European Technology Platform

Plants for the Future

Strategic Research Agenda 2025

Summary

European Technology Platform
‘Plants for the Future’

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25th June 2007

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Document layout

The Agenda is divided into three parts:

- Part one provides a brief and general overview of the **Plants for the Future** Technology Platform and its Strategic Research Agenda for a general readership, including policy-makers, non-specialist scientists, and interested members of the general public and other stakeholders. Part one contains a concise summary of the five challenges and how the Platform proposes to address them.
- Part two contains a detailed exposition of each of the five challenges. For each challenge, it covers an in-depth introduction to the issues pertaining to it, the goals the Platform plans to achieve, and deliverables and research activities for the next two decades. Owing to its length and technical nature, it is likely to be of primary interest to specialists in the particular field covered. However, all stakeholders are invited to read Part two or the sections of it that draw their attention.
- Part three compiles the proposed activities for the period 2007-2010 as the 'Action Plan 2010'.

1. Introduction

Plants support life on earth

Photosynthetic organisms – such as plants, algae and cyanobacteria – sustain life on Earth by capturing carbon dioxide and water and using the energy of sunlight to convert them to organic matter and oxygen. Over geological time, photosynthesis created the oxygen-rich atmosphere that sustains our lives, and the remains of photosynthetic organisms were converted into fossil fuel reserves that today power much of societies' activities. Furthermore, the entire food chain ultimately depends on the productivity of photosynthetic organisms. In this way, photosynthetic organisms have provided the foundations for human existence and prosperity.

Following the Industrial Revolution, this balance has been progressively disturbed. Today's unsustainable use of fossil fuel reserves is predicted to destabilise the global climate, and to lead to reduced food security and increased social dislocation. These factors will be strongly exacerbated by population pressures and ongoing global-scale industrialisation. These are the key global challenges that must be addressed if we are to maintain and extend the benefits of modern society for all of the world's citizens. Plants, having contributed to maintaining a sustainable world for millions of years, can also provide important solutions in the future.

Addressing global challenges

In this Strategic Research Agenda (SRA), we describe how improved know-how and use of plants can help address the key global challenges of underwriting sustainable food and renewable raw material production systems. The SRA establishes a road map for guiding and integrating plant research over the next 20 years such that the full potential of European human capital and knowledge in this field can be realised. We articulate five distinct challenges that will enable Europe to make key contributions:

- Challenge one: Healthy, safe and sufficient food and feed
- Challenge two: Plant-based products – chemicals and energy
- Challenge three: Sustainable agriculture, forestry and landscape
- Challenge four: Vibrant and competitive basic research
- Challenge five: Consumer choice and governance

These five pillars fully support the development of a knowledge-based bio-economy (KBBE) that helps to maintain European economic competitiveness and provides the means to secure future fuel and food supplies in an environmentally sustainable way.

Towards a knowledge-based bio-economy

For each of the world's regions, the key challenge for the coming decades will be to meet local needs for food, in terms of both quantity and quality, while conserving natural resources and biodiversity. Similarly, the development of a supply industry based on renewable plant-derived products as an alternative to the current fossil fuel-based industrial infrastructure constitutes another global challenge and represents a promising opportunity in terms of economic, environmental and societal benefit. The current bio-based economy of Europe – defined as the economic sectors that produce, manage and exploit biological resources – has an annual turnover of over €1.5 trillion and employs 22 million people.

In the knowledge-based economy, these figures are expected to increase and enhance welfare. The most unpredictable aspect to the transition from the current fossil fuel-based economy to a knowledge-based bio-economy is the timing. However, global climate change and the need for sustainable food and fuel production provides a strong social imperative for change, and a combination of 'technology push' and 'market pull' will make the transition to a sustainable bio-based economy a reality. This changeover is receiving strong support from policy-makers and a global financial community that is investing billions of euros in novel industrial initiatives, both in developed and developing countries. Political goals, such as producing 20% of transport fuels from sustainable bio-based processes by 2020, and generating 30% of raw materials for chemical manufacture from plants by 2030, further strengthen the case for developing the knowledge needed to realise these objectives.

