residues and organic wastes, results from a Meta-analysis of different European Level Studies [49]

[49] Rettenmaier N., Reinhardt G., Schorb A., Köppen S., von Falkenstein E. et al. (2008) - Status of Biomass Resource Assessments, Version 1. IFEU and BEE project, Heidelberg
Used sources for this meta-study are:

- Ericsson K., Nilsson L. (2006) - Assessment of the potential biomass supply in Europe using a resource-focused approach. Biomass and Bioenergy 30 (1), p. 1-15.
- Siemons R. Vis M., van den Berg D., Mc Chesney I., Whiteley M., Nikolaou N. (2004) - Bio-energy's role in the EU Energy market, a view of developments until 2020. BTG Report, Enschede, the Netherlands.
- De Noord M., Beurskens L.W.M, de Vries H.-J. (2004) - Potentials and costs for renewable electricity generation, a data overview (Chapter 6). ECN Report, Petten, the Netherlands.
- Krause H., Oettel E. (2007) - REDUBAR: Investigations targeted to the creation of legislative instruments and the reduction of administrative barriers for the use of biogas for heating, cooling and power generation. Project report, DBI Gas- und Umwelttechnik GmbH, Leipzig, Germany.
- Edwards R.A.H., Suri A., T.A. Huld, J.F. Dallemand (2005) - GIS-based assessment of cereal straw energy resource in the European Union. Proceedings of the 14th European Biomass Conference & Exhibition. Biomass for Energy, Industry and Climate Protection, 17-21 October 2005, Paris, France.
- DeWit M.P., Faaji A.P.C. (2008) - Biomass Recourses Potential and related Costs. Assessment of the EU-27, Switzerland, Norway and Ukraine. REFUEL Report, Utrecht University, The Netherlands.
- Ganko E., Kunikowski G., Pisarek M., Rutkowska-Filipczak M., Gumeniuk A., Wróbel A. (2008) - Biomass resources and potential assessment. Final report WP 5.1 of RENEW project, Institute for Fuels and Renergable Energy, Warsaw.
- Nikolaou A., Remrowa M., Jeliazkow I. (2003) - Biomass availability in Europe. Final report CRES, BTG, ESD, Athens, Greece.
- Thrän D., Weber M., Scheuermann A., Fröhlich N., Zeddies J., Henze A., Thoroe C., Schweinle J., Fritsche U., Jenseit W., Rausch L., Schmidt K. (2006) - Sustainable Strategies for Biomass Use in the European Context. Institute for Energy and Environment, Leipzig, Germany.

Currently, the data available on the industrial material use of biomass as feedstock in the EU is limited in both its availability and accuracy. Furthermore on a national level there are only a few studies, mainly for Germany, France, the Netherlands and Great Britain, concerning the material use of forestry and agricultural feedstocks and demands. Thanks to a study on the industrial material use in Germany by the nova-institute a good database on the uses of RRM in German industry is available[50]. In addition, the national Non-Food Crops Centre (NNFCC) and Arthur D. Little Limited produced a market analysis of key renewable materials and product sectors for Great Britain[51] and Bewa provided a study on the current and prospective markets for industrial bioproducts in France, excluding wood and pulp, textiles and health products[52]. For the Netherlands Nowicki et al. published a state-of-the-art assessment on the bio-based economy focusing on the market value of bio-based products[53]. Additionally, data is available for certain industries such as the pulp and paper industry from CEPI or the wood industry as a whole for certain periods.

As a whole the feedstock assessments for industrial material use must be the same as in the bioenergy feedstocks discussed above because all available feedstocks and land can be used for the energy production as well as for bio-based products. One problematic area in the calculation of industrial material use is evaluation on the basis of energy units (Joules) as opposed to mass units (tons) as it is difficult to compare these two measurements.

3.2.2 *Availability of arable land*

According to a recent FAO study using longer term population and income projections, global food production needs to increase by more than 40% by 2030 and by 70% by 2050 compared to average 2005-07 levels[54].

Increased food production will either result from increased yields or from area expansion. Theoretically, according to the OECD/FAO Agricultural Outlook[55], some 1.6 billion ha could be added to the current 1.4 billion ha of cropland. These 1.6 billion ha are referred to as the Net Land Balance (NLB), which is the additional available area for crop production after excluding areas allocated to either forests, urban areas or protected areas. Yet, historically expansion of arable land area has been slow, and bringing more marginal land into production could involve considerable investment and lower average yields, while possibly incurring social and environmental costs[56].

Over half of this NLB is located in Africa and in Latin America. These regions account for most of the available land that has the highest suitability class for rain-fed crop production. Also historically, expansion of arable land has since the 1960s mainly taken place in Africa and Asia while it has continually declined in Europe. However, in practice bringing the additionally available land into production is in many cases hindered by insufficient infrastructure, lack of capital and poor transmission of price incentives to farmers.

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[50] Carus M., Raschka A., Piotrowski S. et al. (2010) - The development of instruments to support the material use of renewable raw materials in Germany. Summary published in May 2010, whole study in press. Download of the study: www.nova-institut.de/nr

[51] Arthur D. Little Limited (2008) - Market analysis of key renewable materials and product sectors. Main Report and Appendices. Report to the National Non-Food Crops Centre, UK, August 2008.

[52] Bewa H. (2007) - Etude du marché actuel des bioproduits industriels et de biocarburants & evolutions prévisibles à 2015/2030. Study conducted for the Agence de l`Environment et de la Maltrise de l'Enerie (Ademe), France, April 2007.

[53] Nowicki P., Banse M., Bolck C., Bos H., Scott E (2008) - Biobased economy. State-of-the-art assessment. Study from the Agricultural Economics Research Institute (LEI), Le Hague, February 2008.

[54] FAO (2009) - How to feed the world in 2050

[55] based on Fischer, G., Van Velthuizen, H., Shah, M., Nachtergaele, F.O. (2002) - Global Agro-ecological Assessment for Agriculture in the 21st Century: Methodology and Results. Research Report, IIASA, Laxenburg, Austria and FAO, Rome, Italy

[56] OECD/FAO (2009) - Agricultural Outlook 2009-2018.

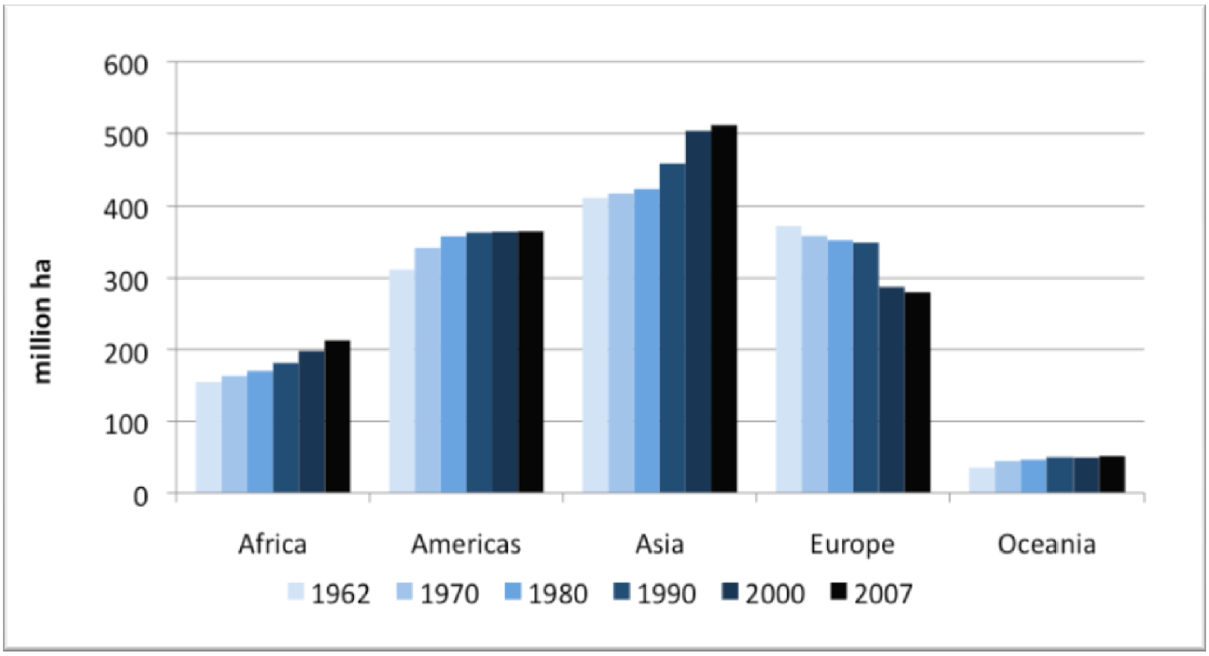

Figure 4: Arable land by region[57]

The following two figures show that the increase in development of total global agricultural area has in reality stagnated and even decreased. Furthermore, the increase in agricultural area has largely been due to vaste increases in land area cultivated for permanent crops (incl. oil palm, cocoa, coffee, natural rubber etc.) rather than for other arable land.

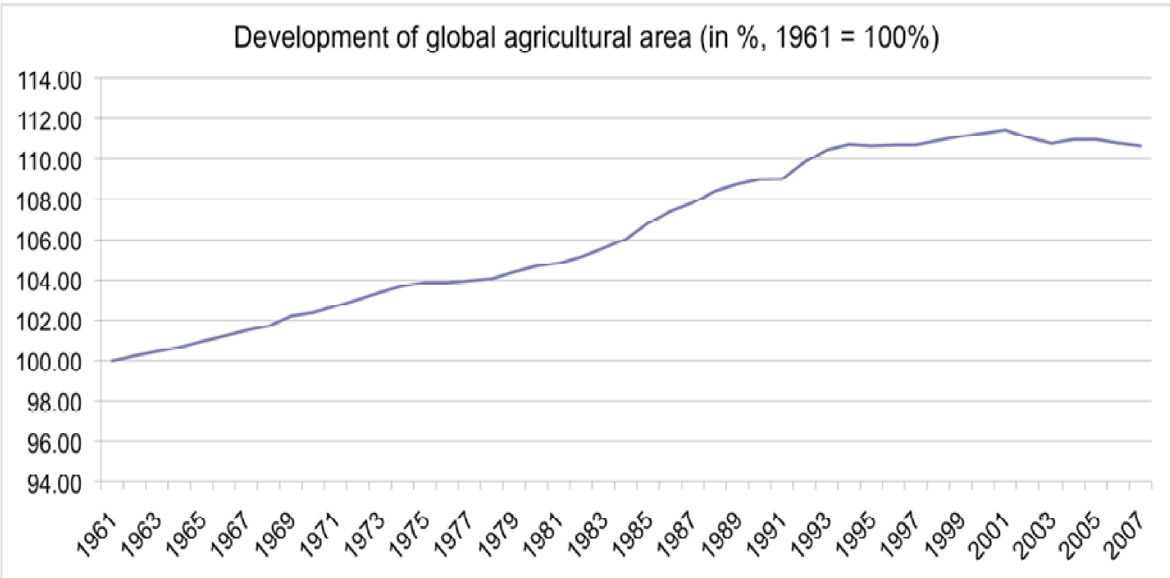

Figure 5: Global agricultural area[58]

[57] Source: OECD/FAO (2009) - Agricultural Outlook 2009-2018
[58] Source : nova-Institut, FAOSTAT

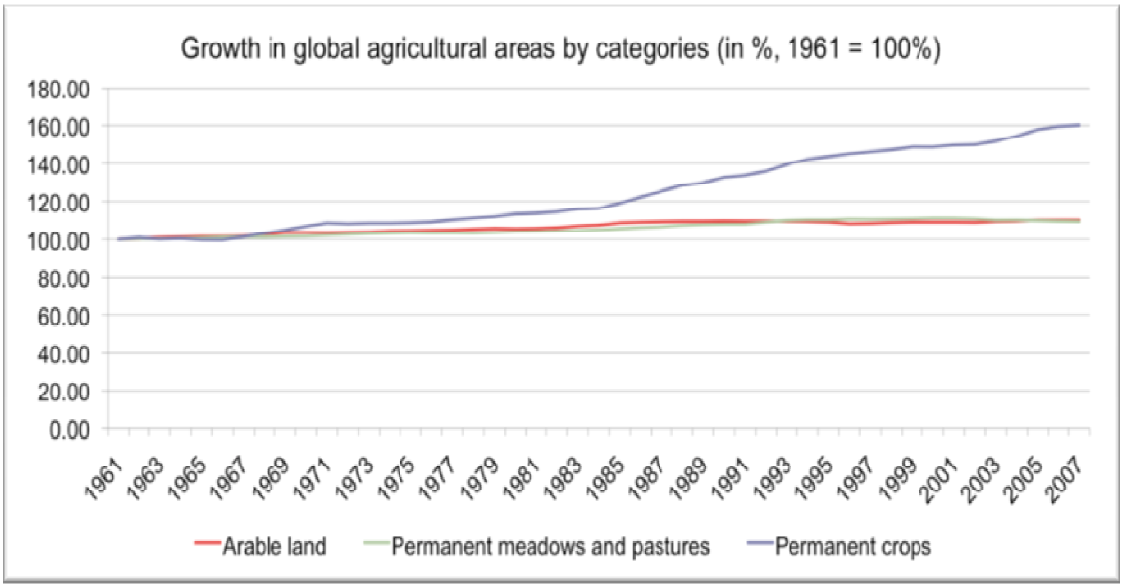

Figure 6: Global agricultural area by categories[59]

Impact on food security is one of the core social factors to be considered in the development of the use of renewable resources for biofuels and material use in biorefineries. The growing market (today largely for biofuels but in the future undoubtedly also for biorefineries) represents a new source of demand for agricultural commodities[60], that must be managed with available land resources and without negative impacts on the food and feed sector.

3.2.3 Research on feedstocks optimisation

Feedstocks are continually adapting to the needs of the modern (agricultural) industry. A key focus of national and international research concerning the availability of feedstocks for a bio-based economy is the optimisation of the yields and materials for different uses. There are a variety of different ways to achieve these aims. This includes the technological optimisation of agricultural processes as well as the direct optimisation of crops (and wood for short rotation plantations) via conventional breeding, refinements of conventional breeding or biotechnological methods. Modern breeding methods offer a wide range of different approaches. In addition to traditional selection procedures and genetic engineering, (green) biotechnology for feedstock optimization receives increasing attention, though some industry sectors, politicians and the general public continue to regard it with suspicion.

Increasing demand from chemical companies for renewable resources for a bio-based economy requires adjustments in plant breeding and production. The main aim is to increase production of the desired plant products or the total biomass by both direct biomass increase and by the development of resistance breeding to increase crop yields. Indeed, this has also been the long-term aim of conventional crop over the centuries to optimize crop yields for the food industry and to produce plants with high contents of for example starch or sugar.

3.2.3.1 Productivity/yield growth

Due to the potential problems related to the expansion of agricultural areas (considerable investment and lower average yields, while possibly incurring social and environmental costs), the alternative method of increasing global food production is to further increase

[59] Source : Nova-Institut, FAOSTAT
[60] FAO (2008) - The State of Food and Agriculture 2008: Biofuels: Prospects Risks and Opportunities

land productivity. From the 1960s and the advent of the "Green Revolution", global cereal yields have continually increased.

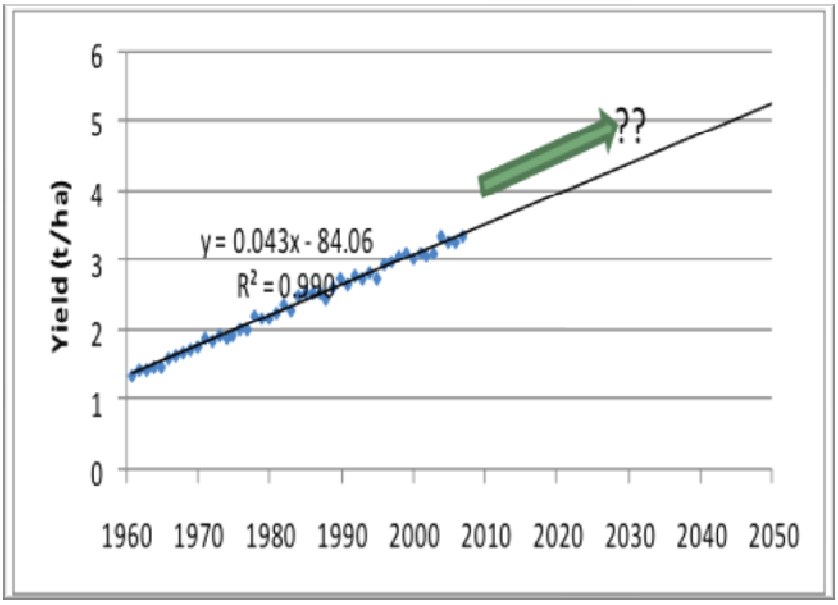

Figure 7: Long-term trend in global cereal yields[61]

The crucial question for the future is whether the trend of increasing global yields will continue at the same pace. The tremendous potential for increasing yields in developing countries is hindered by lack of technology and infrastructure on the one hand and unfavourable agricultural policies on the other. Neither area is easy to change in the short-term.

