POMSEBES:
Policy Oriented Measures In Support of the Evolving Biosystems Engineering Studies in USA – EU

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POMSEBES: Policy Oriented Measures In Support of the Evolving Biosystems Engineering Studies in USA – EU

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CONTENTS

Define New Discipline of Biosystems Engineering

Objective 1. The new (emerging) discipline of Biosystems Engineering

Prepared by
Saied Mostaghimi[1]
B. Briassoulis[2], P. Panagakis[2] & E. Nikopoulos[2]

Contributions by J. P. Douzals[3], G. Scarascia-Mugnozza[4], P. Febo[5], A. Comparetti[5], J. Fehrmann[6], F. Ayuga[7]

(1) Biological Systems Engineering Department, Virginia Tech, USA
(2) Agricultural University of Athens, Dept. of Natural Resources Management & Agricultural Engineering, Greece
(3) Ecole Nationale de Formation Agronomique, ENFA Toulouse Auzeville, France
(4) Università di Bari, Dipartimento PRO.GE.S.A., Italy
(5) Università di Palermo, Dipartimento I.T.A.F., Italy
(6) Dresden University of Technology, Faculty of Mechanical Engineering, Germany
(7) Universidad Politıcnica de Madrid, ETSI Agronomos, Ciudad Universitaria, Spain

Introduction

The origins of agricultural engineering can be traced back to the roots of farming when hunters and farmers needed to develop tools to assist with meeting their daily needs regarding food production (Tao, et al., 2006). The profession of agricultural engineering, however, was firmly established at the beginning of the Twentieth Century with formation of the American Society of Agricultural Engineers (ASAE) in 1907. Many of the charter ASAE members had training in Civil or Mechanical Engineering with interests in agriculture (Tao, et al., 2006). In response to economic stresses, low student enrolment and society's needs for renewable sources of energy, industrial materials, and environmental stewardship, many engineering departments in the U.S. have incorporated various components of biological engineering into traditional agricultural engineering programs. The challenge of defining the profession and marketing the unique roles of agricultural (or biological) engineers to the public continues even today as US celebrates the 100th anniversary of the establishment of the profession. The purpose of this paper is to provide a brief historical background regarding the evolution of Biological Engineering discipline in the U.S., a brief presentation of the current situation in Europe and describe its definition and characteristics, and present information on the impact of the emerging biology-based undergraduate engineering programs on student enrolment.

Evolution of Biological Engineering in the United States

The first notable example of the evolution of agricultural engineering toward biology, as described by Stewart (1979) occurred in 1930s. C.O. Reed, a professor at Ohio State University, was dismayed at the notion that agricultural engineering was simply the application of civil, mechanical, electrical and architectural engineering to the industry of agriculture. He envisioned agricultural engineering to be "engineering of biology" and proclaimed that "This unique kind *of engineering should be based on energy transformation, and transfer conducted by living cells; a methodology and efficiency so based would open a new world to the agricultural engineers"*. Although this concept was appealing to many of the ASAE leaders, no significant action was taken by the ASAE to facilitate the establishment of the biology-based discipline over the next few decades.

In the 1960s, as the Biomedical Engineering profession was struggling to uniquely define its discipline, it was recognized by some that both Biomedical Engineering and Agricultural Engineering could perhaps be included as sub-disciplines of a broader Biological Engineering.

As described by (Tao, et al., 2006), at the 1960 winter ASAE meeting, Professor G.W. Giles stated that "Some may say that the science of biological processes should be left to the pure *scientists and that agricultural engineering should confine its activities strictly to engineering practices. … the fact remains that the mathematical relationships of the physical to the biological processes are basic to developing superior engineering systems… the core of our profession should be built on engineering laws governing the intricate complex processes of plants and animals. This is the thinlg that distinguishes agricultural engineering from other engineering professions."* In 1966, a bioengineering committee was formed within the ASAE with the goal of advancing a more broad-based discipline of Biological Engineering (Cuello, 2006). At about the same time the Agricultural Engineering department at North Carolina State University changed its name to "Biological and Agricultural Engineering" department. Similar departments at Rutgers and Mississippi State University followed suit (Stewart, 1979).

In late 1980s several Agricultural Engineering departments, throughout the U.S., modified their curriculum and program toward Biological Engineering discipline and included the term "Biological Engineering" or different variations of it in the department and/or academic programs names. In response to these changes, the first official action taken by the ASAE was in 1993 when it changed its name from "American Society of Agricultural Engineers" to "ASAE: The Society for the Engineering of Agriculture, Food, and Biological Systems." By 1995, over 30 of the 49 academic departments in the U.S. had modified their department's name to include Biological Engineering or some variations of it (Cuello, 2006). In 2005, ASAE officially revised its name to the "American Society of Agricultural and Biological Engineers" or ASABE).

The current situation of of Biosystems Engineering in Europe

The establishment of programs of studies in Agricultural Engineering in Europe lags very much behind the corresponding developments in the U.S. A few characteristics examples illustrate the kind of the problems faced in Europe by the relevant field of studies.

It was early 50s when extensive discussions were initiated at the Agricultural University of Athens (AUA), Greece, concerning the lack of sufficient number of engineering courses included in the study program and the need to establish a Department of Agricultural Engineering supporting the technical infrastructure of Agriculture. Only in academic year 1963/64 a specialization in Agricultural Engineering under the broad umbrella of Agricultural Sciences was launched and in 1989 an independent Agricultural Engineering Department offering studies in three different specialty areas, specifically Water Resources Management, Soil Resources Management and Structures & Mechanization, was established. This status remains until today unchanged as a significant percentage of the faculty members of the University, most of them with a background in Agricultural Sciences, supports the idea that Agricultural Engineering studies should be based on a strong Agronomy core curriculum and offered as a specialisation without a sound Engineering background. Analogous is the situation in the other two Greek Universities offering studies in Agriculture.

Although the term "Biosystems Engineering" is not used currently in France, the approach of complexity in agronomy, animal sciences, etc. is historically achieved using a systemic analysis. The situation of Agricultural Engineering is very peculiar as only two or three Institutions propose optional modules or specializations in this field without possibilities to deliver a Doctoral degree. In the case of Food Science and Food Engineering and Processing, the notion of Biosystems Engineering is also less used than "Food Process" or "Food Processing". Moreover in France, the Biosystems Engineering (BSE) discipline is a good example of the French paradoxical situation. Although the contents and methodology of BSE statements are taught in many programs of study related to Agricultural Sciences (including Agricultural Engineering specializations), Water and

Forestry Engineering, Food Sciences and Technology, Horticulture Engineering, etc., the discipline itself does not exist on its own as there is no Department of BSE nor accreditation (of courses, personnel and staff) related to this topic.

The above-described cases were shown to be similar with several European countries after the extensive analysis carried out in the framework of USAEE-TN (Proceedings USAEE, 2003). The figures below present the contemporary situation in the majority of cases within Europe (year 2001):

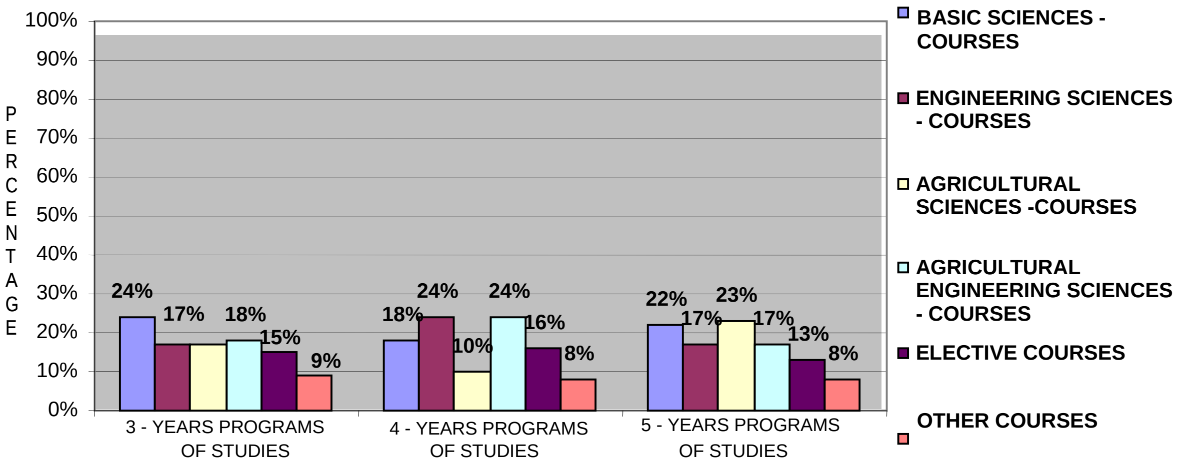

Figure 1a. Percentage of the course categories from various European Universities

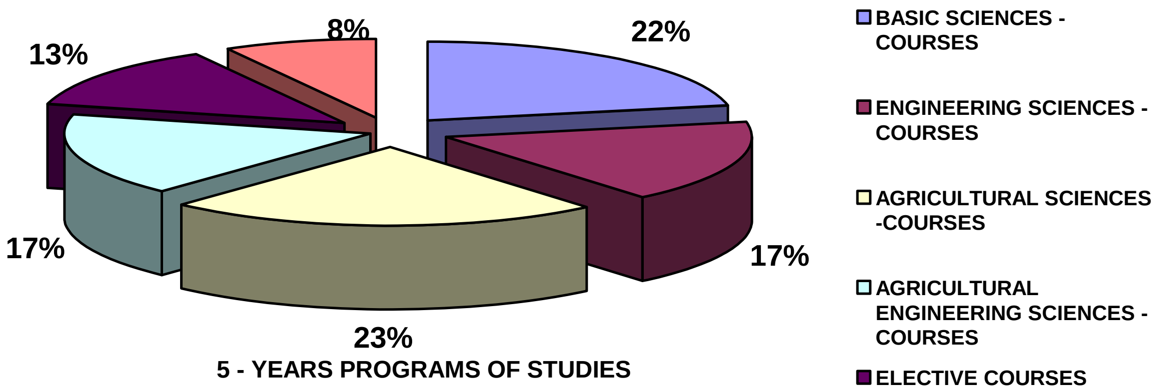

Figure 1b. Courses offered by European 5-year Agricultural Engineering programs of studies

The definition of the classical Agricultural Engineering (USA experience, under development in Europe, following the current work of USAEE TN) is given by 'EDA, Incorporated, Agricultural Engineering', in http://www.edasolutions.com/Groups/AgriEngineering.htm:

"Agricultural engineers help feed the world by combining scientific and engineering knowledge to find unique solutions that make our natural resources more usable while conserving and replenishing them and protecting our environment.

Agricultural engineers apply engineering principles and biological sciences to designing systems that produce food, feed, fiber, and other useful products from renewable bioresources. At the same time they strive to protect the environment by conserving and replenishing our natural resources. Thus, agricultural engineers integrate the biological and environmental sciences with the engineering profession.

By virtue of their education, training, and experience, agricultural engineers are uniquely qualified to design the equipment, systems, and methods that continue the technological advancement in food and agribusiness industries. This includes the production, processing, handling, and distribution of agricultural products throughout the entire food and agribusiness chain".

Characteristics and Definition of Biological Engineering in the US

In late 1980s the economic stresses on the U.S. agriculture led to a significant decline of the traditional agriculturally-based programs and brought about a stronger linkage of the agricultural engineering profession to biological sciences. Young (2006b) reported that in 1997 the number of "bio"- type programs exceeded the number of agricultural engineering programs for the first time. Incorporation of "bio" into agricultural engineering curricula names rose from 4% in 1987 to 85% in by 2002 (Young, 2006b). Young (2006) also reported that in 2002 there were 17 different names for undergraduate curricula and 9 different names for departments with agricultural engineering origin. The most commonly used department names were Biological and Agricultural Engineering (21%), Agricultural and Biological Engineering (16%), Biological Systems Engineering (11%), and Agricultural and Biosystems Engineering (11%), (Young, 2006a).

While the topic of Biological Engineering has been widely discussed by academics and non-academics, the responsibility of implementing its practical challenges has been left to individual departments and institutions. These departments have made a wide variety of attempts to communicate their new emphasis on biology and the unique characteristics of the emerging field of Biological Engineering. Traditionally, the agricultural engineering curricula have been industry-focused by integrating engineering with biology-based problems for the agriculture industry. This is in contrast with other disciplines such as mechanical, electrical and chemical engineering whose curricula have been more science-based. Young (2006a) reported that historical evidence indicates that "science-based" engineering curricula have been more sustainable and have garnered broader recognition than "industry-based" curricula. Thus, the emerging discipline of biological engineering will have a great chance of being sustainable because of its firm foundation on biological sciences.

There are a variety of definitions proposed for biological engineering discipline. Furthermore, several authors have offered thoughts for developing a curriculum for the merging discipline. Pennfield (2002) suggested that Biological Engineering discipline should be based on molecular and cell biology and the best way to define it is to develop and offer an undergraduate curriculum. The ASABE defines biological engineering as a growing specialty within Biological and Agricultural Engineering discipline that *"…applies engineering to problems and opportunities presented by living things and the natural environment."* The Institute of Biological Engineering developed a consensus for definition of biological engineering as *"the biology-based discipline that integrates life sciences with engineering in the advancement and application of fundamental concepts of biological systems from molecular to ecosystem level"* as reported by Scott (2006). While these definitions have not been broadly adopted and used, there seems to be a broader consensus on the key elements of the biological engineering discipline.

These key elements as reported by Scott (2006) include:

- "*An emerging discipline*

• Biology-based foundation
• Fundamental concepts of biological systems
• An appreciation of applications and
• Scale from the molecular to large system."

Scott (2006) reported that since many programs have chosen to emphasize particular areas of their strengths and needs, there are significant uncertainties about a comprehensive understanding and the focus of this new discipline.

In 1987, the ASAE Academic Administrators Committee recommended the development of a core curriculum and offering of undergraduate programs in biological engineering. They concluded that *"Curriculum should be substantially based on the science of biology and should be focused on application in biological systems."* The emphasis areas associated with biological engineering curricula were identified by the Administrative Committee as: biotechnology engineering; bioenvironmental control; machine systems engineering; bioprocess systems engineering; natural resources engineering; and food engineering. The biomedical engineering was not included as an emphasis area.

There is a great need to develop a consistent definition of biological engineering and communicate the concept in a coherent manner to the general public. There is also an immediate need to develop uniform curricula to prepare students to meet the growing needs of the industry. Johnson and Phillips (1995) presented a conceptual framework for a curriculum, basic training needs in engineering and biological concepts, and potential employment opportunities for biological engineering students. A biological engineering discipline-based undergraduate curriculum has been proposed at Cornell University (Scott, 2006).

Impact of name changes on student enrolment

Young (2006a) analyzed data regarding undergraduate enrolment changes following the adoption of "bio"-type curricula names for traditional agricultural engineering. The goal of Young's analyses was to answer the question of "have the academic departments seen an impact on enrolment after changing curricula names to "bio"-type names"? The data were collected in 2002. The following conclusions were made:

- The annual undergraduate enrolment increases for Biological Systems Engineering, Biological Resources Engineering, and Biological Engineering curricula were statistically significant as a result of the changes made to their name. The increases in enrolments ranged from 9.9% to 30.2 % per year,
- In general, all curricula that had "bio" only in their names had a significant enrolment increase over the traditional curricula of agricultural engineering,
- Curricula that had both "bio" and "agr" in their names did not experience significant increases in their enrolment, regardless of the ordering of the respective terms.

Young (2006a) reported that there has been a real transformation from traditional agricultural engineering toward "bio"-type engineering both in name and in curriculum content during the past two decades. The emphasis names reflect various applications including bio-processing, bioenvironmental, biomaterials, bio-systems, bio-production, natural resources, land and water resources, bio-resources, food processing, ecology, aquaculture, bioremediation, biomechanics, and bio-safety. Currently at least two programs in the U.S. offer biomedical curricula.

In 2005, the ED-210, the Committee of Program Administrators within ASABE, expressed its concern about the proliferation of academic department and program names and discussed its potential impacts on student recruitment, professional licensing, accreditation of programs, name recognition and ranking, and placement of graduates. After consideration of various alternatives, the Committee discussed several possibilities to alleviate these potential negative impacts, and passes a motion to encourage departments to limit their number of the accredited undergraduate program names.