The social angle

The transition described above will have immense and far-reaching implications. In agriculture, the large-scale deployment of novel non-food crops constitutes the biggest change for many generations. It will require private investments of billions of euros, and participatory processes to develop social understanding and support for the transformation. Market forces will increasingly determine which crops are grown across Europe and will stimulate farmers to take the lead provided the economics are viable.

Barriers to innovation, such as the stringent regulation of genetically modified crops in Europe, delay the required private investments essential for the transition to the knowledge-based economy and should be mitigated. Achieving a stronger momentum for change will be essential, otherwise the targets of the EU's Biofuels Directive will have to be met through imports. European policy measures to create a strong positive incentive for investment in R&D in all applications of plant-based bio-products and in biofuels will be essential for the transition, as will cooperation at national level.

Shaping the SRA

This SRA was compiled using an open consultative process involving a wide range of stakeholders from Member States and other interested partners. In the past two years, some 1 300 people from 30 countries representing different stakeholder groups: academia, industry, the agricultural and forestry sectors, governmental, consumer and environmental organisations, as well as experts in educational, communications, legal and financial issues, were all involved in the process of producing the SRA, including the Draft Action Plan 2007-2010. They contributed via direct participation in workshops, drafting groups or on-line consultations.

The recommendations described in the SRA provide a flexible and adaptable framework for establishing and conducting research needed to meet the five challenges. This document is not prescriptive, but is intended to enable breakthrough discoveries and technologies to be deployed across the European research landscape in a sustainable and socially acceptable way.

A wider web of collaboration

'Plants for the Future' aims to collaborate directly with other Technology Platforms. These may include 'Food for Life', 'Sustainable Chemistry', 'The Forest-based Sector', 'European Biofuels', 'Innovative Medicines for Europe', 'Farm Animal Breeding and Reproduction', 'Global Animal Health' and 'Manufuture'.

The following section provides a concise summary of each of the five challenges, including goals and proposed research activities to address these challenges.

2. Overview of the five challenges

Challenge one: Healthy, safe and sufficient food and feed

The production of food and feed remains the primary objective of plant science. Over the past 50 years, improvements in our knowledge of plant genetics, physiology and agronomy have underpinned the large increases in crop productivity that have occurred and substantially enhanced access to a far greater diversity of food on a global scale. But new challenges are arising and, over the coming years, European plant scientists will need to pursue a number of objectives, including boosting food and feed output; improving the nutritional and sensory quality of food; ensuring the safety of the food we consume; and developing crops that are resilient to climate change.

To adress this challenge, European plant scientists should focus on the development of diversified and affordable high-quality plant raw materials for food products. These new varieties should produce high yields to keep growers committed to them. This would also ensure that prices are affordable for both consumers and industry. However, productive capacity should not compromise quality. The composition of these raw materials should be optimised for nutritional aspects, as well as for processability, shelf life and sensory characteristics.

In the future, researchers will need to improve understanding of the key components affecting the quality of plant raw materials and to improve varieties accordingly using adapted or state-of-the-art technologies. They will need to pursue an integrated approach which will require close collaboration between all stakeholders in the agri-food chain: from breeders to consumers. Such an approach should not be limited to the main field crops, but should also focus on minor orphan crops, including vegetables, fruits, herbs and spices, all of which are essential for a varied and tasty diet.

High-quality and well performing plant varieties are necessary prerequisites for the sustainable production of food raw materials. Improving food safety and traceability are becoming issues of major consumer concern. Plant scientists will work to develop varieties that are more resistant to pests and diseases. This means that plants will need fewer agrichemicals, leading to lower levels of heavy metals, fungal infection and mycotoxin contamination. This could also help domesticate wild plants to bring them into the human food chain.

Plant scientists could also create new plant raw materials tailored to the specific health needs of individual consumers. These could help prevent the onset of various chronic diseases, including obesity, diabetes, cardiovascular disease and age-related macular degeneration (AMD). It could also assist in the design of customised diets. New nutritionally enhanced products that do not require such additives as sugars and trans-fatty acids can be developed to improve the dietary habits of consumers.
Finally, plant raw materials may have an indirect impact on food products as feed for animals. The increased demand for animal products should be met by ensuring the sustainable production of high-quality, sufficient, and affordable feed. The composition of feed could be optimised in terms of macro and micronutrients for both nutritional efficiency and environmental issues. Palatability and digestibility of feed raw materials will also constitute an important objective for feed improvement.