This is also evidenced by the fact that the global food price spike of 2007 and 2008 has not resulted in a significant supply response from the vast majority of developing country producers. In principle, high food prices provide incentives for farmers to invest, leading to agricultural growth. However, as the FAO shows, there are a number of reasons, why this hope has not materialized in 2007 and 2008.

First, farmers in developing countries suffer in most cases from ill-functioning markets. These market imperfections lead to a lack of access to credit, to an insufficient transmission of price incentives, poorly enforced land rights and many other obstacles. Second, while high product prices often did not reach the farmers, they still suffered from high input prices, especially fertilizer prices. What are therefore needed are wide-reaching agricultural reforms, including world trade reforms.

While yields for major crops continue to grow, the growth rate has markedly slowed down for many crops. Bringezu showed that the global crop yields for all main crops grow slower than in the past and that there is only very little optimization through conventional breeding[62].

The 5-years moving average of yield growth of wheat has slowed down from about 4% in the beginning of the 1960s to less than 1%. In the case of the Americas, the trend is only slightly negative and only Africa is characterized by a slightly increasing trend of the yield growth rate, but with large variations over the years. This reflects the potential to increase yields in Africa, but also its vulnerability[63].

[61] Source: R. A. Fischer, D. Byleree, G. O. Edmeades (2009) - Can technology deliver the yield challenge to 2050? - FAO Expert Meeting on How to Feed the World in 2050, 24-26 June 2009

[62] Source: Bringezu S. (2009) - Biomass use for climate change mitigation and sustainable resource management. Presentation at the JRC Workshop "Biomass resource assessment". Eberswalde 8-9 December 2009.

[63] Analysis of data from FAOSTAT

3.2.3.2 Advanced breeding technologies and green biotechnology

A second focus is the optimization of the plant ingredients such as through a change of the starch molecule for technical uses of the potato (Amflora potato from BASF and TILLING potato with starch containing only amylopectin) or the change of the composition of fatty acids in rapeseed, sunflower or crambe. The German Plant Breeders Association (BDP) declares as one of its main breeding objectives: "increasing the income and improving the quality of the harvested crop, an improved resistance to harmful organisms, to reduce the costs of pesticides, improve tolerance to abiotic stress factors in order to reduce agronomic efforts and to secure yields under changing environmental conditions, the optimization of the content of plant ingredients and an improved intake of nutrients for a reduced use of fertilizers[64]."

Conventional breeding is dedicated, in addition to the development of new breeding objectives, by new technological developments. As a result, the concept of the use of cascades and product chains was established and optimized and breeding aims are defined accordingly. Examples of this may be the breeding of sugar beets with high sugar content or the improvement of the harvest index for rapeseed. The output of these efforts should be additionally used for energetic and material uses. Another level of development is the SMART breeding technology (SMART meaning „Selection with Markers and Advanced Reproductive Technologies"). In this process, the gene responsible for a specific property is identified using molecular methods in the first step (DNA sequencing and next generation sequencing, PCR, molecular markers). In the breeding process this is used to analyze the progeny of a crossbreed very early in regard to the presence of the feature and to select it. Time savings of up to 50% can result from this process and examples of smart breeding can be found for rice[65].

Cisgenetics is a similar approach, where genes of a species are identified, isolated and then reintroduced into the same species to optimize it. With this technology breeding aims can be achieved more rapidly which is why such techniques are often referred to as tools for achieving a second green revolution[66]. Another achievement is the TILLING technology (Targeting Induced Local Lesions In Genomes), where laboratory-intensive mutation breeding has been expanded and improved in efficiency[67]. In addition, EcoTILLING, where natural alleles are identified and used in breedings [68] presents new and exciting possibilities. Newer developments, such as homologous recombination[69] where only genes of certain features and changes are targeted to avoid indirected and therefore unwanted genetic changes, have also increased the accuracy and efficiency of breeding techniques.

Such developments in breeding play a part in the evolution of green biotechnology. In addition, other developments such as embryo-rescue, anther cultures and *in vitro* culture/micro propagation to increase clones also represent areas of significant development. Emerging economies such as China, Brazil and India are embracing these techniques as promising and important technology advances for their nations [70]. The potential of this technology is also shown by the fact that in 2009 more than 134 million ha of arable land were planted with transgenic crops[71]. This is equivalent to 10 times of the available acreage in Germany and represents 10-15% of the global area occupied.

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[64] http://www.bdp-online.de/de/Pflanzenzuechtung/Zuechtung_und_Forschung/Zuechtungsziele/

[65] Kenong Xu et al. (2006) - Sub1A is an ethylene-response-factor-like gene that confers submergence tolerance to rice. Nature Vol. 442, S. 705 – 708

[66] E. Jacobsen and Karaba N. Nataraja (2008) - Cisgenics – Facilitating the second green revolution in India by improved traditional plant breeding. Current Science. VOL. 94, NO. 11, 1365-1366.

[67] Steven Henikoff, Bradley J. Till and Luca Comai (2004) – TILLING: Traditional Mutagenesis Meets Functional Genomics. Plant Physiology 135:630-636.

[68] Comai L, Young K, Till BJ et al. (2004) - Efficient discovery of DNA polymorphisms in natural populations by Ecotilling. Plant J 37:778–86

[69] Shukla et al. (2009) - Precise genome modification in the crop species Zea mays using zinc-finger nucleases. Nature 459, 437-441
Townsend et al. (2009) - High-frequency modification of plant genes using engineered zinc-finger nucleases. Nature 459, 442-445

[70] E. Jacobsen and Karaba N. Nataraja (2008) – Cisgenics: Facilitating the second green revolution in India by improved traditional plant breeding. Current Science 94, 11, 1365-1366

[71] International Service for the Acquisit (ISAAA): ISAAA Brief 41-2009: Executive Summary – Global Status of Commercialized Biotech/GM Crops: 2009. The First fourteen years, 1996 to 2009. See: http://www.isaaa.org/resources/publications/briefs/41/executivesummary/default.asp

3.3 Livestock: from farm to fork

3.3.1 *The importance for the EU economy*

In the EU as a whole, agriculture accounts for 1.8% of GDP and 5.9% of employment. Across the EU, output from the livestock sector makes up 44% of the final agricultural output, though there is considerable variation between countries ranging from a high of over 70% in Ireland to under 30% in Greece.

At EU level, the total output of the sector is composed of the following main components: dairy 41 billion Euro (31%), beef 27 billion Euro (21%), pig meat 31 billion Euro (23%), poultry meat 16 billion Euro (12%), eggs 8 billion Euro(6%) and sheep and goats 5 billion Euro (4%). In general, the farm gate value of these products constitutes a modest part of the final value as paid for by the consumer, ranging for example in Ireland from 20% in the case of milk to 44% for lamb.

A decade ago, the EU was a major exporter of livestock products. In 2000, for example, 5.4% of meat output was exported. Today, Europe is importing a steadily higher proportion of its requirements (particularly beef), and exporting a smaller proportion of its output.

While there are considerable differences between countries, both in the numbers employed and in the pace of change and employment in agriculture and in particular in the livestock sector, the general trend is for a continued decline in employment at production level. Approximately 12.5 million people are employed in production agriculture (22% in the livestock enterprises), while food processing and distribution account for a further 5 million.

3.3.2 *The role of the Technology Platforms*

Animal breeding is a knowledge intensive sector, and for the competitiveness and the future of animal breeding and animal production, high level European research will be indispensable. Two European Technology Platforms (ETP) have now been set up in this sector. The first ETP is the Farm Animal Breeding and Reproduction Technology Platform. This ETP tackles major issues concerning sustainability, animal breeding and reproduction in Europe. Under the umbrella of the ETP, 7 species groups were created including cattle, sheep/goats, pigs, poultry, aquaculture, horses and other farm and companion animals. This ETP evaluates food quality and safety, animal welfare, health and performance and diversity and distinctiveness. It also examines technologies such as animal breeding and quantitative genetics, genomics and bio-informatics, and reproductive technologies. Another ETP has as its remit Emerging and Major Infectious Diseases of Livestock (EMIDA).

3.4 Innovative food production

3.4.1 *The food industry in Europe*

The EU Food and Drink industry is a powerhouse of the European economy, transforming over 70% of the EU's agricultural raw materials and employing over 4.4 million people[72], supporting some 310,000 companies, of which 99.1% are Small and Medium Enterprises (SMEs), with a generating turnover of 965 billion Euro and a positive trade balance with the rest of the world. At present, the EU Food and Drink industry provides 480 million consumers daily with a wide variety of products and services, showing a continuous change over time in many countries serving very large markets[73].

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[72] CIAA (2009) - Data and Trends.
See: http://www.ciaa.be/documents/brochures/ciaa-data%20trend-updated.pdf

[73] EUROSTAT Consumer Prices Research (2009) - An experimental analysis into the measurement of indicative price levels for consumer products (Food and Non- Alcoholic products). See: http://epp.eurostat.ec.europa.eu/portal/page/portal/hicp/documents/Tab/Tab/04_METH_CPR_-_FEB_2009_WEB_0.pdf

These consumers are better informed on nutritional education, and more empowered. They demand innovative, high quality, diversified, healthy, safe food products that offer convenience and value for money[74]. Consumers have increased access to information and increasing awareness, impose to food industry additional requirements on transparency of information and food pricing, traceability and labeling. Moreover, the modern consumer demands sustainable and ethical production systems, innovative packaging and waste disposal, increased shelf life and optimized food chain management[75].

For this reason, the European Food and Drink industry's leadership in the global economy has in recent years invested in significant research, education and innovation programs, in recognition of the fact that innovation is the key driver for growth, for competitiveness and for employment in the food sector in the EU[76].

3.4.2 Research and innovation

3.4.2.1 Food research in Europe

Robust research, coupled with an effective knowledge management system, can assist science-based innovation to support sustainable development, competitiveness and societal objectives[77]. Recent scientific advances in the field of biotechnology, the -omics sciences, bioinformatics, nutrition, food safety issues, nanotechnology[78], information technology, consumer and behavioral science issues and their increased degree of convergence, have the potential to deliver great improvements in public health, food safety and animal health[79]. The science necessary to underpin the sector requires inputs from the social, biological, physical and medical sciences and needs to integrate strategically focused, trans-national research that can deliver innovative processes, products and tools in line with the needs and expectations of the consumer. European consumers want foods that contribute to a healthier lifestyle and that taste good, are convenient to prepare and that are, of course, affordable. Nutritional improvements of a large range of food products also have great potential for public health improvement and therefore provide an impetus for new product development in the food sector.

The R&D initiatives of food and drink manufacturers has traditionally been at a very low level when compared to other industries. However, food and drink companies both within and outside the EU have displayed resilience during the global economic crisis, allowing them to maintain similar levels of R&D investment[80]. In addition, the development of novel food products and processes, including food packaging technologies will be important drivers in realising ambitions for healthy food, healthy lives and for minimising environmental impact[81] by reducing green house gas emissions, energy and water consumption whilst contributing to a more sustainable eco-friendly economy.

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[74] Communication from Commission to the Council, European Parliament, European Economic and Social Committee and Committee of the Regions - Food prices in Europe - COM (2008) 821/4
[75] EC Report to the Council and the European Parliament on the implementation of Dir 94/62/EC on packaging waste and its impact on the environment, as well as on the functioning of the internal market (2006).
See: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0767:FIN:EN:PDF
[76] CIAA (2009) - The competitiveness of the EU food and Drink industry.
See: http://www.ciaa.eu/documents/brochures/Bench%20Reprt%202009_LR.pdf
[77] Discussion document prepared for the Irish Department of Agriculture, Fisheries and Food (2009) - Fostering the Smart green Bio-Economy.
See: www.agriculture.gov.ie/media/migration/2020/2020strategy/2020RD1.doc
[78] HOUSE OF LORDS - Science and Technology Committee (2010) - Nanotechnologies and Food. http://www.publications.parliament.uk/pa/ld/ldsctech.htm
[79] CIAA (2009) - Data and Trends.
See: http://www.ciaa.be/documents/brochures/ciaa-data%20trend-updated.pdf
Despite an increase of 20% in R&D between 1997 and 2001, the EU food industry spents only 0.24% of output in 2001, which is far behind its main competitors (on average 0.35%). A particular concern remains the limited technology transfer from science to enterprises. A better structuring of public research programmes and investments will leverage private investments.
[80] DG Enterprise and Industry (2007) - Competitiveness of the European Food Industry: An economic and legal assessment. See: http://www.scribd.com/doc/29166288/Competitiveness-of-the-European-Food-Industry-An-economic-and-legal-assessment-2007
[81] CIAA (2008) - Managing environmental sustainability in the European Food & Drink industries.
See: http://www.ciaa.eu/documents/brochures/brochure_CIAA_envi2008.pdf

At EU level, food research is brought under the umbrella of "Fork to farm: food, health and well-being" within the Research Framework Programme 7. This activity covers topics such as nutrition, food processing, food quality and environmental impacts. These topics tackle some of our key societal challenges such as how to feed almost 9 billon people by 2050 and a population that is shifting its food preferences towards a greater consumption of meat.

Achievements in the food sector in terms of promoting research and market development for a knowledge-based economy are:

- Generating knowledge (launch of diversified research programmes, from basic to applied research, research infrastructures, training and support to SMEs)
- Reinforcing cooperation and better exploiting research results
- Boosting competitiveness through the active participation of relevant industrial partners in European technology platforms
- Integrating strategically focused, trans-national research that will deliver innovative processes, products and tools in line with the needs and expectations of the consumer.

3.4.2.2 The European Technology Platform "Food for Life"

The European Technology Platform (ETP) Food for Life was created in 2005[82] under the auspices of the Confederation of the Food and Drink Industries of the EU (CIAA). The aim was to strengthen the European-wide innovation process, improve knowledge transfer and stimulate European competitiveness across the food chain. The ETP "Food for Life" programme was aimed at providing infrastructures and at establishing and/or maintaining networks to effectively help creating research and innovation opportunities for the Food and Drink industry, with a particular focus on SMEs, academia, consumers and other interest groups within the food chain.

This initiative has created opportunities for partnerships amongst those involved using a variety of funding sources. SMEs have very little R&D capability of their own and seldom possess the financial and human resources needed to participate in collaborative projects with universities and other research centres. Transfer of research results and of innovative technologies to SMEs in a usable form is thus problematic and therefore represents a major challenge to be tackled in order to boost the competitiveness of SMEs. This ETP has delivered a vision and a targeted Strategic Research Agenda (SRA)[83] based on the clearly identified needs of consumers, 'from farm to fork'.

In the implementation of the ETP SRA[84], particular attention was devoted to the development of products, tools and services to boost research and innovation for the food sector in order to:

- Improve health, well-being and longevity,
- Build consumer trust in the food chain,
- Support sustainable and ethical production.

Each of these objectives has responded to consumer concerns and interests, stimulated competitiveness, job creation and economic growth, helped deal proactively with the need to enhance sustainability and has underpinned the requirements of regulatory authorities and national and European policymakers.