The European concept of Biosystems Engineering

The diversity of definitions of Biosystems Engineering in Europe

Very few members of the Greek discipline-specific academic community and profession see the necessity to advance from the traditional Agricultural Engineering to the Biosystems Engineering discipline. These members strongly believe that the program of studies should be fortified in terms of concrete knowledge on basic sciences (e.g. mathematics, physics, and informatics) along with engineering (i.e. strength of materials, thermodynamics, heat-transfer, etc.) and biological subjects (i.e. cell biology, ecology, etc.). They define Biosystems Engineering as an evolving science-based engineering discipline that integrates engineering science and design with applied biological, environmental and agricultural sciences. In a presentation during a workshop at AUA, the discipline of Biosystems Engineering was defined as: *"Biological engineering is the branch of engineering that prepares students to apply engineering to solve problems in biological systems"* (Briassoulis et al, 2006). This definition has been distinguished from the definition of Agricultural Biotechnology: *"The broad definition of biotechnology is simply the industrial use of living organisms (or parts of living organisms) to produce foods, drugs, or other products. The oldest biotechnologies include fermentation and plant and animal hybridization. The newest biotechnologies range from protein separation technologies to genomics and combinational chemistry. A sampler of fields that fall under biotechnology's broad umbrella would include: bacteriology, biochemical engineering, bioinformatics, bioprocessing, cell biology, chromatography, computational & mathematical modeling, developmental and molecular genetics, DNA technologies, electrophoresis, embryology/immunology, materials science, microbiology, nucleic acid chemistry, protein engineering, virology (www.biotechmedia.com/definitions-b.html)".*

The French definition of Biosystems and Biosystems Engineering corresponds to sciences and technologies leading to describe, understand, control and optimize such complex biological states of the matter. One must distinguish two definitions of the term "Biosystems Engineering". The first definition (INRA) concerns *Biotechnology and Biochemistry* (from the cell to the process; figure1c) where several applications are under development:

- ✓ *Biorefining: extractions from cereals, flex fuel production and biomass valorisation, green oils.*
- ✓ *Biosystems Engineering: from cell to process in food processing, pharmacy and cosmetics.*
- ✓ *Bioproduction: the plant-factory concept, target seeds, cell cultivation (for vaccine and therapy), cell therapy.*

Multi-scale Biological Models:

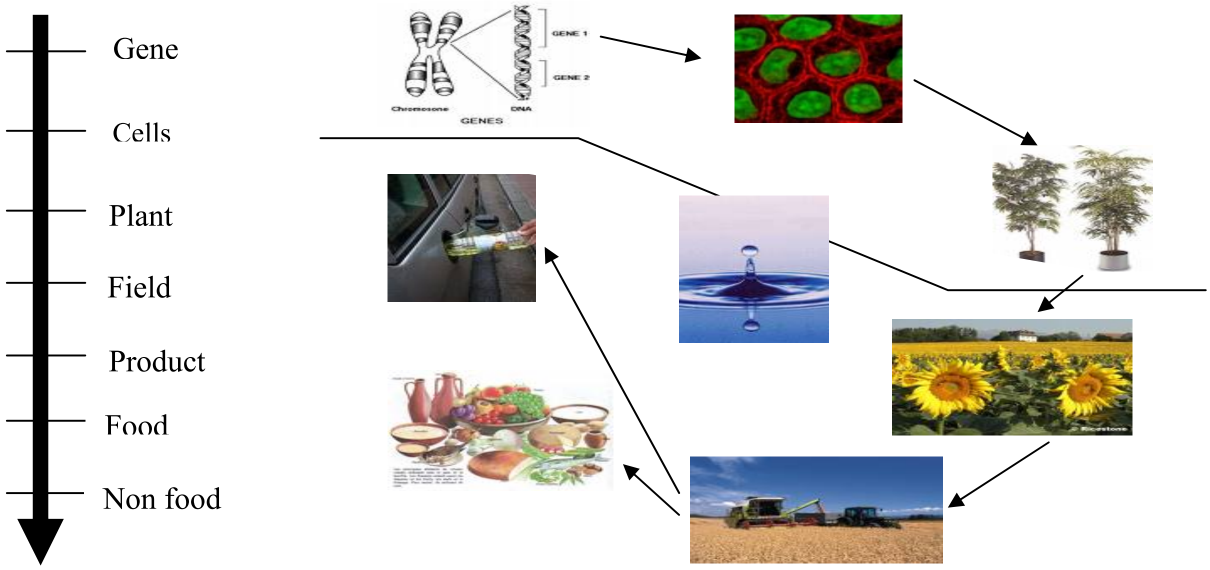

Figure 1c. Different scales of Biological systems

The second definition of *Biosystems Engineering concerns larger scales of study in Biological and Agricultural Sciences from cells to crops and prior/post harvest processing.* It is the way all disciplines of Agricultural Engineering are involved to understand and control Biosystems. In this last case a Biosystems is analogous to a mechanical system (using functional analysis):

- *Function of Production: system modelling, applied mechanics, CAD, hydraulics, electrotechnics, applied thermodynamics, etc.*

- *Function of Information: traceability of crop, electronics, sensors, automation and control, computer sciences, image analysis, etc.*

In this case, the object of study is focused on the sensor/actuator and its effects on the Biosystems than the Biosystems itself. Another example can be found in *Precision Agriculture where technologies are used to characterize crop/soil variability and to optimize field inputs/outputs.*

According to the Italian colleagues, *Biosystems Engineering is defined as the engineering discipline related to the overall agricultural activity, such as production, processing, storage and distribution of agricultural (food and non-food) products (e.g. plant and animal production, livestock buildings, animal health and welfare, agricultural, forestry and food machines and plants, post harvest technology, process engineering, ergonomics and safety, safe food production), the protection of the natural environment and the preservation of the natural resources (e.g. land planning, soil conservation, rational water management, air pollution control, waste management, preservation of natural habitats).* Moreover the Italian Association of Agricultural Engineers has recently defined its activity through the following goals: (1) Development and application of techniques for analysis, control and assessment of risk and vulnerability of local resources and land potential, (2) application of precision farming for chemicals and production systems reduction, (3) enhancing and exploitation of renewable energy resources, (4) improvement of irrigation efficiency also with regards to the use of waste water, (5) control and reduction of soil erosion for soil and water preservation, (6) intervention for rural building heritage restoring, (7) design and planning of modern rural buildings, for crops and animal production and food processing, for landscape and environment protection, (8) design of plants, tools and agricultural machinery taking into account human health and safety and environmental protection, and (9) reduction of costs and increase of quality of raw materials from crops and animal production.

In Germany, Biosystems Engineering (Biosystemtechnik) does not have a unambiguous definition. There are Mechanical Engineering Departments (e.g. Dresden University of Technology) where *Biosystems Engineering mostly refers to Agricultural Machinery and Food/Process Engineering*. However, there are also Universities (e.g. Leibniz University of Hannover) with sections (i.e. Biosystems and Horticultural Engineering Section) where subjects such as 'Process Engineering in Horticulture', 'Automation and Bio-Robotics Plant Cultivation', 'Application and Evaluation of Environmentally Sound Production Processes in Plant Cultivation' are been taught or Organizations (Federal Agricultural Research Centre; FAL) with Institutes (Institute of Technology and Biosystems Engineering) where research is undertaken, among others, on subjects such as: 'Advanced ploughing system', 'Precision irrigation', 'Animal identification and livestock control', 'Improvement of stable air quality for animals and human beings'. According to ASIIN (Accreditation Agency for Degree Programmes in Engineering, Informatics/Computer Science, the Natural Sciences and Mathematics) there is no accredited program of studies in Biosystems Engineering as such. On the contrary, there are (ASIIN, 2006) subject specific criteria for accrediting Process and Biological Engineering Bachelor's and Master's degree programs. Among others, subjects in natural sciences (not specified) should be included so as 'to create focal points of studies'. Appendix 1.A. provides a list of Institutions involved in various aspects of Biosystems Engineering.

In Spain during the discussions concerning the new degrees (4 years degree named graduate -equivalent to a Bachelor- with the name open to each University proposal) a working group with all the directors of the Schools teaching Agricultural and Forestry Engineering (the official names at the moment) was formed to make proposals to the government. This group proposed three new degrees "Agricultural Engineering", "Agrifood Engineering" and "Forestry and Nature Engineering". Obviously they insisted on traditional names with no options for Biosystems Engineering or even Biological Engineering. However, if the decree is implemented the name Biosystems Engineering will have an opportunity if some of the 30 Spanish Universities that now offer Agricultural and Forestry Engineering degrees choose this name. Besides, there is also the possibility to propose Biosystems Engineering as a name for a Master degree (postgraduate is the name adopted in Spain) where the freedom for University proposals is even greater. The Master degree will consist on 1 or 2 years and could be labour or research oriented. In both cases the major issue is not the name but the content of the programme. In Spain traditionally the Agricultural and Forestry Engineering degrees were considered a branch of Engineering and focused strongly on Basic Sciences (Mathematics, Physics, etc.) and Engineering background. However, during the decade of the 90's the Basic Sciences and Engineering part of the syllabi decreased greatly resulting in graduates who have lost the "engineering way of thinking" and have lower competences. Even so there are some Universities which express interest in an engineering-based modern degree for solving biological and environment problems, including agriculture, food and other traditional fields.

A search in European academic sources and journals has resulted in the following definitions:

University College Dublin (Biosystems Engineering program of studies): *Biosystems engineering is the industry of the 21st century, revolutionising the production, processing and manufacture of biological materials through new engineering technologies.*

Biosystems Engineers play pivotal roles in these areas, pioneering numerous innovations in a global industry. New technologies include precision systems for production and harvesting; satellite remote sensing in planning and monitoring production and environmental conditions; biosensors to optimise food process automation; advanced packaging systems to maximise product quality; recycling of materials and prevention of emissions to protect the environment; information technologies to optimise bioprocess strategies.

Catholic University of Leuven (Faculty of Biosystems Engineering; Department of Biosystems): The command and administration of biological systems permits the 'Bio-Engineer' to make an important contribution to the needs of the community at large.

A greater knowledge of the biotope 'environment, soil, micro-organism, plant and animal' in a variety of climates together with techniques of intervention and control systems will contribute towards the production of better quality raw materials for food on a world scale. An ever increasing grasp of the chemistry, microbiology and technology of preservation and transformation processes, supplemented by knowledge of human dietetics will make it possible for the Bio-Engineer to increase the yield of agricultural products for the consumer. The importance of well-organised and productive agriculture as an inherent requirement for good social policy is the concern of the 'Bio-Engineer in Agriculture', a key position above all in the developing countries. As a further consequence of his/her multi-disciplinary training, the knowledge and impact of the Bio-Engineer on biological processes will continue to give him or her central position in study, control and intervention. At the same time the Bio-Engineer will play a pivotal role in the protection and preservation of the natural environment. (i.e. soil water and air pollution brought about by human systems of production (over fertilisation; draining of sewage; phytopharmaceutical and herbicidal products; gas and vapour emissions; soil and plant absorption of radio active contamination, landscape; land development; land, water and forestry control; environmental planning, etc.).

Biosystems Engineering Journal: *Biosystems Engineering concerns education and research in the physical sciences and engineering to understand, model, process or enhance biological systems for sustainable developments in agriculture, food, land use and the environment.*

Trends in Europe

Contemporary societal needs for cleaner environment, preservation of earth resources, healthier food staff and sustainable production emphasize the urgent need and pave the way for restructuring the classical Agricultural Engineering program of studies towards Biosystems Engineering in Europe. Traditionally Agricultural Engineering graduates had been involved in the following: (a) design and technology for the life support of plants and animals (e.g. structures, machinery, processes, management models, energy systems or controlled environments), (b) design processes and equipment for the production, storage, and processing of food and fibre, (c) assessment of food quality and safety, (d) expanding use of biological products and (e) monitoring and assessment of environmental and pollution control of land, water and air resources. Graduates from an engineering science-based program of studies, Biosystems Engineers, with a strong Engineering background, could be involved in: (a) the development and application of technologies to diagnose diseases, protect living organisms from hazardous conditions and improve human and animal health, (b) the design of bioreactors for bacterial/pharmaceutical applications, (c) bio-fuels, bio-materials, biological waste processing and management and (d) reclamation, restoration and remediation of environmental damages.

At the European level, changes in the direction of the emerging discipline of Biosystems Engineering currently include these two programs of study:

1. Biosystems Engineering at University College Dublin
2. Faculty of Biosystems Engineering; Department of Biosystems at Catholic University of Leuven

Also the European Society of Agricultural Engineers has changed the title of its official journal from Journal of Agricultural Engineering Research into Biosystems Engineering [6].

The description of the topics covered by the Journal offers a clear indication of the European concept about Biosystems Engineering:

"Remit of Biosystems Engineering: research in the physical sciences and engineering to understand, model, process or enhance biological systems for sustainable developments in agriculture, food, land use and the environment.

Topics are broadly classified under the following nine Interest Fields and each paper is allocated to the most appropriate category:

- *Automation and Emerging Technologies (AE) - intelligent machines; automatic control; navigation systems; image analysis; biosensors; sensor fusion; engineering for biotechnology.*
- *Information Technology and the Human Interface (IT) - communications and field bus protocols; ergonomics; geographical information systems; operational research; biosystem modelling and decision support; machinery management; risk and environmental assessment; operator health and safety; work science.*
- *Precision Agriculture (PA) - agro-meteorology; food, fibre and forage crop production; extra-terrestrial bioproduction; yield, weed and soil mapping; geographical positioning systems; input reduction; integrated pest management.*
- *Power and Machinery (PM) - tillage and earthmoving equipment; machines for the establishment, protection and harvesting of field, protected, and orchard crops; tractors and agricultural vehicles; dynamics, vibration and noise; forest engineering; hydraulics and turbomachinery; clean technology.*

- *Postharvest Technology (PH) - properties of biomaterials; crop drying, processing and storage; opto-electronic size grading; ripeness, quality, damage and disease detection with optical reflectance, nuclear magnetic resonance and X-ray tomography; food packaging and processing; food chain integrity and foreign body detection.*
- *Structures and Environment (SE) - design of buildings and control of their environment; livestock housing; dust and odour control; crop stores; horticultural glasshouses and plasticulture; composting and waste treatment; gaseous emissions.*
- *Animal Production Technology (AP) - livestock welfare and ethology; health monitors; robotic milking and shearing; feed handling; animal draught; integrated stock management; stock handling, weighing, transport and slaughter; meat processing.*
- *Soil and Water (SW) - soil structure and properties; soil dynamics in tillage, traction and compaction; soil erosion control; crop water requirements; infiltration and transport processes; irrigation and drainage; hydrology; water resource management; hydroponics and nutrient status.*
- *Rural Development (RD) - renewable energy; pollution control; protection of the rural environment; infrastructure and landscape; sustainability".*

Another relevant international journal is 'Bioprocess and Biosystems Engineering'. In the description of the journal, it is mentioned that:

"Bioprocess and Biosystems Engineering" provides an international peer-reviewed forum to facilitate the discussion between engineering and biological science to find efficient solutions in the development and improvement of bioprocesses. The aim of the journal is to focus more attention on the multidisciplinary approaches for integrative bioprocess design. Of special interest are the rational manipulation of biosystems through metabolic engineering techniques to provide new biocatalysts as well as the model based design of bioprocesses (up-stream processing, bioreactor operation and downstream processing) that will lead to new and sustainable production processes.

Contributions are targeted at new approaches for rational and evolutive design of cellular systems by taking into account the environment and constraints of technical production processes, integration of recombinant technology and process design, as well as new hybrid intersections such as bioinformatics and process systems engineering. Manuscripts concerning the design, simulation, experimental validation, control, and economic as well as ecological evaluation of novel processes using biosystems or parts thereof (e.g., enzymes, microorganisms, mammalian cells, plant cells, or tissue), their related products, or technical devices are also encouraged'.

It is quite interesting that among the fields of interest included are also areas that are clearly outside the biosystems engineering. The fields of interest described are: Bioprocess Engineering, Biosystems Engineering, Bioengineering, Biochemical Engineering, Biotechnology, Biocatalysis, Systems Biology, Biology, Tissue Engineering, Life-Science Engineering, and Medicine. This is considered to be a positive issue with regard to a much broader area of audience, scientific subjects and marketing targets covered by the Biosystems Engineering discipline as compared to those covered by the classical Agricultural Engineering discipline.

From an employee's perspective, a very interesting description of Biosystems Engineering is given in Appendix 1.B below: 'It's difficult to define what biosystems engineering is, or even what biosystems engineers actually do, except to say that we apply engineering principles to life. Our work is a mélange consisting of biology, chemistry, computer science, and engineering, which has both its positive and negative aspects depending on which way you want to look at it…'

Conclusions

Agricultural Engineering has made serious attempts to transform itself from a traditional industry-based to a science-based discipline of Biological Engineering over the past several decades in the US. However, as US celebrates the 100th anniversary of the establishment of the profession, the challenge of defining the profession and marketing the unique roles of agricultural (or biological) engineers to the public still continues. The proliferation of program and department names and lack of a uniform curriculum is hampering our efforts in enhancing our identity, recruiting and placing students, and meeting the needs of industry. Biological Engineering programs would greatly benefit by developing a unified vision for research and education for the discipline. The work in progress in the framework of the joint US-EU project POMSEBES will help in this direction.

Findings & Action Steps of the first Workshop of POMSEBES

During the 1st POMSEBES Workshop which was held on June 14-15, 2007 in Minneapolis, Minnesota, the sub-group responsible for Objective 1 proposed the following findings/conclusions:

1. Define the relationship between the traditional Agricultural Engineering and emerging Biosystems Engineering discipline in Europe/USA.
2. Do exclude Biomedical Engineering, Bioengineering and Biotechnology from Biosystems Engineering.
3. The new discipline of Biosystems Engineering is a natural evolution of Agricultural Engineering, which is more biology-based and applies to all living organism systems with the exception of human

The same sub-group developed the action steps presented below.

1. Translate the findings/characteristics into a common definition by seeking inputs from project participants.
2. Disseminate the proposed definition to professional societies / policy makers / other stakeholders to develop a common a consensus of the discipline and reduce the confusing associate issues / both in US/EU.
3. Disseminate the information regarding the definition of the discipline to all European universities / institutions offering Agricultural Engineering/similarly named programs.
   Develop a mechanism for continuing the discussion/promotion of the new discipline beyond the time limit of the project. Submit a follow-up proposal to ATLANTIS or other relevant funding agencies.

1) During the last decade, Agricultural Engineering University studies in Europe faced dramatic problems such as decrease of student enrolment, reduced prestige, declining funding, etc. The dramatic situation within this specific field of studies along with its chaotic state in terms of programme content was the motivation behind the establishment of the former USAEE-TN project (01/10/2002-30/09/2006)[1]. It defined Agricultural Engineering as an application-based discipline related to the production and processing of goods of biological origin from the field and the farm to the consumer (i.e. plant and animal production, post-harvest technology, process engineering, etc.). *Agricultural Engineering* was traditionally related to the protection of the natural environment and the preservation of the natural resources (i.e. soil conservation, rational water management, air pollution control, waste management, preservation of natural habitats, etc.).

[1] University Studies of Agricultural Engineering in Europe; a Thematic Network (Reference No: 104939-CP-1-2002-1-GR-ERASMUS-TN)

This traditional field of science is nowadays evolving into the *Biosystems or equivalent Agricultural and Biological Engineering* field, which is a science-based engineering discipline, that integrates engineering science and design with applied biological, environmental and agricultural sciences, broadening in this way the area of application of Engineering sciences not strictly to agricultural sciences, but to the biological sciences in general, including the agricultural sciences.

Biosystems engineers design processes and equipment for the production, storage, and processing of food and fiber; for the assessment of food quality and safety; and for the expanding use of biological products. They are involved in the development and application of technologies to diagnose diseases, protect living organisms from hazardous conditions, and improve human and animal health. Graduates of this discipline may find career opportunities in environmental quality and monitoring; non-point source pollution control, land, water, mineral, wetland and air resources; bioreactors for bacterial/pharmaceutical applications; drainage and environmental control for agricultural production; biofuels, biological waste processing and management; reclamation, restoration and remediation of environmental damages; and production, storage and handling of agricultural products. Graduates may well be part of a team that pioneers a scientific breakthrough in biotechnology or work to preserve and protect the earth and its resources. The systems they design for the life support of plants and animals may include structures, machines, processes, management models, energy systems or controlled environments.

In order to describe distinctly the relationship of the discipline between Europe and US, a brief review of the background of the Higher Educational area in Biosystems Engineering was carried out.