The specific goals of this challenge are:

- Develop and produce sufficient, diversified and affordable high-quality plant raw materials for food products
- Produce, trace and control safe plant raw materials for feed and food
- Tailor plant raw materials for certain health benefits and specific consumer groups
- High-quality, sufficient, affordable and sustainable feed

Challenge two: Plant-based products – chemicals and energy

The deployment of novel non-food crop species on a scale of tens of millions of hectares in the coming decades requires major changes at the policy, regulatory, taxation and industrial levels. Biofuel production in Europe can be cost competitive on the international market, provided that high-tech energy crops, adapted to the different climatic regions and optimised for sustainable biomass yield under low input agriculture can be realised. It is imperative that new biotechnologies, such as genetic modification, can be used to ensure a competitive position for Europe in the emerging bio-economy.

Frontier science is transforming the very plants themselves into 'green factories'. These will provide six significant groups of green products: pharmaceuticals, speciality chemicals, enzymes, plant-derived oils as industrial feedstock, transport fuels, polymers and fibres.

This challenge will concentrate on three specific goals:

- Biochemical production
- Bio-energy production
- Enabling research for plant-based products

Production of biochemicals

We already obtain bulk materials from plants in the form of wood, carbohydrates, oil, fibre and protein. These make up about 5% of our industrial raw material needs. The remainder comes mainly from fossil fuels, such as petroleum and natural gas. By 2025, 30% of the raw materials needed for chemical manufacture in the EU could be obtained from plant-derived renewable resources, subject to appropriate research and development.

Plant-based resources can certainly furnish far more for society and industry than at present. These may relate to commodity-scale products, as well as to new uses for materials and molecular components, whether in native form or following post-harvest modifications. New plant raw materials may include medicines, speciality chemicals and enzymes, industrial feedstocks, polymers and fibres. These materials will have applications in the health, nutrition and materials industries.

Bio-energy and biofuel plants

Plant-derived bio-energy currently supplies less than 1% of Europe's requirements, but is expected to develop dramatically in the coming decades. This bio-energy is provided either directly through simple combustion, primarily of wood products, or after the conversion of biomass from a variety of plant sources into different liquid and gaseous biofuels, such as bio-ethanol, biodiesel and biogas.

By 2020, 20% of transport fuel should be derived from biomass, according to the EU's recent Biofuels Directive. The key technological challenges for the production of renewable biomass-based fuels require a high degree of optimisation of the cost-efficiency of biofuel production, including biomass yield, nutrient and water-use efficiency, and energy conversion efficiency.

