



# **Agricultural Engineering and Technologies**

## **Vision 2020 and Strategic Research Agenda**

of the European Agricultural Machinery Industry and  
Research Community for the 7<sup>th</sup> Framework Programme for  
Research of the European Community

Brussels  
October 2006

## Preface

The community of agricultural engineering in Europe has formulated, for the very first time, a common vision of how agriculture and its driving engineering technologies could look in 2020 and of the strategic technological necessities to translate this vision into reality. Thanks to the commitment of individuals from industry, research and other associations, this paper shows the future fields of research on Agricultural Engineering and Technologies (AET). Within these fields, the first specific topics for research and technological development have been defined. With growing knowledge, further topics will arise and will be added continuously into plans during the coming years. This paper contains the Vision 2020 and the AET Strategic Research Agenda (SRA).

The European agricultural machinery sector is a world leader in supplying enabling technology to the various businesses of crop and livestock farming. With this, AET is part of the value-added chain for food production as well as for the increasingly important production of bio-materials and energy crops. Since there is a strong connection to other production and manufacturing technologies, the AET Working Group that elaborated this paper was established under the umbrella of the European Technology Platform *MANUFUTURE*. That is why this document presents an AET Vision 2020 and SRA from an independent position but with a strong link to the Vision and SRA paper of *MANUFUTURE*. Additionally advanced agricultural engineering and technology is fundamental for further proposed research actions of related Technology Platforms mentioned in this paper.

Many thanks are due for all contributions to this important paper. Though the statements are built from a scientific base, the messages are of high relevance for practical applications in future due to the significant input from industry.

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## **Chapter I:**

### **Vision 2020**

#### **The society in the year 2020**

The situation for European society has changed dramatically. This has mainly been driven by influences from the “global village”, with changes in the importance of countries and continents. China has, all in all, the world number one market position, with India in second place.

Much of industry that is dependent on handmade construction has moved from Europe to less-developed countries with low skilled workers or with very cheap labour. In Europe, service industries have continued to increase.

Energy availability is a major challenge to all countries worldwide. The rate of crude oil production has passed its maximum. Renewable energies are of major importance. In highly-developed countries, high energy demand continues for transport and leisure. Transport requires oil substitutes like ethanol or bio-based synthetic fuels (BAL).

In society, there is an ongoing process of understanding and active cooperation in conservation of nature and natural resources. People are looking for high quality food. The share of organic food consumption is increasing. Consumers call for specific information on food production and food processing in both conventional and organic farming food chains.

Following the Lisbon Strategy, the EU has become the one of the world's most dynamic and competitive knowledge-based economies between 2010 and 2020, with research, education and innovation being key contributors to delivering targets on economic growth and employment.

#### **Agriculture in the year 2020**

Agriculture is still under significant EU regulation, with subsidies for nature conservation and regional support through structural funding. Structural change in general continues but broad regions have stabilized at a high farm size. The proportion of the workforce in agriculture is still decreasing with a major impact coming from increasing farm size. Subsidies for nature conservation are reducing production of some commodities that have previously been in excess, but demands for biomass and other commodities for the bioenergy and renewables market are growing rapidly, and low cost, low environmental impact production systems are in great demand. For some products, production limits and support still exist to protect a European supply base for key commodities in an uncertain international climate. European farmland remains of similar size, slightly decreased by urban land consumption and by increasing terrestrial traffic requirements.

##### *Farmers:*

The average age of farmers and landlords is still very high. Youngsters in more rural areas generally leave their homes for more interesting jobs in urban environments as well as for higher salaries.

The education of the younger generation is a top priority and of a high standard but shows differences between the EU member states. In general there is a broad acceptance of technology and of improved and visionary developments in particular.

Farmers know and understand that they are in charge of their businesses and increasingly accept responsibility for animal welfare and environment protection.

Hand labour has minimal attraction, except for niche markets, with automation and robotics accepted by everyone and everywhere, and considerable demand for new techniques and machines that enhance traceability and control.

#### *Farming:*

Precision Agriculture has been accepted as the only efficient and sustainable farming system. It is used in different ways.

In “Precision Livestock Farming”, animals are kept under “near free range” conditions. No animal is tied up and nearly all livestock housing has natural ventilation. Feed supply, milking of dairy cows and healthcare are undertaken by both fixed and, increasingly, by mobile robots. A wide range of sophisticated sensors gather and transmit information to the management systems and people by wireless networks. Feed production and feed preparation are largely delegated to contractors and other types of cooperation.

In “Precision Crop Farming”, site-specific treatment is the common approach. Conventional tillage, conservation tillage and no-till systems are in use. Autonomous field scouts gather management information. On-the-go variable-rate technology is based on online-sensors (soil, water, crop growth, infestation) and application maps. Several new types of harvesting technology driven by new logistical solutions are used. They measure yield and components, dividing the material flow “on demand” into different storage locations according to quality parameters measured on-the-go. Post-harvest management, including dehumidification of crops with high moisture contents, begins immediately after harvesting.

In Horticulture, robots have taken over most of the hand work in orchards and in viticulture. Other precision farming technologies are accepted. The greenhouse sector has saved 40-50% of energy consumption by the use of solar energy (smart storage, optimal use and supply), wind energy and biofuels. With an optimal control strategy and dehumidification of the air, zero energy use is being achieved. CO<sub>2</sub> emission has been dramatically reduced and automation and robotics are common in greenhouse businesses.

Farmland use is increasingly a competition between the production of food, feed, bioenergy and renewable materials. This competition and growing demand have led to a significant increase of some agricultural product prices. Economic constraints continue to require high yields. New crop rotation systems allow improved nitrogen balances with less leaching and provide other ecological benefits. New services are offered by all stakeholders in the value-added chain, including suppliers, contractors and consultants. Closed loop systems in a broad sense, including no-waste and energy self-sustaining farms, are becoming economically successful and are seen more frequently.

Farm management has access to sophisticated information and management technologies, and communication systems that allow networking with all stakeholders in the value-added chain.

#### *Technology:*

European agricultural technology for field work and for livestock husbandry leads the world. Electronics, automation and robotics are widely used. Wireless communication technologies offer access to broadly spread farming facilities and link them to decentralised web-based processing and information sources. Sophisticated up-to-date software packages, expert systems and fixed and mobile farm technology are provided for the farmer.

Farm power and machinery has changed to use renewable energy sources like bio-based synthetic fuel, hydrogen and fuel cells. New power train systems include decentralised electric drives. Tractors and self-propelled farm machinery still operate with a driver on-board but are fully automated. Unmanned followers are in use for some production technologies like harvesting. The first small autonomous vehicles are being deployed for scouting, weeding and cultivation. Automatic data gathering for documentation purposes and for improved farm management is a fundamental component in all farm equipment technologies.