Very few viable Biosystems Engineering programs currently exist throughout Europe and those initiated are at a primitive stage of development, in contrast to the American educational system that has been undergoing tremendous change over the past decade. Thus, there is a critical need for enhancing the modulation and compatibility among the programs of Biosystems Engineering, to aid their recognition and accreditation at the European and International levels and to facilitate greater mobility of skilled personnel, researchers and students. One attractive outcome could be recruitment of highly qualified students from developing countries to the European and US universities in the area of Biosystems Engineering.

In response to these changes, the first official action taken by the ASAE[2] was in 1993 when it changed its name from "American Society of Agricultural Engineers" to "The Society for the Engineering of Agriculture, Food, and Biological Systems - ASAE". By 1995, over 30 of the 49 academic departments in the U.S. had modified their names to include Biological Engineering or some variations of it. In 2005, ASAE officially revised its name to the "American Society of Agricultural and Biological Engineers" or ASABE). The reasoning behind these last developments was to fulfil the new tendency that "*current students are looking for science based engineering curriculum founded on biology as the underlying science that allows them to work with living systems, because such curriculums give them a broader background with more professional flexibility*".

These concerns have led to rapid changes in the educational systems of Agricultural Engineering in the US, where most of the high ranking Departments have transformed their programs from agricultural engineering to science-based biological engineering which agricultural engineering is included. Enrolment in these programs has been steadily increasing.

[2] American Society of Agricultural and Biological Engineers, http://www.asabe.org

In short, whereas Agricultural Engineering applies Engineering sciences to agricultural applications, Biosystems Engineering or Agricultural and Biological Engineering, extends this application of Engineering Sciences to all living organisms applications, including agriculture. Agricultural and Biological engineers can also be involved in the expanding new areas of biological engineering (i.e. biomaterials, bio-fuels, bio-mechatronics, etc.), in the assessment of food traceability, quality and safety and in the design of environmentally friendly and sustainable systems. In contrast, Biosystems or Agricultural and Biological Engineering would not pertain to human medical applications.

However, as the Biomedical, Bioengineering and Biotechnology Engineering profession was struggling to uniquely define their disciplines, it was recognized by some in USA that both Biomedical Engineering and Agricultural Engineering could perhaps be included as sub-disciplines of a broader Biological Engineering discipline. In Europe, these areas are considered independent disciplines under autonomous Departments. Biotechnology has not and needs not Engineering background as such and so it does not require an Engineering core curriculum (as Agricultural or Biosystems Engineering does). Biomedical Engineering on the other hand, has already been established by other classical Engineering Departments in cooperation with Medical Schools. It is not considered feasible to include in one program of studies what is foreseen as Biosystems Engineering plus Biomedical Engineering or Bioengineering. Such a combination might be feasible possibly at the level of a School with several Departments, each offering an independent program of studies, one of which would be Biosystems Engineering.

2) In order to disseminate the information regarding the definition of the discipline to all European universities / institutions offering Biosystems Engineering or similarly named programs, discussions were initiated in order to determine how the results might be used, who could make most effective use of the results, and how to best communicate the results to the most important audiences. The methods used were the following:

a) establishment of the project's web-site:
(https://secure.hosting.vt.edu/www.bse.vt.edu/06/research/Atlantis/)
b) face to face meeting and conference presentations that took place within the 1st POMSEBES Workshop in Minneapolis, U.S.
c) full paper to be presented and included in the AgEng 2008 Conference Proceedings on "Agricultural & Biosystems Engineering for a Sustainable World" to be held in June 2008 in Crete, Greece
d) presentations made at a University level to brief the Greek National policy makers

3) Developing Sustainability practices will be achieved by means of cooperation between Universities as well as synergies and links with other related thematic networks, academic/professional bodies, and private sector, stakeholders and decision makers.

References:

- ASIIN, URL: http://www.asiin.de/english/newdesign/index_ex5.html
- ASIIN. 2006. Subject-specific criteria relating to the accreditation of Bachelor's and Master's degree programmes in mechanical engineering, process engineering and chemical engineering
- Briassoulis, D., Papadakis G. and Panagakis P., 2006, On the Need to Establish a Department of Biosystems Engineering, Troptolemos 21: 77-81 (in Greek)
- Cuello, J. L. 2006. The Descent of Biological Engineering. International Journal of Engineering Education 22(1): 35-44.

- Johnson, A. T., and W. M. Phillips. 1995. Philosophical Foundations of Biological Engineering. Journal of Engineering Education 84(4): 311-318.
- Pennfield, P. 2002. What is a Discipline? A Presentation to the ABET Board of Directors. http://www-mtl.mit.edu/~pennfield/pubs/abet-02.html
- Proceedings of the 1st USAEE Workshop. 2003. Current Structure of European University Studies in Agricultural Engineering. Madrid, Spain.
- Research group on Biosystems Engineering: from the cell to the process. GDR 3071 CNRS - University of Toulouse-INRA
- Stewart, R.E. 1979. Seven Decades that Changed America: A History of the American Society of Agricultural Engineers, 1907-1977, ASAE, St. Joseph Michigan.
- Scott, N. R. 2006. DNA of Biological Engineering: An Engineering Discipline? International Journal of Engineering Education 22(1): 9-13.
- Tao, B. Y., D. K. Allen and M. R. Okos. 2006. The Evolution of Biological Engineering.
- International Journal of Engineering Education 22(1): 45-52.
- Young, R.E. 2006a. The “Bio”-Type Engineering Name Game. International Journal of Engineering Education 22(1): 23-27.
- Young, R.E. 2006b. Comparisons of “Bio”-Type Engineering Undergraduate Curricula from Agricultural, Medical and Chemical Origins. International Journal of Engineering Education 22(1): 14-26.

APPENDIX 1.A

Organisation Name: Fraunhofer Institute for Interfacial Engineering and Biotechnology http://www.igb.fraunhofer.de/start.en.html

Description: The work of the Institute aims at economically attractive and ecological solutions in the fields of biotechnology and environmental engineering. Core expertises comprise interfacial engineering and membrane technology as well as molecular biology, biochemistry, cell biology and biotechnical / biochemical engineering. The Institute offers R&D solutions in the fields of health, environment and technology. Our competences comprise interfacial engineering and membrane technology as well as biotechnology, cell biology and bioprocess engineering. We offer solutions from market analysis through research & development till the finished product.

Organisation Name: University of Hohenheim, Institute for Agricultural Engineering in the Tropics and Subtropics
www.uni-hohenheim.de/i3ve/00000700/00117041.htm

Description: The Institute for Agricultural Engineering in the Tropics and Subtropics, provides information on it's staff, abstracts of ongoing projects and links to related sections, e.g. for post-harvest technology and energy in agriculture. It consists of two sections, namely: Post-harvest Technology and Energy in Agriculture, Mechanisation and Irrigation

Organisation Name: University of Giessen, Institute of Agricultural Engineering
http://www.uni-giessen.de/landtechnik/

Description: The Institute has a section on agricultural engineering in developing countries with focus on adapted land preparation systems, fodder harvest, adapted cattle livestock systems and shared use of machinery.

Organisation Name: Federal Research Centre for Nutrition and Food, Institute of Process Engineering
http://www.bfel.de/cln_044/nn_785106/EN/organisation/tasks/ipe__content.html

Description: The Institute has the task of developing objective methods to characterize foods, studying methods for the gentle preservation of foods, and contributing to the improvement, development and optimization of food processing methods. It also investigates use of tropical food crops:

Organisation Name: University of Bonn, Institute of Urban Planning, Land Management and Water Engineering
www.isbk.uni-bonn.de/

Description: The Institute's departments of land management, land valuation and land registration as well as that of agricultural water engineering and water resources, carry out research projects with focus on the tropics and subtropics.

APPENDIX 1.B

Biosystems Engineering--A Multifaceted Approach to Research
Barry van Bergen, Canada, 1 November 2002

BACK TO THE FEATURE INDEX

It's difficult to define what biosystems engineering is, or even what biosystems engineers actually do, except to say that we apply engineering principles to life. Our work is a mélange consisting of biology, chemistry, computer science, and engineering, which has both its positive and negative aspects depending on which way you want to look at it.

The Melting Pot

Within the Department of Agricultural and Biosystems Engineering at McGill University, there is more diversity in scientific backgrounds than perhaps any other department I know of. There are analytical chemists, food engineers and scientists, soil scientists, computer programmers, microbiologists, post-harvest engineers, agricultural engineers, chemical engineers, and others, all working together in the field of biosystems engineering. Many of the scientists have studied internationally at other universities, bringing with them a wide range of approaches to research. And collaborative projects within the department extend to places as diverse as Egypt, India, Panama, and China.

It may not be the case everywhere, but our department is research based, and there are perhaps as many graduate students as there are undergrads. Not surprisingly, the research is diverse, with projects ranging from neural network-based modelling of various systems to pulsed electric field treatment of food products.

Bioremediation, for example, has become a major focus of late, mainly as a result of increased awareness of our environment--as well as stricter government regulations. Within a group like this, it wouldn't be uncommon to find analytical chemists, botanists, engineers, soil scientists, and a couple of computer simulation specialists, working on models of, say, leaching of phosphates in soils, or developing methods for removing heavy metal contamination.

Then there's post-harvest engineering. To preserve the products we eat on a daily basis in a premium state requires research. How do you get a guava from South America to Canada without it going bad? Controlled atmospheres are usually the answer, and any controlled environment requires engineering. Physiologists work side by side with control systems engineers to determine the necessary conditions for keeping fruits and vegetables in optimum shape from harvest to delivery. Obviously there are different levels of quality in fresh produce too, so how did you sort the produce out according to size and quality? It would be fine to do it by hand if you only had a couple of bushels to deal with, but most producers deal with tons. This makes hand-sorting operations virtually impossible, because the product must be stored in a controlled environment quickly to prevent losses. For this, mechanical sorters are needed that can sort according to various criteria such as colour or shape. Enter another facet of biosystems engineering that requires software engineers: machine vision.

There are also food engineers in our department, working on such topics as inactivating micro-organisms to prevent spoilage and food poisoning. They apply techniques such as pulsed electric fields to destroy harmful bugs without impacting too much on product quality. Microbiology, food science, and an understanding of engineering principles come into play here.

Degrees in science and engineering are obviously the most common backgrounds in the programme, but there are people with far more diverse backgrounds doing research that incorporates the social sciences. It's of no use to draw conclusions about inefficient agricultural practices in Panama, for example, if you cannot transfer the information gained from research to the local population that actually depends on that land for their livelihood. Using a combination of engineering and scientific knowledge gained from field studies, as well as interaction with communities in developing countries, some researchers in our department are developing methods to effectively communicate information about best practices to the farmers, as well as methods to train them by example.

Fermentation Engineering

My own field of research is fermentation engineering, a field that requires knowledge of engineering, microbiology, and more recently, genetics. An example of fermentation engineering is the development of a microbial culture-based treatment system to degrade a phenol, which is toxic and very stable, to a liquid that can be safely disposed. The field is becoming increasingly important, particularly in the biotech industry. For instance, liquid culture fermentation is used to produce large quantities of insulin and erythropoietin used to treat diabetes and anaemia, respectively (the latter has also found notoriety in distance sports, such as cycling and marathon running, for its endurance enhancing properties). Fermentation engineers are responsible for engineering the organism that produces the product of interest, developing large-scale production processes (which, by the way, is not as easy as you might think), and figuring out how to process large quantities of raw material.

I started out with a bachelor's degree in food science at Stellenbosch University in South Africa, taking biochemistry, food engineering, and food microbiology amongst other courses. My university was in the heart of the wine region of South Africa, and many of my friends were studying oenology and viticulture. Like food science, these areas fell under the faculty of agriculture, and some overlapping courses led me to become interested in fermentation processes. I decided that I wanted to pursue further studies in this field. I also thought that it would be a good career move to study abroad. So, I chose the program at McGill University for its location and worldwide reputation for academic excellence.

With an interest in beer production, I began a master's degree in biosystems engineering, studying the physical properties of brewing yeast. Beer is a fine example of an economically (and socially) important bioprocess. Annual production at one company alone can approach or even exceed 10 billion litres.

The more I studied, the more interested I became in the field and knowing that I did not want to become an academic, I started contacting companies with the hope of getting a start as a researcher in the brewing industry. The response was encouraging, but as I have a desire to be in Europe, I determined that a PhD would be the only way in due to EU job-market protection regulations. I had already started numerous projects outside of my degree that were not yet complete and when done, would be perfect CV building material. As a result of that, and the enriching learning experiences I have had at McGill, I decided to stay on to complete a PhD in the same department. That's where I am now, and I'm enjoying the challenge!

A Case of Misinterpretation

There are both positive and negative aspects to multidisciplinary nature of biosystems engineering. On the plus side, it promotes interaction with researchers in fields (and places) other than your own and stimulates interest in other topics. I, for one, prefer to be a generalist and know a lot about many things than everything about one thing, so the field suits me.

But the broad nature of biosystems engineering can pose problems when it comes to finding positions. The fact that the field overlaps with numerous others means that biosystems engineers are often competing for the same jobs with biological scientists, and so the competition is fierce, particularly when a company is looking to fill a niche position. It's my impression that the hiring individuals don't sufficiently understand or appreciate the skill set of a biosystems engineer and overlook them because they think that the degree doesn't sound specific enough, like 'food science' or 'mechanical engineering'. Sadly, the problem lies in misinterpretation, because biosystems engineers are equipped to deal with a wide range of issues.

Perhaps that will change in the future. In a world of ever increasing rationalization, employers will likely be leaning toward hiring people that can do multiple jobs. With more people getting postgraduate degrees and entering their respective professions as specialists, those who will have a competitive edge may well be the students who have ensured that their research touches on several fields. Biosystems engineering may well fit the bill in this regard. Regardless, it's certainly worth considering for those looking for a different kind of challenge.

Identify Current/Future Employers

Objective 2. Identify current/future employers

Prepared by F. Ayuga[1], R. Kanwar[2] & H. Ramon[3]

(1) Universidad Politιcnica de Madrid, ETSI Agronomos, Ciudad Universitaria, Spain
(2) Department of Agricultural and Biosystems Engineering, Iowa University of Science and Technology, Iowa, USA
(3) Laboratory for Agricultural Machinery and Processing, Katholik University of Leuven. Leuven, Belgium

History

The activity of Agricultural Engineers in Europe began with the 19th century. Some years before the first civil engineers started their activity in mining and public works. Probably the first engineering activity that can be considered Agricultural Engineering was connected with the measurement of fields for tax payment and making maps with no military interest.

In the USA, the Agricultural Engineering activity begun more or less at the same time, but more focussed on agricultural machinery, with great inventors such as Eli Withney, Cyrus McCormick or John Deere. It spread very quickly all over the country and early was founded the American Society of Agricultural Engineers in 1907.

Economical planning of Agriculture, Forestry and the rural areas, land reclamation and rural development were also assisted by technicians in collaboration with politicians early during the 19th century.

Due to this political collaboration interest in preparing professionals in the field of Agricultural Engineering grew, and the first Institutions were created in Europe. Some examples are [1]:

In *Germany*, the Hohenheim Institution for agricultural teaching was established as early as 1818 and in 1847 it became the Academy of Agriculture and Forestry. In 1818 was also founded an Agricultural Institute of the Rheinische Friedrich-Wilhelms-Universität of Bonn in Poppelsdorf. The agricultural college of the Humboldt University of Berlin was founded in 1881 and became the Faculty of Agriculture in 1889.The Technical University of Munchen has an Agricultural Department since 1872 incorporating in 1930 the College of Agriculture and Brewing in Weihenstephan founded in 1919.

In *France, the* l'Ecole Nationale des Eaux et Forêts de Nancy was established in 1824, and L'École Nationale Supérieure d 'Agriculture de Grignon in 1826. L'Institut National Agronomique was established in Versailles in 1848 while l'Ecole Nationale du Génie Rural in Paris in 1919.

In the *United Kingdom,* the Institution of Water and Environmental Management was established in 1895. The University of Oxford founded the Institute of Agricultural Engineering in 1924 and became the Silsoe National Institute of Agricultural Engineering (NIAE).

In *Poland,* the Warsaw Agricultural University was created in 1816, in Spain the Central Agriculture School was founded in 1855 in Aranjuez, near Madrid, in Italy the Istituto Tecnico Superiore de Milano was created in 1859 with the degree in Agricultural and Mechanical Engineering.

Only in *Belgium,* the Catholic University of Leuven established in 1878 the Institute of Agronomy under the initiative of a group of Catholic landowners and not by public initiative.

At the same time a similar progress can be seen in the *United States*:

- Probably the first Institution on Agriculture higher studies in USA was the Pennsylvania State University. It was founded on 1855 as the Farmers' High School of Pennsylvania, although in 1862, the school's name was changed to the Agricultural College of Pennsylvania
- In 1859 the State Agricultural College and Model Farm of Iowa was founded, being one of the first technical teaching Institutions in USA.
- The College of Agriculture and Mechanic Arts was established on 1870 in Missouri. The University of Georgia received federal funds for instruction in Agriculture and Mechanical Arts in 1872. The Florida Agricultural College begun in 1884 and in 1905 along with three other Colleges became the University of Florida.
- At the beginning of the century in 1900 the Cornell University started the College of Agriculture, with a division of Rural Engineering and Agriculture in 1907. In 1905 was founded the Davis campus of the University of California to teach scientific and practical agriculture, initially named as University Farm.

Engineers coming from these Institutes continued the tasks assumed previously by others, and started new activities such as the storage of water and its transportation and distribution, a traditional civil engineering field, but when this water is not for human use but for irrigation it became one of the first Agricultural Engineering activities in the Southern European countries and in the US.

There were also many countries that by the end of the 19th century promoted Research Institutions on Agriculture that became working places for a good number of graduates.

Some activities described so far are under the umbrella of the public sector, and in some way public administration can be considered the first employer of Agricultural Engineers in Europe and the USA.

But there were also important private clients. For example in those years the first food industries (flour mills, beet sugar factories, wineries, canning industries etc.) were designed with engineering principles and using new steam engines. This new “industrialisation” was shared with other engineers and architects, but some of the factories were so connected with the Agricultural sector that designers should be considered as Agricultural Engineers (in some countries with a University degree with such name or something similar and in other countries without it). And the work of the engineers did not finish with the factory design; they work also for factory owners in the production process and for the industry of machinery for the factories as sellers and developers.

There were also some companies that started their history with the beginning of the 20th century, the farm machinery industry, and they joined Agricultural Engineers and Mechanical Engineers that many times overlapped functions.