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[82] ETP Food for Life (2005) - Vision Document. See:
http://etp.ciaa.be/documents/BAT%20Brochure%20ETP.pdf

[83] ETP Food for Life (2007) - Strategic Research Agenda 2007-2020 and NTPs (National Technology Platforms) SRAs/
See: http://etp.ciaa.be/asp/documents/docs.asp?cat=Documents

[84] ETP Food for Life (2008) - Implementation Action Plan.
See: http://etp.ciaa.be/documents/Broch%20ETP_IAPlan_1.pdf

3.4.2.3 *The network of National "Food for Life" Technology Platforms*

Through its extensive consultation process with influential industrialists, key research workers throughout Europe, representatives of consumer organisations and the national public bodies that support research, the ETP also influences the future direction of national research activities. Since national branching is considered one of the major success factors for Food for Life, the platform has encouraged and supported the establishment and the related work of national platforms. Since 2006, 36 National Technology Platforms (NTPs)[85] have been established under the umbrella of the ETP Food for Life.

The ETP Food for Life supports this network of NTPs as a useful tool in communicating and addressing the needs and opportunities of the Platform across Europe. The NTPs will contribute to the content of the Implementation Plan via data collection of national research priorities and funding possibilities.

The National Food Platforms, have a key role to play in conveying the programme of the ETP to the national industry, especially to SMEs, the research community and to the other stakeholders in the national language(s). The main task is to strengthen and develop further the networking activities of the national food platforms and to exploit the potential for their collaboration.

They are also important for dissemination, information gathering, training, technology transfer and fostering innovation, and in collecting national feedback to ETP proposals and inputting into position papers. Their collaboration and networking activity contributes significantly to:

- the exchange of expertise,
- the collation of best practices,
- ensuring that a joint, coherent research programme on food is realised in each country, and
- ensuring that their programmes are harmonized with the programmes of other European countries.

3.4.2.4 *Success Story : Belgian Technology Platforms "Food for Life"*

- ***Flanders' FOOD, the Flemish NTP***[86]

  Flanders' FOOD is an initiative of the food industry and was approved by the Flemish Government in 2005. Flanders' FOOD supports companies in strengthening their competitive position through innovation. This is a critical feature in enabling successful development and continuous economical growth. Flanders' FOOD is the link between companies from the food industry and related sectors on the one hand, and research centres on the other. The central theme is "*Food of tomorrow: full of quality, balanced and tasty*", and is focusing on health, ingredients, sensory benefits, trends, food quality and preservation, food safety, technology and packaging. By the end of 2009, 215 food companies and 27 research groups were member of Flanders' FOOD.

  This regional platform initiates and financially supports research projects. Between 2006 and 2009, 12 research projects with 129 food companies were carried out. In 2010, 10 new collaborative research projects were initiated with 73 food companies participating in these. In addition to research projects, Flanders' FOOD offers food companies scientific and technological advice, seminars, training and workshops.

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[85] Overview of national "Food for Life" Technology Platforms.
See: http://etp.ciaa.eu/asp/nftp/index.asp?doc_id=615
[86] www.flandersfood.com

- ***WagrALIM, the Wallonian NTP***[87]

  Since its creation in 2006, WagrALIM has gathered together 80 companies, 37 scientific groups and several training organizations and institutional partners in Wallonia. WagrALIM launched five project calls, which led to 14 Research and Innovation projects and 8 Training projects. Most of the projects are still running. The total budget for these 22 projects is over 62 million Euro, and 50 companies including 29 SMEs are involved. From these results, many practical results are potentially exploitable, including antioxidant organic chocolates, a prototype of biodegradable packaging, an assortment of food products naturally enriched in Omega-3 and healthy pork meat products. In order to commercialize the results, WagrALIM yearly participates in several international actions in Europe and globally including with Brazil, Canada and the USA.

  A second mandate was attributed to WagrALIM for 2010-2013. The Cluster identified four strategic areas dedicated to healthy food and nutritional quality, industrial efficiency, food packaging and development of sustainable food chains.

3.4.2.5 Optimising skills

A successful food market requires the interplay of a wide range of skills. An understanding of consumer and behavioral science[88], nutrition, food safety issues, information technology, food processing technologies and management of the food chain all underpin the success of an enterprise. Where such a wider range of skills cannot be employed within an enterprise, easy access to these is needed, and could be satisfied through, for example, regional centres of technology transfer who can deliver them. Many research centres in Europe that focus on the food sector are also unable to offer such a wide-ranging input of skills to their industries or are not closely enough aligned with their server communities. In this regard, a new professional figure, known as **techno-scientific mediator or TSM**, has recently been engaged to facilitate successful technology transfer in the food sector of certain European countries[89].

3.4.2.6 The open innovation model

Most Member States face challenges in ensuring that research investment is determined by:

- Scientific developments,
- Recognition of the market needs,
- Focus on the export opportunities for potential products,
- Greater integration with neighbouring Member States or those with similar markets.

The model for engaging the production and research sectors, which has been adopted by some of the Northern European countries, requires analysis together with its potential applicability to other countries. In order to reach "OPEN INNOVATION" status a new paradigm involving a wide range of actors, including firms, universities, research and public or private technology organizations (RTOs), consultants and suppliers must be developed[90].

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[87] www.wagralim.be

[88] Social Science Research Unit of the Food Standards Agency (2009) - An Evidence Review of Public Attitudes to Emerging Food Technologies.
See: http://www.food.gov.uk/multimedia/pdfs/emergingfoodtech.pdf

[89] TRUEFOOD Traditional United Europe Food project (2009) - Guideline on effective knowledge and technology transfer activities to SMEs in the food sector with particular focus on traditional food manufacturers . See: www.truefood.eu

[90] Report of an Expert Group to the European Commission (2009) - The role of community research policy in the Knowledge-based economy.
See: ec.europa.eu/research/era/pdf/community_research_policy_role.pdf

3.4.3 EU policies

3.4.3.1 European Food Sustainable Consumption and Production (SCP) Round Table Initiative

In order to sustain its vital contribution to societal well being, the food and drink sector, depends heavily on maintaining a healthy eco-systems in which its raw materials are grown. The sector is particularly vulnerable to the negative impacts of climate change on the availability of agricultural raw materials, both in terms of quality and quantity.

Actors within the food supply chain are already united together under the European Food Sustainable Consumption and Production (SCP) Round Table initiative in order to face current and future sustainability challenges. The Round Table is a multi-stakeholder forum comprised of 23 European food chain organisations, co-chaired by the European Commission, which aims to

- Establish common principles and methodologies for the environmental assessment of food and drink products,
- Identify suitable communication tools to consumers,
- Promote continuous environmental improvement initiatives along the whole food chain.

3.4.3.2 The High Level Group for the Competitiveness of the Agro-Food Industry

High Level Group (HLG) on the Competitiveness of the Agro-Food Industry[91] was set up by Commission Decision (2008/359/EC) and was officially launched in 2008 by Vice-President Verheugen. The formal objective of the exercise was to identify the factors, future challenges and trends that influence the competitive position of the European Agro-Food Industry. In addition, the group aims to formulate recommendations for actions over the short, medium and long term in public policy and the regulatory framework which would enhance the sustainable development and competitive position of the sector.

HLG members sought to establish an integrated approach to their task that would encompass all relevant existing policy areas with influence on either the supply or demand side of the industry (from farm to fork). This approach aims to ensure coherence among the different policy objectives and to increase the efficiency and consistency of agreed measures. The recommendations and the action plan adopted in 2009 by the High Level Group for the Competitiveness of the Agro-Food Industry provides a sound basis for an integrated policy that will allow sustainable growth for the sector.

In this respect, the following areas of interest were addressed during the HLG discussions:

- **Agricultural and Environmental Policy**
  The Common Agricultural Policy or CAP has shifted to a more market-oriented system where financial support to farmers is decoupled or partly decoupled from production. As a result this is now conditioned on producers' respect of food safety, environmental protection, plant health, animal health and welfare standards as well as on the requirement to keep all farmland in good agricultural and environmental condition. Moreover, access to raw materials at competitive prices is vital for the European food industry in order to provide foodstuffs at affordable prices to consumers.

  As a consequence, the HLG members[92] acknowledge that the entire supply chain is more capable of adapting to the challenges of globalization and international competition. Nevertheless, taking into consideration the recent price fluctuations of raw materials in addition to the fact that the ratio between current European prices for

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[91] End report of the High Level Group for the Agro-Food Industry (2009). See: http://ec.europa.eu/enterprise/newsroom/cf/document.cfm?action=display&doc_id=2604&userservice_id=1

[92] End report of the High Level Group for the Agro-Food Industry (2009). See: http://ec.europa.eu/enterprise/newsroom/cf/document.cfm?action=display&doc_id=2604&userservice_id=1

agricultural products and world prices varies greatly per product, they believe that further improvements are necessary to enhance the long-term competitiveness of the European food industry.

With regards to environmental policy, three elements can be identified in the food chain context:

- The need to ensure adequate supplies of food for human requirements.
- The need to ensure that human activities in the food processing industry and in the primary sector are consistent with the requirement of protecting the environment.
- The need to maintain a vibrant economy and more employment designed to give a good standard of living and working conditions, notably by facilitating the generation of added value through economic activity.

- **Internal Market for Food**
  The high level of consumer protection guaranteed by compliance with EU food law may well contribute to the reputation of EU food products both on the EU and on the world market, and thus directly supports the market position of the European food industry. However, improvements could be achieved with regard to administrative burdens and lengthy authorisation procedures. This is particularly relevant for SMEs. In the framework of legislation affecting food and/or food supply chain, it is of great importance to combine a high level of consumer protection with a high level of competitiveness in the Agro-food industry. In order to identify opportunities for EU legislators to create a science-based, proportionate regulatory environment and to reduce regulatory burdens in order to achieve a high level of competitiveness in the EU, the HLG made recommendations in the following areas of interest:
    - Impact Assessment
    - Enforcement of Legislation
    - Pre-market authorisation of innovative products linked to the applicant
    - Incident Management

- **Operation of the Food Chain**
  There is a general agreement among the HLG Members that reducing the administrative burden can play a crucial role in enhancing the competitiveness of the food supply chain. Furthermore, they recognize that further efforts need to be made to improve the productivity and efficiency of the various actors at all stages of production as well as the linkages with the consumer. In particular they have focused on the following areas considered of particular importance for the European food industry:
    - Small and medium sized enterprises (including access to funding)
    - Relationships along the food chain
    - Consumer Issues
    - Workforce and Skills
    - Business Services to the food chain.

  In addition, the Commission highlighted the other important reforms in the EU Better Regulation agenda aimed at improving the quality of legislation. These include measures aimed at improved impact assessment, wider stakeholder consultation and simplification of existing measures.

- **Research and Innovation**
  Research and Development (R&D) are among the main engines of innovation, productivity growth and structural change and hence are essential to guarantee continued competitiveness of the European food industry[93]. Access to funding is closely intertwined with the success and continuity of the research and development efforts, as well as the innovative performance of the food industry. In this respect, a major tool currently available for the stakeholders is the 7th Framework Programme for Research and Technological Development for 2007–2013. The administrative procedures required for participation in the funding programs, as well as instruments

[93] DG Enterprise and Industry (20074) - Competitiveness of the European Food Industry: An economic and legal assessment.
See: http://www.scribd.com/doc/29166288/Competitiveness-of-the-European-Food-Industry-An-economic-and-legal-assessment-2007

used to support the operation of the SMEs should be simplified and better communicated specifically to agri-food SMEs. Furthermore the ETP Platform Food for Life was highlighted during the HLG discussions as having major importance for the agri-food industry in better aligning EU research priorities to industry's needs through public-private partnerships.

- **Trade and Exports**
  Supply chains are becoming increasingly global and consequently, progressively opening trade can lead to significant increases in growth and productivity for the sector. On the other hand, as the EU market is mature, the growth in domestic consumption is lower than in the past. Consequently, the development of European Agr-food companies becomes more and more dependent on the external dimension and access to foreign markets both for exporting and importing goods. To this end, EU trade and commercial policy is vital for them to achieve sustainable development and to operate under fair trade conditions. Multilateral and bilataral agreements and export promotion schemes as well as promotion and enhancement of measures to fight against counterfeit were all identified as actions which could lead to benefits for parts of the European agri-food industry.

3.5 Innovative bio-based products

3.5.1 *The development of a bio-based economy*[94]

Europe has become the leading region for the development and production of **enzymes**. Around 64% of all enzyme companies are located in the EU, and the main enzyme producers by volume are in Denmark, where Danish companies account for almost half of worldwide enzyme production. Because enzymes play a crucial role for applications in many other industrial sectors, this sector represents significant potential for the EU in terms of escalating global leadership in the area of biobased products and processes.

In the United States however, the **biofuels** industry (mainly bioethanol) has expanded rapidly since 2005, largely because of mandatory use regulations and tax incentives implemented by federal and state legislation.

Another established sector is the production of **biochemicals**, such as amino acids, lipids, organic acids, vitamins, etc., which find applications in the pharmaceutical industry, the food and feed industry, the production of detergents and cosmetics, and many other sectors.

In the chemical industry, an important step in increasing the share of biobased chemicals is the creation of **biotechnological platform intermediates** based on the use of renewable carbon sources. In this way, renewable feedstock can be transformed into a similar portfolio of end-products (organic chemicals) produced today from fossil fuel. Examples of such bio-based platform chemicals are fumaric, malic, succinic and itaconic acid which are currently used as food acidulants and in the manufacturing of some polyesters, and which can find new application as building blocks for the synthesis of new polymers and biodegradable plastics.

Although **bio-based polymers** and plastics are still in their infancy, this industry has been characterised by an annual grow rate of almost 50% due to new synergies and collaborations. The global capacity of bio-based polymers was estimated to be 0.36 billion tones in 2007, with an annual growth rate of 48% in Europe and 38% globally, and its market share is expected to be 10-20% by 2020. Figure 8 gives an overview of the development stage of bio-based polymers. Today we see also the results of the recent

[94] Based on:
- JRC (2007) - Consequences, Opportunities and Challenges of Modern Biotechnology for Europe.
- M. Kircher (2010) - Trends in Technology and Applications. Discussion paper at the OECD workshop: Outlook for Industrial Biotechnology (Vienna 13-15 January 2010)

developments of new processes combining biotechnology and chemical synthesis, such as the production of ethylene from bio-ethanol.

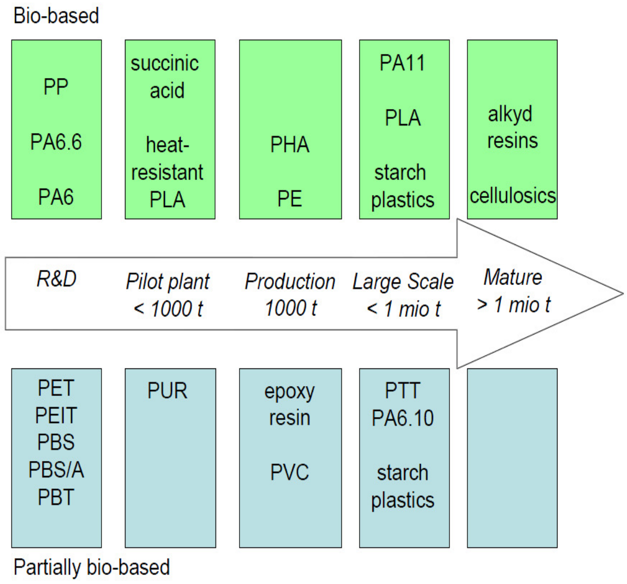

Figure 8: Development stage of bio-based polymers[95]

3.5.2 Research and innovation

3.5.2.1 Research at EU level

Since 2004, several KBBE related Technology Platforms were set up (see also 3.1) and have developed their Strategic Research Agenda (SRA), giving recommendations on priority R&D topics to be pursued to support the long-term development of their respective sectors. The implementation of the SRAs started at the EU level with the 7th Framework Programme and in the Member States and associated countries via their national research programmes where some of them integrated in ERA-nets. The development of the KBBE as a concept and the creation of the KBBE-net by the European Commission helped to significantly stimulate awareness at an EU and Member State level.

3.5.2.2 Research at member state and regional level

Specific public research funding for bio-based products is very limited in the EU Member States. Only a few countries are running dedicated research programmes, mainly in the area of industrial biotechnology. Some are funded via general research programmes or supported via parallel programmes (such as energy, agriculture, etc.)[96]. In addition, several European Technology Platforms have developed a database monitoring the implementation of their Strategic Research Agenda. Examples are the Forest-based Sector ETP[97] and the Biofuels ETP[98].