Farm equipment is more specialised and more optimised than ever before. Based on standardised electronic communication, the tractor is controlled by the implement and responds to the requirements of soil and plant in the most suitable way. Pest management and plant protection measures have moved significantly from solely chemical applications to adopting highly precise physical treatments. Fertiliser application technology reacts to the needs of small areas of the crop or even single plants.

Technologies for new and advanced cropping systems have been developed and are in use. They fulfil the demand for plant production for bioenergy as well as for more renewable bio-materials with a strong focus on fibre quality or on starch or sugar content.

Harvesting technology has changed from the simple collection of field crops (even for animal forage and feed) to on-the-go pre-processing or quality dependent sorting into different hoppers. Measurement of components is done in real-time during the harvesting process.

Also the technology in cattle, dairy, pig and poultry husbandry has changed to networked systems. Sensor-based monitoring of ethological parameters as well as health and fertility measures is used. Individual animal feeding is performed by automated feed dispensers. Dairying is dominated by use of milking robots around the clock, either in a conventional dairy or in a mobile environment on the pasture. Robotic “sheepdogs” are responsible for management tasks as well as for shepherding activities in cattle and sheep husbandry.

New logistics technologies are available. Intelligent RFID tags permit food chain monitoring as well as for management of production processes and facilities.

### **The challenge of agricultural engineering technology in 2020**

European manufacturers of agricultural engineering technologies are the number one players worldwide. They have the highest rate of world exports of agricultural technology and they lead the world in the development of future-oriented new technologies. The big European manufacturers continue to be part of multinational global businesses, but the main development centres of new enterprises are located in Europe to access the knowledge economy and infrastructure.

Besides the large companies, many European agricultural equipment manufacturers are still small and medium-sized but technology-driven enterprises (SME). They often act as supplier, sub-contractor or alliance partner to the larger companies, but also as the source of innovations, translating ideas from science etc. Most innovations are created by these SMEs, thanks to increased financial support from outside but often with less resource in their R&D departments. Therefore broad forward-looking research in universities and high-performance research centres is of crucial importance, and is supported by industry and government.

SMEs have also extended their production portfolio into environmental technologies and processing technologies for renewable energy and bio-materials. To deliver this new and

future-oriented field of engineering, European manufacturers have taken the worldwide lead in innovation and development.

Overall agricultural technology is an enabling technology, underpinning high efficient processes in agriculture and related areas. It enables:

- production of healthy food and feed and of renewable resources of required quality
- reduction of human workload in all fields of agriculture processes
- high efficiency in agricultural machines and processes
- appropriate animal husbandry
- sustainable handling of natural resources
- maintenance of the landscape and biodiversity

The European Agricultural Machinery industry's worldwide leadership in technology and exports extends beyond tractors and self propelled working machines into specialist sectors such as milking equipment, climate control engineering for greenhouses and livestock production, efficient farm buildings, and precision application of fertilizers, animal manures and chemical sprays. All this is dependent on continuing innovation and development to maintain the world position and the high level of technical employment in this sector. Agricultural technology enterprises are providing the capabilities for the agriculture and food industry to be a major component of the European economy, as well as for the developing sector for biomass utilisation in the production of energy and materials.

To provide these major contributions to European society, to meet the environmental challenges and to provide enough food for the growing world population, concerted actions have been undertaken. They may be illustrated by the technology in the following picture, which becomes common practice in crop farming and in animal husbandry. In order to achieve this vision, networking and coordinated supply of new technologies is essential and is outlined in the Strategic Research Agenda (Chapter II).

## Chapter II:

# Strategic Research Agenda for European Agricultural Engineering and Technologies

### Summary

This chapter presents the outcomes of discussions between individuals and organisations representing a broad range of the agricultural engineering sector and seeking to establish a Strategic Research Agenda for European Agricultural Engineering and Technologies. It has been produced following a workshop in Brussels on 31 January 2006 entitled “Keeping ahead of Agricultural Engineering Technologies: Sectorally Coordinated Research and the Road to European RTD” and further meetings of experts and working groups.

The knowledge-based economy that underpins Europe's future aspirations requires significant advances in the technologies to manage food and renewable production. The European engineering industry for this sector is internationally competitive, and has recognised the importance of a coordinated approach to the identification and pursuit of research priorities, and the translation of innovation into practice.

The vision for agricultural engineering (“Vision 2020”) presented in Chapter I highlights the major changes expected in the shape of agriculture and the importance of new technologies and new ways of communicating information and making decisions. This second chapter records discussions leading to lists of prioritised research themes under four topic areas: Quality and Product Security; Sustainable Plant Production; Sustainable Animal Production; and Bioenergy and Renewable Materials. It is now important to further extend the engagement with the agricultural engineering community, member state and EU research funders, and the breadth of industry organisations in order to grasp these opportunities. A Working Group has been established under the umbrella of the European Technology Platform, *MANUFUTURE*, to develop these ideas and establish cooperative and collaborative actions.

### Introduction and Background

#### *The background to the workshop.*

Members of the European agricultural technology industry and research institutions have contributed opinions on priorities for the future areas of systems research in the entire field of agricultural and biosystems technology, during the preparation of the 7<sup>th</sup> EU Framework Programme for Research. Particular importance has been attached to ensuring that innovative enterprises operating successfully in Europe contribute their vision of the future to the thematic structure of research support. European associations of manufacturers and engineers have expressly supported an initiative that brought industry and academics together to produce a paper entitled “Building the Europe of Knowledge: Agricultural Technology” early in 2005. The challenge for the workshop in Brussels on January 31, 2006 was to widen the engagement with research and industry communities in Europe and define how this priority area could have greatest impact on the decisions about research initiatives, particularly in Framework Programme 7. This chapter reports the key contributions to that workshop and its outputs, particularly the definition of the Strategic Research Agenda for the area. The discussions following the workshop led to several extensions and adjustments that are included in this paper.

The workshop was limited to fifty people by the venue and resources available, but these fifty came from 15 different European countries, representing 6 different companies, 20 Universities and Research Institutes, and 10 Associations and authorities. Its objectives were to:

- Bring an EU-wide group together to translate early ideas into a European view of needs and priorities
- To communicate the progress of the initiative
- To develop a common understanding of the future demands for research
- To establish a working group that can translate the workshop ideas into practical actions that influence research initiatives and implementation of the 7<sup>th</sup> Framework Programme

*EU Research Programmes and European base for agricultural engineering and technology.*

Under the Lisbon Strategy, the EU seeks to become the world's most dynamic and competitive knowledge-based economy by 2010, with research, education and innovation being key contributors to delivering targets on economic growth and employment. New targets have been set for Member States to expand their research budgets to 3% GDP, largely through increases in industrial investment in R&D, and for greater coordination of research policies and activities across the European Research Area.