Bigger European farmers also employed Agricultural Engineers in their farmlands to improve the production systems and to introduce modern techniques and breeds and this situation was more evident in America with bigger farms.

In some countries it was common for students of the teaching Institutes of Agricultural Engineers to come from landowner and/or noble families.

From the beginning it was clear that in Europe two kinds of technicians were connected with the rural development. On one hand there were graduates coming from an evolution of Civil Engineering and Mechanical Engineering programmes, focused on surveying, buildings and machinery applied to rural areas. On the other hand there were graduates coming from Botany, Biology or Natural Sciences programmes specialised on crop production and improvement. We can call them "Agricultural Engineers" and "Agronomists" although their real names changed from one country to another and even in the same country in different ages.

By those days, in some European countries there was a clear differentiation of studies, but in most of them there was some overlap and very often it was difficult to know the real engineering background of the professionals even if they had the title of "Engineer" in their degree.

In the United States, on the contrary, this difference was not so clear and the name "Agricultural Engineer" more common.

In the first half of the 20th century more activities were assumed by the Agricultural Engineers, for example:

- livestock planning and animal housing,
- agricultural economics and agricultural business management,
- power supply and transport,
- food processing and marketing, post harvest technology,
- fertilization, pest and disease control,
- soil and water technology,

More recently other activities have been incorporated to the list, such as:

- environmental engineering and management,
- waste engineering and management,
- land management,
- biotechnology,
- new sources of energy,
- landscape architecture,
- telecommunications and information technology in rural areas

All of them have broadened the typology of employers and also the overlap with other professionals.

During the 20th century the "Agricultural Engineer" and "Agronomist" confusion has grown in Europe and other technicians (Food Technologists, Hydraulic Engineers, Horticultural Engineers, Environmental Engineers, etc.) started to appear, producing a chaotic situation that should be cleared in order to increase the transfer of students, professionals and professors between countries.

It seems evident that Agriculture is not the only target of Agricultural Engineers any more and changes in names, teaching Institutions and programmes of studies should be tackled.

Identification of current/future employers

The situation for the employability of Agricultural Engineering graduates in Europe has been analysed extensively in the framework of the USAEE TN project. The following figures represent the situation of the employability status of the profession at a European level in 2006 [2].

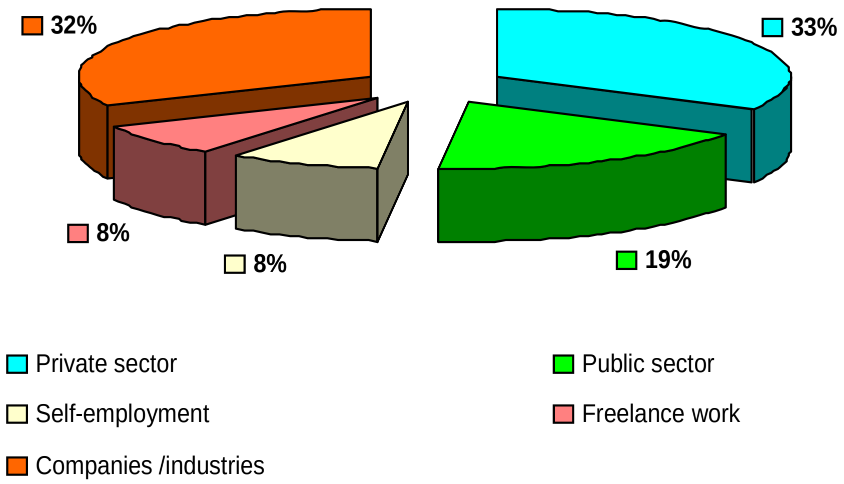

Figure 2.1. Sector of economy Agricultural Engineering graduates are employed in 2006

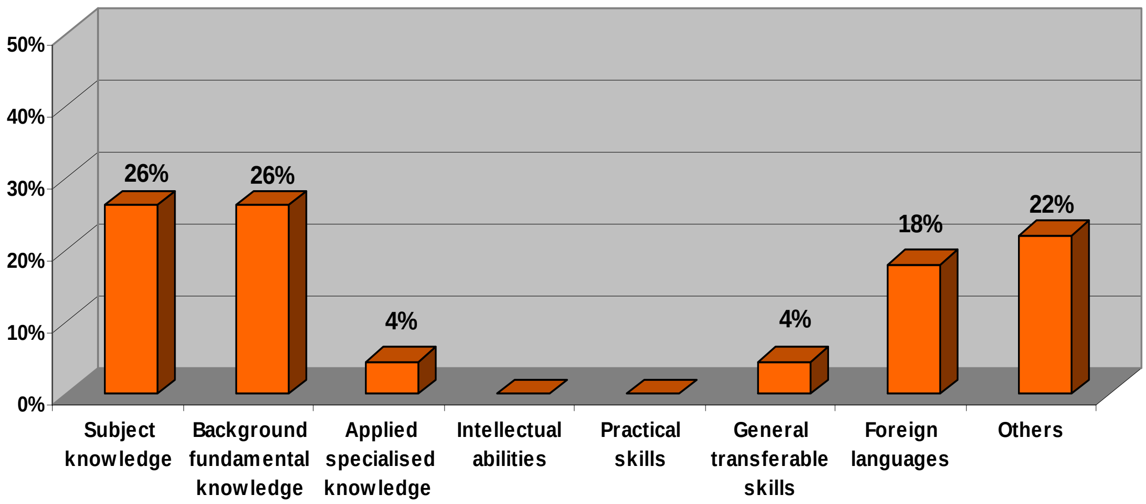

Figure 2.2. Competences in Agricultural Engineering considered most useful to enter a job (2006).

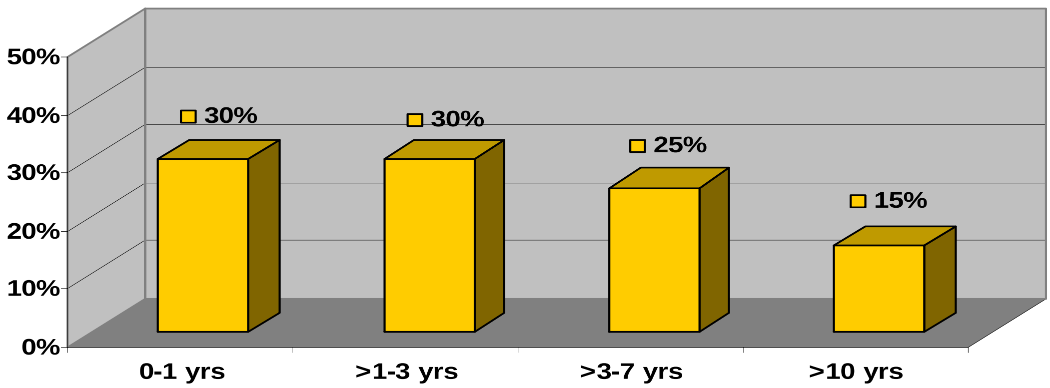

Figure 2. 3. Number of years between graduation and 1st time employment in a discipline of Agricultural Engineering related to the degree (2006)

But we can present the situation in some European countries as an example of the present situation of labour market. A more complete view of all European countries can be found in [3].

The experience in **the UK** today is described by the Institution of Agricultural Engineers (IAgrE), the professional body for engineers, scientists, technologists and managers in agricultural and allied land-based industries, including forestry, food engineering and technology, amenity, renewable energy, horticulture and the environment (http://www.iagre.org/). In particular, membership of the Institution provides a status that has won recognition throughout the world as an important career qualification (refer to APPENDIX 2.A).

Their activities cover a broad technical and administrative spectrum in engineering research and testing; design, development and manufacture; marketing and sales; teaching; training; consultancy and farming. The particular technical interests covered include: food engineering and technology, precision farming, forestry engineering, livestock engineering, machinery management, soil and water management, amenity and ecological engineering, renewable energy, vehicles, overseas development, agro-industrial products and pioneering technology.

In another case, contemporary information is provided concerning current employment opportunities and needs in the classical area of Agricultural Engineering in the UK (APPENDIX 2.B). Based on the information provided, there are around 45,000 people working in land-based engineering businesses in the UK. Jobs are available throughout the country. This is a growing sector with opportunities to enter the industry at craft/technician level, or with a degree or HND. All new agricultural engineers complete a period of initial professional development (IPD) when they start work. Larger employers may offer structured training schemes. Continuing professional development (CPD) is an important element of all engineering disciplines and professional engineers can register with the Engineering Council UK at engineering technician, incorporated engineer and chartered engineer levels.

In **Germany** Agricultural Engineers can have two different background programmes. On one hand there are the mechanical engineers with Agricultural Engineering as one of two major courses in there studies. On the other hand there are the students of agricultural sciences with the main course on Agricultural Engineering.

Graduates of both kinds can find a job in all agricultural machinery companies (Deutz-Fahr, Claas, Fendt, John Deere, Krone and also smaller ones), but those who came from the first kind can additionally find a job in nearly every machinery company (not only agricultural) (Daimler-Chrysler, Volkswagen, MAN, Bosch, Bosch-Rexroth and so on). The students are enabled to transfer there knowledge to the development of other kinds of machines. Graduates of the second kind find jobs additionally in administration, government or advisory services (always where agricultural science knowledge is needed). The economy in Germany is very good and at the moment all students are getting jobs.

In **Italy** Agricultural Engineering is a recent degree, so there are no previous experience, but the employers that now contract the Agronomists having competences about Agricultural Engineering are industries (of tractors and agricultural machines), companies (e.g. for the commercialisation of structures, irrigation plants and equipment in rural areas), private (e.g. agricultural farms and food processing industries) and public sectors (local governments, e.g. for the management of agricultural and livestock wastes, planning and management of green areas and parks), Universities (for research and teaching), high schools (for teaching), internal job position or external consultancy for the growth of developing countries, within international bodies (e.g. EU, FAO), besides freelance professional activity (consultancy about irrigation plants, land planning and management, rural buildings, agricultural mechanisation, etc.).

In **France** four main professional profiles are found:

- Firms in Farm Machinery and equipments : particularly International Companies from big International Groups (Agco, Argo, Deere, Claas, …)
    - Design, research development – prototype testing
    - Marketing (+ export)
    - Sales department (+ export)
    - After sales, spare parts (National Companies + export)
    - Vocational trainers
- Food Industry: National and International Companies.
    - Process manager
    - Product manager
    - Quality and control manager
    - Provisions manager
- Research and development in Institutes and Research Centres :
    - Develop new research protocols
    - Technologies and decision making tools in agronomy and agricultural engineering.
- Miscellaneous : Advising, Journalism, Education, Farmer

Although all previous employers are still the principal employers of French engineers, transversal skills are required such as international mobility and foreign languages. In terms of professional sector, cooperatives and machinery dealers offer now interesting jobs such as those which can be found in big companies. Finally, in BSE sector, French graduates are rather employed in marketing/sales/communication departments than in Engineering and design departments.

At the present, in **Greece** and in other European countries, only a few employers take into service Agricultural Engineers graduating from the Agricultural Universities in order to employ them for various technical tasks within the classical area of Agricultural Engineering. As a result current employment and career opportunities for Agricultural Engineering graduates are far beyond their orientation. They usually work as Agronomists for commercial or productive enterprises (sales, agricultural machinery, greenhouses, livestock units, soil analysis laboratories, fertilizers / pesticides / insecticides companies, food conservation establishments, etc.), as civil servants (Ministry of Agriculture, prefectures with tasks that may vary from animal science to phytopathology) and as private professionals (i.e. commercial activities - sales, landscape architecture, garden design, planning of agro-industries, consulting in animal housing and greenhouse design, environmental studies, etc.). An appreciable percentage of these graduates find a job that has nothing to do with the Agricultural sector (e.g. banks, consulting technical companies, etc.).

In **Spain** the work titled "Libro blanco de los títulos de grado en Ingenierías Agrarias e Ingenierías Forestales" [4] carried out by the Spanish Agricultural and Forestry Engineering Schools for the Spanish National Agency for Quality Assessment and Accreditation (ANECA), published in 2005, shows the Spanish Agricultural Engineer employers features:

Employer type:

Public – 17 %
Private – 77 %
Semi-public- 6%

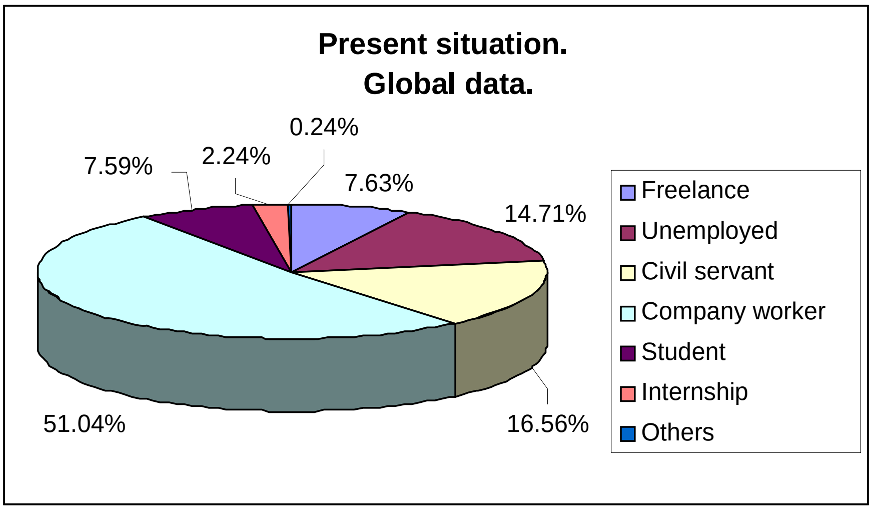

Figure 2.4. Spanish situation of young Agricultural Engineering graduates (2005)

It must be taken into account that these results were based in a population of students that had finished their degree in the last five years before the survey was made. That could be the reason of higher unemployment and student figures.

Activity of the company:

- Agricultural an agrifood industries – 29%
- Engineering services – 12 %
- Public sector – 10 %
- Associations of producers - 8 %
- Research and development - 6 %
- Farms - 5 %
- Landscape and gardening - 5 %
- Forest management – 3 %
- Livestock - 2%
- Forest industries – 1

In **Hungary** many of the Agricultural Engineers work in the public sector (Ministry of Education, Ministry of Agriculture and Rural Development, Ministry of Environment, Governmental enterprises) although recently the number of civil servants is decreasing. When working privately they find a job in well-known international companies such as Mercedes, Claas, Sauer, Linde, Perkins, New-Holland, John Deere, etc. and sometimes get jobs initially offered for mechanical engineers.

In **Finland** about 30% of the Agricultural Engineers are working on their farms, about 30% have found their job in education, research and governmental offices and about 20% are in agricultural machinery trade or industry.

In **Lithuania** graduates of the faculty of Agricultural Engineering are occupied in different companies (manufacture, service and trade of agricultural machinery, food processing), consultancy, education, technical supervision, energy generation and supply companies. Part of graduates established private companies for technical services and trade. Small part of graduates works in other fields of economy. Graduates with qualifications in Engineering are successful enough in labour market of Lithuania. Growing economy provides new workplaces.

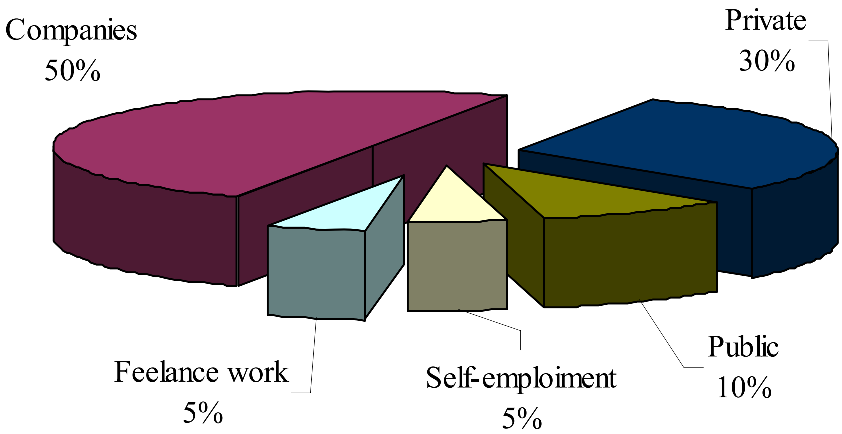

Figure 2.5. Sectors of employment of Agricultural Engineers in Lithuania

The majority of employed graduates are involved in subjects related to their degrees in Mechanical Engineering or Energetic. They are designers of the technical systems and equipment, quality supervisors, teachers, consultants and managers for manufacture, maintenance and trade.

With respect to the **United States of America** the database of the American Society of Agricultural and Biological Engineers (ASABE) can be used, because most of the graduates in Agricultural Engineering (and related) degrees belong to this Society and they are asked when entering the Society about their major job function, employer type, primary work area, and technical interest (Dixon, 2000). [5]

Using this database Dixon elaborated the next tables:

Employment Category	Number of Members	Percent of Total
Agri-business	350	6.75
Association	37	0.71
Consultant	917	17.68
Distributor	51	0.98
School	1009	19.45
Experiment station	117	2.26
Producer/farmer	114	2.20
Government agency	756	14.57
Library	3	0.06
Manufacture, components	276	5.32
Manufacture, equipment	1366	26.33
Processor	140	2.70
Supplier	52	1.00
TOTAL	5188	100.00

Table 2.1. Employer type – The kind of business where employed

In this table it can be seen that Manufacture employers are one third of the total and that Universities (Schools) and Government are also very important employers even today. The next position goes to Consultant companies.

When asked about the primary working area the answers can be seen in table 2.2.:

Primary Work area	Number of Members	Percent of Total
Crop processing	142	3.15
Crop production	238	5.28
Electronic & Control systems	218	4.84
Electronic distribution & applications	109	2.42
Environmental quality	133	2.95
Environmental systems, livestock & crops	347	7.70
Farmstead engineering	218	4.84
Structural Design	304	6.74
Food processing	21	0.47
Irrigation equipment & systems	318	7.05
Machinery design	1404	31.14
Safety	151	3.35
Turf & landscape	55	1.22
Water quality & management	850	18.86
TOTAL	4508	100.00

Table 2.2. Primary work area – A member's main job function

In this case Machinery design is the major working area followed by Water quality and management. As Dixon appointed it is remarkable that Food processing shows very low figures, but surely it can be explained because these engineers prefer to be members of other Societies such as the Institute of Food Technoligsts (IFT) or the American Institute of Chemical Engineers (AIChE).