3.5.2.3 The biorefinery model

Biorefineries are similar to petroleum refineries in concept. However, biorefineries use biological matter (as opposed to petroleum or other fossil sources) to produce

[95] Source: Shen L., Haue J., Patel M (2009) - Product overview and market projection of emerging bio-based plastics. European Polysaccharide Network of Excellence and European Bioplastics. Utrecht, The Netherlands
[96] See member state reports at www.bio-economy.net
[97] http://www.forestplatform.org/
[98] http://www.biofuelstp.eu/

transportation fuels, chemicals, and heat and power. An integrated and diversified bio-refinery is a systems concept of a processing plant where renewable feedstocks are converted into a wide range of valuable products. Because they combine and integrate the technologies necessary to convert renewable raw materials into industrial intermediates and final products, they can straddle the whole value chain.

The European Commission has funded several Coordination and Support Action (CSA) projects under FP6 and FP7 analysing the biorefinery research situation in the European Union:

- **Biorefinery Euroview**[99] (FP6): the aim of this project was to prepare for future EU research and technological development activities, including monitoring, assessment activities in the field of biorefineries, and the implications for agriculture and forestry policy.

- **BIOPOL** [100] (FP6) the objective was to assess the status (technical, social, environmental, political, and implementation) of innovative biorefinery concepts and the implications for agricultural and forestry policy.

- **SUSTOIL**[101] (FP7): aiming to develop advanced biorefinery schemes to convert whole European oil-rich crops into energy, food and bio-products making optimal uses of the side streams generated during farming/harvesting, primary processing and secondary processing.

- **BIOREF-INTEG** [102] (FP7): the aim of this project is to develop advanced biorefinery schemes to be integrated into existing industrial fuel processing complexes.

In a recent joint call (FP7) on biorefineries, the Commission is funding a specific support action on biorefineries, the **Star-COLIBRI[103]** project (Strategic Research Targets for 2020 – Collaboration Initiative on Biorefineries). This project involves 5 European Technology Platforms and 5 major European Research organisations. Star-COLIBRI aims at overcoming fragmentation and promoting cross-fertilisation in the area of biorefineries research. The project will support innovation by speeding up and facilitating industrial exploitation of research results in the biorefinery field, as well as by promoting coordination in the field of future R&D funding and facilitating the creation of Public-Private Partnerships.

Beginning of 2010, the European Commission also launched several projects under FP7 on the development of new ways to convert biological feedstock into energy and valuable material using biorefinery technology. The Commission will fund the programmes with 52 million Euro for 4 years. 81 partners from universities, research institutes and industry in 20 countries will invest an additional € 28 million. Three large collaborative projects will address the entire value chain from the production of biomass, logistics, intermediary processing steps and its conversion into end-products with the feasibility of techniques shown at pilot scale:

- **BIOCORE[104]** (Biocommodity Refinery) is a 20,28 million Euro project with the aim to create and demonstrate a lignocellulosic biorefinery for sustainable processing of agricultural residues (wheat and rice straws), wood (poplar) and hardwood forestry residues, into second generation biofuels, bulk chemicals, polymers, speciality molecules, heat and power.

- The **EuroBioRef**[105] project (European Multilevel Integrated Biorefinery Design for Sustainable Biomass Processing) is a 37 million Euro project developing a new highly integrated and diversified concept including multiple feedstocks (nonedible), multiple processes (chemical, biochemical, thermochemical), and multiple products

[99] http://www.biorefinery-euroview.eu
[100] http://www.biorefinery.nl/biopol/
[101] http://www.sustoil.org/
[102] http://www.bioref-integ.eu/
[103] http://www.star-colibri.eu/
[104] http://www.biocore-europe.org/
[105] http://www.eurobioref.org/

(aviation fuels and chemicals). The project has a specific aim to overcome the fragmentation in the biomass industry. As efficiency is the key to the bio-refinery processes, this implies taking decisive actions to facilitate better networking, coordination and cooperation among a wide variety of actors.

- **SUPRABIO** (Sustainable Products from Economic Processing of Biomass in Highly Integrated Biorefineries) is a 19 million Euro project focusing on innovative research and development of critical unit operations, by using process intensification to match economic production to the scale of available feedstock and by process integration that provides energy from process waste, optimizes utilities to minimize environmental impact and maximizes value from the product mix.

Finally the European Commission is also financing several COST actions, such as COST Action FP0602 - Biotechnology for lignocellulose biorefineries (BIOBIO)[106]

At member state level, we see an increasing number of biorefinery oriented research programmes. A few examples are:

- In **Finland**, the BioRefine 2007-2012 programme of TEKES[107] which has allocated 137 million Euro to the development of innovative technologies, products and services based on national strengths and related to biorefineries and the processing of biomass in general for the international market. It also promotes the development and use of second-generation production technology in biofuels for transport.

- In **Sweden**, Vinnova[108] (The Swedish Governmental Agency for Innovation Systems) in June 2008 granted SEK 13 million (around 1,2 million Euro) to a project called "The biorefinery of the future[109]" .

- In the **UK**, the "Integrated Biorefining Research and Technology Club[110] (IBTI Club)" was launched in 2009. This group consists of a research and technology partnership involving the Biotechnology and Biological Sciences Research Council, the Engineering and Physical Sciences Research Council, industry and the Bioscience for Business Knowledge Transfer Network (KTN). The club will interface with the KTN's wider Integrated Biorefinery Technologies Initiative (IBTI) and will invest around £6 million in industrially relevant, innovative, basic biological, chemical and engineering research in biorefining technologies.

A complete mapping of all biorefinery related research projects in Europe is done by the Star-Colibri consortium. The results are published on their Biorefinery Research Portal[111].
More than 300 research projects have been identified in Europe (EU, national and regional projects), with a total budget of around 1.2 billion Euro, of which more than 808 million Euro is public funding. Although France and Finland seem to have the highest number of biorefinery related research projects, the top 3 budgets come from France, Germany and The Netherlands.

International initiatives in which European organisations participate include the so-called Task Forces of the Bioenergy Agreement of the International Energy Agency (IEA), such as the IEA Bioenergy Task 42 on Biorefineries[112]. The participating parties and countries in this task force are: Austria, Canada, Denmark, France, Germany, Ireland and the Netherlands, plus the European Commission.

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[106] http://viikki.helsinki.fi/CostFP0602/
[107] TEKES – www.tekes.fi
[108] Vinnova - http://www.vinnova.se
[109] http://www.processum.se
[110] http://www.bbsrc.ac.uk/business/collaborative-research/industry-clubs/ibti/ibti-index.aspx
[111] www.star-colibri.net/wiki
[112] Biorefineries: Co-production of Fuels, Chemicals, Power and Materials from Biomass. See http://www.biorefinery.nl/ieabioenergy-task42

3.5.2.4 The growing importance of clusters and public-private partnerships

Because of the high R&D investments needed to develop an innovative bio-based product, we see a growing number of public-private partnerships developing. There is a clear need for a coordinated technology development covering different technologies and parts of the value chain (feedstock development, product development, production optimization, innovative application development). Cooperation in cluster structures rather than in single-company partnerships is significantly accelerating the development of processes and their penetration into the industry. Figure 9 shows an schematic example for the bio-based products sector.

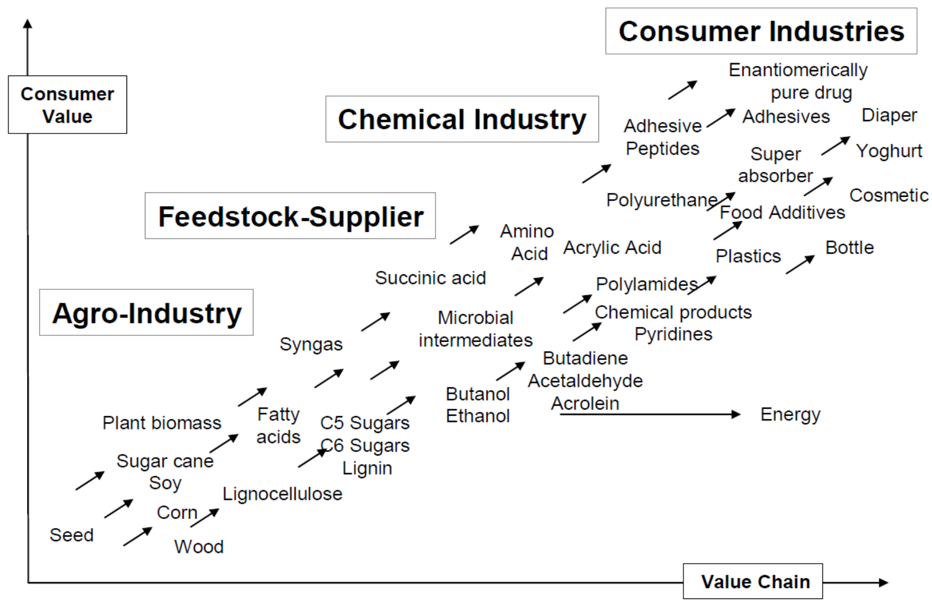

Figure 9: Production-oriented value chain (CLIB2021)

Some examples:

- In 2010 in the Netherlands, knowledge institutes, the Dutch government and industry decided to cooperate more intensively and at international level to speed up the introduction of the bio-based economy via the **BE-BASIC** consortium[113] (Bio-Based Ecologically Balanced Sustainable Industrial Chemistry), by placing the emphasis on scale-up research, an open innovation model and a proactive role for the financial sector. This initiative includes a R&D budget exceeding 120 million Euro, of which 60 million is made available by the Dutch Ministries of Finance and Economic Affairs. BE-Basic also plans a multi-purpose facility for scale-up research.

- A different model is represented by **CLIB2021**[114] in Germany. This cluster has been initiated by the German Federal Ministry of Education and Research. It started in 2007 with 32 founding members. Since then the cluster grew to include up to 70 academic institutes, companies and investors, launched R&D projects with a total volume of 50 billion Euro, founded 5 start-ups and attracted 10% of its international members in Europe, North-America and Russia. CLIB's main task is initiating and coordinating academic and industrial R&D in industrial biotechnology for the chemical industry.

[113] http://www.be-basic.org
[114] http://www.clib2021.com

- **BioHub**[115] is a cereal-based biorefinery in Lestrem, France targeting on platform-chemicals like succinate and isosorbide. Partners include Roquette, DSM and the University of Georgia (USA) amongst others. The project is funded by the French Industrial Innovation Agency. The isosorbide demonstration plant has been launched in July 2009.

3.5.2.5 Pilots and demonstrators

As a first step toward commercial bio-refineries, pilot plants and demonstration activities can close the critical gap between scientific feasibility and industrial application. The future competitiveness of cellulosic biorefineries for biofuels and biochemicals depends on solving difficult technical and organizational challenges. A biorefinery needs to flexibly use different biomass feedstocks and to produce different products. Similarly, efficient production of biofuels or other products from micro-organisms or algae requires solutions to the scaling up of production.

An overview of the existing pilot and demonstration facilities[116] in Europe has been prepared by EuropaBio, as part of the SusChem ETP (industrial biotechnology section), and the IEA Bioenergy Task 39[117] has recently collected data on 2nd generation biofuels pilot and demonstration facilities. Some recent examples from the EU include:

- **Bio Base Europe**[118], a joint initiative by Europe, Belgium and the Netherlands which is currently building research and training facilities for the bio-based economy in Ghent (Belgium) with an overall budget of 21 million Euro. The flexible and diversified pilot plant, capable of scaling up and then optimising a broad variety of biobased processes up to the 10 m^3 pilot scale, is a one-stop-shop that can perform the entire value chain in a single plant, from the green resources up to the final product.

- The so-called third generation or advanced biorefineries process uses multiple feedstocks to produce multiple products. The first advanced biorefinery demonstration plant in the world was commissioned recently in Oulu, Finland. The **Chempolis**[119] demonstration plant produces sample materials and production batches for further processing and refining. It is third-generation because it uses the entire vegetable matter to produce a number of biomass-based products and chemicals. In addition, it is used as a test plant for new materials and the final testing of new biorefined products.

3.5.2.6 A European action plan for Key Enabling Technologies

Towards the end of 2009, the European Commission published an action plan on **Key Enabling Technologies (KET)**[120], as part of the preparation for the new European plan for innovation. KETs are of systemic relevance as they enable the restructuring of industrial processes needed to modernise EU industry and secure the research, development and innovation base in Europe. Industrial biotechnology was one of the five technologies selected by the Commission. The purpose is to develop an action plan with measures to remove obstacles hindering further development and to fully exploit the results of research (such as demo projects and better coordination of the activities between EU and Member States for example through joint calls or joint programming).

[115] http://www.biohub.fr/
[116] www.bio-economy.net
[117] http://biofuels.abc-energy.at/demoplants/index.php
[118] http://www.biobaseeurope.eu
[119] http://www.chempolis.com
[120] COM(2009) 512/3 - Preparing for our future: Developing a common strategy for key enabling technologies in the EU

3.5.2.7 Supporting SMEs via the BIOCHEM initiative

SusChem's European Innovation project - BIOCHEM[121] - was selected at the beginning of 2010 for funding by the European Commission under its INNOVA scheme. INNOVA[122] is part of the Competitiveness and Innovation Programme (CIP) managed by DG Enterprise. The proposed total cost of the BIOCHEM project is 4.5 million Euro.

Initially, using its network of partners, BIOCHEM will define and promote bio-based product opportunities in the chemical sector. The project will also facilitate and help finance new bio-based business ideas to proof-of-concept, including facilitating access for organizations to European test facilities. The project will develop tools, methodologies and processes (such as innovation management, life cycle methodologies, business planning, fund raising etc.) that are targeted towards those SMEs who aspire to innovate in the bio-based products market. It will facilitate partnering of technology providers (from both industry and academia) with solution seekers, through new on-line open innovation support tools. In addition, it will build capacity with regional and national Innovation Management organisations and chemistry cluster organisations to improve innovation management with local SMEs.

A novel concept will be the market testing of a "federated" Bio-Based Products Investment Fund (BBP-IF) to involve at least five regional funding agencies, business angels and early-stage funders in different European countries. This should improve access to capital and provide support to early stage ventures and accelerate their international growth.

3.5.3 Regulations and policies as drivers for innovation

3.5.3.1 Bioenergy

Specific policies for the development of biobased products are more extensive for bioenergy (including liquid biofuel use and solid biomass applications) than for biochemicals or biomaterials. Worldwide, many governments support their emerging biofuel industries far more than other KBBE sectors via subsidies, mandates, adjustments to fuel taxes and incentives for the use of flexi-fuel vehicles.

In Europe, the first so-called biofuel directive[123] aimed for a 2% share of renewables by the end of 2005 and a 5.75% share by the end of 2010, and a second directive[124] declared that biofuels are exempt from tax on mineral oil products. The Renewable Energy Directive[125] of 2009 is calling for a mandatory target of a 20% share of renewable energies in the EU's energy mix by 2020, and by the same date each Member State must ensure that 10% of total terrestrial transport such as road transport and train fuel comes from 'renewable energy', defined to include biofuels and biogas, as well as hydrogen and electricity. In addition, to stimulate the use of the so-called second generation biofuels, biofuels from waste, residues, non food cellulosic material, and lignocellulosic material will count twice towards achieving the renewable energy transport target. Biofuels produced on degraded lands, believed to reduce pressure on natural ecosystems, are also incentivised. The overall 20% renewable energy target to be achieved by 2020 will require a rapid deployment of solid biomass applications for heat and electricity.

In the US, The Energy Policy Act of 2005[126] established the first-ever Renewable Fuels Standard (RFS) in federal law, requiring increasing volumes of ethanol and biodiesel to be blended with the U.S. fuel supply between 2006 and 2012. The Energy Independence and Security Act of 2007[127] amended and increased the RFS, requiring 9 billion gallons of

[121] http://www.biochem-project.eu
[122] http://www.europe-innova.eu
[123] Directive 2003/30/EC
[124] Directive 2003/96/EC
[125] Directive 2009/28/EC
[126] http://www.gpo.gov/fdsys/pkg/PLAW-109publ58/pdf/PLAW-109publ58.pdf
[127] http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_bills&docid=f:h6enr.txt.pdf

renewable fuel use in 2008, stepping up to 36 billion gallons by 2022. The numbers of liquid biofuel producers and establishments more than doubled between 2004 and 2007[128].