Within the EU, changes in political priorities and aspirations demand a new approach to agricultural research. Global demands for trade liberalisation and public concerns about the rural environment are leading, through CAP reform and other measures, to new objectives for agriculture:

- Reinforcing farmer's market orientation and entrepreneurial role
- Encouraging competitive agriculture and agro-industry in a world market
- Enforcing standards for environment, food safety and animal welfare
- Steering sustainable rural development

The Agricultural Engineering and Technology Sector is recognised as key to the production of high-quality food and feedstuffs, to Europe's role as a competitive food exporter and to the management of the majority of Europe's land area and green environment, whether for food, feed, or renewable resources or biodiversity and other environmental benefits. The European industry is the major worldwide exporter of agricultural machinery. It leads in adoption of new technology and is an important employer. The research agenda needs to be targeted on knowledge-based products with high potential for uptake and able to deliver efficient sustainable agriculture and land use. Agricultural science and engineering has the potential to produce innovative approaches to problems that include:

- Knowledge-based competitive machinery and process technology
- Food production with documented quality
- Production processes that are fully compatible with environment and animal welfare regulations
- Technology for production and utilisation of renewable resources and efficient use of by-products
- Efficient machines to operate in optimised production systems, for example more automated tractors and harvesters, equipped with plug-and-play electronically-controlled implements, networked or autonomous or semi-autonomous, guided via telematic links with a control station

Overall the EU goal is to improve competitiveness and sustainability by enabling growth based on research and innovation. The Lisbon goal of creating a European knowledge-based society through collaborative knowledge generation, advanced training and superior education sets a challenge to the research education and industry sectors associated with agricultural engineering to define and deliver on priorities.

Direct investment in research by industry and through the research programmes of Member States will be important in coordinated delivery of these challenges. The Framework Programmes of EU Research provide key elements of the context for coordination, and are offering new mechanisms for industry to engage fully in the development and implementation of the programmes. At this time it is therefore very important to establish how the agricultural engineering and technology sectors can engage with and influence the 7<sup>th</sup> Framework Programme, and become fully involved in industry-led and Member State programmes that reinforce its delivery. The industry is strongly represented in specific European regions (e.g. concentration of SMEs producing livestock technology and crop production machinery in North Germany) and will be well placed to build regional initiatives and collaborations as recommended by the European Research Advisory Board (EURAB 05.041).

#### *EU Framework Programme 7.*

The 7<sup>th</sup> Framework Programme builds on the major strands of past Programmes, addressing collaborative research, frontier research, human potential and research capacity. The agricultural engineering and technology sector needs to influence or contribute to get engaged in the thematic priorities in the specific programme for “Cooperation – collaborative research”. The key Thematic Priorities of relevance are:

- 2. Food, Agriculture and Biotechnology
- 3. Information and Communication Technologies
- 4. Nanosciences, Nanotechnologies, Materials and New Production Technologies
- 5. Energy
- 6. Environment

Though Theme 2 addresses agricultural production targets that benefit from engineering innovation, the research drivers of importance to the agricultural engineering industry are also strongly represented in the New Production Technologies strand in Theme 4, and also through ICT in Theme 3. Bioenergy and the broad challenges set by agriculture’s impact on the environment are relevant to the targets in Themes 5 and 6.

*Theme 2: ‘Food, agriculture and biotechnology’.* The key objective of this theme is to build a European Knowledge-Based Bioeconomy, capable of responding to social and economic challenges (including sustainable food production and sourcing clean biomaterials from renewable resources). The programme has three strands:

- Sustainable production and management of biological resources from land, forest, and aquatic environments
- “Fork to farm”: Food, health and well being
- Life sciences and biotechnology for sustainable non-food products and processes

Under strand 1, there is particular importance for the agricultural engineering and technology sector in:

- Enabling research on converging technologies
- Development of new technologies and equipment for safe and sustainable production
- Animal welfare and safe disposal or reutilisation of animal wastes

under strand 2 in:

- Improved food and feed processing
- Efficient management of by-products, waste and energy
- Improved quality and safety of food and feed

and under strand 3 in:

- Improved outputs for energy, environment, and high added value industrial products
- Novel farming systems
- New bio-refinery concepts
- Forestry and forest based products and processes

*Theme 4: 'Nanosciences, Nanotechnologies, Materials and New Production Technologies'*. This diverse theme has the objective to improve the competitiveness of European industry and ensure its transformation from a resource-intensive to a knowledge-intensive industry, by generating breakthrough knowledge for new applications at the crossroads between different technologies and disciplines. The four strands are:

- Nanosciences and nanotechnologies
- Materials
- New production technologies
- Integration of technologies for industrial applications

Under these strands, relevant opportunities include:

- Enabling new products and processes, including the use of biomaterials and their processing
- Innovative production capabilities
- Integrating production technologies in sectoral and cross-sectoral applications

#### *European Technology Platforms.*

It is recognised that the goals for the development of the EU knowledge-based economy under the Lisbon Strategy require effective engagement of industry and other stakeholders to provide a shared vision on priorities, maximise coordination of research and to mobilise public and private funding sources. The establishment of European Technology Platforms by stakeholders, led by industry, is proving a key contribution to this process. They are proving to be powerful actors in the development of European research policy, in particular in orienting the Seventh Research Framework Programme to better meet the needs of industry.

The overall concept for ETPs is of "Stakeholders, led by industry, getting together to define a Strategic Research Agenda on a number of strategically important issues with high societal relevance where achieving Europe's future growth, competitiveness and sustainability objectives is dependent upon major research and technological advances in the medium to long term". The common vision for the technology should ensure that a critical mass of research and innovation effort is mobilised.

Of specific importance and relevance to manufacturing within the agricultural engineering sector is the *MANUFUTURE* Technology Platform, whose activities are outlined below. This ETP has already recognised the importance of links to other ETPs. From the perspective of agriculture, the ETPs of specific relevance to the development of research include 'Global Animal Health', 'Food for Life', the Industrial Biotechnology section within 'Sustainable Chemistry', and 'Forestry Resources'.

*The MANUFUTURE Technology Platform.* The debate about the European manufacturing of the future began with a conference challenging the "role of research and education for European leadership" in December 2003. This led to the establishment of one of the earliest-formed Technology Platforms, *MANUFUTURE*. This ETP has the objective "to develop a 'research and innovation' strategy based on a long term vision for a field where there are many technological and economic variables and in consequence to assist the transformation of the European manufacturing industry towards a knowledge-based economy and the achievement of a world leadership in manufacturing". This is recognised to be particularly relevant to the renewal, revival or restructuring of traditional industrial sectors.

Manufacturing is a major sector in the European economy, contributing 41% of value added and 30 % of jobs in the EU-25. The challenge from the Asian economies is a major driver to shift from a resource-based economy to a knowledge-driven economy, thus improving the competitiveness of EU industry in accord with the Lisbon Strategy.