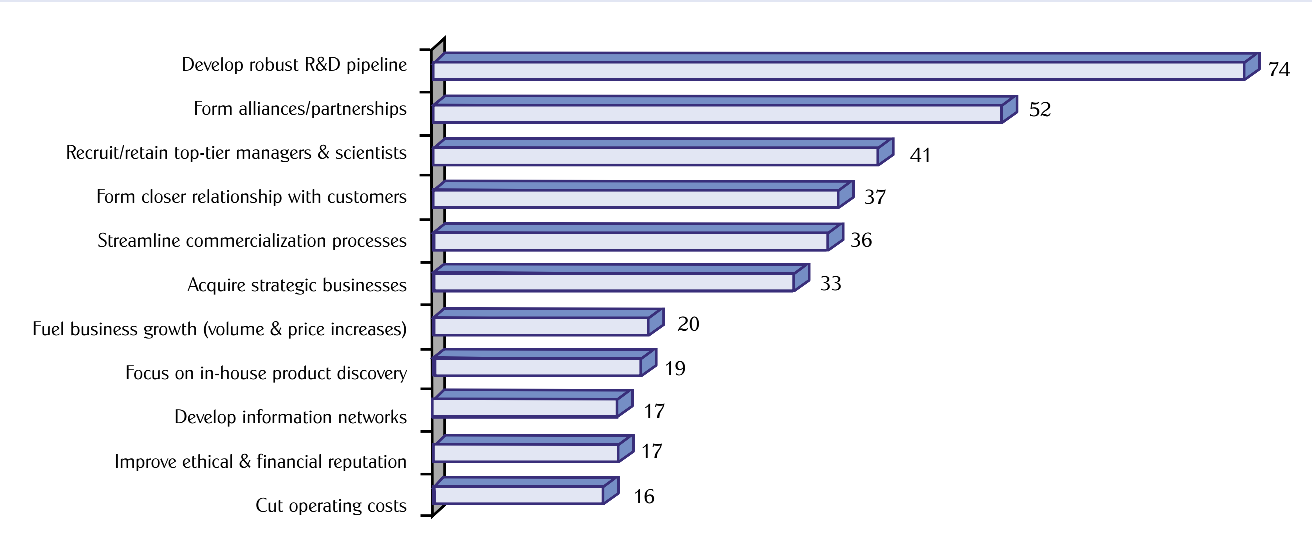
This can be achieved through the development of successive generations of biofuel crops. The first generation is food and feed crops, such as wheat, sugar beet, corn or oilseed rape. The second generation will be tailored specifically to the production of biofuels with optimised biomass yield and input requirements. In the longer term, a third generation of multipurpose biofuel crops will be designed for the combined production of specific biochemicals and a variety of biofuels.

Converting plants into production factories

Here, the overall objective is to transform plants into green factories for the production of biochemicals and energy. The enabling research required is broadly categorised into deliverables in two areas: the development of production platform crops, and extraction processes and systems for plant production.

Which of the following strategies are most important in securing your company's succes through 2015?

Source: Copyright © 2006 Deloitte Development LLC. All rights reserved. (% survey respondents)



Challenge three: Sustainable agriculture, forestry and landscape

Agriculture and forestry have always been dedicated to providing humanity with food, animal feed, energy and biomaterials. Cultivating more and more land has been the traditional answer to addressing the growing needs of the population. However, the volatility of agricultural systems and their vulnerability to uncontrollable climatic conditions has meant that supplying the needs of the human population has never been an easy task.

Although starvation is a thing of the past in Europe, some parts of the world still suffer from periodic famines and, today, some 800 million people (13% of the world's population) are malnourished. For cereals, which provide more than 70% of the world's food and feed supply, production level over the past decade have not kept up with burgeoning demand (more than 2 billion metric tons in 2006), leading to a dramatic fall in world 'carry over' (242 million metric tons, which leaves a food reserve of less than two months consumption). It is not exaggerating to state that global food production stands on a knife edge.

Since the human population will continue to grow over the coming 25 years, urbanisation will increasingly encroach on agricultural land and forests, while reservoirs of new land are very limited. Furthermore, farmland is being degraded in too many countries. Thanks to the skills of European farmers and the introduction of new techniques, land fertility potential has been maintained at a good level in the EU. Continuing to maintain this potential just by reducing EU production is not a sustainable option: Europe cannot stand as a global importer of food and feed in the middle of an ocean of malnutrition. Therefore, Europe will have to find ways of boosting its contribution to global output of food, feed and renewable resources in a more sustainable way.

To achieve this will require the use of novel tools to study plants at various biological and environmental levels. At the same time, genomics could help to enhance plant breeding techniques, leading to improved varieties and agricultural practices.

An array of novel technologies has emerged which allow researchers to identify the sources of crop and tree improvements, namely the genes that contribute to the improved productivity and quality of modern crop varieties and the genes that enhance tolerance to stresses, whether biotic or abiotic, or to a better utilisation of inputs.

These tools may also help scientists to characterise and manage plant genetic diversity and genetic resources, as well as to improve crop and tree biodiversity. A deeper understanding of how the domestication process works is likely to lead to the emergence of new approaches and methods. In addition to research in these fields, researchers should develop predictive methods, including modelling and simulation. That would help to forecast the adaptive response of crops and forest trees to unpredictable environmental changes linked to global warming in various geographical regions in Europe.