3.5.3.2 Bio-based products

In the case of bio-based products, research and innovation have reached a stage where products are ready for market introduction, but renewable raw materials are only used in certain product categories. Although Europe plays a leading role in research and science, it is less successful in converting the science-based findings into commercially valuable products. At the same time, markets have long been recognised as important drivers of innovation and, more recently, as a target for innovation policy. This is why the Commission has developed a so-called demand-based innovation policy. The Lead Market Initiative[129] (known as LMI), adopted in December 2007 by the European Commission, aims at fostering the emergence of markets with potentially high economic and societal value. It has identified six lead market areas to serve as pilot markets for the approach and for the implementation of their action plans. The aim is to promote and stimulate innovation by strengthening the demand base which in turn should enable enterprises to gain a better return on their innovation efforts. The added-value of the LMI is about developing a prospective, concerted and tailored approach of regulatory and other policy instruments, including legislation, public procurement, standardisation, labelling, certification, and complementary instruments. One of the areas selected by the Commission is the area of the bio-based products (industrial and consumer products based on renewable, biological raw materials). This initiative excludes food, traditional paper and wood products and biomass as an energy source, but includes bio-plastics, bio-lubricants, surfactants, enzymes and pharmaceuticals.

An Ad-hoc Advisory group has developed a series of concrete recommendations and actions[130], ranging from improving the implementation of the present targets for bio-based products over standardisation, labelling and certification to ensure the quality and consumer information on the new products.

3.6 Sustainability aspects of the KBBE

In a recent report WWF claimed that industrial biotechnology and biobased products could save the planet between 1 billion and 2.5 billion tons of CO_2 emissions per year by 2030[131]. The report also highlighted that this will require land resources of between 47-223 million hectares.

Sustainability is not solely about greenhouse gas emissions reductions or climate change, as it also concerns waste reduction, minimizing energy consumption and efficient use of resources. In Europe it is an important driver for many of our policies, and several of the demand-side policies include sustainability aspects such as 'green' public procurement. An example is the European Renewable Energy Directive, and in particular the support for second generation biofuels, and the introduction of specific sustainability criteria for the use of biomass.

Because of the interdependencies between processes involved in growing, harvesting, manufacturing, distributing and disposing of a product, sustainability requires a life cycle analysis encompassing the whole value chain. This includes the production of biomass (e.g. land use, consumption of water, energy, pesticides and fertilizers), the processing of biomass, and the production and use of the final products. Some national and international efforts to develop more comprehensive, systems-oriented sustainability frameworks for bio-based products are currently under development[132].

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[128] USITC (2008) - Industrial Biotechnology: Development and Adoption by the U.S. Chemical and Biofuel Industries
[129] http://ec.europa.eu/enterprise/policies/innovation/policy/lead-market-initiative/
[130] EC (2009) - Taking bio-based from promise to market. measures to promote the market introduction of innovative bio-based products
[131] WWF (2009) - Industrial biotechnology: More than green fuel in a dirty economy?
[132] OECD (2010) - Towards the development of OECD best practices for assessing the sustainability of bio-based products. Workshop Report, Montréal, 23-24 July 2009

The KBBE certainly represents an important opportunity to deliver environmental, social and economic benefits. However there is growing amount of evidence about the potential risks associated with recent developments in the field. This is especially important because in most of the cases the demand for the products we are aiming to deliver is growing rapidly. As a result the demand for land, water and other resources needed to produce the feedstocks is also increasing. According to WWF's Living Planet Report [133], current consumption patterns exceed the planet's regenerative capacity by approximately 30%. This indicator is closely linked with another indicator related to biodiversity loss. The Living Planet Indicator has declined by nearly 30% in the last 35 years.

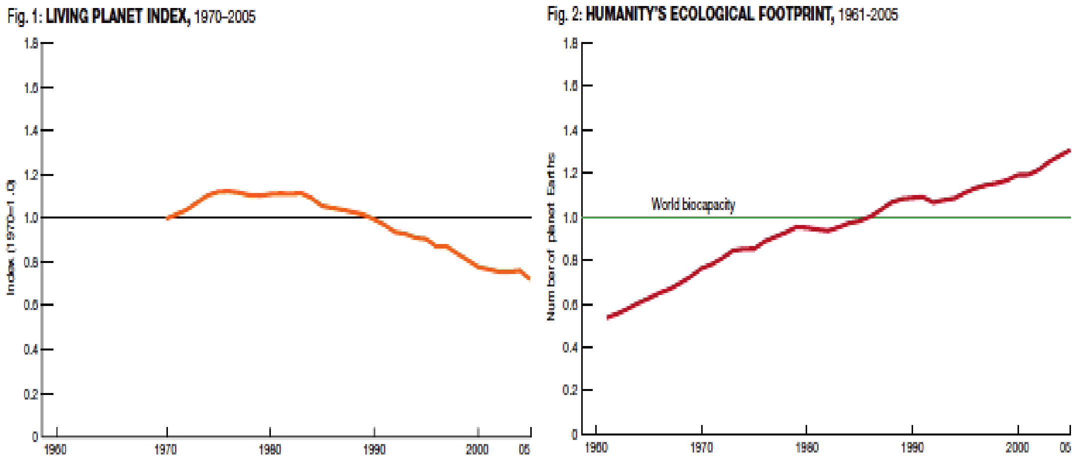

Figure 10: Trends of the Living Planet Index and the Humanity's Ecological Footprint[134]

In the EU alone, the current 10% renewable energy target in the transport sector will likely require (under optimistic yield scenarios) approximately 12 million hectares of additional land, and the US bioethanol mandate will probably double the land requirements. It is safe to assume that existing, global biofuel mandates will require at least 50 million hectares of land by 2020 [135]. By 2020 biofuels will provide less than 5% of global liquid fuel consumption, yet this will require approximately 3% of the agricultural land used at the moment.

While land availability is the risk mentioned most frequently, freshwater resources will probably be a much bigger limitative factor. A significant share of the freshwater used for irrigation at the moment is wasted and improvements in management practices could free up some capacity in use at the moment. Developing technologies requiring less water will also help.

In this context the sustainability of bioenergy, especially liquid biofuel requirements outlined in the European Renewable Energy Directive (RED) are an interesting case study. While the main framework is the RED, additional legislation will have to be considered. For example, the EU has recently agreed to outlaw illegal timber for the common market. It is estimated that a significant share of the wood products in the EU come from illegal sources. Once the legislation is implemented, operators will have to ensure that wood products come from legal sources. This will have an influence on the bioenergy sector, given that more than 60% of the renewable energy produced in the EU is wood based. Unfortunately the EU did not introduce legally binding sustainability requirements specifically for biomass used in heat and electricity production (as it did for liquid biofuels).

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[133] WWF (2010) – Living Planet Report (to be published).
See http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/
[134] Source : WWF (2008) – Living Planet Report
[135] Ecofys (2010) – (to be published)

The implementation of the RED has opened up new opportunities in delivering responsibly produced products to European customers. The legislation will recognise private initiatives, labels and standards of proof of compliance with legally binding requirements. Private initiatives with broad stakeholder support will be undoubtedly in a good position to deliver products with a lower ecological footprint. Certification schemes such as the Roundtable on Sustainable Biofuels (RSB)[136], Better Sugarcane Initiative (BSI)[137] and the Forest Stewardship Council (FSC)[138] etc. are supported by leading NGOs and industry. There is also a growing amount of evidence about the benefits of these initiatives for biodiversity, producers and consumers[139]. Additionally, several governmental lead processes aim to develop ambitious frameworks to ensure that commodities are produced using best management practices.

While it is premature to judge the efficacy of the sustainability requirements outlined in the European Renewable Energy Directive these are undoubtedly a step in the right direction. Hopefully they will also lead to greater consideration of our impacts arising from other end uses. Less than 5% of the palm oil imported to the EU is used in the energy sector. More than 90% is used for food (not always essential food) and cosmetics. There are no substantial arguments why the EU should have differentiated sustainability requirements for various end-uses. A spillover effect is expected in other sectors too.

[136] http://cgse.epfl.ch/page65660.html
[137] http://www.bettersugarcane.org/
[138] http://www.fsc.org/
[139] See: http://www.whyfsc.com/index1.asp?menu=4&sub=104

4 THE KBBE TOWARDS 2020: MAIN CHALLENGES AND NEEDS

4.1 Towards an more integrated approach of the KBBE in 2020

Over the next 10 years we can expect a shift in practice from a sectoral approach towards a more integrated approach of the KBBE. For example, a long-term increase in the cost of fossil fuels resulting from a decline in the supply of low-cost sources of petroleum coupled with an increase in demand for energy, and restrictions on the production of greenhouse gases (GHGs) could create a growing market for biomass, including non-food crops such as grasses and trees, as a feedstock for biofuels, chemicals and plastics. Other potentially innovative applications include the use of plants to produce valuable chemicals such as biopharmaceuticals and the production of nutraceuticals from plant and animal sources. All of these trends are likely to increase investment in agricultural technologies.

4.2 Sustainable feedstock production for food and non-food

In case of a sustainable feedstock production for food and non-food significant challenges remain to be solved for the future. In Europe in particular there needs to be a concise strategy to satisfy the demands of a range of stakeholders for the use for food, feed, fuel and materials. On this basis "food versus non-food" debates and the biomass competition between energy and material still needs to be resolved (see below).

Other challenges concerning the feedstock needed for different applications involve similar barriers to those set out in the section on KBBE (see 2.3). These largely address the growing demands for food, fuels and materials in the context of an expanding worldwide human population as well as the adaptation and optimisation of existing feedstocks for the given land that can be used for agriculture. In this field in particular the use of advanced breeding technologies and green biotechnology should be discussed and evaluated in the context of new challenges concerning global warming, pressure of natural resources and sustainable agriculture.

4.2.1 *Food versus Non-Food - Only Non-Food crops for industrial use?*

There is a wide consensus that food crops should only be used for food and feed and NOT for industrial use. This discussion first gained attention in 2008 during a supposed worldwide food crisis. The quick and simple conclusion that was reached was that only non-food crops should be used for industrial use.

However, even the question of food versus non-food crops for industry is itself misleading and a more thorough and in depth discussion is needed on the question of feedstock. Indeed, it will be a key question in establishing a bio-based economy. When considering the question of feedstock:

- Firstly: a country or a region should calculate which areas are needed for the domestic demand for food and feed.
- Secondly: it should determine which areas are needed to produce food and feed for export market. With an increasing world population the demand for food and feed will increase and therefore this too needs to be considered.

If there are agricultural areas left, which are not necessary for food and feed production to satisfy domestic and worldwide demand, this area can then be used for industrial material use of renewable raw material (RRM) or energy crops without any impact on the food market. Whether farmers grow food or non-food crops on this free areas will therefore have no impact on the food supply. The real question is: how can we use these free areas for industry with the highest resource efficiency and the highest climate protection. In many cases food crops will best fulfill these criteria, precisely because they have been breaded to produce maximum yield over many, many years. By contrast, a less optimised non-food crop will use more area, being less efficient.

Therefore, a new discussion is needed on feedstock for industrial material use of RRM and bioenergy which better evaluates resource and area efficiency and climate protection. Food versus non-food crops is in this way an oversimplified as well as a misleading question and when this alone is taken into consideration it can lead to misallocation of agriculture resources. We therefore need a comprehensive concept for feedstock for food, feed, industrial material use of RRM and bio-energy.

4.2.2 Competition biomass for energy versus industrial material use

The sector of industrial material use of renewable raw material (RRM) is - including wood - still bigger than the bio-energy sector. Already today we see competition between both sectors in Europe as more and more wood is directly used for granted energy use. This involves not only by-products of wood but also higher-quality wood which is also in demand by the furniture industry. Wood prices are increasing and, according to a range of studies. a shortage in supply for the particle board and OSB (Oriented strand board) industry is expected in Europe until 2020.

In agriculture the situation is similar. High subsidies for energy crops lead to high land prices which make industrial material use unattractive. In order to implement and establish a high-volume bio-based economy, including green chemistry, bio-based plastics, composites, lubricants and others, we will immediately encounter feedstock shortages. Therefore, a new balance is needed between the financial support of bioenergy and industrial material use of RRM. In the case of RRM its use mainly for the energy sector would represent a serious misallocation of resources. Indeed, its use in green chemistry and green materials is saving more CO_2/ha*y, is more resource efficient and leads to more employment than using the equivalent land area for the production of bioenergy[140]. Moreover after use the bio-based products produced from these processes can then be used for energy themselves resulting in multiple utilization or "cascading".

Renewable energy can also be produced by wind and solar energy with much greater efficiency. In order to produce the equivalent amount of energy 50-100 times more land would be needed for energy crops than for solar energy (and wind energy, which does not require significant land use). The reason for this is the low efficiency of photosynthesis in crops compared to the conversion power now available through technical photovoltaic methods.

Using more wind and solar energy instead of bioenergy will liberate huge tracts of land, which can then be used for the production of industrial material and also for food and feed.

Therefore, a new political-economic framework is needed to rebalance the financial support of energy and industrial material use of RRM in order to provide enough feedstock for the growing bio-based economy, green chemistry and bio-based plastics production. This new framework should be linked to the aims to the EU Commission and the Parliament including climate protection, resource efficiency, employment and innovation. This will automatically lead to a better support of the industrial material use or RRM.

4.2.3 Research, breeding technologies and green biotechnology

In 2009 the Royal Society published a document on the key worldwide challenge of food security in view of the food needs of the global population of 9 billion people by 2050. It stated that "this must must be done in the face of changing consumption patterns, the

[140] Carus M., Raschka A., Piotrowski S. et al. (2010) - The development of instruments to support the material use of renewable raw materials in Germany. Summary published in May 2010, whole study in press.

impacts of climate change and the growing scarcity of water and land". It went on to state that there is a "pressing need for the 'sustainable intensification' of global agriculture in which yields are increased without adverse environmental impact and without the cultivation of more land[141]." To reach this goal an increase in research, mainly in the fields of agricultural sciences including agronomy, soil sciences and agro-ecology, is needed and all technological approaches to breed new crop varieties as well as agro-ecological crop and soil management practices should be discussed. The claims are backed up by acclaimed agronomist Willy de Greef who states that today we are not including enough agronomic science in the debate on feedstock in the EU[142].

Advanced breeding technologies and green biotechnology may be an important factor for the optimization of biomass yields and crop features. Some technologies are judged to be more controversial than others or are, due to different interpretations, classified as more classical, more biotechnological or gene-technological. However, the perception and classification of this technology varies widely in various countries which in turn results in enormous differences on their applicability and marketability.

For example in Europe there is skepticism against biotechnology especially with regards to GM crops and genetic engineering in plants[143].

However, the technologies used today for conventional and advanced breeding are only a sample of those that can be used for the optimisation of raw materials according to the breeding goals to tackle the challenges of the future demands on agricultural feedstocks. What they can accomplish in detail and what advantages and disadvantages they have (such as potential for discharge to the environment), where there is competition or synergy, and what effect this has on the marketing of agricultural raw materials produced in this way, has not yet been fully investigated and should certainly form part of future research and discussions.

According to the Royal Society report no techniques and technologies should be ruled out in view of the challenges of food security[144]. The new Barroso II Commission, with its decision to authorize the cultivation of the genetically modified starch potato EH92-527-1, known as Amflora, for feed and industrial uses has indicated that genetically engineered crops with optimized characteristics can be part of the European crop and feedstock landscape[145]. For industry the first approval of a GM crop for cultivation in 12 years was seen as a welcome return to science-based decision making although many other GM products still await authorization and approval. However, opponents of GM crops and food saw the approval as a threat and the possible beginning of a flood of approvals of more transgenic varieties [146]. However, green biotechnology and other advanced technologies and new research are not only needed for yield increase. They are also an opportunity for the optimisation of feedstock qualities and crop management together with the deployment of existing best technologies[147].

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141 The Royal Society (2009) - Reaping the benefits – Science and the sustainable intensification of global agriculture. London, October 2009

142 Willy De Greef (2009) - Feedstock for the bio-based economy. Presentation at the "European Forum for Industrial Biotechnology 2009", Lissabon.