The ETP ([www.manufuture.org](http://www.manufuture.org)) produced a Vision 2020 at its conference in 2004, and presented a Strategic Research Agenda in June 2006. Workshops identified an extensive list of important research areas for each sector, and discussed prioritization of these areas. It was recognised that some research should be carried out with partners outside Europe, for example where global manufacturing, global initiatives (climate change, environmental issues) and global standards are involved.

The agricultural engineering industry in Europe has already engaged closely with the *MANUFUTURE* Technology Platform, and considers that many of its interests can be developed and targeted on research initiatives within Europe through the development of a sectoral activity within the ETP.

#### *SCAR: ICT and Robotics for Agriculture*

An important final component within the research infrastructure for Europe is SCAR, the newly reformed Standing Committee for Agricultural Research, now under DG Research. SCAR's role is to support the Commission and Member States towards better coordination of agricultural research across the European Research Area. As well as high-level strategic discussions and support for cooperation, the Committee has established a range of working groups, including collaborative working groups (CWG) to develop specific topics deemed of high priority. These collaborative working groups are important in the development of a Common Research Agenda for agricultural research across Europe.

The CWG of greatest relevance to agricultural engineering is 'ICT and Robotics in Agriculture' and this group has already made considerable progress bringing together the national and regional efforts and resources in this area in Europe. It is also developing a vision of the research agenda for the area. It highlights the importance of new and advanced technologies for future developments in the agricultural sector, and provides a further opportunity for influence on the implementation of Framework Programme 7, particularly at the interface between themes, where agriculture, ICT and manufacturing may have common interest in a coordinated initiative to meet the distinctive challenge that bioproduction systems bring.

Other CWGs may have relevance to the application opportunities for innovative engineering concepts. They include 'Renewable Raw Materials for Non-Food Industries' and ones addressing specific issues relating to Mediterranean agriculture, sustainable development, and climate control in greenhouses and livestock housing.

### **Industry Research Needs**

European agricultural engineering and technology is of worldwide importance to food production and to meeting the foreseeable increase in world demand that will result from population growth and increasing incomes in developing countries. The challenge for the industry is to develop and implement systems that produce high-quality and safe food and feedstuffs whilst also being efficient, environmentally acceptable, and sustainable. These systems of appropriate agricultural technology are also required for production and utilisation of renewable raw materials and must also take into account the social implications, e.g. the shaping of rural areas, the preservation of cultural landscapes, etc.

The economic importance of the agricultural technology industry to society in Europe should not be underestimated. In the agricultural machinery industry alone (without considering animal production technologies) 250,000 people are employed in the EU-25 countries, in 4,500 businesses of which 1,065 have more than 20 employees. In addition, there are a further 125,000 related jobs in business and trade. Agricultural technology enterprises provide the capabilities for the agriculture and food industry, a major component of the

European economy, as well as for the developing sector for biomass utilisation in the production of energy and materials. The decline in the proportion of household budgets spent on food (in Germany from 44% in 1950 to around 16% now, including 4% for luxury items) highlights the importance of economic efficiency in food production. High-performance, cost-efficient agricultural technology innovations have contributed greatly to price stability of foodstuffs and the associated benefits in terms of social welfare. The European Agricultural Machinery industry has become a worldwide leader in technology and exports. The total turnover of European manufacturers of agriculture machinery and tractors in 2004 was 19.7 bn €. There is considerable trade between countries within the Community but also 22% of production is exported from the EU-25 countries. Competition from America (North and increasingly South too) is already strong and competition from Eastern Europe and Asia will be there soon. The whole European Agricultural Machinery industry must continue to innovate and develop if it is to maintain its world position.

The industrial sector of agricultural engineering is characterized by a few large businesses (4 enterprises have turnovers > 1 bn €) and a very high number of small and medium sized enterprises (SMEs). All world-leading companies have facilities in Europe. The bigger companies invest between 2 and 4% of their turnover into product development. That is enough for the mid-term (5 years) innovation process. Significant underpinning research however can only be done by one or two companies, if at all. The others are mostly developing just for the next generation of products - and that will be not enough for the challenges of the future. The agricultural technology industry contributes considerable added-value to the European economy and also makes major impacts on environmental goals through systems engineering and process technology. It must continually develop innovative high-tech solutions in order to be able to produce agricultural products economically in accordance with exacting quality and environmental requirements within Europe's high wage economy. Investment in research and technology innovation is therefore essential now to meet the requirements of industry, government policy and society.

Agricultural Technology is an enabling technology, underpinning high efficiency in agriculture and related areas through advances in systems, machines and processes. It contributes to the production and handling of safe food, feed and renewable resources of required quality. It enables reduction in human workload and use of appropriate animal husbandry, and enhances the sustainability of natural resources and the maintenance of the landscape and biodiversity. The future vision for these areas has been described in Chapter 1: Vision 2020.

Innovation is needed for new products, but also for processes, tools etc. Therefore we need well-educated engineers and high-level research outputs. In the 21<sup>st</sup> century we find agricultural engineering research institutes and universities have developed a worldwide recognized expertise that is not fully put to use for future industrial developments due to limited public support and unnoticed challenges facing our agricultural and rural communities. We must strengthen university departments and research institutes and ensure that their research work can provide the backbone for future product innovations. We also need well-educated engineers as drivers of the innovation process. We have to act now if we are to sustain the leading position of our agricultural machinery industry. In many parts of the sector, SMEs are an important element of the industry base delivering technical solutions, and will be integral to future developments.

The highly-skilled people and the know-how in Europe have allowed the industry to reach a high level of technology, and develop high-end solutions in many sectors. This includes, for example, fuzzy algorithms in automation solutions, laser sensors for edge detection, high accuracy GPS systems for location and navigation, ICT for remote maintenance, etc. We can now drive the industry further to meet key EU development goals:

- Increasing R&D expenditures and dynamic knowledge growth in an important enabling technology

- Sectorally coordinated research involving SMEs
- Innovative, competitive and expanding agricultural machinery industry
- Enabling economic production of high quality safe food and renewable resources
- Strengthened European position as a leading exporter of food and machinery

European industry and governments therefore need to engage in a strong research agenda that addresses opportunities like:

- Automation and ICT requirements for both advanced land-based production systems and innovative machinery manufacture
- Energy-efficient machines and production systems, including bioenergy production
- Machines and systems that protect the soil, water and aerial environments, minimising use of energy and water
- Increased use of technology in rural communities, providing and sustaining employment in attractive well-paid jobs

Ting and Grift (Resource magazine, ASAE, October 2005) have highlighted the challenges and opportunities for automation in bioproduction and these messages highlight the opportunity we need to take in Europe. The challenges are to

- make return on investment attractive
- optimise systems by proper integration of automation, culture, and environment
- balance fixed automation and flexible automation (i.e. identify the appropriate level of machine intelligence)
- consider multiple use of machines or parts of machines
- address the limited market demand and acceptance,
- continuously improve research development and education capabilities
- in order to grasp these opportunities there is a requirement for
- a higher technology acceptance level
- building on the past success of agricultural engineering technology
- using the excellent communication systems and platforms for sharing technical advances
- and improved economic viability for automated systems
- with potential spin-off technologies and ability to facilitate implementation of emerging technologies.