In the coming decades, we anticipate the creation of more efficient plants (able to use water and fertiliser more efficiently and to be self-resistant to pests), leading to more efficient farms and new economic opportunities.

To respond to this challenge, the SRA has identified three general goals:

- Improve plant productivity and quality
- Reduce and optimise the environmental impact of agriculture
- Enhance biodiversity

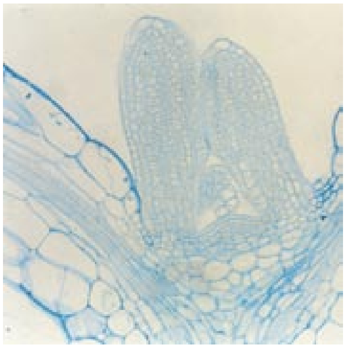
Challenge four: Vibrant and competitive basic research

Vibrant basic research is essential for EU competitiveness in plant-based industries. In the knowledge-based economy of the future, competitive and innovative new products will spring from fundamental discoveries. Knowledge and intellectual property will be critical to fulfilling the goals outlined in the other four challenges.

The cutting edge of basic plant research is rapidly evolving from understanding the function of single genes to studying networks of genes that control complex biological processes. This new era of systems biology enables us to determine how the interconnected networks of genes and gene products work together in steering biological processes. For instance, to produce fruit and grain, or to determine the performance of the plant under different specific environmental conditions. This new research paradigm must be fuelled by sustained investment in whole genome sequencing. This includes both, genomes of plant species of scientific and industrial relevance to Europe, as well as genomes of all major plant pathogens that affect important European crops. The whole genome sequences will provide the foundation from which the inventories of natural variants within species or closely related species can be obtained.

Genome sequences provide the list of parts that contribute to building and sustaining plant life. New technologies must be developed to analyse molecules and biological processes at cellular and sub-cellular resolution. Major investments and developments in bio-informatics will be required to allow effective storage, analysis, integration and mining of the functional data provided by these technologies. Phenotyping platforms for all major European crops will need to be deployed in order to select genotypes or alleles and/or genes which maximise agricultural output. Systems biology research should be established for all basic biological processes relevant to crop productivity and quality.

Skilled human resources are an essential building block for competitiveness. Supporting the mobility, in particular of young scientists, will help to widen their skill base and to develop links within and between the academic and industrial research environments.



Additional key infrastructures need to be made available to guarantee access to biological and genetic resources, including access to well-developed bioinformatics and data mining capabilities.

In the coming decades, education and training should cater for both, new fields and more traditional ones. Training platforms need to be established that are very flexible in subject, capacity and timing to respond efficiently to the needs of scientists and students. To be able to translate exciting academic findings into benefits for European society, closer co-operation between academia and industry is required. This will help to channel some academic research more towards solving real-world problems and will also involve industry in the latest scientific developments. Finally, mechanisms and opportunities to promote larger scale trans-European research collaborations need to be established to enable greater creativity and productivity in basic plant research.

Essential for genomics research are high-throughput or large-scale biology requiring specialised research facilities equipped with expensive instruments, robots and computers. The genomics revolution also has considerably increased the responsibility of stock centres in the collection, maintenance, curation and distribution of diverse types of molecular and genetic resources.

Five specific goals will be explored under this challenge:

- Genome sequences of European crops and major pathogens
- Detailing the parts list of genomes
- From gene to phenotype
- Systems biology and prediction of novel traits
- Building human resources, infrastructure and networking

Challenge five: Consumer choice and governance

If the plant science sector is successfully to innovate and bring new plant products to the marketplace, an important goal that must be achieved will be to increase the involvement of the public and consumers in discussing research and development goals. Firstly, there will be a need to increase the public's knowledge of the field, while developing within the plant sector a greater awareness of public and consumer attitudes and behaviour towards agricultural research and production systems.

Real effort must be made to increase dialogue between the public and the plant sector so as to rebuild trust and to increase the public's participation in setting the plant science research agenda. To achieve the necessary increased dialogue among stakeholders, there will be a real need to develop better and more innovative communication vehicles.