143 Based on:

- Juan Enriquez (2001) - Green biotechnology and European competitiveness. Trends in Biotechnology Vol.19 No.4, 135-139.
- Mark Cantley (2007) - An Overview of Regulatory Tools and Frameworks for Modern Biotechnology: A Focus on agro-Food. Report prepared for OECD Project on "The Bioeconomy to 2030: Designing a Policy Agenda".

144 The Royal Society (2009) - Reaping the benefits – Science and the sustainable intensification of global agriculture. London, October 2009.

145 European Commission (2010) - Commission Decision of 2 March 2010 authorising the placing on the market of feed produced from the genetically modified potato EH92- 527-1 (BPS-25271-9) and the adventitious or technically unavoidable presence of the potato in food and other feed products under Regulation (EC) No 1829/2003 of the European Parliament and of the Council. See: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:053:0015:0018:EN:PDF

146 Gerhart U. Ryffel (2010) - Making the most of GM potatoes. Nature Biotechnology 28 (4); p. 318.

147 Willy De Greef (2009) - Feedstock for the bio-based economy. Presentation at the "European Forum for Industrial Biotechnology 2009", Lissabon.

4.3 Livestock: from breeding to cloning?

4.3.1 Research and innovation

The animal populations which underpin much of Europe's agriculture and food production are all in the process of continuous change and adaptation. Breed and strain substitutions respond to changing market and production demands. Competitive breeds are subject to highly sophisticated and effective genetic selection and cross breeding programmes, while others are the object of conservation programmes. All of this dynamic change and adaptation is made possible by the continuous advance of a range of technologies in genetics and reproduction. New horizons in science are now presenting both opportunities and challenges for this sector.

The revolution in genomic studies has opened up the possibility of new levels of precision and effectiveness in selection programmes. The rapid reduction in the cost of applying these technologies will continue, and widespread use will follow. This will increase efficiency of selection and will push the levels of performance in animals to test new boundaries of physiological adaptation, with additional challenges on grounds of animal welfare and public acceptability.

Gene transfer (GM) between species has now been a reality in plant breeding and selection for two decades. It has been achieved technically in animal species as diverse as goats, pigs and fish. The debate on the public acceptability of these techniques in food animals has already begun in the United States, and is likely to be even more contentious in Europe. In parallel, the cloning of animals is also now technically feasible, though still far from commercially viable. Nevertheless, this technical advance is also likely to become a significant issue for public acceptability. The use of genetically modified bacteria to produce bovine somatotropin (BST) which is then used to stimulate additional milk production in dairy cows has been a commercial practice in the United States for the last ten years, but is not permitted in Europe. The coming decades are therefore likely to be dominated by issues of public acceptability.

4.3.2 Cloned animals for food: between ethics and food safety

As of January 2008, cloned animal products have been approved for food use in the United States.[148] However, it is thought that no food from cloned animals is currently on the United States or EU markets due to an ongoing voluntary moratorium[149]. Currently, the EU is in the midst of determining how to regulate these products. The European Commission has consequently asked the EU's Food Safety Authority (EFSA) for a scientific opinion on the implications of animal cloning on food safety, animal welfare and the environment. In parallel, they asked the European Group on Ethics for Science and New Technologies (EGE) to give an opinion on the ethics of cloning. These requests for opinions came shortly after the United States Food and Drug Administration's (FDA) draft risk assessment stated, in December 2006, that meat and milk products from cloned cattle, pigs and goats were safe for consumption.

Back in 2008, the European Food Safety Authority (EFSA)[150] found no clear safety concerns related to food products from clones of cattle, pigs or their offspring. However, its scientific opinion underlined that there was not enough scientific data on the subject and that the practice has major repercussions on animal health and welfare.

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[148] U.S. Food and Drug Administration (2008) - *Animal Cloning Risk Management Plan for Clones and Their Progeny*. See: http://www.fda.gov/cvm/CloningRA_RiskMngt.htm.

[149] U.S. Department of Agriculture, Statement by Bruce Knight, Under Secretary for Marketing and Regulatory Programs on FDA Risk Assessment on Animal Clones, *FDA's Final Risk Assessment, Questions and Answers: Management Plan and Industry Guidance on Animal Clones and Their Progeny*, Release No. 0012.08 (15 January 2008). See: http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?contentidonly=true&contentid=2008/01/0012.xml. (last accessed 9 December 2008.)

[150] EFSA (2008) - Food Safety, Animal Health and Welfare and Environmental Impact of Animals derived from Cloning by Somatic Cell Nucleus Transfer (SCNT) and their Offspring and Products Obtained from those Animals. See: http://www.efsa.europa.eu/en/scdocs/scdoc/767.htm

In its opinion adopted in 2008[151], the European Group on Ethics for science and new technologies (EGE) has advised against cloning animals for food, stating that "considering the current level of suffering and health problems of surrogate dams and animal clones, the EGE has doubts as to whether cloning animals for food supply can be ethically justified".

In the US, an official risk assessment published by the FDA[152] in 2008 concluded that "meat and milk from clones of cattle, swine, and goats, and the offspring of clones from any species traditionally consumed as food, are as safe to eat as food from conventionally bred animals".

Recently, the European Parliament's Environment Committee (2010) voted in favour of entirely excluding food derived from cloned animals and their offspring from the scope of the regulation on novel foods. The Commission's initial proposal would have included food derived from cloned animals but not their offspring, although the European Council was in favour of including food from both groups. Recently, however, Members of the European Parliament have asked the Commission to present a separate legislative proposal to prohibit food derived from both cloned animals and their offspring.

A recent issue paper from the Council for Agricultural Science and Technology[153] concludes that when science, ethics, religion, and social science are viewed concurrently in light of previous attempts to regulate animal biotechnology, it becomes apparent that society is struggling to develop public policies that appropriately reflect the diverse set of considerations that bear on applications of animal biotechnology in agriculture and the food system.

4.4 Innovative food production for a growing population

4.4.1 *Research and innovation: prevention of diseases and promotion of health*

Improving the quality of our diet and nutrition is a major factor in the shifting approach from a defensive policy of treating illness to a preventive approach of promoting health[154]. By improving levels of health and well-being amongst the European population the overall human capital in Europe can be increased significantly. By decreasing the incidence of diet-related chronic diseases the participation to society, and ultimately, the productivity of the European work force will increase.

The area of research in health, food and diet-related diseases is both complex and fragmented. At the same time, there are a number of pressing challenges on a European-scale that can only be tackled through a combination of public policy development, academic research and industry developments in European Member States and Associated Countries. These efforts will include:

- Prevention of chronic diseases through promoting collaborative research, sharing data and results on health impacts of nutrition, lifestyle and effective interventions.
- The creation of a coherent long term, public health research programmes on diet related diseases from molecular to population levels by integrating systems including biology, genetics, nutrition, epidemiology and social sciences.

[151] European Group on Ethics in Science and New Technologies (2008) - Opinion n° 23 :"Ethical aspects of animal cloning for food supply. See: http://ec.europa.eu/european_group_ethics/activities/docs/opinion23_en.pdf
[152] US FDA (2008) – Animal Cloning: A Risk Assessment. See: http://www.fda.gov/AnimalVeterinary/SafetyHealth/AnimalCloning/UCM055489
[153] Council for Agricultural Science and Technology (2010) - Ethical Implications of Animal Biotechnology: Considerations for Animal Welfare Decision Making. See: http://www.effab.org/LinkClick.aspx?fileticket=F2MGDA0AbRg%3d&tabid=151&mid=496
[154] White Paper on nutrition, overweight and obesity-related health issues (2007). See: http://register.consilium.europa.eu/pdf/en/07/st15/st15612.en07.pdf

- Enhancing competitiveness of the European food industry (including producers, retailers, catering)[155] by stimulating R&D for innovative, high quality food products and processes that contribute to a healthy population.

Changes in both population demographics and life span demand that European public health policies focus on healthy ageing, which not only includes the prevention of diseases but also delaying the deterioration of health status.

The challenge for the long-term will be to influence an individual's rate of ageing and to deliver a personal regime of nutrients (tailor-made nutrition), lifestyle and advice for healthy longevity. Dietary measures and lifestyle modifications, including physical activity, which could counteract these ageing related disorders, would be a real breakthrough in an ageing society.

Today, in Europe healthcare systems and R&D funding spend most of their resources on treating ill health. Moreover an ageing population, declining birth rates and longer life expectancy, characterise key demographic trends. These changes in themselves may present new health and dietary-related challenges in future years. For example, the increased prevalence of obesity, particularly in children, is a major public health concern, compounded by the associated disorders of diabetes, heart disease and cancer.

4.4.2 Policies stimulating innovation and securing food supply

4.4.2.1 Authorisation of novel food products

Currently, companies and industry find it difficult to seek authorisation for novel food products, because of the lengthy procedures and the uncertainty of the outcome. The cost factor discourages many from patenting food products or new processing techniques, in particular Small and Medium Companies[156].

The revision of the Regulation should stimulate innovation in the food and drink industry, protect the functioning of the internal market and public health, and, at the same time, facilitate market access for novel food products. In 2007, the European Commission announced its intention to revise Regulation 258/97/EC on Novel Foods and Novel Foods Ingredients.

4.4.2.2 Food security and agricultural production

Currently around 500 million EU citizens and 6,8 billion people worldwide rely on high quality food for their subsistence, nutrition, health and well-being[157]. To overcome this growing challenge in line with predicted global population expansion, the total amount of agricultural output will have to triple over the coming decades.

Aspects of specific relevance to the food and drink sector can be summarized as follows:

- **Climate change and agriculture**
  The main environmental linkages between agriculture and climate change are 3-fold:

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[155] Outcomes of the Competitiveness Council on Conclusions on guidance on future priorities for European research and research-based innovation (2009).
See http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/intm/111723.pdf
[156] CIAA (2009) - The competitiveness of the EU food and Drink industry.
See: http://www.ciaa.eu/documents/brochures/Bench%20Reprt%202009_LR.pdf
[157] OECD (2007) - Household behaviour and the environment, Chapter 5 " Environmentally responsible food choice". See: http://www.oecd.org/dataoecd/19/22/42183878.pdf
Consumers generate significant direct environmental impacts through the way they transport, store and prepare food, as well as the amount of waste they generate, and how they dispose of it. Intensified environmental education will be vital to raise consumer awareness of the sustainability impacts of their behavior and decisions. Reliable environmental information is an important tool to enable consumers to make informed choices and to follow their individual preferences.

- First, agriculture is a source of GHG emissions, including CO_2 and non-CO_2 gases like methane and nitrous oxide. It represents about 9% of total EU-27 GHG emissions and about 14% of total global GHG emissions.
- Second, agriculture can positively contribute to mitigating climate change by binding carbon in soil and biomass.
- Third, climate change will adversely impact global agricultural productivity.

Climate change is expected to have a profound and increasing impact on food production through factors such as rising temperatures, altered rainfall patterns and more frequent extreme events[158].

- **Mitigation in agriculture**
  Mitigation strategies in agriculture include a broad range of techniques, such as improved farming practices, including fertilizer and agricultural input use, carbon sequestration, soil conservation, livestock and manure management and the production of biogas through anaerobic digestion. While many of these techniques are already widely practiced, others require increased R&D efforts and practical experience to promote their technical viability and dissemination as future general practice. This requires long-term financial support, technology transfer and capacity building in order to help local farming communities reduce emissions and conserve natural resources.

- **Adaptation in agriculture**
  Independent of international mitigation efforts, the adverse effects of climate change over the next decades, such as heat waves, changes in rainfall patterns and water availability, will directly affect agricultural productivity[159].

  These adverse impacts require effective adaptation policies at all levels, including managerial, infrastructural and technical measures, knowledge transfer and the establishment of relevant partnerships. Research provides the backbone for adaptation and mitigation methodologies. It needs to be linked with social science research on how to introduce new methodologies, crop varieties, etc., to communities, whether they will be taken up, and how different members of vulnerable communities can benefit.

Moreover, this challenge of delivering food security in the context of climate change also means that it is necessary to find innovative ways of increasing efficiency and reducing waste throughout the food chain in order to make the most of the resources and raw materials available[160]. The EU food industry is dedicated to efficient resource use (e.g. the development of enhanced water management processes) and waste reduction[161]. Another important contribution of the food industry is the reduction of food losses by introducing modern collection, processing, storage and transportation methods.

Implementing the technologies involved in areas like life sciences, engineering and process control provides opportunities applicable Europe but also transferable to developing countries to meet their food needs.

At the same time, it is vital to take a holistic approach to environmental policy-making by taking account of other, equally pressing environmental challenges, most notably, water use, but also biodiversity and land use change, all of which are intrinsically linked.

The design of the future, market-oriented common agricultural policy (CAP) should safeguard and facilitate the production of adequate levels of European raw materials, whilst at the same time, being open to non-EU raw material, according to the specific needs of the food and drink industry.

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[158] FAO (2008) - Climate change adaptation and mitigation in the Food and Agriculture sector.
See: ftp://ftp.fao.org/docrep/fao/meeting/013/ai782e.pdf
[159]SIWI Policy Brief (2008) - Saving Water: From Field to Fork.
See: www.siwi.org/documents/.../PB_From_Filed_to_Fork_2008.pdf
[160] European Food Sustainable Consumption and Production Round.
See: http://www.food-scp.eu/
[161] CIAA (2008) - Managing environmental sustainability in the European Food & Drink industries.
See http://www.ciaa.eu/documents/brochures/brochure_CIAA_envi2008.pdf

4.5 Innovative bio-based products in a sustainable bio-based economy

4.5.1 *Major trends and opportunities*[162]

The area of biofuels is likely to offer increasing opportunities due to the mounting price of oil and the growing policy support in order to combat climate change. In addition, this will go hand in hand with significant technological progress in order to produce more sustainable advanced biofuels at competitive prices.

In the other areas, strong growth is expected for fine chemicals, especially due to the growing importance of chiral active pharmaceutical ingredients and to new simplified synthesis paths (via metabolic engineering) for complex molecules. Significant growth in the bio-based polymers sector will result from the development of new polymers with new properties, greater incentives to reduce costs through the use of renewable materials, and increasing regulatory pressure to reduce carbon footprint (for example for packaging applications). In addition, enzymes will be increasingly in applications, due to improvements and advantages particularly in the food, cosmetic and textile industries in line with customer requirements and stricter environmental regulations.

One of the major strengths and drivers in Europe is the presence of a strong chemicals industry which is in itself an important driver for the development of bio-based products, as well as a strong biotechnological and chemistry R&D base in academia and industry. In addition, although availability of renewable resources is limited, the variety of crops cultivated is diverse (including sugar beet, potato, cereals, etc.) and there are huge opportunities opening up in the Eastern Europe in terms of available farmable land and feedstock.

The US, on the other hand, will lead the market in its production of ethanol and with a large share of the production of corn and soy and will likely maintain its lead in the production of lingo-cellulosic ethanol. In other countries such as Brazil, the large production of sugar cane and the commercialization of biorenewable carbon sources is the main driver, and this will be accelerated by the development of biorefineries producing not only bioethanol, but also biobased plastics.

A recent report by the World Economic Forum (WEF)[163] concluded that converting biomass into fuels, energy, and chemicals has the potential to generate upwards of $230 billion to the global economy by 2020.The report also identified industrial biorefineries as one possible solution that may help mitigate the threat of climate change and the seemingly boundless demand for energy, fuels, chemicals and materials. However, the report also concludes there are still numerous challenges – including both technical and commercial as well as sustainability challenges – hampering industrial commercialisation on a large scale.