## **Science Developments**

Agricultural and other complex biological systems (biosystems) pose a complex set of scientific and engineering challenges that need to be addressed if engineering solutions are to deliver new and more sustainable production systems. The agricultural and biosystems engineering research base in Europe has the capability to progress the underpinning science and work with industry to deliver solutions. The mission of the agricultural engineering and technology community is to propose engineering research and innovation capable of speeding up the rate of agricultural transformation in Europe, securing high added value employment with efficient production systems (of raw and processed products) in a knowledge-driven economy.

The characteristics of the problems include:

- complexity of biological objects and systems operating at different scales of time and space
- time variable nature and dynamics of these systems
- processes that are frequently non-linear
- high degree of variability and disturbances
- major interactions determine key processes, e.g. between machines and soil, crops and weather

We are in a position at the start of the 21<sup>st</sup> century to address a number of these challenges, and produce solutions that can be put into practice. Among the critical advances are

- the development of mathematical techniques to handle uncertain (fuzzy) systems and identify probabilistic approaches to manage them
- the availability of high speed and low cost devices to process information rapidly and define optimal decisions
- rapid communication systems that allow information from field machines, remote sensors and databases to be utilised in complex decision processes
- increasing availability of new physical and biological sensors (biosensors) that are the first step in monitoring system performance and open the door to real time control
- increased understanding of the performance of biological systems and materials at the finest scales (nanotechnology and molecular science)

We can consider automation as an example area that draws on many of these opportunities and will be critical in delivering new engineering systems for sustainable land-based industries in the future. Many agricultural systems currently require substantial manual labour at low skill levels (and therefore poorly paid) and in difficult environments. Automation is an important target if these production systems are to be sustainable within Europe. The delicate nature of fruit and vegetable harvesting and the risks of repetitive strain injury associated with manual handling operations are particular examples. Others arise in the high levels of aerial pollutants in livestock or mushroom production environments. Automation and new technology can redefine environments and reduce loads on the workforce, whilst also bringing in higher skilled employment associated with new machinery management.

Addressing these issues raises challenges in relation to:

- Safety and quality demands: monitor and control growth and development as well as treatment needs at the level of a single plant (or animal) or of a small area in the field
- Measurement and quality control (chemical/physical state, physiological development, disease incidence, future text/taste) during the growing process
- Tools for flexible chain management: optimal process control for growing (rearing) and harvesting to meet customer requirements, not just production-oriented

A major new demand will be for data harvesting and mathematical modelling. The systems models must be appropriate to practical management of the processes, leading to decision models. The modelling methods will need to be able to interpret variable and uncertain data as an input to decision-making. This is a vital element if we are to get strong solutions based on automation or utilising new sensing systems. The innovations here will open up control opportunities and in addition the availability of extensive, accessible and detailed records will open routes to enhanced traceability and communication in the food chain.

In delivering the advances in science and innovation, it will be important to take a holistic approach, and marry the advances that will be available from biology and engineering, and from science and industry. Co-design or co-engineering will be important so that design of equipment is achieved through close cooperation between engineering and biology/agronomy. Inspiration from biological systems may also be key to future developments, as new materials and novel actuators are introduced.

The opportunities that new science in these areas can deliver, in conjunction with developments in materials science, power train technology and a wide range of other disciplines that feed into operational systems for agriculture and land use, are best highlighted through identifying research themes within major topic areas for agricultural technology.

## Future Fields of Research

The discussions at the workshop addressed four topics: Quality and product security; Sustainable plant production; Sustainable animal production; Bioenergy and renewable materials.

### **Topic 1: Quality and Product Security**

Quality assurance in agriculture and food production is increasingly becoming a matter of public importance, and is the subject of EU regulations on food safety and feed hygiene. The approach builds a comprehensive concept of quality that extends from farm to fork, including process quality and hygiene management as well as specific attributes of the product itself.

In agriculture, process quality control begins with the selection of the production location and seed, and extends to the ability to deliver outputs from the farm to the consumer in ways that preserve key characteristics that the consumer desires, with minimal risks. The future vision is of comprehensive quality management that delivers consumer specifications. The organisational solutions for quality management in food production must give due regard to technical feasibility and economic efficiency. Some of the topics and issues raised here closely parallel priorities identified by the Food for Life ETP.

*Sensor development and application.* Sensors enable data capture for automatic control functions and documentation. They are therefore of central importance for future quality assurance tasks and procedures. In the plant production process chain, the use of sensors is particularly important for the capture of process and quality parameters concerned with growth, harvesting, transport and logistics, storage, preparation and selection, and processing. Density and crop mass measurements based on laser, radar or lidar can help in risk assessment for diseases or can serve as inputs for predictive models for crop quality or expected quality of the end product.

During growth, parameters influencing future product quality need to be captured. In this approach to developing “speaking plants”, changes in mass and constituents during the growth period provide significant indicators. Crop information concerning growth conditions (e.g. water stress or nutrient deficiencies) and plant health (e.g. mycotoxin risk) can support important decisions concerning subsequent crop management measures and harvesting.

For optimal timing of harvesting, sensors are required that can determine crop maturity. Recording plant product parameters, e.g. using near infrared (NIR) measurements, will permit separation into different quality levels in the harvesting machine or in the subsequent transport or storage chain. The recording of quality data facilitates operations and provides new opportunities e.g. for the control of marketing or for bringing the product to the market at the optimal quality stage. In addition measurable parameters corresponding to the subjective quality perceptions of consumers, e.g. the crispness of cucumbers and the tenderness of asparagus, must be found or further developed. For further processing, plant agricultural products must be unambiguously classified. In future, product identification using a “biological fingerprint”, combined with recorded quality characteristics, will be able to provide product-oriented traceability that can extend beyond processing. The widespread implementation of new sensors and sensor applications linked to rapid analytical systems can support quality evaluation throughout the production process.

For livestock production, similar sensor developments can capture components of conditions and product quality throughout the chain from animal feeding to livestock product distribution. New sensing methods, particularly based on biosensors, can be expected to enhance biosecurity and address concerns about disease.

*Documentation and information management.* Automated data capture relating to work and product applications (e.g. for fertilisation and plant protection) will require a focus on the processing of sensor data to generate information and on one-time documentation. Automated data capture during work processes and automated data transfer, e.g. via wireless transmission to a central management system in the agricultural business, can lay the foundations for one-time documentation and traceability purposes. The data will also need to be processed to generate information for internal optimisation by control processes or expert systems, or through intervention of external experts. Appropriate data formats need to be developed for the entire data flow through and beyond the business to external organisations.