An important aspect of restoring and boosting trust will be to build ethical issues into the research agenda and R&D programmes. First, it will be necessary to build a wider academic forum to consider plant science and the interaction of social and ethical issues that may arise. Secondly, there will be a need to build a greater understanding within European society of the ethical importance of conducting plant research and development to meet our needs in a responsible way. This will also provide the public with a better understanding of the crucial role played by the plant science community in meeting society's needs.

The EU has established a rigorous safety-based regulatory system that evaluates innovative crop plants before they can be placed on the market. However, this is not generally understood by the public. In addition, EU legislation requires the labelling of products derived from genetic modification so as to provide consumers with informed choice in what they purchase.

To provide consumers with real choice, there is a need to consider how farmers and the agri-food chain can maintain the integrity of the food and feed that is derived from different plant types and farming practices. Further research to facilitate the coexistence of different types of crop plants grown by farmers both through different technologies in plant development and through refined farming practices has been identified as necessary. This would minimise the cross-pollination and resulting gene flow between different types of the same crop families.

One common barrier to the commercialisation of innovative products is the difficulty faced by start-ups in gaining adequate financing to take ideas from the lab to the market. This necessitates the establishment of strong public and private funding components.

To response to the issues raised in this challenge, three goals have been identified:

- Public and consumer involvement
- Ethics and food security
- Legal and financial environment



3. Methodology

General background

The European Council asked in its conclusions following the Spring Council meeting in March 2003 to "create European technology platforms … to strengthen the European Research and Innovation Area … in areas, such as nanotechnology and plant genomics".

Such platforms should bring together stakeholders – such as companies, research institutions, funding bodies and regulatory authorities – at the European level to define a common research agenda which should mobilise a critical mass of national and European, public and private resources.

The **Plants for the Future** European Technology Platform aims to strengthen the European Plant Research and Innovation Area, mobilising support – both public and private – at the European, national and regional level. It was launched in June 2004 by then European Research Commissioner Philippe Busquin with a document entitled *2025 a European vision for plant genomics and biotechnology*.

Since then, the Platform's stakeholder forum was developed further to embrace a wide cross-section of companies, research institutions, farmers organisations, regulatory bodies, education and communication experts, as well as financial, consumer and environmental groups.

Using the vision paper as their starting point, the stakeholders set about developing a draft Strategic Research Agenda 2025 to signpost the road to fulfilling this ambitious vision over the next two decades. It was compiled by four dedicated working groups. Four workshops attended by leading experts and stakeholders were held to help draft the document in autumn 2004. The SRA also included a more detailed Draft Action Plan.

The SRA proposal was launched in July 2005 with speeches by current Science and Research Commissioner Janez Potočnik and the then chair of the European Parliament's Committee on Industry Research and Energy, Giles Chichester.

In 2005 and 2006, a broad consultation on the proposed SRA took place, involving over 1 000 stakeholders in 19 Member States, as well as European Parliament members and European Commission officials.