Finally the applicants were asked about their primary technical area of interest. There are a greater number of answers because this question can be answered not only by the engineers but also by the students. The results are shown in table 2.3.:

Primary Technical Area	Number of Members	Percent of Total
Aquacultural engineering	115	1.73
BE	9	0.14
Bioengineering	208	3.13
Forest engineering	55	0.83
Food & process engineering	565	8.51
Information & electrical technology	421	6.34
Power & machinery	2630	39.59
Structures & environment	728	10.96
Soil & water	1912	28.78
TOTAL	6643	100.00

Table 2.3. Primary technical area – The ASAE classification of member's interest

The main area is Power and Machinery followed by Soil & Water and Structures & Environment.

A summary of the current employers in Europe and United States of America can be found in tables 2.4. and 2.5. for the Public and Private Sector respectively.

National Institutions			
	Ministry, Department		
		Agriculture	Foreign
		Food	Education
		Environment	Research
		Development	Comerce
		Economy	Energy
			Transportation
			....
	Public companies		
		All kind of activities	
Regional Institutions			
		The same as National	
Local Institutions			
		Urban Planning	
		Green spaces	
		Urban services	
		......	
Agencies or Institutes			
		Development	Taxes
		Public insurance	Land reclamation
		Public loans	Research centers
		Land management	Environment mangement
		Disaster protection	Transport planning
			....
Education			
		Universities	Technical labour
		High Schools	

Table 2.4. Public sector current employers

Agriculture supply companies		
	Agricultural and forestry machinery	Fertilizers
	Energy infrastructure and machinery	Pesticides
	Irrigation infrastructure and machinery	Postharvest technology
	Transport infrastructure and machinery	Management
	Seeds and breeds	……..
Food industries		
	Food processing equipment and machinery	Sales and marketing
	Quality control	Management
	Manufacturing and Production Control	……..
	Postharvest equipment	
Civil works companies		
	Roads	Infrastructures
	Buildings	Greenhouses
	Construction components suppliers	Storage
	Environment protection	………….
Consultancy		
	Technical projects	Environmental reports
	Company assessment and advise	Land planning
Farms		
	Management	Sales and buyings
	Innovation	
Markets		
	Hypermarket buying department	Laboratories
	Hypermarket quality department	Management
	Supermarkets	
Insurance companies		
	Crops and livestock	
	Farm buildings and infrastructures	
	Machinery	
Banks		
	Loans and credits assessment	
	Farm economy assessment	
Research		
	Research, Development and Innovation	Universities
	Research companies	Private teaching Institutions
	Journals	

Table 2.5. Private sector current employers

Trends

The present situation of many Agricultural Engineers in Europe can be in danger in the near future. There is a great confusion on the graduate names, Institutions providing degrees in Agricultural or similar Engineering, background of the students, programmes of studying, and overlap with other professionals. In general, it can be appreciated all over Europe a decrease in the duration of studies and more emphasis in the biological background and less in the technological background [6],[7].

If the technological background of the studies is not maintained or increased, the Agricultural or similar Engineers can lose their traditional role in technological companies. For example: graduates employed by irrigation companies require very good skills in CAD, in addition to a good knowledge in irrigation and hydraulics and soil and water issues; graduates working in companies constructing greenhouses and farm structures, could realise that their graduates lack basic knowledge in structural design, etc. Companies specialising in agricultural machinery could prefer to employee graduates from institutes of Technology (with a poor scientific background, but a good low-level applied technical knowledge in agricultural machinery) or preferably mechanical and electrical engineers, graduates from Technical Universities.

All these employers would be willing to hire a new generation of graduates with a sound Engineering background and would support the development of teaching Institutions in Biosystems Engineering. Their graduates will be able to support their enterprises with a good technical background and an integrated knowledge of the biological systems. Concerning the Public sector, the only change would be that the new employees coming from such Institutions of Biosystems Engineering will be able to offer more comprehensive solutions to the complex problems faced today by the society in the sectors of Agriculture, Food and Environment.

The market is not willing anymore to hire graduates who claim to "know nothing of everything' (e.g. their current programs of studies cover the whole range of Agricultural Sciences)! The learning outcomes described in the FEANI (Fédération Européenne d'Associations Nationales d'Ingénieurs) document of USAEE-TN [1] offer a very good guidance about the direction to be followed in restructuring the current programs of studies in Agricultural Engineering in Europe and subsequently the current and future programs of studies in Biosystems Engineering in Europe. This fact has been recognised in the framework of the work of the USAEE-TN and analysed systematically. It is now the moment that the education of Agricultural and Biosystems Engineers in Europe meets the needs of the European market in the broader area of Biosystems Engineering.

Nowadays the agricultural sector, despite of it is a strategic sector, have few importance in the developed nations. However there are other aspects that have gained importance like environment, food security and safety, innovation in food products and their production, products traceability, rural development and the new systems of energy production. That means many job opportunities for the future graduates.

To sum up, all the activities that need engineers in relation with biological products, the environment or the countryside, will be job opportunities for the agricultural/biosystem engineers

Searching the European market related to Biosystems Engineering business activities are found in all areas of the classical Agricultural Engineering, while several SMEs are now active in innovative areas of bio-fuels, bio-materials and bio-instrumentation. Policy-makers have long known how significant SMEs are to the European economy and, in turn, how research and innovation are vital for the competitiveness of these companies. About 25 million SMEs account for approximately two-thirds of Europe's employment and GDP. Therefore, it comes as no surprise that SMEs are a key component of the research and innovation system and that they play an important role in transforming knowledge into new products, processes and services. Due to their ability to adapt quickly to market changes, SMEs are often better positioned to exploit new and emerging research opportunities that address ongoing social, environmental and economic challenges as is the case with various innovative applications in the broader area of the evolving Biosystems Engineering discipline.

A characteristic example is shown in APPENDIX 2.C for the case of employment opportunities for Process Engineers. Based on this information, process engineer develops economical industrial processes to make the products on which modern society depends. These products include: food and drink; fuel; artificial fibres; pharmaceuticals; chemicals; plastics; toiletries; energy; and clean water. Of course several applications are beyond the scope of a Biosystems Engineer. Many other however, do. In any case, process engineers are expected to work closely with other specialists, including: scientists responsible for the quality control of raw materials, intermediates and finished products; engineers responsible for plant maintenance; commercial colleagues on product specifications and production schedules; and the operating crew.

The Development of European Agricultural Machinery Markets in 2006/2007 is presented in Appendix 2.D. Like other branches of the mechanical engineering industry, the agricultural machinery industry is currently in a boom phase. In Germany as a production location, growth rates were disproportionately high in the past three years. The most important sales market for the domestic industry is Western Europe with its main markets France and Germany, followed by the agricultural nations in Eastern Europe, which are recovering again. In 2006, the western European market was able to maintain its level, while the central and eastern European region once again provided a considerable growth impulse.

In an open directory project, a list of current on-line announcements for relevant job opportunities in the UK, Europe and world-wide appears (Appendix 2.E). The categories included in both, the classical Agricultural Engineering area and in the emerging Biosystems Engineering area are indicative of the general trends of employability in the two corresponding areas.

In the United States of America the trend to include Biological and Environmental categories jointly with the classical Agricultural Engineering was produced years ago. Now the name of the Society and the teaching Institutions and Departments reflects the change operated in America and can be considered a closed discussion. Now the trends and challenges are mainly focused on the new big market of Biobased Products. In the near future crop production and industries for biobased products will require new farmers and engineers. The next table provided by the Iowa State University shows a picture of the present situation of the industry in the United States.

Biobased Product Sector	Iowa Sales ($ millions)	U.S. Sales ($ millions)	Iowa Jobs	U.S. Jobs
Ethanol [2,3]	3,200	12,000	4,500	15,000
Biodiesel [4,5,6]	90	700	140	1,000
Biopower [4,7]	70	9,400	410	73,000
Biochemicals [4,8,9]	NA	31,000‡	NA	63,000‡
Bioproducts [4,8,10]	50†	17,000†	350†	28,000†
Total	**3,410†**	**70,100**	**5,400†**	**180,000**

†Minimum, ‡ Estimated, NA = Not available

Table 2.6. The Biobased Product Sector in Iowa and the United States

And the U.S. Department of Energy has established targets for biopower, biofuels, and bioproducts that can be seen in table 2.7.:

	Units	2000	2004	2010	2015	2020	2030
Biofuels	Market share (%)	0.7	1.2	4.0	6.0	10.0	20.0
	Consumption (billion gasoline-equivalent gallons)	1.1	2.1	8.0	12.9	22.7	51.0
Biopower	Market share (%)	3.0	3.0	4.0	5.5	7.0	7.0
	Consumption (quadrillion Btu)	2.0	2.1	3.1	3.2	3.4	3.8
Bioproducts	Production (billion lbs)	12.8	17.6	23.7	26.4	35.6	55.3

Table 2.7. Vision for Bioenergy and Biobased Products in the United States.

These data show the magnitude of the opportunities and the need for engineers with enough background on biology, agriculture, biological products processing and so on.

Table 2.8. shows a summary of the new areas with job opportunities

biotechnology, genetics	natural risk assessment and decision planning
bioprocessing	food process engineering, food quality assurance and food safety
nanotechnology	fibre, plant, animal and humans physical behaviour
biomaterials, bioplastics	traceability of agricultural products
biological struggle	machinery maintenance and production
non food crops	mobility and safety of machines)
information technologies and agricultural informatics	robotics and mechatronics
bioenergy (liquid and solid biofuels, flexfuel, biogas, biolubricants, green oils, bioelectricity and heating)	precision agriculture development and advising
renewable energy resources	satellite imagery applications in agriculture and environment
sustainable agriculture	climate data sensors
environmental technology	carbon dioxide management
water and soil management	green areas, parks and open air sports
reduction of agricultural pollutants	agrotourism
waste management, reuse and recycling	multifunctional aspects of agriculture

Table 2.8. A non-complete list of new areas with job opportunities

References:

[1] Web pages:

http://www.agroparistech.fr/index.html
http://www.engref.fr/bref.htm
http://www.isa.utl.pt/home/
http://www.ensia.fr/presentation/histo.php
http://www.biw.kuleuven.be/english/history.aspx
http://www.inapg.fr/spip_en/
http://www.landtechnik.uni-bonn.de/
http://www.ucd.ie/cigr/history.htm
http://www.agraria.unimi.it/storia.htm
http://zope.hu-berlin.de/ueberblick-en/history/
http://portal.mytum.de
http://www.brdisolutions.com/default.aspx

[2] USAEE. 2006. http://www.eurageng.net/files/usaee-corecurriculum.pdf. Last visit 20th January 2007

[3] Briassoulis D. and P. Panagakis (editors) P. “Restructuring Agricultural/Biosystems Engineering studies and employability in Europe”. Proceedings of the 7th USAEE Workshop, Vilnius, Lithuania. April 1-2, 2006.

[4] ANECA (2005). Libro blanco de los títulos de grado en Ingenierías Agrarias e Ingenierías Forestales.
http://www.aneca.es/modal_eval/docs/libroblanco_agrarias_forestales_def.pdf

[5] Dixon, J. E. “Work Areas of ASAE Members”. In Henry, Z.A., J.E. Dixon, P.K. Turnquist, and J. L. Schinstock.. “Status of Agricultural Engineering Educational Programs in the USA”. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Vol. II. August 2000

[6] Briassoulis D and Panagakis P (editors) ‘Current Structure of European University Studies’. Proceedings of the 1st USAEE Workshop, Madrid, March 28 – 29, 2003.

[7] Briassoulis D. and P. Panagakis (editors) ‘Research Activities in European University Institutes of Agricultural Engineering’, Proceedings of the 2nd USAEE Workshop, Palermo, September 26 – 27, 2003

APPENDIX 2.A

Membership of the Institution provides a status that has won recognition throughout the world as an important career qualification. Members are classified into grades from Associate (including students) up to Fellow. Their activities cover a broad technical and administrative spectrum in engineering research and testing; design, development and manufacture; marketing and sales; teaching; training; consultancy and farming. As a nominated body of the Engineering Council UK, IAgrE is able to offer Professional registration with the Engineering Council as Chartered Engineer, Incorporated Engineer, Engineering Technician to suitably qualified members.

IAgrE is a founder constituent body of the Society for the Environment (SocEnv), a new umbrella body for those professionals active in the field of sustainable development. Since 2004, through its constituent bodies, SocEnv has offered the professional qualification of Chartered Environmentalist (CEnv). Those working in the land based sector are welcome to contact IAgrE for further details of SocEnv and the proposed CEnv. qualification. Click for further information on SocEnv.

Activities include branch meetings, conferences and events, and technical groups meetings. These involve members with particular technical interests, including food engineering and technology, precision farming, forestry engineering, livestock engineering, machinery management, soil and water management, amenity and ecological engineering, renewable energy, vehicles, overseas development, agro-industrial products and pioneering technology. A Young Engineers' section is aimed at students and those embarking on a career in agricultural engineering. These activities provide a forum for technical updating and for meeting friends and colleagues within the industry.

Reports of the proceedings at national and branch meetings and other matters of technical and current interest are published six times a year in the Institution's Journal Landwards. The Library of Cranfield University - Silsoe (adjacent to the Institution offices) is the official library of the Institution. Members are eligible for low-cost subscriptions to Biosystems Engineering (formerly JAER) through membership of the European Society of Agricultural Engineers.

The Institution is staffed by a Secretariat based at Silsoe (click for Location Map), and is governed by an elected Council. It is a Company Limited by Guarantee. It is the UK member of EurAgEng, the European Society of Agricultural Engineers.

APPENDIX 2.B

JOBS4U Carrers database:

http://www.connexions-direct.com/jobs4u/index.cfm?pid=48&catalogueContentID=168

Agricultural engineers develop new equipment and technology for use in land-based industries, such as agriculture, horticulture and forestry. They usually work in one of the following areas:

- manufacturing - designing, testing and demonstrating new products such as tractors and sprayers
- field engineering - developing solutions and new equipment to deal with issues such as soil erosion and irrigation
- service engineering - training operators and installing and repairing machinery on site
- environmental control - designing electronic systems which control the conditions inside buildings used to house livestock or store crops
- environment - working on land reclamation and projects to create habitats.

Agricultural engineers usually work 37.5 hours a week, although hours may vary depending on seasonal demands, deadlines and whether they are on call. They spend time working both indoors and outdoors. The work involves a lot of standing and walking, as well as climbing ladders and working in confined spaces.

Salaries range from around £18,000 to £50,000 a year.

Agricultural engineers need:

- good practical and ICT skills
- the ability to organise their time and work to deadlines
- to be methodical and inventive
- the ability to record and analyse data
- physical fitness for outdoor work
- to enjoy working with the latest technology and machinery.

There are around 45,000 people working in land-based engineering businesses in the UK. Jobs are available throughout the country. This is a growing sector with opportunities to enter the industry at craft/technician level, or with a degree or HND. There is no maximum age limit for entry.

All new agricultural engineers complete a period of initial professional development (IPD) when they start work. Larger employers may offer structured training schemes.

Continuing professional development (CPD) is an important element of all engineering disciplines and professional engineers can register with the Engineering Council UK at engineering technician, incorporated engineer and chartered engineer levels.

There are generally good prospects for promotion to managerial roles. There are also opportunities to work abroad. Some agricultural engineers may set up their own consultancies.

APPENDIX 2.C

Process engineer: Job description and activities

http://www.prospects.ac.uk/cms/ShowPage/Home_page/Explore_types_of_jobs/Types_of_Job/p!eipaL?state=showocc&idno=264&pageno=1

Job description

A process engineer develops economical industrial processes to make the products on which modern society depends. These products include: food and drink; fuel; artificial fibres; pharmaceuticals; chemicals; plastics; toiletries; energy; and clean water.

The work concerns large-scale chemical and biochemical processes in which raw materials undergo change. This involves scaling up the manufacture of products and processes from the laboratory bench to full production plants.

Designing equipment, understanding the reactions taking place, installing control systems, and starting, running and upgrading the processes are all part of the job. Protecting the environment and safety are also significant concerns for process engineers.

» Typical work activities

Work is project-orientated and you may be working on a number of projects, all at various different stages, at any given time.

Typical work activities will include:

- reviewing existing data to see if more research and information need to be collated, and assessing the adequacy of the existing processes and equipment;
- designing, installing and commissioning new production units, monitoring development (ie, modifications and upgrades) and troubleshooting existing processes;
- applying the principles of mass, momentum and heat transfer to process and equipment design;
- conducting process development experiments to scale in a laboratory;
- using computer modelling and simulations to design and evaluate processes and operating systems for the manufacture of products;
- preparing reports, flow diagrams and charts;
- assessing the availability of raw materials and the safety and environmental impact of the plant;
- managing the cost and time constraints of projects;

- supporting the conversion of small-scale processes into commercially viable large-scale operations;

- assuming responsibility for risk assessment, necessitating hazard and operability (HAZOP) studies, for the health and safety of both company staff and the wider community;

- monitoring and improving the efficiency, output and safety of a plant;

- ensuring the process works at the optimum level, to the right rate and quality of output, in order to meet supply needs;

- making observations and taking measurements directly, as well as collecting and interpreting data from the other technical and operating staff involved;

- assuming responsibility for environmental monitoring and ongoing performance of processes and process plant;

- ensuring that all aspects of an operation or process meet specified regulations;

- liaising with other process engineers, perhaps working on associated plants;

- working closely with other specialists, including: scientists responsible for the quality control of raw materials, intermediates and finished products; engineers responsible for plant maintenance; commercial colleagues on product specifications and production schedules; and the operating crew.

APPENDIX 2.D

The Development of European Agricultural Machinery Markets in 2006/2007.
(http://www.vdma.org/wps/portal/Home/en)
Like other branches of the mechanical engineering industry, the agricultural machinery industry is currently in a boom phase. In Germany as a production location, growth rates were disproportionately high in the past three years. The most important sales market for the domestic industry is Western Europe with its main markets France and Germany, followed by the agricultural nations in eastern Europe, which are recovering again. In 2006, the western European market was able to maintain its level, while the central and eastern European region once again provided a considerable growth impulse.