For such tracking and tracing of agricultural intermediate and final products, records of procedures carried out at individual process levels will need to be made available to other parts of the system. Here research is required concerning integrated data management and product-identifying hardware. In order to achieve integrated data management, it is necessary to define the information required within and beyond individual process steps. Data formats must be standardised for all hardware systems, so that information can flow smoothly. It will be necessary to integrate protocols across many agricultural machine systems, establish standardised communications between machinery and farm management applications for operational data capture, and link to future telecommunications systems. Documentation of all operations during crop production will eventually help the agricultural sector to better understand the production processes at a detailed level. It is already noticeable that, in sectors where such documentation and monitoring systems exist, it is possible to strongly reduce chemical use while maintaining a healthier crop.

Identification in and beyond the individual levels of processing will present considerable challenges, especially in the case of bulk commodities. Initial approaches including miniaturised radio-frequency identification (RFID) tags and isotopic and genetic markers seem promising, and must be further analysed and developed in terms of technical feasibility, cost and user-friendliness. New service opportunities arise from the need to support traditional supply chain participants in realising documentation systems.

## **Topic 2: Sustainable Plant Production**

Sustainable plant production requires management and utilisation of natural resources in the light of modern agricultural knowledge, in order to conserve or enhance the environment, biodiversity and landscape whilst producing products required by the market at competitive prices. This means that sustainability has always to take into consideration the ecological, economical and social aspects. Production processes and the utilisation of farmland must contribute to increasing soil fertility and quality, and must ensure sufficient crop yield and quality for the farmer year on year. Production processes also need to be developed and adapted to the social requirements of consumers and society. Soil conservation, the elimination of erosion, the reduction of flood risks or of mud flows into urban areas or rivers are requirements to which engineering and technology must respond. This will require different approaches depending on location, climate regions and terrain conditions. Innovative agricultural engineering and technologies have to provide technical and business solutions to meet these demands.

Future farm concepts will be based on integrated systems along the value-added chain of production. Technical, operational and organisational solutions for setting up networks have to be developed as a continuous system. All stakeholders from management, production technology via quality assurance to logistics, maintenance, service, and consulting have to be involved.

In order to ensure that production processes maintain or enhance soil quality, a range of integrated research approaches will be required. Crop rotations and soil management will

need to work together, using high performance crops that can improve soil conditions alongside soil tillage methods that protect soil and minimise energy use and cost. It will be important to link with developments in machine design, particularly the use of new light materials that can minimise machine mass, in order to reduce compaction and damage. New machine concepts and undercarriage solutions will be necessary. The long-term soil response to agricultural and technical changes has to be investigated. The resulting understanding will need to be built into decision algorithms and decision support systems for soil tillage adapted to the location and the specific crop.

Novel management of material flow will be needed, whether of inputs or crop outputs. Key to this will be innovative methods of sensing, interpreting and utilising data that characterise the crop, its environment and processes for crop management. This information can then be an integral part of product traceability and quality assurance for the food chain. Advanced machine systems will be needed that can utilise the information for management purposes, either as part of current operational machines or through the development of task-specific micro-robots. In particular, systems that have the capability to adjust inputs in relation to local crop or environmental needs will advance the concept of precision in crop management e.g. in fertiliser application and plant protection. This will be an integral part of a whole farm and landscape approach to minimising environmental pollution, and sustaining biodiversity and unfarmed ecosystems.

The advanced engineering technologies required will include robotic systems, advanced engine and drive systems, and automatic guidance concepts. Efficient energy use can be improved through development of environmentally-friendly and intelligent drive systems, using state-of-the-art drive management, and improved and safer chassis design. More ergonomically designed and efficient human-machine interfaces are needed, especially when new devices are included (such as on-board computers). With these knowledge-based solutions, new agricultural machinery including tractors, self-propelled working machines and a wide variety of implements can successfully compete in the international marketplace. Automation and robotics can contribute to efficiency in use of inputs, by precise targeting and application, and in operation of systems by linking automatic guidance with management of field operations.

Advances in sensors and the translation of data into management information will be important to delivering new science concepts into practice. Mathematical modelling and its translation into decisions support systems will underpin the take up of new technologies by end users. Sensing quality, readiness for harvest and the presence of pests and diseases will lead to advanced crop management that can improve both economic and environmental aspects of production sustainability.

There will also need to be developments that improve water conservation, both to address current pressures and to respond to likely impacts of climate change, which will require changes in production methods. Developing economical irrigation and drainage systems, including production processes and associated machine systems that counteract water evaporation, drip irrigation systems with low-pressure requirements, optimised automatic control systems and solar-powered pumps can ensure production systems are more in tune with likely future climates and demands.

### ***Topic 3: Sustainable Animal Production***

The challenge for livestock production is to develop systems that are appropriate to the animals and acceptable for human beings and the environment - these diverse requirements are often mutually contradictory. Research and development must therefore address complex system problems and propose optimal compromises in both construction and process technology. To achieve an overall sustainable increase in efficiency (both economic and environmental), natural resource use (e.g. energy and construction materials) must be

reduced, and animal health and useful life together with ergonomic and labour conditions must be improved. Emissions to the environment need to be more accurately specified before they can be optimised, particularly for open and partially open buildings. In all areas, advances in sensing of both animal condition and environment are also required as the basis for monitoring, information management and automatic control.

General objectives thus include:

- Reducing production cost
- Increasing competitiveness
- Enhancing product and process quality, animal health and appropriateness for the species
- Reducing emissions
- Increasing product safety and traceability
- Improving working conditions for human beings

Advances in sensing, data acquisition and management will be the basis for science-based innovations to control both production regimes and environmental impacts. These approaches can then be applied to evaluation and further development of building systems, leading to solutions for emission problems and resource conservation. Linking sensors with mathematical models of animal growth performance can ensure that feed supply and feeding techniques are an integral part of optimised production. Moreover, the continuous recording of product quality and characteristics, with regard to both quality assurance and animal health monitoring (e.g. in milk production), is of great importance. Advances in animal recognition techniques and the ability to determine the optimal conditions for animals by monitoring their behaviour can lead to the creation of optimal individual spaces and environments. New process technologies and advances in the ergonomics of indoor livestock systems will also be important to the livestock production systems of 2020. Small and medium-sized companies are important in delivering solutions for this area.

#### ***Topic 4: Bioenergy and Renewable Materials***

The production of renewable materials from agriculture and forestry and their use for energy generation and materials has a long tradition, though suppressed over the last two centuries in many sectors by the availability of oil and natural gas. The accompanying dramatic development of internal combustion engines and petrochemistry means that renewable raw materials have been almost completely replaced by fossil raw materials. The concerns over greenhouse-gas driven climate change require that we find new and improved ways of feeding biological materials into industry both as energy sources and as construction materials.