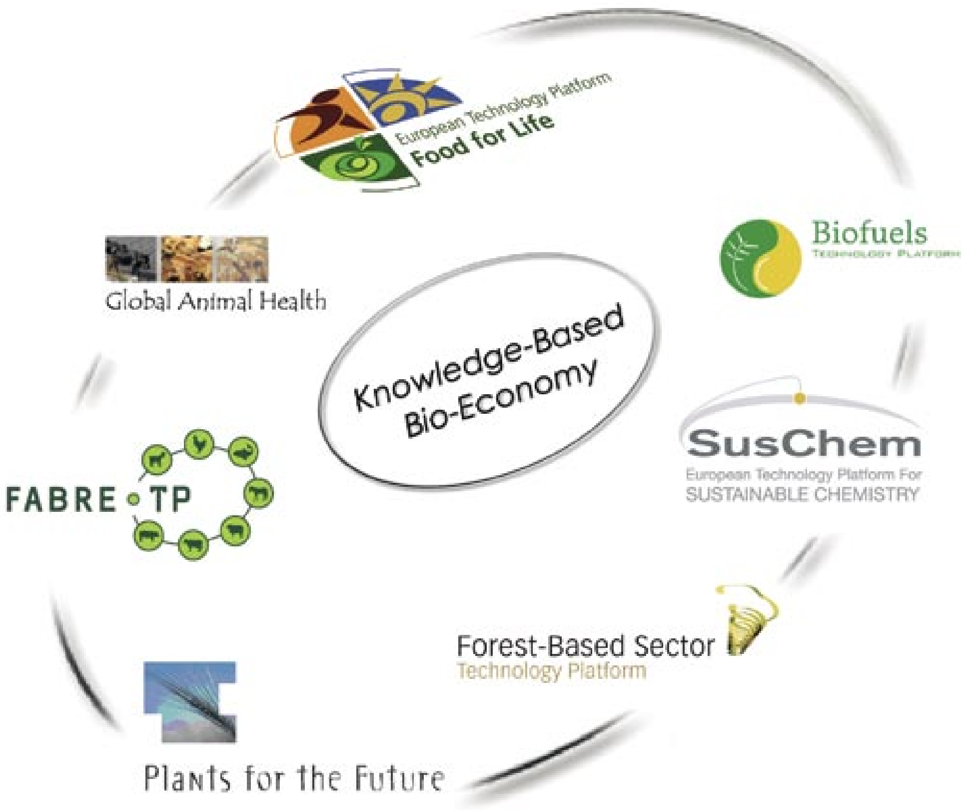
Based on the results of the consultation, the Plants for the Future has now produced a final Strategic Research Agenda, launched at the European Parliament in June 2007.

The next step forward

The next step in the strategic process initiated in 2003 is the implementation phase. Plants for the Future will use various instruments at European and national level in order to implement the SRA, integrate it into national and European research strategies, promote the development of national platforms, and enhance the public profile of plant sciences. In addition, emerging instruments such as the lead market initiative, the European Institute for Technology (EIT) and the possibility to use structural and social funds, will be considered. For the coming years, the ETP will focus on facilitating the implementation of the Action Plan.

To accomplish this, Plants for the Future will work in a wider web of collaboration with the six other technology platforms related to the knowledge-based bio-economy as shown in the graphic below. In addition, Plants for the Future is developing closer collaboration with related European Research Area networks, such as the ERA-NET on Plant Genomics, and more distant technology platforms like 'Manufuture' and 'Innovative Medicine'.

Plants for the Future encourages all interested bodies at European, multi-national, national and regional level, to contact our secretariat to discuss how to foster joint implementation of the SRA to transform Europe into a knowledge-based bio-economy.



4. Selected glossary

Abiotic stress:	Nonliving environmental factors (such as drought, extreme cold or heat, high winds) that can have harmful effects on plants.
Agri-food sector:	the sector of the economy that produces agricultural and food products.
Agribusiness:	agriculture-related industries.
Agri-food industry:	agriculture and food related industries.
Bio-economy:	all industries and economic sectors that produce, manage and otherwise exploit biological resources (and related services, supply or consumer industries), such as agriculture, food, fisheries, forestry, etc.
Biofuels:	fuels derived from living organisms, as opposed to fossil fuels.
Biomaterials:	materials derived from living organisms, as opposed to synthetic materials
Biotechnology:	technologies for cultivating, modifying or deriving products from living organisms.
Biotic stress:	Living environmental factors (such as viruses, bacteria, fungi, insects etc.) that can have harmful effects on plants.
Coexistence:	the cultivating of conventional, organic and genetically modified crops in the same area without them affecting one another.
Genetics:	science and technology of hereditary factors.
Genetic modification:	scientific technique for altering the genetic make-up of living organisms which results in genetically modified organisms (GMOs).
Forestry:	the cultivation of trees and the management of forests and woodland. Related sectors include paper and pulp industry.
Knowledge-based bio-economy (KBBE):	the knowledge-based approach to all industries and sectors of the economy which produce, utilise or manage biological resources.
Plant genomics:	the science and technology of the genetic make-up of plants.

5. Working groups

The working groups, which were set up by the ETP Steering Council to draft this document, comprised:

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It is neither exhaustive nor comprehensive and covers only selected aspects of broader issues.
The Strategic Research Agenda, views and information expressed in this document are those of the group as a whole and do not necessarily reflect the opinions of any single member, their organisations, or of the European Commission.

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