In addition to the large locations in North and South America, the agricultural machinery industry which produces for the world market is mainly located in western Europe. The production volume of the approximately 1,000 agricultural machinery manufacturers in the European Union amounted to about € 19.8 billion in the year 2005, which corresponds to 42% of the estimated worldwide production value of € 47 billion. Germany is the largest producer of agricultural machines and tractors in Europe with a share of almost 25% in the year 2005 followed by Italy (22%), France (17%), and the UK (9%). While agricultural machines or at least components of them are manufactured in almost all European countries, tractors are produced or assembled in only nine countries of the European Union. In the past three years, the production volume amounted to approximately 227,000 units. With regard to quantity, Italy is the biggest location. The tractors are mainly produced for the European market. The western European markets are considered saturated replacement markets. In Eastern Europe, however, many basic investments are still being made. In addition to Europe, exports to the large North American market are still playing a role given a 10-15% export share for the German industry. From the viewpoint of the individual countries, Germany can consider itself export world champion and has been significantly ahead of the USA in the past years thanks to the high exchange rate of the euro. In Germany, the export share was greater than 70% in the past years. The sum of exports is three times higher than the sum of imports. Thus, Germany is a clear net exporter in contrast to France, for example. In Western Europe, the industry once again recorded a sales growth of more than 5% in the year 2006 due to a stable domestic market and larger exports. Germany occupied an eminent position given a growth of approximately 12% to € 5.3 billion, which resulted from the considerably better development in the eastward export business. On the main markets Russia and Ukraine, primarily machines for tillage, sowing, and harvesting from Germany and Western Europe are in demand. For most countries in central and Eastern Europe, Germany is the main supplier of used or new agricultural machinery and accounts for an average share of 35% of the total import of the individual countries. In 2006, however, the exports of France, Italy, and the UK to this region also grew significantly. The great demand for replacements in the machinery parks and the enlargement of existing farms provides potential which German and western European industry can exploit for years. The most important influencing factors on the established western European market were positive: In addition to high or at least increased producer prices of important agricultural products (meat and grain), which result in growing customer incomes, expanding agricultural operations still need to invest, whereas the total number of farms continues to decrease. Within the European Union, agricultural policy was reoriented for the period up until 2012. Since this revised policy was introduced in the Member States in 2005/2006, it has been a relatively reliable factor. According to present estimates, the market volume in the European Union reached the value of the previous year (€ 17.5 billion) in 2006. At almost 170,000 newly registered tractors, the tractor market forecasts for the end of the year 2006 are also at the level of the year before. Due to the greater size of the new tractors, this means a slight sales increase. The powerhouses of European business in 2006 were Germany with a market growth of ca. 8% as well as the smaller markets in the Netherlands, Denmark, and Belgium, which also achieved high growth rates. In 2007, the overall development on the western European market is expected to remain stable because the so-called market indicators are not changing significantly. After steady growth in the previous years, the volume of the largest European market, France, showed a decline at the end. By October 2006, the number of newly registered tractors was 8% below the value of the previous year. Machines for arable farming and harvesting incurred a similar or even more significant reduction in the past season 2005/2006. An exception was the combine market, which grew for the third consecutive year. The new machinery business in Italy and Spain also did not provide any impulses. The British market seems to remain just below the level of the previous year after the number of orders had developed more dynamically again in the second half of the year 2006. At € 3.2 billion, the size of the German market was similar to the volume of the French market in 2006. Especially sales of large harvesting machinery were decisive for this development. The combine- and forage harvester market maintained its high level, and the efficiency of the new models improved significantly. By October 2006, tractors reached a plus of 16%. Therefore, the forecast for the end of the year 2006 is 27,000 units. According to current expectations, the German market will exhibit a slightly less dynamic development in 2007. Even though no negative circumstances can be discerned so far, farmers and contractors invested more than expected in new machinery. As a result, the demand has decreased, and the number of agricultural machines and tractors sold is decreasing slightly again.

In addition to the large locations in North and South America, the agricultural machinery industry which produces for the world market is mainly located in Western Europe. The production volume of the approximately 1,000 agricultural machinery manufacturers in the European Union amounted to about € 19.8 billion in the year 2005, which corresponds to 42% of the estimated worldwide production value of € 47 billion. Germany is the largest producer of agricultural machines and tractors in Europe with a share of almost 25% in the year 2005 followed by Italy (22%), France (17%), and the UK (9%). While agricultural machines or at least components of them are manufactured in almost all European countries, tractors are produced or assembled in only nine countries of the European Union. In the past three years, the production volume amounted to approximately 227,000 units. With regard to quantity, Italy is the biggest location. The tractors are mainly produced for the European market. The western European markets are considered saturated replacement markets. In Eastern Europe, however, many basic investments are still being made. In addition to Europe, exports to the large North American market are still playing a role given a 10-15% export share for the German industry. From the viewpoint of the individual countries, Germany can consider itself export world champion and has been significantly ahead of the USA in the past years thanks to the high exchange rate of the euro. In Germany, the export share was greater than 70% in the past years. The sum of exports is three times higher than the sum of imports. Thus, Germany is a clear net exporter in contrast to France, for example. In Western Europe, the industry once again recorded a sales growth of more than 5% in the year 2006 due to a stable domestic market and larger exports. Germany occupied an eminent position given a growth of approximately 12% to € 5.3 billion, which resulted from the considerably better development in the eastward export business. On the main markets Russia and Ukraine, primarily machines for tillage, sowing, and harvesting from Germany and Western Europe are in demand. For most countries in central and Eastern Europe, Germany is the main supplier of used or new agricultural machinery and accounts for an average share of 35% of the total import of the individual countries. In 2006, however, the exports of France, Italy, and the UK to this region also grew significantly. The great demand for replacements in the machinery parks and the enlargement of existing farms provides potential which German and western European industry can exploit for years. The most important influencing factors on the established western European market were positive: In addition to high or at least increased producer prices of important agricultural products (meat and grain), which result in growing customer incomes, expanding agricultural operations still need to invest, whereas the total number of farms continues to decrease. Within the European Union, agricultural policy was reoriented for the period up until 2012. Since this revised policy was introduced in the Member States in 2005/2006, it has been a relatively reliable factor. According to present estimates, the market volume in the European Union reached the value of the previous year (€ 17.5 billion) in 2006. At almost 170,000 newly registered tractors, the tractor market forecasts for the end of the year 2006 are also at the level of the year before. Due to the greater size of the new tractors, this means a slight sales increase. The powerhouses of European business in 2006 were Germany with a market growth of ca. 8% as well as the smaller markets in the Netherlands, Denmark, and Belgium, which also achieved high growth rates. In 2007, the overall development on the western European market is expected to remain stable because the so-called market indicators are not changing significantly. After steady growth in the previous years, the volume of the largest European market, France, showed a decline at the end. By October 2006, the number of newly registered tractors was 8% below the value of the previous year. Machines for arable farming and harvesting incurred a similar or even more significant reduction in the past season 2005/2006. An exception was the combine market, which grew for the third consecutive year. The new machinery business in Italy and Spain also did not provide any impulses. The British market seems to remain just below the level of the previous year after the number of orders had developed more dynamically again in the second half of the year 2006. At € 3.2 billion, the size of the German market was similar to the volume of the French market in 2006. Especially sales of large harvesting machinery were decisive for this development. The combine- and forage harvester market maintained its high level, and the efficiency of the new models improved significantly. By October 2006, tractors reached a plus of 16%. Therefore, the forecast for the end of the year 2006 is 27,000 units. According to current expectations, the German market will exhibit a slightly less dynamic development in 2007. Even though no negative circumstances can be discerned so far, farmers and contractors invested more than expected in new machinery. As a result, the demand has decreased, and the number of agricultural machines and tractors sold is decreasing slightly again.

APPENDIX 2.E

Open directory project:
http://dmoz.org/Regional/Europe/United_Kingdom/Business_and_Economy/Agriculture_and_Forestry/

In the category *'Regional: Europe: United Kingdom: Business and Economy: Agriculture and Forestry (877)'* one can see the following distribution:

- **Agricultural Chemicals** *(9)*
- **Agricultural Fairs**@ *(31)*
- **Aquaculture** *(11)*
- **Arable Farming** *(18)*
- **Associations** *(26)*
- **Consultancies and Services** *(47)*
- **Equipment and Materials** *(28)*
- **Fertilisers** *(11)*
- **Food and Beverage**@ *(494)*
- **Forestry** *(40)*
- **Horticulture** *(385)*
- **Livestock** *(69)*
- **Machinery** *(184)*
- **Pest and Disease Control** *(25)*

Under the Category "Business: Agriculture and Forestry (9,572)":

- **Aquaculture** *(442)*
- **By Region** *(0)*
- **Field Crops** *(204)*
- **Food and Related Products**@ *(7,575)*
- **Forestry** *(765)*
- **History**@ *(13)*
- **Horticulture** *(1,212)*
- **Industrial Hemp** *(39)*
- **Livestock** *(4,966)*
- **News and Media** *(74)*
- **Publications**@ *(47)*

- **Aerial Application** *(18)*
- **Agricultural Chemicals**@ *(405)*
- **Barns and Structures** *(136)*
- **Biologicals** *(85)*
- **Equipment and Supplies** *(1,013)*
- **Farm Real Estate** *(125)*
- **Fencing** *(124)*
- **Instruments and Supplies**@ *(80)*
- **Software** *(47)*
- **Tractors, Machinery, and Implements**@ *(870)*

- **Associations** *(39)*
- **Consulting** *(111)*
- **Cooperatives** *(19)*
- **Directories** *(18)*
- **Economics**@ *(31)*
- **Employment** *(20)*
- **Import and Export** *(9)*
- **Marketing and Advertising** *(4)*
- **Marketplaces** *(29)*
- **Trade Shows** *(46)*

While under the Category *'Business: Energy and Environment: Renewable: Biomass: Biodiesel (110)":*

- Ageratec AB - Offers biodiesel production equipment. Lists references, an overview of the transesterification process, and environmental benefits of biodiesel. Norrköping, Sweden.
- AGRA Biofuels - Has a production facility which can produce 3 million gallons of biodiesel a year. Based in Middletown, Pennsylvania, United States.
- Agri-Green Biodiesel Inc - Produces 2 million litres per year in Sparwood, British Columbia, Canada.
- ALF Industries - Specializes in the production and marketing of biodiesel. Carroll, Ohio, United States.
- Allegro Biodiesel Corporation - Produces and sells biodiesel fuel from its facility located in Pollock, Louisiana. Plans to develop other biodiesel production facilities and distribution assets in the United States. Based in Los Angeles, California.
- ALTERRE - Texas, United States company producing biodiesel virgin and used vegetable oil. Discussions the industry, the benefits of biodiesel, and their processes.
- American AgFuels - A three million gallon per year biodiesel processing facility in Defiance, Ohio, United States.
- American Bio Energy - Working to construct and operate a 30 million gallon per year biodiesel production and blending facility in central ohio. They will be using soybean oil, canola oil, palm kernel oil, and recycled fryer oil. Lewis Center, Ohio, United States.
- Amical Bioenergy - A biodiesel manufacturing plant in Maharashtra, India using jatropha curcus. Also sells biodiesel processors.
- Argent Energy - Produces biodiesel from tallow and used cooking oil by-products. Located near Motherwell, Scotland.
- Axios Energy LLC - A capital and technology project development firm serving the biodiesel industry in the US and around the world. Based in Jersey City, NJ.
- Bay Area BioFuel, Inc. - Produces biodiesel from recycled sources including used cooking vegetable oil. They offer pick-ups and delivery. Richmond, California, United States.
- Bay Biodiesel LLC - Biodiesel producer in Martinez, California, United States. Their fuel is distributed by Golden Gate Petroleum.
- Bently Biofuels - They produce biodiesel from seed oils and recycled restaurant grease in Minden, Nevada, United States.
- Better Biodiesel - They use a solid catalyst that eliminates the need to "wash" the fuel to remove the acid or base catalyst used in typical production processes. Based in Orem, Utah, United States.
- Bio G-3000 - Griffin Industries offers premium biodiesel. Lists benefits, general information, federal requirements, and news items. Based in Cold Spring, Kentucky, United States.
- Biodiesel Garware - A manufacturing facility available for companies to outsource their biodiesel production on a joint venture basis. Located in India.
- Biodiesel Holding - Offers equipment that produces biodiesel. Lists the different units available and the various processes they are knowledgeable in. Based in Slovakia.
- Biodiesel Industries Inc. - They have created a large network of biodiesel production facilities in the United States. Describes biodiesel, affiliate projects, and research information.
- Biodiesel Industry Directory - Lists contact information for over 600 companies serving the biodiesel industry, broken down by category.
- BioDiesel International (BDI) - Manufactures plants for producing clean, renewable biodiesel fuel from waste vegetable oil and other resources. Lists products, describes their processes, and their feedstocks.
- Biodiesel of Las Vegas, Inc. - Uses virgin soybean oil and waste fryer oil to make their fuel. Production of about 20,000 gallons a day. Nevada, United States.

- Biodiesel S.A. - A small engineering firm providing small, affordable biodiesel equipment in Argentina. Catalog of offerings, discussion on the biofuels industry, and their processes.
- Biodiesel Systems, LLC. - They plan, design, supply, build, and invest in turn-key biodiesel and glycerin refining plants. Describes the biodiesel market, a plant drawing, their production process, and a sequence of typical projects. Based in Madison, Wisconsin, United States.
- BioDiesel Technologies GmbH - Containerized biodiesel manufacturing equipment and related environmental technologies. Company history, products offered, references and FAQs. Based in Austria.
- Biodiesel Technologies, Inc. - Holds exclusive licensing rights for technology it developed with Cornell University for the production of biodiesel. Lists their vision, press releases, and benefits of biodiesel.
- BioDieselToday.com - Promotes the cultivation of jatropha curcas as the best source for biodiesel. Discusses the advantages and uses of seed, the benefits of biodiesel, seeds for sale, and an overview of the company's philosophy.
- BioEnergy of Colorado, LLC. - They produce biodiesel from virgin soy oil in Denver, Colorado, United States. Lists prices, pictures of the facility, and their philosophy.
- BioFuel Canada Ltd - Offers batch biodiesel plants that are pressurized steel units designed for individual or co-op use. They also offer regular usage demonstrations. Based in Calgary, Alberta, Canada.
- Biofuel Systems - Offers a range of biodiesel processing equipment from simple, compact processing kits to a full-scale commercial plant with equipment, personnel and training provided as required. Also offers fuel additives. Based in Neston, England, UK.
- BioKing - Offers compact processing kits to a full-scale commercial plant with equipment, personnel and training provided. Based in The Netherlands.
- Biopetrol Industries AG - Working to be one of the largest biodiesel producers in Europe. Based in Zug, Switzerland.
- BioPur Inc. - Produces biodiesel for residential (personal vehicle and home heating) and commercial customers. Bethlehem, Connecticut, United States.
- Bioro - One of Belgium's first biodiesel refineries founded in 2005 and located in the Port of Ghent. Produces biodiesel and glycerin from vegetable oil feedstock.
- BioRoute - Biodiesel suppliers in the UK by tanker truck. Lists benefits of the fuel and benefits fleet owners will experience.
- Biotane Fuels - Producer of various grades of biodiesel in Coachella, California. Lists their policies, announcements and news articles affecting this industry.
- Biox Corporation - Uses their own process to develop ASTM D6751 and EN 14214 grade biodiesel from any feedstock, vegetable oils, and other oils. They operate a 1 million litre capacity plant in Oakville, Ontario Canada.
- BQ-9000 Quality Management Program - A cooperative and voluntary program for the accreditation of producers and marketers of biodiesel fuel.
- Campa- Biodiesel GmbH & Co. KG/ Ltd. - A member of a network of biodiesel fuelling stations called Biodiesel Partner-Tank. Based in Ochsenfurt, Germany.
- Canadian Bioenergy Corporation - Distributor of biodiesel in western Canada. Describes the company, the fuel, and lists news items.
- Central Iowa Energy - Plans to have a biodiesel plant in Newton, Iowa, United States. Contacts, news items, and pictures.
- CentralBioDiesel HTP S.A. - Manufactures biodiesel reactors that can produce approximately 200 gallons a day and can be expanded to over 2300 gallons a day. Based in Costa Rica.
- Circle Biodiesel & Ethanol Corporation - Offers biodiesel production equipment and also consulting services. Based in Cardiff, California, United States.

- Community BioFuels - A consulting, marketing and manufacturing company bringing biodiesel and bioheating oil to the motor fuel and heating oil markets.
- Community Fuels - Producer of biodiesel in California, United States. FAQs, upcoming events, and announcements.
- D1 Oils plc - A global biodiesel producer produced from the Jatropha Curcas tree. Based in London, England.
- Diesel Verde - A small production company that converts used vegetable oils into biodiesel. Lists benefits of their fuel, services offered, and FAQs. Located in Cairate, Italy.
- DistributionDrive - They supply biodiesel, SVO, WVO, and conversion kits. They also distribute Willie Nelson Biodiesel. Company history, benefits of biodiesel, and FAQs.
- Duff Science Co., Inc. - Engaged in the development and manufacture of biodiesel and additives, other plant-based products, and a range of chromatography supplies. Also offers chemistry consulting.
- Earth Biofuels - A producer, distributor, and retailer of biodiesel fuel in the southern region of the United States. News items, investor relations, and FAQs.
- Ender LLC, Inc. - Produces biodiesel (B100) from virgin soybean and rapeseed oil feedstocks for the diesel market in the United States. Based in Detroit, Michigan.
- Euro BioDiesel Limited - Provides products and services for bio-diesel industry, from a simple container through to the most complex of production plants.
- FryAway.com - A Minnesota biofuel company that creates and designs, custom MVO systems and biodiesel reactors for use in diesel engines.
- GeoGreen Fuels, LLC - Producing biodiesel in Gonzales, Texas, United States. Announcements, projects, and news coverage.
- GoGreen Industries Inc. - Building a major biodiesel plant in the Pacific Northwest of the United States. Describes the fuel, its challenges, and its opportunities.
- Greasebrothers - They offer consulting in gathering waste vegetable oil and converting it into fuel. Vehicle conversions are also offered. Based in Gibsonton, Florida, United States.
- Greenergy International Limited - Suppliers of biofuels. Includes FAQ and company history. Offices in England, Germany, and Switzerland.
- GreenFuel Technologies Corporation - Developing an algae bioreactor to utilize carbon dioxide in smokestack gases to grow biomass that can be converted into biodiesel. Based in Cambridge, MA.
- Greenline Industries - Develops technologies for biofuels industry, including processing machinery that produces biodiesel from vegetable oils and animal fats. Vallejo, California, United States.
- Greenstar Biofuels - Produces biofuel and biodiesel from waste cooking oils and fats. Provides details of the fuel, production process, and emissions. Based in Somerset, England.
- Grown Fuel Biodiesel Consultancy - An independent consultancy in Australia with experience in every aspect of the biodiesel industry, offering tailor-made biodiesel production plants using proven production methods as well as feasibility assessments.
- HydroDynamic Technology, Inc. - An engineering and manufacuring company offering biodiesel production equipment based on the concept of hydrodynamic cavitation. Based in Chatsworth, CA.
- Imperium Renewables - Produces biodiesel refining and manufacturing technology. Seattle, Washington, United States.
- Independent Palmsel Producers Association (IPPA) - A non-profit trade association representing companies engaged in the production of Palmsel biofuel, and the companies and individuals which support Palmsel production and distribution activities.
- Integrity Biofuels - Offers B100 soy biodiesel. Lists their services and company history. Morristown, Indiana, United States.