Fossil energy sources need to be replaced by renewable energies. Utilisation of hydroelectricity, wind power and solar energy are growing, and alongside these we must address the use of biomass for energy generation. The European Union has therefore set ambitious goals (European Biomass Action Plan, COM (2005) 628 final, Bio-energy – Presidency conclusions, 6601/06): by 2010, biogenic fuels should account for 5.75% of total fuel consumption. The use of renewable raw materials for material production is also increasing in importance. As well as the more favourable greenhouse gas balance, the biodegradability of biomass-based products and decreased risks to human health make them attractive. Other positive aspects of the cultivation and utilisation of renewable raw materials include their contribution to the development of multifunctional agriculture, the creation of new jobs in rural areas and the maintenance of cultural landscapes.

Development of bioenergy production on the farm will of course be dependent on EU and member state energy policy. With energy prices at the levels of the last decade, on farm use was the only competitive approach without subsidy. Member states have supported, to a greater or lesser extent, the development of the basic tools and at present there are many

examples of local energy use. Production of gas that can be competitive on the free market depends crucially on the levels of fossil fuel pricing. With current 2006 levels, the concept of biogas feeding into national systems begins to be feasible with subsidisation and has a chance as energy on the farm or in small networks without subsidies. If crude oil prices were to exceed 100\$ a barrel, bioenergy would have a chance on the free market without subsidies.

To realize any of these opportunities, given the likely continuing volatility in fuel prices, requires a continuing research and development focus on high efficiency production and conversion technology. Bioenergy feeding into national energy systems will contribute to the vision of a sustainable energy economy and forms part of the challenge for European industry to take the lead in non-food production and utilisation technologies.

The agricultural production of renewable raw materials can benefit from advances in food crop production technologies, particularly those related to improvements in sensing and management of crop-soil systems. However completely different plant species, cultivation, harvesting and post-harvest techniques are often involved. The systems engineering for optimal production, handling and management of what will be bulky, low unit-value commodities will need specific research and development. Even more important is the need for new technologies for the production of energy and materials from the raw commodity. There is a considerable need for research, on the one hand in order to provide the foundations for the development of innovative technical solutions by industry, and on the other hand to demonstrate economic feasibility and evaluate environmental and social implications.

The targets for production of renewables include biomass for energy, bio-diesel, vegetable oil, bio-ethanol, fibre production and ingredients for green chemistry (innovative chemical technologies that reduce or eliminate the use or generation of hazardous substances in chemical products). In developing energy crops and renewable materials, it will be of great importance to address systems problems and seek integrated solutions. Farm crops that can provide biomass may also be able to provide fibres for industrial use. Optimising the production of higher value fibre or other industrial product streams is likely to be an integral part of making some on-farm biomass crops viable. This will require involvement of producers and users in the research and development programmes, and this will be particularly important for the development of the engineering technologies for handling, processing, separating and storage of materials.

### ***Priority Themes***

These considerations and others highlight the fields and themes for future research. At the workshop, group sessions discussed, developed and then evaluated the proposed themes under each topic. These evaluations defined a priority ranking on the basis of direct judgements of the theme by individuals at each session and by ascribing scores in relation to a set of criteria. The criteria were:

- Benefits
- Strengthening competition
- Market potential
- Supporting EU policy
- Contribution to solve the problems of society and consumers

The tables below give the fields of research and their ranked priority (1 = highest), based on the opinions of those attending the group session, and later discussions with experts. On the basis of later discussions, "Agricultural systems and networks" has been added to topic 2.

## **Topic 1: Quality and Product Security**

1. Standards for quality measurement
  - Standard methods to analyse physical/chemical parameters of quality perception
  - Non-destructive measurement techniques appropriate to process control
2. Sensors and technologies to reduce residues and contaminants
  - Sensitive field detection methods for multiple pesticide residues and toxins.
  - Instrumentation and technology for rapid hazard detection or elimination on farm.
3. Materials and surfaces
  - Non-contaminating liquids in lubrication and drive systems
  - Self-cleaning surfaces and fastening/mounting methods that allow for efficient cleaning
  - Efficient indicators of surface cleanliness and monitoring of machine component wear.
4. Logistics and origin certification
  - Electronic tags and tracking systems for products through the entire handling chain,
  - Rapid detection systems for indicators of product origin or product components.
  - Machine-readable tracing and quality tags on raw materials and process ingredients.
  - Sensors for quality control and for abuse detection at source and in the chain.
  - Efficient logistics in food and feed chain to increase food safety, reduce risk of abuse, adulteration or accidental mixing of incompatible ingredients, reduce handling steps and validate storage conditions from field to consumer
5. Special consumer food
  - New concise information systems about product origin and social, environmental, technological characteristics of food chain processes to meet consumer demand.
  - Novel production methods to meet nutritional and other consumer requirements.
6. Reduction of mycotoxins
  - Develop detection systems and models to track microbes, toxins and contaminants and evaluate treatments throughout production and handling chain.
  - Application technologies for novel bio-derived and bioengineered chemicals or antagonistic organisms with enhanced action and safety.
7. Avoiding spread of pests
  - Equipment design for easy cleaning and decontamination to minimise transfer of pathogens etc in sequential harvesting operations.
  - Automatic detection of cleaning efficiency, contamination or possible disease risks
  - Safe design of waste transport/handling equipment to minimise cross contamination.
8. Life cycle analysis
  - Systems analysis including Life Cycle Assessment (LCA) to identify and quantify the environmental impacts of individual products and services and compare scenarios.
  - Inclusion of sustainability indicators to compare scenarios and monitoring progress towards sustainability.
  - Multi-criteria decision models optimized to show interactions between indicators.
  - Life cycle analysis of technology and life-span of agricultural processes.
9. In-field processing
  - Novel processing to reduce waste, transportation costs and time to market, including detection, handling, control logistics and tracking procedures.
10. Waste treatment
  - Reduction in energy, water and materials use in raw material production, primary and secondary processing, packaging, waste management and reprocessing, including use of sustainability analysis of novel technological solutions throughout the food chain.
  - Waste quality detection and separation systems and energy recovery from waste. .