4.5.2 *Research and innovation*

4.5.2.1 *Investments in R&D will be a key challenge*[164]

A key technology in the development of innovative bio-based products is **industrial biotechnology**. However, there is a serious mismatch between the level of private sector investment in industrial biotechnology R&D and the potential market opportunities for the

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[162] Based on following studies
- Discussion papers of the OECD workshop on "Outlook on Industrial Biotechnology", Vienna, 13-15 January 2010
- EuropaBio (2006) – Industrial Biotechnology: a policy agenda for Europe
- OECD (2009) - The Bioeconomy to 2030: Designing a Policy Agenda

[163] World Economic Forum (2010) – The Future of Industrial Biorefineries.
See: http://www3.weforum.org/docs/WEF_FutureIndustrialBiorefineries_Report_2010.pdf

[164] Based on following studies
- Discussion papers of the OECD workshop on "Outlook on Industrial Biotechnology", Vienna, 13-15 January 2010
- OECD (2009) - The Bioeconomy to 2030: Designing a Policy Agenda

sector and for convergence with agriculture in the future. For example, only 2% of biotech R&D went to industrial biotechnology in 2003, while OECD expects industrial biotechnology to contribute up to 39% of biotech's gross value added (GVA) in 2030. Furthermore, since this figure excludes the potential contribution of biofuels, there is a clear underestimation of the potential share of GVA that industrial biotechnology – and biobased products could deliver. Thus, the mismatch will be undoubtedly even more significant than the above figures suggest.

In addition, the amount of R&D support for **biofuels** is substantially lower when compared with other areas. Member states of the IEA spent just over USD 250 million in 2006 on bioenergy R&D. To put this in context this figure is 13 times less than the amount spent on nuclear fission and fusion R&D and 4 times less than was spent on R&D into fossil fuels. However, it should also be noted that there was more public spending on fossil fuel research than for all renewable sources of energy combined. Research activities in the EU concerning lignocellulosic bio-ethanol and second generation biofuels in general, are modest when compared with the massive efforts of the U.S. and Brazilian governments. That said, a European Biofuels Technology Platform has now been established, so as to implement a strategic research agenda for biofuels, and this includes the development of advanced conversion technologies, especially from lignocellulose to ethanol and integrated biorefineries.

Today **algae** are used for production of high value niche products, and due to their high level of lipids algae is also being considered as feedstock for the production of bio-diesel. However algae-based biofuel is not yet cost competitive, and to reach competitiveness, this emerging technology request strains of highly productive algae, high density cultivation processes reactors, new transparent reactors distributing light efficiently and efficient aeration systems to disolve CO_2 in the broth.

In addition, **marine or blue biotechnology** offers several new opportunities[165], such as the biochemical diversity important for biodiscovery, the possible biotechnological exploitation of biomass, and innovative aquaculture technologies important for nutrition. However, the exploitation of these technologies is still in its infancy as today less than 1% of the marine microorganisms can be cultured. There is a clear need to develop poly-cultural systems for growing organisms in the aquatic environment in order to master the environmental conditions, and there is also a lack of knowledge about the micro- and macrobiota composition in most ocean areas.

4.5.2.2 Demo projects as a tool to shorten time to market

It is important to foster the synergies between various participating sectors for example through the stimulation of public-private partnerships. This cooperation must extend downstream to demonstration projects that facilitate the development of flexible, research-oriented pilot plants to validate the concept of integrated and diversified biorefineries. Pilot infrastructures to demonstrate the technologies and to test new feed-stocks and pre-treatment processes already exist to some extent but these need to be complemented by larger scale demonstrators to verify scale-up of processes. The initial construction of bio-refinery pilot and demonstration plants is not only a costly undertaking but it also involves bringing together market actors along a new and highly complex value chain. This ranges from the diverse suppliers of biomass raw materials (farmers, forest owners, wood and paper producers, biological waste suppliers, producers of macro- and microalgae etc.) with industries providing the technologies and industrial plants to convert the raw materials and the various end users of intermediate or final products.

Countries like the US, Brazil, China and others are increasing investment into research, technology development and innovation, and are supporting large scale demonstrators in which many European companies already participate. For example:

- On 5 May 2009 the US Government's Department of Energy (DoE) announced plans to provide USD 786.5 million from the American Recovery and Reinvestment

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[165] Marine Board of ESF (2010) – Updated European Marine Strategy Paper (to be published September 2010)

Act as additional funding for commercial-scale biorefinery demonstration projects[166]. DoE anticipates making 10 to 20 awards for the construction of new refineries of a variety of scales and designs with the aim of having them up and running within a three year period. The projects selected will work to validate integrated biorefinery technologies that produce advanced biofuels, bioproducts, and heat and power in an integrated system, thus enabling private financing of commercial-scale replications. A further USD 176.5 million will be used to increase the federal funding ceiling on two or more demonstration - or commercial-scale biorefinery projects. In December 2009, they announced an additional investment of USD 600 million in advanced biorefinery projects[167].

- In February 2010 the Brazilian government announced the launch of the Brazilian Bioethanol Science and Technology Laboratory (CTBE)[168] in São Paulo. The new research centre aims at strengthening the country's leadership in the sustainable production of sugarcane ethanol and clean energy innovation and its advanced laboratory equipment and pilot plant will enable a joint effort in research and development from around the world in the production of ethanol from biomass. With an initial investment of USD 40 million, research programmes will focus on sustainability, agriculture, virtual bio-refineries and basic science, including the development of second generation biofuels.

4.5.2.3 Incentives to lower high investment and production costs

Producing chemicals through bio-chemical routes is currently still more expensive compared to traditional production routes. In addition, existing production facilities for chemical syntheses cannot be converted to biotechnological production without massive new investments, and in many cases there are clear economic restrictions in biotechnological production processes due to higher operating costs and higher levels of R&D costs and investments.

In the US – at Federal as well as at State-level - numerous programmes have been set up to stimulate the construction of new plants (producing bio-based products) and/or new biorefineries (e.g. in Kansas and in New York).

4.5.3 Dedicated policies for biobased products

4.5.3.1 Biofuels[169]

In accordance with the EU's new Renewable Energy Directive the share of renewable energy should rise to a minimum 10% in every Member State by 2020, whether this is electricity or hydrogen from renewable energy sources, or 1st or 2nd generation biofuels. The Directive also aims to ensure that as we expand the use of biofuels in the EU we use only sustainable biofuels, which generate a clear and net GHG saving and have no negative impact on biodiversity and land use.

Government policies - via subsidies, mandates or targets - to stimulate the production and use of biofuels also play a key role in other parts of the world:

- In the **US**, in December 2004, the Natural Resources Defense Council argued for an investment of over USD 1 billion in applied research, development, and demonstration between 2006 and 2015 to make biofuels affordable to American consumers. Under the Energy Policy Act[170] of 2005, an even larger amount of

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[166] http://www.energy.gov/news2009/7375.htm
[167] http://www.energy.gov/news2009/8352.htm
[168] http://www.brasil.gov.br/para/press/press-releases-1/brazil-announces-new-laboratory-to-research-second-generation-ethanol
[169] Based on: David Batten (2010) - International Policy Approaches and Challenges in Industrial Biotechnology. Discussion paper of the OECD workshop on "Outlook on Industrial Biotechnology", Vienna, 13-15 January 2010.
[170] http://www.gpo.gov/fdsys/pkg/PLAW-109publ58/pdf/PLAW-109publ58.pdf

financial support has been allocated, and a clear distinction between conventional corn and second-generation cellulosic bio-ethanol has been introduced. Since then the goal of developing and commercialising lignocellulosic bio-ethanol has turned into a national effort to establish a new industry which can strengthen the energy security of the U.S. economy by reducing its dependency from oil. Early in 2010, President Barack Obama announced that his Administration would take a series of steps designed to help grow the U.S. biofuels industry to reduce dependency on foreign oil. In support of this:

- the Environmental Protection Agency (EPA) has finalized a rule to implement the long-term renewable fuels standard of 36 billion gallons by 2022 established by Congress
- the U.S. Department of Agriculture has proposed a rule on the Biomass Crop Assistance Program (BCAP) [171] that would provide financing to increase the conversion of biomass to bioenergy
- the President's Biofuels Interagency Working Group released its first report[172] "Growing America's Fuel", which sets out a strategy to advance the development and commercialisation of a sustainable biofuels industry to meet or exceed the nation's biofuels targets

• In the 1970s, the Proálcool policy was introduced in **Brazil**. This involved an extensive ethanol production programme run in parallel to a plan to build passenger cars to run on ethanol. The initiative led to a nationwide distribution network supplying ethanol in all service stations with the result that since the late 1980s, ethanol had a larger market share in the transportation sector than petrol.

• In 2001, the **Chinese** State Council launched a Fuel Ethanol Program. Polices such as free income tax, VAT refunding, and fiscal subsidies were made available to ethanol producers. Under the revised National Plan, fuel ethanol production is to increase to 3 million tonnes/year by 2010 and to 10 million tonnes/year by 2020. Biodiesel is to grow to 300,000 tonnes/year in 2010 and to 2 million tonnes/year in 2020. The Chinese government's overall policy for biofuels is to move this technology forward in such a way that it doesn't compete with arable land. It also considers giving subsidies and tax breaks to demonstration projects that use non-grain feedstock and to plantations growing non-food crops.

• In **Australia**, the Federal government recently announced a USD 15 million R&D program for second generation biofuels. Called the "Gen 2" program, it is part of the government's Clean Energy Initiative being implemented through the Australian Centre for Renewable Energy. In addition, the government has developed a broad range of policy instruments that affect the production of biofuels. These instruments include a production target, fuel taxes (excise), fuel quality standards, grants and labeling.

4.5.3.2 Biobased chemicals and plastics

At present, the drivers for bio-based products – especially plastics - differ substantially: in the US, resource security and utilisation are the main drivers, while in Japan, there is a strong drive towards products with a green image. In Europe, resource utilisation, GHG emissions, and compostability are the important drivers in developing supporting policies.

However, in contrast to biofuels, there is currently no European policy framework to support biobased materials. As a result, these products suffer from a lack of tax incentives or other supporting regulations. Although the Ad-hoc Advisory Group for the Lead Market Initiative for Bio-based Products has developed a series of recommendations to stimulate market uptake and development these measures still have to be implemented. Other demand-driven policies focus on the sustainability agenda (including green public procurement) and are often implemented as a mix of public procurement procedures, legislation and direct financial incentives.

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[171] http://www.fsa.usda.gov/FSA/webapp?area=home&subject=ener&topic=bcap
[172] Growing America's Fuel - An Innovation Approach to Achieving the President's Biofuels Target (2010) - http://www.whitehouse.gov/sites/default/files/rss_viewer/growing_americas_fuels.PDF

However, such policy frameworks have been developed in other parts of the world[173]:

- In the **US**, The BioPreferred[174] program aims to increase the purchase and use of renewable, environmentally friendly biobased products.

- In **Japan**, in 2002 the government initiated the Biomass Nippon Strategy, requiring that 20% of all plastics consumed in the country be sourced renewably by 2020. This prompted Toyota, NEC and others to accelerate levels of R&D into bio-based plastics and to raise the bio-based content of their products. Bio-based chemicals and bioplastics benefit from usage, waste management, and labelling legislation.

- In **China**, industrial parks for chemical R&D are being established, and specific projects for liquid biofuels and bio-based products are funded by a national high-tech R&D program. Feedstock prices are regulated, reportedly held below international levels, and sometimes frozen. Support for bio-based chemicals includes numerous incentives for producers and a preferential tax treatment for selected firms in emerging biochemical industries. In addition, since 2005 a specific programme promotes production and consumption of biodegradable plastics.

- In **Korea**, government-funded research institutes are developing technologies to produce chemical raw materials from biomass, and scaling-up R&D for biochemical and production technologies. The Korean government also supports the use of biodegradable materials in refuse bags and fishing nets. One-time use products cannot be made from conventional plastics, and polystyrene is banned in food packaging.

Also an increasing number of companies are integrating "bio-based" principles into their strategy. A few examples are that:

- Japanese vehicle manufacturer **Toyota** is planning to switch 20 per cent of the plastics used in its vehicles to bio-sourced plastics by 2015. Toyota expects bioplastics to help in its efforts to accomplish its company-wide goal of reductions in CO_2 emissions.

- **DSM** estimates that a shift to biobased chemical production across the industry could account for up to 20% of the global Kyoto greenhouse gas emissions reduction target.

- By 2015, **DuPont** wants to double their revenues from non-depletable resources.

4.5.3.3 Regulations and specific standards

At this moment, there is still a lot of confusion between certified compostable plastics based on functionality, and bio-based plastics produced from renewable resources only. Two different concepts underlie the term "bioplastics":

- **Compostable plastics** are certified according to EN 13432 or EN 14995 (Europe), ASTM D-6400 (USA) or ISO 17088 (other countries). Biodegradability and compostability are properties caused by the molecular structure of polymer materials, and do not depend on the raw material source. However a product certified via the EN 13432 standard for the European market requires biodegradation of 90% of the materials in a commercial composting unit within 90 days. The ASTM 6400 standard, the regulatory framework for the USA, sets a less stringent threshold of 60% biodegradation within 180 days.

[173] David Batten (2010) - International Policy Approaches and Challenges in Industrial Biotechnology. Discussion paper of the OECD workshop on "Outlook on Industrial Biotechnology", Vienna, 13-15 January 2010

[174] http://www.biopreferred.gov

- **Biobased plastics** are plastics produced on the basis of renewable resources, with a focus on their raw materials basis. Rather than using fossil carbon in manufacturing conventional plastics, bio-based polymers use carbon from renewable resources like sugar, starch, vegetable oils or cellulose in their production. Bio-based polymers are not in all cases biodegradable and compostable. There is currently no clear European standard in place.

At present, very few EU Member States have nationwide industrial composting systems in place and operational. For example, in the Netherlands EN 13432 certified packaging is allowed to enter the composting system. Although Germany and other EU Member States have existing composting infrastructure (BE, IT, SE, DK, FIN, etc.), there is no clear policy support for the composting of biodegradable and compostable products. Today the bio-based and biodegradable plastics industry must face the challenge that composting as well as the use of compost as fertiliser is not permitted, even when the products comply with the strict criteria of the harmonised EN 13432 standard (in Germany and in France).

4.6 Policies for a sustainable KBBE

Addressing sustainability issues through all segments of the value chain of bio-based products (from biomass production to end-use) in a fair, evidence-based regulatory framework, represents an enormous policy challenge. Addressing these sustainability concerns is a major challenge for biofuels and other bio-based products, and the sector has to demonstrate that it possesses sustainability credentials in order to gain a strong “license to operate” from governments and consumers, especially if supporting policies have to be developed. Unfortunately the lack of a widely-accepted scheme to assess and confirm sustainability is an important barrier to consumer and government confidence.

The OECD is currently working out best practices in assessing the environmental and economic sustainability of bio-based products. This is based on an analysis of existing approaches and on the identification of key elements of “best-practice” assessment methodologies. A report on this is expected to be published in the months ahead.

5 MAIN RECOMMENDATIONS

5.1 Need for an integrated policy for the KBBE

According to the OECD[175], in order to achieve a competitive bio-economy, broad approaches, such as creating and maintaining markets for environmentally sustainable products, funding basic and applied research, and investing in multi-purpose infrastructure and education will be necessary. In addition, these will need to be combined with shorter term policies such as the application of biotechnology for improving plant and animal varieties, improving access to technologies for use in a wider range of plants, fostering public dialogue and increasing support for the adoption and use of internationally accepted standards for life cycle analysis together with a range of other incentives designed to reward environmentally sustainable technologies.

EuropaBio recently published a policy guide setting out just such requirements[176] and calling for a more integrated and strategic approach, with supportive policies in the areas of climate change, energy security, renewable feedstock supplies, research and innovation, the environment and trade.

However, in order to make the KBBE a success it will be critical to ensure that feedstocks used in this sector are produced using better management practices. The current approach, which focuses largely on certain end-uses (biofuels), is unlikely to be efficient and moving forward. Feedstocks must be produced according to broadly supported sustainability criteria.

5.2 Research and innovation

5.2.1 *More public funding for research*

Since the bio-economy will provide the solutions to some of societies most significant challenges (see 2.3), it should also be considered for increased levels of public funding. In addition, in order to make a swifter shift towards developing more integrated and sustainable production and processing systems, the level of R&D funding in the bio-economy should be increased through multidisciplinary research programmes at national and European level.

Furthermore, improved coordination and collaboration between member state, regional and European public programmes for research and innovation is the only way to avoid overlap and fragmentation and to keep track of the massive research programmes in the US and in the BRIC countries. In addition, an operational framework should be established in order to facilitate the assembly of European, national, and regional funds to ensure European cooperation and competitiveness in this area[177]. This should be done in conjunction with improvements in the cooperation between the private and public sectors.