 JatroDiesel - Biodiesel refiner and equipment manufacturer based in Mason, Ohio, United States. Lists products and services as well as a message forum.
 Keystone BioFuels Inc. - Has a biodiesel production facility in Shiremanstown, Pennsylvania, United States. FAQs and information about the use of biofuels for home heating oil.
 LA BioFuel Inc. - Distributes and produces biodiesel, which is a non-toxic and biodegradable alternative to petroleum diesel. Benefits of the fuel, trivia, history of diesel engines, and links.
 Lereno Sdn Bhd - A multi feedstock, dedicated process plant producing biodiesel in Perak, Malaysia and headquartered in Hamburg, Germany.
 MBP, Bioenergy, LLC - A company based in North Conway, New Hampshire, United States working to establish plants in various states to product 5 million gallons of biodiesel annually.
 Milligan Bio-Tech Inc. - Produces a diesel conditioner that is a blend of canola based products for their cleaning and lubricity properties. Based in Foam Lake, Saskatchewan, Canada.
 National BioFuels, L.P. - Provides biodiesel through a network of domestic and international producer and distributor partners. Describes their products, an overview of the company, and the type of ventures they pursue.
 Naturally Renewable Group, LLC - Producer of biodiesel and a diesel engine modification system allowing for use in all temperatures.
 New Fuel Company - A biodiesel production facility in Dallas, Texas, United States. They will also establish a filling station concentrating on other alternative fuels.
 New Fuel S.A. - Offers fully-automated, commercial-sized biodiesel processors. Describes their various size units, inputs and operating costs for the units, and a comparison of biodiesel standards by country. Based in Buenos Aires, Argentina.
 NewDiesel - Producing and distributing biodiesel in the Lake Tahoe and Carson Valley ares of Nevada, United States. Also gives an illustration of one homebrewer's efforts to produce their own fuel.
 Nexsol Biodiesel - International marketer and producer of biodiesel fuel and biodiesel home heating fuel.
 Northeast Biodiesel LLC - The produce biodiesel and also provide conversion kits to allow diesel engines to use vegetable oil. Based near Utica, New York, United States.
 Octana Biodiesel Industry Services - Provides multi-feedstock technology for the production of biodiesel and delivers complete solutions for the development of biodiesel production plants. Madrid, Spain.
 Pacific Biodiesel, Inc. - Produces a clean, renewable diesel alternative fuel from waste vegetable oil. Includes press releases, contact details, and media resources. Based in Kahului, Hawaii.
 Palmsel - PSP Global is a technology developer and producer of a palm oil based biofuel for small- and medium-sized diesel power generator sets. Based in Hong Kong.
 Patriot BioFuels Inc. - Biodiesel company with production facilities in Stuttgart, Arkansas, United States.
 Philadelphia Fry-o-Diesel LLC - A company dedicated to producing renewable, cleaner burning fuel from waste grease. Gives some industry statistics, staff listing, and a project timeline. Based in Pennsylvania, United States.
 Phillips BioFuel Supply Co - Distributor of biodiesel from World Energy LLC. throughout Vermont, United States. Lists pump locations, delivery pricing, and an overview of the company
 Propel Biofuels - A privately-held biodiesel distribution and services company based in Seattle, Washington, United States.
 PT Rainbow Energy BDI - Palm oil supplier for biodiesel that ships from the major ports in Indonesia.
 Renewable Energy Group - Designs and builds turn-key biodiesel plants based in Ralston, Iowa, United States. Project updates, facilities, definitions, and a certificate of analysis.

 Rix Biodiesel Limited - They manufacture, blend, and resell biodiesel in East Yorkshire, England, UK. Lists automobile warranties with respect to biodiesel, their distributors, and fuel standards.
 Rocky Mountain Biodiesel Consulting - Works to develop the commercial biodiesel industry in the United States. Based in Glenwood Springs, Colorado.
 Rothsay Biodiesel - Commercial-scale producer of biodiesel in Dundas, Ontario, Canada. Describes the fuel, the company, and statistics about their production.
 Seattle Biodiesel - A wholly-owned subsidiary of Imperium Renewables, Inc. producing 5 million gallons of biodiesel per year. Based in Seattle, WA.
 Simple Fuels - Constructing an industrial-scale production facility that will utilize local restaurant grease as their feedstock. Reno, Nevada, United States.
 Smithfield BioEnergy - A processor of various meats to provide biodiesel. Lists history of biodiesel, news items, and products offered.
 Solix Biofuels - A company working with Colorado State University to mass-produce biodiesel from algae. Fort Collins, Colorado, United States.
 SoyPower - West Central Cooperative produces biodiesel as well as other related products in Ralston, Iowa. Lists products, benefits, news items.
 Superior Process Technologies Inc. - Provides biodiesel methyl ester fuel production technology, complete plant engineering and process design services. Describes their process as well as its advantages.
 Sustainable Systems - They provide biodiesel in blends of B2 to B100 and also provide a line of biobased lubricants, fluids and specialty products in the Pacific northwest of United States.
 Triangle Biofuels Industries - Manufactures biodiesel in Raleigh, North Carolina for business and government from virgin and waste vegetable oils.
 UKFuelTech - UK makers of biodiesel machines. Describes what the units do, the advantages of the fuel, their demonstration events, and a catalog of products offered.
 The Ultimate Biodiesel Guide - Sells a guide to making and using biodiesel fuel for home heating, transportation, and boating. Also offers a newsletter about biofuels.
 United Biofuels, Inc. - They use both virgin soy oil and used vegetable oil to produce biodiesel. Based in York, Pennsylvania, United States.
 US BioFuels LLC - Producer of b100 and glycerin located near Chicago, Illinois. Minimum order is a truckload.
 Virginia BioDiesel - Describes the uses, benefits, and characteristics of biodiesel. Lists current prices and news synopses.
 West Coast Bio Fuels - Offers biodiesel in 1 gallon, 5 gallon, 55 gallon and bulk deliveries for users in southern California, United States.
 Western Iowa Energy, LLC. - 30 million gallon biodiesel production facility in Wall Lake, Iowa, United States. Announcements, partners, and benefits of the fuel.
 Willie Nelson's Biodiesel - Partners with Texas fuel stations to supply biodiesel at their pumps. Lists benefits of biodiesel and its history.
 WISE Energy - Developing a commercial biodiesel production plant Victoria, British Columbia, Canada. Describes the fuel and its benefits, their projects, and lists related links.
 World Energy - Provides alternative fuel (biodiesel) solutions for federal, state, utility, transit, municipal, and private fleets.
 Yelpo - Factory producing rapeseed oil for sale to biodiesel manufacturers. Located in the Gabrovo region in Bulgaria.
 Zurex Corporation Sdn. Bhd. - Produces biodiesel out of palm and other oils. Sabah, Malaysia

Under the Category *'Technology: Energy: Renewable: Biomass and Biofuels: Biodiesel (57)":*

- B100 Fuel - Blog that discusses news releases concerning the biodiesel industry in the United States.
- Bio Diesel in the News - A collection of links to news articles about biodiesel with brief summaries. Updates daily.
- Bio Lyle's Biodiesel Worskshop - A Seattle, Washington man promoting the use of biodiesel. Includes videos, supplies used and where he sources them, how he gets his oil, and production methods.
- Biodiesel & SVO Discussion Forums - Discussion of biodiesel and straight vegetable oil use, classifieds, and upcoming events.
- Biodiesel America - A campaign whose mission is to change 100,000 diesel school busses to biodiesel by 2010. Contains FAQs, news items, how to donate to their cause, and how to get involved.
- Biodiesel Association of Australia - Promotes the acceptance of biodiesel fuel. Includes technology information and links.
- Biodiesel Association of Canada (BAC) - Promotes the development of a Canadian commercial biodiesel industry. Introduction to biodiesel, fuel uses, news items, where to buy, and publications.
- Biodiesel Blog - A blog that discusses and links to news items and events in the world of biodiesel in the United States.
- Biodiesel India - A website dedicated for the development of Biodiesel in India and showing that vegetable oils, in particular Jatropha oil, can and should be used in place of petroleum diesel. Details on biodiesel, where to purchase it, and the need for it.
- Biodiesel Investing - A news aggregator of events in the biodiesel industry categorized by topic.
- Biodiesel Pumps - A user-maintained listing of locations to purchase biodiesel in the United States.
- biodiesel SOLUTIONS - Promotes biodiesel use in Canada by supporting community-based biodiesel groups and developing and delivering educational resources. Links, fuel benefits, news items.
- Biodiesel Station - Portal of links to biodiesel news items, pricing, suppliers, and forums.
- Biodiesel Works - A resource for people interested in making their own biodiesel or for purchasing biodiesel for use in their vehicles.
- Bio-diesel WWW Resources - Provides information and links to various sites of interest for biodiesel users.
- BiodieselMom.com - Personal site promoting biodiesel fuel for average, busy people. Provides biographical information, her family's use of biodiesel, FAQs, and several locations where it can be purchased.
- BioDieselNow.com - Promotes the use of biodiesel. Offers forums, promotional items, and testimonials.
- BIOPA - Biodiesel Pardubice - A free working association for research, development and industrial realisation of technological methods of biodiesel production. Overview of their purpose, their members, their experience, and what they offer.
- BioTrucker.com - Provides information regarding biodiesel availability, trucker testimonials, technical information and current news from the biodiesel industry.
- The California Biodiesel Calendar - A list of biodiesel-related classes, conferences, festivals, meetings, and workshops in California.
- Centre for Jatropha Promotion - Provides information and facilities to promote cultivation of this plant. Includes assistance, possible products, background information. Located in Churu, India.

- Collaborative Biodiesel Tutorial - Their goal is to help people learn how to make biodiesel. Contains detailed tutorials, equipment suggestions, forums, and advanced topics.
- CU Biodiesel - A University of Colorado at Boulder non-profit student organization dedicated to advancing the use and knowledge of biodiesel. Includes upcoming events, member profiles, and Project Yellow Bus, an effort to teach kids about renewable energy.
- Dangerous Laboratories: How to make your first batch of biodiesel - Lists necessary equipment, step-by-step instructions, and pictures of the process.
- Earthrace - An attempt to circumnavigate the world in record time in a biodiesel powered speedboat. Site describes the boat, the crew and the race, including schedules, current news and sponsorship information.
- European Biodiesel Board - A non-profit organisation established to promote the use of biodiesel in the European Union group the major EU biodiesel producers. Legislative documents, news items, and a mailing list.
- EYA - UBC Biodiesel Project - Project to build and test an affordable community-scale biodiesel processing facility which is financially self-sustainable and can supply biodiesel fuel at a competitive rate. Vancouver, British Columbia, Canada.
- GoEarth.org - Supports farmed fuels such as biodiesel and vegetable oil. News articles, a carbon cycle diagram, and benefits of biodiesel on emmissions.
- Grassolean.com - Promotes the use of biodiesel. Includes news items, how to purchase the fuel, a chatroom, forums, and services they provide.
- Green Car Congress: Biodiesel - News articles concerning the biodiesel industry.
- Green Depot - Working to increase awareness, advocacy and implementation of biomass fuels such as biodiesel based in southern California. Membership details and a survey.
- Hemp Car - An alternative-fuel vehicle utilizing biodiesel derived from hemp. Hemp car promotes environmental fuel technologies and drug law reform.
- It's Good 4 US - Contains numerous questions and personal answers to biodiesel questions and a promotional flyer for download. Also includes information about ethanol.
- Kitchen Biodiesel - An illustrated, step-by-step set of instructions to make a 1 liter batch of homebrew biodiesel in a plastic soda bottle.
- Make Your Own Biodiesel - Detailed description of methods of creating biodiesel and its related issues.
- Making-biodiesel-at-home.com - Compilation of details on making various types of biodiesel production kits as well as general information about biodiesel.
- MGR-Biodiesel - Promotes awareness of jatropha curcas and its potential to supply biodiesel.
- National Biodiesel Board (NBB) - Provides news and resources by maket segment including reports, fact sheets, press releases, audio and video. With maps of suppliers, distributors and retailers.
- National Biodiesel Conference and Expo - Annual event of the National Biodiesel Board covering the biodiesel industry, held in February. Includes list of events and speakers, registration details and a scholarship contest.
- Northeast Biofuels - A UK cluster group developing supply chains in renewable industrial and transport fuels; typically biodiesels and bioethanol petrol additive in the north east of England. Describes benefits, what they do, and publications.
- NREL - A Look Back at the U.S. Department of Energy's Aquatic Species Program: Biodiesel from Algae - 328-page report published in 1998 includes an executive summary, program summary, technical research and documentation. [PDF]
- Pacific Regional Biomass Energy Partnership - Encourages the development of bioenergy in Alaska, Hawaii, Idaho, Montana, Oregon and Washington. Resources, links, and upcoming events.

- Riverstones Biodiesel - A Salt Lake City, Utah resident describes his experience with producing biodiesel. Links, statistics on fuel production, calendar of events, tips, pictures, and interviews.
- 21st Century Green Alternative Fuel Consultants: Purchasing Biodiesel in California - Lists biodiesel retail outlets, distributors, and outlets in the California, United States.
- UNH Biodiesel Group - An inter-departmental group at the University of New Hampshire in the United States focusing on a variety of projects related to this alternative fuel. Articles, goals, and about the group.
- US Department of Energy - Alternative Fuels: Biodiesel - Information about biodiesel including benefits, research and development, federal legislation, publications and resources.
- Veggie Avenger - A movement to promote biodiesel as a diesel alternative. News items, videos, pictures, links to cooperatives, and a forum.
- Veggie Van - Fueled with used vegetable oil from fast food restaurants, this van can go up to 65 mph and has traveled 10,000 miles.
- Veggiepower - Promoting biodiesel as a "Green" fuel.
- Wikipedia - Biodiesel - Hyperlinked encyclopedia article about biodiesel includes its history, fuel properties and standards, production and availability.
- Yahoo! Groups : local-b100-biz - A discussion list for very small-scale commercial biodiesel producers and distributors in the United States and a focus on community-based B100 fuel distribution.
- Yahoo! Groups: Biodiesel - Active group discussion of biodiesel.
- Yokayo Biofuels - History of Biodiesel - A short history of biodiesel and biofuels and their relationship to the diesel engine.
- Ökologisch ohne Ökosteuer - Personal page describing one man's usage of biodiesel in his Mercedes Benz station wagon in Germany. Pictures, movies, and links.
- Christian Science Monitor - Algae: Like a Breath Mint for Smokestacks - Article about GreenFuel Technologies which uses algae to clean up power plant emissions while creating biodiesel and ethanol. (January 11, 2006)
- UNH Biodiesel Group: Widescale Biodiesel Production from Algae - Michael Briggs describes how much biodiesel would be needed to replace all petroleum transportation fuels in the United States and how algae could be used to achieve that goal. (August, 2004)

XML Feeds:

- B100 Fuel, living on BioDiesel - Lists articles which involve the increasing availability of biodiesel as a replacement for diesel fuel. [RSS]

Category: *'Business: Energy and Environment: Renewable: Biomass: Vegetable Oil Fuels (9)'*:

- ELSBETT - A German company that sells a conversion kit to heat vegetable oil before it enters a vehicle's motor. Lists other products, kits available, and benefits of vegetable oil.
- Frybrid - Manufactures a commercial conversion system for automobiles to run on WVO/SVO. Describes how it works, kits for sale, and biodiesel sales information.
- Greasecar Vegetable Fuel Systems - Allows mechanically injected diesel vehicles to run on straight, filtered vegetable oil. Lists testimonials, a message forum, assembly pictures, and technical details.
- Greasel.com - Offers kits and accessories to allow diesel cars and trucks to run on straight vegetable oil. Includes FAQs, illustrations, a chat room, and technical specifications.
- LoveCraft BioFuels - They convert vehicles to run on vegetable oil and they have set up biodiesel fueling stations throughout the region. Based in Los Angeles, California, United States. Also has forums and tips on collecting oil.

- PlantDrive.com - Offers a straight vegetable oil conversion kit for diesel vehicles. FAQs, a blog, product benefits, kits offered, and pictures.
- Veg Oil Motoring - Offers one- and two-tank conversions for diesel vehicles in the Wales, United Kingdom. They also sell duty-paid vegetable oil.
- Veggie Fuel Systems - Offers straight vegetable oil conversions, parts, and kits. Also provides on-site installation in central Florida, United States and conversions for all diesel applications.
- Vegoil Conversions by Dana Linscott - Develops, tests, and markets simple components designed for conversion of diesel and turbine engines and provide guidance to those wishing to convert their engines on vegetable oil. Contains links, contact information, and an overview of the kit.

Category: *'Business: Energy and Environment: Renewable: Biomass: Vegetable Oil Fuels (11):*

- B.I.O. Tour - Public awareness campaign to highlight alternatives to America's fossil fuel addiction and to help grow the movement to use alternative fuels and sustainable energy in a vegetable oil-powered schoolbus.
- FillUp4Free.com - Resource for running a car on WVO and SVO. Contains a map of filtered oil sources, photo gallery, links to news items, and a discussion forum of conversion projects.
- Fusel.Com - Discusses diesel vegetable oil conversion systems. Reviews, assorted information, links, and tips.
- Good Grease - Provides news and promotes the use of WVO (waste vegetable oil) as an alternative to diesel fuel. Links, news articles, and a message forum.
- GreenGreaseMonkey.com - They help people in the United States convert their diesel engines to run on waste vegetable oil. Lists benefits, links, and contact information.
- NFA/GC Veggie Golf - A 2002 Volkswagen Golf that was converted to run on straight vegetable oil. Lists specifications of the car, FAQs, team member biographies, a forum, and news items.
- Passat 2005 Running on Used Soy Oil and B100 - A blog of a Los Angeles, California resident who runs his Volkswagen car on waste vegetable oil and biodiesel.
- The Veggie Bus - Advocates of sustainable living and promoting the use of waste vegetable oil and biodiesel. FAQs, pictures, tips to users, crew biographies, and benefits of alternative fuels.
- Veg-Oil-Car.com - How to convert a car to run on Vegetable Oil. Includes costs, fuel information, and a forum.
- Waste Vegetable Oil Fuels - Blog that tracks one man's usage of WVO in a Mercedes 300TD.