## ***Topic 2: Sustainable Plant Production***

1. Energy-efficient crop management:
  - Enhanced energy efficiency of machines and soil and crop management processes
  - Improved environmental footprint of drive systems
  - Novel materials and designs to reduce the mass of field machinery
2. Preserving soil quality
  - Integrated approaches to soil management to improve sustainable soil quality
  - Link to machinery design and use to reduce soil damage
  - Sensing and decision support to deliver technology benefits effectively
3. Robotics for crop management
  - Improved precision/reduced residues by sensing and control in crop management
  - Automatic targeting, monitor and manage pests/diseases with precision pesticide application, gentle produce handling, self steering of machines
4. Human-machine interface
  - Improved systems understanding for safe and efficient use of advanced machinery
  - Understanding human factors that determine uptake and impact of new technologies
  - Use ergonomic approaches to enhance technology uptake
5. Agricultural systems and networks
  - Novel farming concepts and systems, building new value added chains
  - Closed loop (waste and energy) farming, and other integrated approaches;
  - Beneficial modular combination of production lines and information technologies
6. Sensors to target inputs
  - Novel chemical/biological/physical sensors to enhance the targeting of inputs
  - Use new data streams to enhance more sustainable systems and machines
7. Model-based control
  - Intelligent interpretation of management information for decision support
  - Approaches to handle uncertain data, manage spatial variation and optimise inputs
  - Integrate sensors, models and machines
8. Optimised harvesting systems
  - Development of machine chains for different harvesting processes
  - Optimizing cost, environmental impact and traceability
  - Integrating sensors
9. Systems models
  - Develop systems models and life cycle assessment to target environmental impacts
  - Identify optimal land use practices and assess benefits of innovative machinery
10. Water resource management
  - Precision water resource management using sensors, models and novel machinery
  - New approaches to minimise losses, maximise targeting and optimise decisions
  - Energy efficient control and delivery
11. Crop design
  - Work with new biology to optimise crop systems for production and environment
  - Systems engineering for novel biological production and control

## ***Topic 3: Sustainable Animal Production***

1. Standards for animal health, welfare and sustainable production
  - Define objective standards across EU for animal health, welfare and sustainability.
  - Develop sensors and sensing techniques for objective measurements of animal environment and condition to facilitate control to these standards in the field.
2. Development of disease prevention strategies:
  - Develop technology for automatic real-time animal health monitoring at farm level.

- Integrate data/information handling at regional, national and EU levels to minimise disease spread and address other health and welfare problems with whole stakeholder community
3. Business models of future livestock farming in the EU.
    - Evaluate new business models for livestock farming; services, products and information systems for consumers for whom price is not the sole criterion.
    - Develop on-line monitoring and information systems to communicate about animal health, pollution, energy use, working conditions etc. to support new markets.
  4. Improved environmental conditions in relation to labour, human health and ergonomics.
    - Improved spatial and temporal environment control for man and animals
    - On-line monitoring of farmer health (e.g. sound analysis, biosensors, behaviour analysis, etc), to improve the working conditions.
  5. Working conditions, reduction of risks and accidents.
    - Develop novel scenarios for animal production environments meeting needs for farmers' physical and mental health, particularly in intensive production systems
  6. Improved process and product quality:
    - Develop multi-sensor on-line monitoring approaches and models for a range of process variables and their use in active process control based on measurements.
    - Evaluate novel concepts for process control linking key processes such as feeding lines, climate control, disease management, and energy policy for example.
    - Link approaches into integrated management systems for animal production where component processes are jointly optimised for better process and product quality.

#### ***Topic 4: Bioenergy and Renewable Materials***

1. Technologies and logistics for production, preservation and storage
  - Development and optimization of novel cropping systems for non food use
  - Development and optimization of machines and techniques for planting, harvesting, storage, transport, pre-treatment and conversion of biomass into material that can be feed into conveyer systems
  - Development of technologies for plantation of tree crops and using grassland and brushwood
  - Optimization of the transport infrastructure and logistics (grid connections, just in time delivery)
2. Optimization and standardisation of biofuels
  - Amendments to all "biofuel standards" (solid, liquid and gaseous) to facilitate the use of a wider range of biomass, included imported biomass
  - Definition of the quality of novel biomass used for bioenergy
3. New biomaterials and definition of quality criteria of intermediate and end products
  - Definition of the properties and the quality criteria of intermediate- and end products based on biomaterials
  - Implementation of new plants and the adequate techniques for the production of new biomaterials
  - Development of certification schemes and on-field/ on-line quality management systems
4. Technologies for cost effective production of bioenergy and biomaterials
  - Technologies for using all potentials of cost effective forms of biomass for heating, cooling, electricity and transport
  - Development of on-field/on-line information systems (including sensors) so biomass used satisfies minimum sustainability requirements and quality standards
  - Development of novel preservation techniques to substitute campaign delivery to continuous "just in time" delivery of biomass to the conversion industries

5. Bio-refinery concepts of whole crops in sustainable production processes
  - Realization of the “bio-refinery” concept, finding valuable uses for all parts of the plant
  - Development of technologies using biodegradable fractions of waste and residues of food production for energy and raw materials
  - Improving the cost efficiency of conversion technologies
6. Plant breeding and cultivation
  - New crop breeds for non food use
  - Improving the energy content of the agricultural crops used for first-generation biofuels
  - Improving the chemical and physical properties (contents of substances) of crops used for biomaterials

### ***Conclusions and Future Actions***

The overall target of this initiative is to develop an understanding across Europe, in public and private sectors, of the priorities for research and development in agricultural engineering and technology. As well as stimulating national initiatives in member states and direct partnerships between research organisations and industry, we also need to identify and promote priority themes and work packages of agricultural engineering and technology in the upcoming 7<sup>th</sup> Framework Programme of the European Community for research, technological development and demonstration activities (2007 to 2013).

The workshop on January 31, 2006 succeeded in

- bringing together people involved in and responsible for the European sector of agricultural engineering and moving what was a national initiative onto an European stage
- drawing attention to the initiative
- identifying and prioritising the future fields of research and developing a common understanding
- setting up a group to transfer our visions to more concrete definitions of research fields and address opportunities particularly within the 7<sup>th</sup> Framework Programme

A Working Group for Agricultural Engineering Technologies has been established. It operates under the umbrella of the *MANUFUTURE* Technology Platform, and also includes a range of experts from key sectors and disciplines to ensure opportunities are identified and pursued in relevant programmes and initiatives in the 7<sup>th</sup> Framework Programme and under other initiatives.

## Acknowledgements

The workshop that was central to the development of the Strategic Research Agenda was organised by VDMA and VDI, and supported by CEMA and EurAgEng. This paper has largely been developed from initial papers, from contributions of the participants and from the presentations at the meeting, which were made by Dr. Ludger Frerichs, Professor Heinrich Flegel, Dr. Christian Patermann, Christos Tokamanis, Björn Hedlund, Professor Josse De Baerdemaeker, Professor Walter Meier, Professor Bill Day and Dr. Johann Schrottmaier. The Vision 2020 chapter was developed by Professor Hermann Auernhammer, with input from Professor Bill Day, Dr. Ludger Frerichs, Professor Aad Jongebreur and Mr. Alexander Sassenberg. The Implementation Plan was developed from the inputs of a wide range of the participants in all parts of this exercise. Many thanks are given to them and to the participants of the workshop, the members of the working group, the experts and those who supported them.

Special thanks to Professor Bill Day for his continuous and great involvement not only for the content of these papers but also for the correct wording and grammar.

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