5.2.2 *Support for specific technologies*

In order to make full use of the biomass, for food as well as for non-food applications, it is important to develop **efficient and robust enzymes**, particularly for the conversion of lignocellulosic material from a variety of feedstock.

Synthetic biology and **metabolic pathway engineering** are examples of emerging technologies that will significantly increase the diversity of biotechnological processes and products, driving the development of innovative products. These techniques lead to the

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[175] OECD (2009) - The Bioeconomy to 2030
[176] EuropaBio (2010) - Builing a bio-based economy for Europe in 2020
[177] Becoteps White Paper (2010) – to be published. See: http://www.becoteps.org

development of the so-called "microbial cell factories", which are production hosts that produce desirable products in high yields and with high productivity.

However, some of these biorefinery products will require further chemical processing and unless these chemical processes are made available there will be no market for these precursors. Therefore dedicated research on the combination of technologies such as biochemical and chemical processes should also be given a special attention[178].

The OECD estimates that approximately 75 percent of the future economic contribution of biotechnology and significant environmental benefits are likely to come from applications derived from **agricultural and industrial biotechnology**. However, these sectors currently receive less than 20% of all research investments made by the private and public sectors. Therefore there is a pressing need to boost research in agricultural and industrial biotechnologies by increasing public research investment, reducing regulatory burdens and by encouraging private-public partnerships.

It is also crucial to secure a sustainable supply of feedstock for the KBBE. This will require further research into methods of **improving feedstock yields** and/or the composition of biomass for optimal conversion efficiency. This research will involve both plant genomics and new breeding programmes, and also research into efficient crop rotation, land management and land-use change issues.

5.2.3 Better integration of the different research areas

The successful development of the KBBE in the long term requires successful innovation. For this reason adequate research must be financed, and this should result in commercially viable products. Crucially, such research programmes should cover the entire value chain including plant engineering, crop harvesting and local processing, logistics, pre-treatment in the biorefinery, enzymes, fermentation organisms, secondary manufacturing, compounding, side-product valorisation and product recovery. It should also extend to the supply side, incorporating research to improve the yield and sustainability of new feedstock, such as crops and trees, for raw materials supply. By supporting pre-competitive research covering the entire value chain – from feedstock to end-product – the programme will stimulate integration of the individual KBBE sectors, facilitate innovation and encourage the uptake of its results by the industrial partners involved. For example, in the food sector, it will be important to develop concepts for sustainable food production, such as by increasing production efficiency so that more output is produced with less input at affordable prices for the consumer.

In the longer term, we can expect not only a closer integration of the different sectors of the KBBE, but also between the different research areas across food as well as non food commercial applications. Knowledge spillovers across research disciplines and commercial applications will also help to maximize the economic and social benefits of the bio-economy.

5.2.4 Better coordination between Academia and Industry

In order to better align academic knowledge to industry needs, industry will need to develop an earlier understanding of the application potential of new technologies provided by academia. Similarly, academic researchers will need a sharper focus on industry's needs and specifications. Therefore, building competence networks between industry and academia could be key to overcoming the knowledge gap and competence hurdle that currently exists. In addition, better interdisciplinary and collaborative research would also lead to new business activities.

[178] M. Kircher (2010) - Trends in Technology and Applications. Discussion paper at the OECD workshop: Outlook for Industrial Biotechnology (Vienna 13-15 January 2010)

5.2.5 Clusters and public–private partnerships, essential to stimulate innovation

Moving forward, Europe needs to mobilise sufficient resources to support a Europe-wide coordinated research programme by means of a public-private partnerships. This would help build upon the successes of the European Technology Platforms (ETPs), FP7 and national research programmes. This type of joint undertaking would achieve a pooling of resources which would help in setting more ambitious goals in terms of reducing the time-to-market and which would also help industry to adopt long-term investment plans in the field of the bioeconomy, taking into account the market perspective. The main objectives of such projects are to share the risk of the development of innovative products and processes through support for research of a more "pre-competitive nature". This should cover the entire value chain, and should also encourage the uptake of research results by industry. Indeed, one of industry's major challenges is to translate research into products, including the development of new product applications. Such public-private partnerships can also optimise knowledge transfer and dissemination of knowledge towards SME's.

5.2.6 Public support for the development of demonstration projects

Lessons learnt from existing biorefineries teach us that the construction of demonstration activities is a crucial step towards developing a fully fledged biorefining industry. Demonstration activities are able to close a critical gap between scientific feasibility and industrial application. They enable us to measure actual operating costs, and specific strengths and weaknesses of technological processes before costly, large-scale facilities are built. They dramatically reduce the risk of introducing new technology on an industrial scale and therefore make a biorefinery venture much less risky for investors. Stimulating the construction of demonstrators via public-private partnerships is therefore one of the most important measures that can be taken in the development of the bio-economy[179].

5.3 Towards economic-sustainable and innovative SMEs

SMEs play a crucial role in knowledge development and uptake across all sectors of the KBBE.

Spin-offs and high-tech SMEs are key for technology and knowledge development, and investing in research and innovation is the only way for these enterprises to survive. For these SMEs it is very important to improve access to finance as, due to the worldwide credit crunch, venture capital and private equity funding have become even tougher to access.

Without larger scale validation, it remains very hard for SMEs to attract the large industrial partners or other private investors that they need to reach sustainability. Developing grants for "Proof of Concept" studies for environmentally friendly technologies could help partially overcome this problem[180]. Consideration should also be given to the creation of grant foundations, such as the ones operating in the U.S[181]. Such foundations could have a mandate to give preference to industrial applications listed in a regularly reviewed hierarchy of industrial "hot spots" relating to key enabling technologies in order to provide maximum economic, social and environmental benefits. Such action would also help significantly in attracting new investment. In addition, existing national schemes could also be used as an example, such as the small scale Dutch Small Business Innovation Research (SBIR) pilot programme[182] inspired by the US SBIR programme[183]. Here, contracts are awarded based on the three key criteria of feasibility, research and commercialisation.

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[179] EuropaBio (2010) - Builing a bio-based economy for Europe in 2020
[180] EuropaBio (2006) - Industrial or White Biotechnology: a policy agenda for Europe
[181] Example of the William T. Grant Foundation.
See http://www.wtgrantfoundation.org/funding_opportunities/research_grants
[182]http://www.senternovem.nl/english/products_services/encouraging_innovation/small_business_innovation_research_sbir_programme.asp
[183] http://www.sbir.gov/

The many SMEs in the more "traditional" sectors (such as agriculture, forestry, aquaculture and the food sector) are crucial for the viability of the European KBBE. However, one of their weaknesses is that many of them do not have the in-house technical skills necessary to absorb the results of cutting edge research and to take up the results of innovation. Supporting tech transfer or stimulating SMEs to participate in "open innovation" programmes could be one way to overcome this problem.

5.4 Communication and education

In general, there is a lack of awareness of the KBBEs potential both in the manufacturing industry and amongst policy makers, consumers and even investors[184]. To facilitate the long-term development and implementation of the technologies, a strategy for communication and stakeholder involvement is necessary. This would help to raise awareness of the technologies and their benefits and would also help to develop insight into the long term objectives, applications and products needed by society in general. For example, in order to boost consumer trust in the food chain, new scientific opportunities need to be communicated to consumers in such a way as to make them understandable for their potential benefits as opposed to focusing simply on their safety.

Stakeholders must be involved and engaged in order to raise further awareness. Indeed, in its recent bio-economy report, the OECD[185] suggests creating an ongoing dialogue between regulators, citizens and industry, as many of the policies to support the bio-economy and its sustainability will require the active participation of these groups. From previous experience it is clear that information and communication are not synonymous with public acceptance. Instead, a long-term process needs to be developed by industry and governmental organisations in order to build trust through a transparent process of engagement on values, risk management and critical self-evaluation. Sustainability characterised by the triple bottom line of People, Planet and Profit, should be made more visible as the core value driving the development process.

Improving education in order to develop a highly skilled workforce is one of the recommendations of the Becoteps[186] white paper. For a successful bio-economy, it is necessary to have a multi- and interdisciplinary work force, remaining up-to-date on new knowledge and developments. To achieve this multidisciplinary education, good international training programmes and efficient lifelong learning will be necessary. In addition, due to a gap in education, biotechnology and chemistry are still too often perceived as "competing technologies" instead of as being complementary[187].

5.5 A strong EU common policy for agriculture: the new CAP (post 2013)

Efficient agricultural policy is essential for guaranteeing equitable competition conditions within the EU. Maintaining a single market for agricultural products must remain the guiding principle for the future. It is important to ensure that national flexibilities and exemptions do not create distortion that would harm the single market and the supply of raw materials to the food and non-food industry.

Absolute coherence is needed across all policy areas driving supply, including food safety, innovation and new technologies, trade, development, the environment, animal welfare, consumer and public policies. Impact assessments should be a mandatory requirement when legislation which could significantly impact on food supply or feedstock availability for industrial production, is amended or imposed. Horizontal policy coherence should result in

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[184] EuropaBio (2006) - Industrial or White Biotechnology: a policy agenda for Europe
[185] OECD (2009) - The Bioeconomy to 2030
[186] Becoteps White Paper (2010) – to be published. See: http://www.becoteps.org
[187] EuropaBio (2010) – Building a bio-based economy for Europe in 2020

reduced raw material market disruptions and should also contribute to a competitive EU agriculture.

To become a lead market for biobased products, one necessary prerequisite is the assurance of a secure, varying, sustainable and affordable supply of biomass achieved without disruption to food supply. Until now, the hope that biomass will show less cyclicality than crude oil prices has not been realized. Furthermore, in debates around biofuels, land use remains a controversial issue. Converting land for the production of energy crops (or any bio-based raw materials) competes with other land uses. This will remains an issue notably with regard to food production, where there are rising food and feed demands driven by population growth and increasing prosperity. Until these issues are effectively tackled they will continue to place limitations on the uptake of industrial biotechnology. The EU pursues a far stronger set of regulations in this respect than the US or Asia. In addition, the acceptance problem of green biotechnology, especially in Europe, could have an indirect impact on availability and/or price of renewable feedstock in the long term.

For these reasons it will be essential that the new CAP promotes sustainable and competitive agricultural production, and that it ensures balanced access to raw materials for the food and feed sectors, as well as for industrial applications without disrupting food supply. Through the new CAP, we should maintain a competitive supply that meets EU standards, notably in the areas of safety, environment, and animal welfare[188]. The CAP should also address situations of extreme price volatility, and act as a safety net ensuring security of supply by preventing crisis situations and remedying temporary market imbalances.

In order to stimulate the development of local biorefineries and to support rural development, it is important to develop and support a reliable upstream supply chain able to mobilize a sufficient level of feedstock for conversion. This must of course be achieved without negative impacts on either food production or land use[189]. For this reason it is also important to invest in local and regional infrastructures and logistical capabilities to allow all biomass, including agricultural, forestry and waste-based raw material, to be utilized[190].

5.6 Support reconversion towards low-carbon renewable-based production systems

Competitiveness must be a key focus for the future. When competing against a running process based on fossil carbon sources, the alternative bio-process must also show competitiveness in scenarios with high energy- and feedstock-cost volatility. Additionally, investments required for building a new bio-industrial facility - especially if it competes with the conventional one – might present a significant barrier. For SMEs, such investment might represent an insurmountable hurdle which is of critical importance since the development of new technologies and products often starts in niche-markets served by SMEs prior to their wider distribution amongst customers.

In addition, it has became even more difficult to obtain bank loans and funding required for investing into building new full-scale commercial plants and infrastructure as result of the worldwide credit crunch. Governments too tend only to provide financial support and incentives on a relatively short-term basis, while pathway to success for many enterprises is a long term process. For this reason governments interested in supporting biorefineries for reasons of environmental protection, energy security and innovation leadership need to support market growth, and to carefully regulate the industrialisation process in order to trigger private sector investments[191]

[188] CIAA (2008-2009) - The competitiveness of the EU food and Drink industry. http://www.ciaa.eu/documents/brochures/Bench%20Reprt%202009_LR.pdf
[189] World Economic Forum (2010) – The future of industrial biorefineries.
[190] EuropaBio (2010) – Building a bio-based economy for Europe in 2020
[191] World Economic Forum (2010) – The future of industrial biorefineries.

5.7 Policies stimulating the market for KBBE products

Authorities have the ability to help drive innovation by implementing a framework of **incentive based and demand stimulating policies**. Mandates, subsidies and incentives are provided by governments all over the world to help stimulate the demand for sustainable bio-based products. The European Commission's Lead Market Initiative for bio-based products[192] is a good example of a programme that stimulates demand for these products by setting indicative or binding targets, tax incentives for certain products categories and public procurement targets. Initiatives such as these should be further develop and build upon[193], with similar initiatives being developed for the food sector or for the KBBE as a whole.

The implementation of a source separated, high quality composting system for organic waste treatment could also help boost the market **development of biodegradable and compostable plastics**. The organic recycling of biodegradable and compostable plastics would offer many benefits to boost the market as composting is both cost-efficient and is a concept that consumers can easily engage with and participate in. For short life products such as fresh food packaging, biowaste, shopping bags or disposables such as compostable packaging for catering, composting is the best method to recover and recycle biodegradable and compostable plastics.

In terms of **novel food**, when applicable, a simplified authorization procedure, without prejudice to the primary focus on safety to enhance the efficiency of the Novel Foods Regulation and provide a more proportionate system for risk management is needed to promote innovation[194].

5.8 Science based sustainability criteria

Consumers increasingly demand products with low environmental impacts. While the primary focus is currently on carbon, impacts on biodiversity are less frequently taken into account. In addition, there is currently no standard procedure available to measure this criterion as a part of Life Cycle Analysis.

Sustainability criteria addressing the different KBBE sectors should aim to measurably (if possible) reduce the key impacts associated with feedstock production, consumption and use. While dependency on the feedstock variations will persist, it is likely that key aspects to consider for the future will be biodiversity, soil protection, water conservation, carbon dioxide emissions reductions, air quality and social sustainability. These will have to be introduced in addition to basic requirements such as legality both on environmental, biodiversity issues and also on social performance. Implementation of measures will necessitate the active participation of all stakeholders in the supply chain. For example:

- Industry and enterprises will have to ensure that production and processing of materials is done using best management practices.
- Governments will need to focus on wider sustainability issues, such as managing demand, food security, competition between various end-uses and incentives
- Financial institutions must ensure that sustainability filters are applied in their lending policies.
- International organizations should provide support to producer countries to enable them in establishing harmonized, robust frameworks for feedstock production.

Recent developments in the biofuel sector in the EU will make it possible to use private standards to prove compliance with sustainability requirements. While some of the schemes have ambitious sustainability criteria going beyond the minimum EU requirements,

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192 http://ec.europa.eu/enterprise/policies/innovation/policy/lead-market-initiative/biobased-products/index_en.htm
193 EuropaBio (2010) – Building a bio-based economy for Europe in 2020
194 End report of the High Level Group for the Agro-Food Industry (2009). See: http://ec.europa.eu/enterprise/newsroom/cf/document.cfm?action=display&doc_id=2604&userservice_id=1

most of these only address a proportion of the concerns. Moving forward, wider sustainability requirements will need to be addressed by governments in partnership by the private sectors. Feedstock producing countries - especially in the global South - will also need significant technical and financial support to implement adequate safeguards.

6 CONCLUSIONS

With its new EU strategy for 2020, the EU has created a framework through which to achieve an ambitious series of goals – economic, social and environmental – by the end of this decade. The growth of the KBBE opens up diverse pathways towards the achievement of these goals.

The KBBE offers Europe the potential to accelerate its transition to a more sustainable growth model while developing a high-value, globally competitive sector capable of generating high quality jobs, in rural as well as urban environments.

Although Europe has made great progress over the last 5 years in the different domains of the KBBE, both in terms of research and supportive policy development, other continents have also made similar, if not more rapid progress in certain areas of the KBBE.

Over the next 10 years we can expect to see a shift in practice from a sectoral approach towards a more integrated approach to the KBBE. Therefore, there must be consistency and coherence across policies and product sectors, coupled with the political impetus to ensure that this goal is treated as a priority. The potential benefits for the economy, the environment and society as a whole are significant. It is up to all stakeholders to work together to make the European KBBE a reality.

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