XML Feeds:

- Waste Vegetable Oil Fuels - Blog that tracks a man who built and uses a biodiesel processor to fuel his diesel Mercedes. [RSS]

Category: *'Science: Agriculture (2,375)'*:

* Conferences (21)
* Databases (20)
* Directories (21)
* Economics@ (31)
* Education (68)
* History (13)
* Institutions (52)
* Organizations (40)

* Products and Services (80)
* Publications (47)
* Social Issues@ (4)
* Software@ (47)
* Animals (352)
* Biotechnology@ (28)
* Environmental Aspects@ (23)
* Field Crops (306)
* Forestry (199)
* Horticulture (344)
* Pests and Diseases (141)
* Practices and Systems (251)
* Soils (285)
* Sustainable Agriculture (124)
* Weather News@ (11)

See also:

* Business: Agriculture and Forestry (9,572)
* Science: Biology (20,681)
* Science: Biology: Botany: Seed Biology (11)
* Science: Technology: Food Science (224)
* Society: Issues: Business: Agriculture (53)

Of special interest is the category: 'Science: Biology (20,693)", as there are several sub-categories on Bio-systems Engineering:

- **Associations** *(16)*
- **Directories** *(25)*
- **Education** *(148)*
- **Employment** *(20)*
- **Ethics** *(0)*
- **History** *(138)*
- **Humor**@ *(20)*
- **Institutions** *(138)*
- **Meetings** *(26)*
- **Methods and Techniques** *(50)*
- **News and Media** *(5)*
- **Philosophy**@ *(22)*
- **Products and Services** *(310)*
- **Publications** *(40)*
- **Reference** *(28)*
- **Software** *(19)*
- **Women**@ *(5)*

- **Flora and Fauna** *(12,071)*

- **Agriculture**@ *(2,375)*
- **Anatomy**@ *(44)*
- **Bioarchaeology**@ *(5)*
- **Biochemistry and Molecular Biology** *(1,260)*
- **Biogeochemistry**@ *(65)*
- **Bioinformatics** *(542)*
- **Biomechanics** *(44)*
- **Biophysics** *(78)*
- **Biotechnology** *(323)*
- **Botany** *(725)*
- **Cell Biology** *(345)*
- **Genetics** *(937)*
- **Genomics**@ *(33)*
- **Histology** *(17)*
- **Immunology** *(255)*
- **Medicine**@ *(11,185)*
- **Microbiology** *(371)*
- **Mycology** *(103)*
- **Neurobiology** *(288)*
- **Paleontology**@ *(1,009)*
- **Pathology**@ *(184)*
- **Physiology** *(148)*

- **Cryobiology** *(137)*
- **Developmental Biology** *(86)*
- **Ecology** *(928)*
- **Evolution** *(166)*
- **Exobiology**@ *(32)*
- **Food Science**@ *(224)*
- **Sociobiology** *(46)*
- **Taxonomy** *(65)*
- **Theoretical Biology** *(20)*
- **Toxicology** *(98)*
- **Virology**@ *(49)*
- **Zoology** *(675)*

See also:

- **Kids and Teens: School Time: Science: Living Things** *(2,475)*
- **Science: Employment** *(113)*

This category in other languages:

Azerbaijani *(0)*	Basque *(8)*	Bulgarian *(9)*
Catalan *(244)*	Chinese Simplified *(72)*	Chinese *(134)*
Croatian *(17)*	Czech *(89)*	Danish *(180)*
Dutch *(123)*	Esperanto *(22)*	Finnish *(66)*
French *(688)*	German *(1,159)*	Hebrew *(26)*
Hungarian *(20)*	Italian *(420)*	Japanese *(561)*
Korean *(20)*	Lithuanian *(17)*	Norwegian *(21)*
Polish *(328)*	Portuguese *(82)*	Romanian *(11)*
Russian *(141)*	Serbian *(11)*	Slovak *(7)*
Spanish *(458)*	Swedish *(173)*	Turkish *(31)*
Ukrainian *(18)*		

For example, the sub-category *'Science: Biology: Bioinformatics (541)'*:

- **Software** *(87)*

- **Companies** *(141)*
- **Directories** *(11)*
- **Education** *(48)*
- **Employment** *(2)*
- **Hardware** *(3)*
- **Online Services** *(161)*
- **Programming**@ *(30)*
- **Publications** *(9)*
- **Research Groups** *(70)*

See also:

- **Health: Medicine: Informatics** *(254)*
- **Science: Biology: Biochemistry and Molecular Biology: Biomolecules: Proteins and Enzymes: Proteomics** *(138)*
- **Science: Biology: Genetics: Eukaryotic: Animal: Mammal: Human** *(231)*
- **Science: Environment: Biodiversity: Informatics** *(11)*

This category in other languages:

French *(42)* Italian *(10)* Japanese *(6)*

- **The Bioinformatics Organization, Inc.** ☆ - Bioinformatics society open to all people. Strong emphasis on open access to biological information as well as Free and Open Source software.
- **The Ensembl Project** ☆ - Ensembl is a joint project between EMBL-EBI and the Sanger Centre to develop a software system which produces and maintains automatic annotation on eukaryotic genomes.

- Bioinformatics and Biological Computing - Comprehensive bioinformatics site, with access to multiple database searching and sequence analysis tools - from the Weizmann Institute of Science.
- Bioinformatics Resources - Resource for searching genetic databases, online tools, journals, and recent news.
- DNA Structural Atlas - Easy-to-use summary of genomic information currently available for all organisms-from the Technical Univ. of Denmark.
- European Molecular Biology Network - EMBnet is the only organisation world-wide bringing bioinformatics professionals to work together to serve the expanding fields of genetics and molecular biology.
- The International Society for Computational Biology - The International Society for Computational Biology is dedicated to advancing the scientific understanding of living systems through computation; the emphasis is on the role of computing and informatics in advancing molecular biology.
- Society for Bioinformatics in the Nordic Countries - SocBiN is a non-profit organisation for people working with and interested in bioinformatics. One task of the society is to arrange annual conferences on Bioinformatics.
- Wikiomics - Editable by the whole bioinformatics community, Wikiomics provides bioinformatics tutorials and reviews that are kept up-to-date by the readers themselves.

Identify Areas of Expertise in the Discipline

Objective 3. Identify areas of expertise in the discipline

Areas of Expertise in Biological and Agricultural Engineering

prepared by
Gerald Riskowski
Biological & Agricultural Engineering Department,
Texas A&M University,
USA

In recent decades, the Biological & Agricultural Engineering (BAE) discipline has expanded its horizons beyond the traditional areas of food, fiber and timber production. BAE now includes many new areas where engineering principles are applied to the basic science of biology. The natural environment is being challenged with ever increasing demands for production of food, energy, and biologically based goods. Rapid advances in our knowledge of biology have increased the opportunities to engineer new systems for the benefit of society. Consequently, our discipline has expanded and modified our areas of expertise to embrace these new needs and opportunities.

A recent issue of *Discover* published by the American Society of Agricultural and Biological Engineers in 2004 gave a good introduction to the discipline:

"Just what is Biological and Agricultural Engineering?

> *Biological and agricultural engineers ensure that we have the necessities of life: safe and plentiful food to eat, pure water to drink, clean fuel and energy sources, and a safe, healthy environment in which to live. More specifically, biological and agricultural engineering (BAE) is the application of engineering principles to any process associated with producing agriculturally based goods and management of our natural resources.*
>
> *Biological and agricultural engineers. . .*

- *Devise practical, efficient solutions for producing, storing, transporting, processing, and packaging agricultural products*
- *Solve problems related to systems, processes, and machines that interact with humans, plants, animals, microorganisms, and biological materials.*
- *Develop solutions for responsible, alternative uses of agricultural products, byproducts and wastes and of our natural resources - soil, water, air, and energy.*

And they do all this with a constant eye toward improved protection of people, animals, and the environment."

However, we are continuing to expand the envelope and we need to discuss all of the areas of expertise more specifically. As new technology and information emerge, specialty areas are created, and many overlap with one or more other areas.

Biological Engineering
The newest area of expertise includes a broad range of specialties and is expanding rapidly. Biological engineering applies engineering practice to problems and opportunities presented by living things and the natural environment. Biological engineering involves a variety of new interests that continue to emerge as our understanding of science and nature grows. Areas of expertise include environmental protection and remediation and production of pant- and animal-based medicines, pharmaceuticals and bio-materials. Design medical implants,

bioinstrumentation, biosensors, imaging products, and other devices. Develop strategies for natural pest control and treatment of hazardous wastes, for composting, and for enzyme or other bio- processing of biomass, food, feed, and wastes.

Natural Resources/Soil &Water

It is imperative that society protect the quality of its air, water and soil resources. This specialty uses environmental expertise to better understand the complex mechanics of these resources, and utilizes them efficiently and with minimum degradation. Determine crop water requirements and design irrigation systems. Apply hydrological principles to controlling drainage, control soil erosion and reduce the environmental effects of sediment on stream quality. Design, build, operate and maintain water control structures for reservoirs, floodways and channels. Includes ecological engineering, protection of surface and ground water resources, developing soil-water relationships, and environmental modeling. Design systems for water treatment, wetlands development or preservation, and other water issues.

Machine and Power Systems

This specialty concentrates on designing advanced equipment, making it more efficient and less demanding of our natural resources. Design machine and power systems for agricultural and biological production including tractors, tillage equipment, irrigation equipment, and harvest equipment. This also includes equipment for biomass processing, highly precise application of chemicals and nutrients to crops, agricultural commodity and waste transport, turf and landscape maintenance, construction equipment, as well as equipment for specialized tasks.

Information & Electrical Technologies

Information and electrical technologies engineering is a specialty area that is applied to most other specialty area, including machinery systems, soil properties, and control of biological processes. Design and utilization of geographic information systems, global positioning systems, machine instrumentation and controls, remote sensing, electromagnetics, bioinfomatics, biorobotics, machine vision, sensors, spectroscopy. Intelligent machine design includes robotics, operation automation, specialty sensors, and control systems.

Structures & Environment/Controlled Environment Agriculture

Design structural and mechanical systems to create and maintain a healthy environment for plants, animals and their products, and for protecting workers within the facilities. This must be done without diminishing natural resources, environmental quality and quality of life. This specialty includes nursery and greenhouse operations, animal production facilities, light-frame structures and post-harvest preservation processing and storage. The Controlled Environment Agriculture (CEA) aspects of this specialty include design of control systems for temperature, humidity, and ventilation; hydroponics, tissue culture, and seedling propagation, greenhouse irrigation, operation automation, disease and pest control, and nutrient and feed application. Develop best management practices and systems for storing, recovering, reusing, and transporting waste products. Develop post-harvest processes and facilities to ensure the safety and quality of biological materials, including crop drying, processing and storage. Also, includes protecting air quality near production facility from gas, odor, and particulate emissions. Modeling impacts of emissions on surrounding regions.

Aquacultural Engineering
Design production systems for raising fish and shellfish, as well as ornamental and bait fish. Develop systems to maintain water quality and natural resources, and utilize the latest biotechnology, feeding systems, aeration systems, and water sanitation systems. Design systems to reduce pollution from aquacultural discharges, to reduce excess water use, and to reduce production costs. Develop aquatic animal harvesting, sorting, and processing facilities.

Food and Bioprocess Engineers
The production of food, fiber, and timber have been expanded to include biomass fuels, biodegradable packaging materials, nutraceuticals, pharmaceuticals and many other products that add value to biological materials. Utilize microbiological processes to create useful products, to treat municipal, industrial and agricultural wastes, and to improve food safety. Develop processes for pasteurization, sterilization, and irradiation, and for the packaging, transportation and storage of perishable products. Design manufacturing methods to develop economical and responsible processing solutions for industry. Develop ways to reduce waste by devising alternatives for treatment, disposal and utilization.

Forest Engineering
Forest engineering involves a wide range of activities in natural resource management and forest production systems. Develop systems to solve natural resource and environment problems in forest production systems and related manufacturing industries. Design equipment for handling and manufacturing of forest products, design forest access systems and construction equipment; analyze machine-soil interaction and erosion control; analyze forest operations and seek improvement; develop decision-making models; and develop wood products.

Energy Systems Engineering
Develop energy conservation strategies to reduce costs and protect the environment, and design traditional and alternative energy systems to meet the needs of biological and agricultural systems. Develop and apply alternative energy sources that are renewable and sustainable, and create few undesirable byproducts. Possible energy sources include: biomass, methane, plant oil, ethanol, mixed alcohols, solar, and wind. Design systems to have optimum energy efficiency.

Safety, Health and Ergonomics
Farming is one of the most dangerous activities with high risk for injuries, illness, and death. Analyze health and injury data, the use and possible misuse of machines, and equipment compliance with standards and regulation. Develop methods to improve the safety of equipment, materials and farming practices and communicate safety and health issues to the public. Develop systems to ensure safe aerial environments in production facilities such as animal facilities. Develop good ergonomic systems for workers to reduce injuries, discomfort and menial labor, and to insure a reliable source of human resources.

Identify Research Needs/ Opportunities

Objective 4: Identify research needs/opportunities in Biosystems Engineering

prepared by
G. Scarascia Mugnozza[1], A. Comparetti[2], P. Febo[2], K.C. Ting[3]

(1) Università di Bari, Dipartimento PROGESA, Via Amendola, 165, 70126, Italy
(2) Università di Palermo, Dipartimento ITAF, Viale delle Scienze, 90128, Italy
(3) University of Illinois at Urbana-Champaign, Department of Agricultural and Biological Engineering, U.S.A.

Contributions by J.P. Douzals[3], D. Briassoulis[4], P. Panagakis[4], E. Nikopoulos[4], D. Wulfsohn[5]

(3) Ecole Nationale de Formation Agronomique, ENFA Toulouse Auzeville, France
(4) Agricultural University of Athens, Dept. of Natural Resources & Agricultural Engineering, Greece
(5) University of Copenhagen, Department of Agricultural Sciences, Denmark

4.1. Identify research needs/opportunities in Biosystems Engineering

prepared by G. Scarascia Mugnozza, A. Comparetti, P. Febo

4.1.1. History

History says that agriculture was born in Mesopotamia (now Iraq), however in Europe the first applications of Agricultural Engineering can be found in the Roman age and are concerned with hydraulics, aqueducts, field area measurement, wood production from forests and, then, earth movement for field cultivation, wetland reclamation, roads and rural infrastructures.

In 1700s the industrial revolution happened in England, so that at the beginning of 1800s this event caused the start of agricultural mechanisation.
Then, Agricultural Engineering aimed at obtaining the following objectives, which gradually developed:

- increase of crop yield;
- increase of working capacity and productivity;
- establishment of new extensive cultivations;
- reduction of harvest and storage losses;
- replacement of manual work with mechanical one, performed by tractors and agricultural machines (before, fixed point ones, then, pulled, semi-mounted and mounted ones and, finally, self propelled ones);
- drainage of lands to be cultivated, which in Italy started in 1854 with that of Fucino Lake (Abruzzo) elevated plain (whose area ranged from 6000 and 40000 ha), decided by Torlonia princes;
- irrigation of semi-arid climate areas, such as, for example, those of Southern Italy;
- artificial canalisation of watercourses for irrigation, whose masterpiece in Italy is Cavour canal (Piedmont) for rice cultivation, built between 1863 and 1866;
- food storage (inside silos) and processing;
- animal husbandry inside rational buildings (e.g. cowshed, pig houses), aimed at improving livestock management (cleaning, feeding and milking) and increasing the animal productions of bovines, pigs, chickens, turkeys and sheep (e.g. milk, meat, eggs);
- improvement of the livestock hygienic conditions;
- establishment of protected structures and plants for nurseries, horticultural and floricultural crops;
- improvement of human safety at work;

- implementation of forestry engineering (slope arrangement aimed at erosion reduction, watercourse regimen and irrigation, by means of check-dams, recessed surfaces, etc.);
- use of machines for reforestation, earth movement, land removal and wood processing (cutting, transportation and stump cutting).

Before the Second World War the research needs in Agricultural Engineering also included the conservation of agricultural and food products (inside silos).

During the Second World War the soil less cultivation was firstly experienced.

Therefore, Agricultural Engineering research was addressed not only to the production and conservation of agricultural and food products but also to their processing.
Around 1960 the four wheel drive tractors were designed and manufactured.

In 1973, after the Kippur war, the world energy crisis started, so that from 1972 to 1973 the oil price per barrel rushed from 2-3 to 12 US Dollars. This event determined new research needs in Agricultural Engineering, i.e. the reduction of energy consumptions by agricultural and food production processes, the search of alternative and renewable energy sources, the rational use of machines and tyres (including the design and manufacturing of new tyres, aimed at reducing fuel consumption and soil compaction), studies about biogases deriving from biomass, including livestock slurries, production of biofuels (non-food production), introduction of solar thermal plants, thermo-dynamical and photovoltaic ones, wind turbine, hydro-electrical and geo-thermal plants.

Then, Agricultural Engineering research was addressed to improve product quality and, more recently, to reduce the environmental impact caused by agricultural and food production processes.
Around 1980 electronics was applied to agricultural and food production processes, so that Agricultural Engineering research discovered new needs and opportunities concerned with this event.
Around 1990 several USA University departments and research centres changed their name from “Agricultural Engineering” to “Biosystems Engineering”.

In Europe sadly the beginning of the third millennium brings a crisis in Agricultural Engineering sector. As a consequence, several institutes, departments and research centres of Agricultural Engineering were closed or had their staff significantly reduced. Meanwhile, with the advent of new topics (e.g. precision agriculture, robotics, information systems for agriculture), in several Universities the department of Agricultural Engineering changed its name and research topics towards Applied Biology. This trend also implied the progressive substitution of the name “Agricultural Engineering” with “Bio-Engineering” or “Biosystems Engineering”. In order to take into account this trend, since 2002 the European Society of Agricultural Engineers (EurAgEng) changed the name of its official journal from “Journal of Agricultural Engineering Research” into “Biosystems Engineering” [1].
Since its birth the research carried out in Europe about the subject area of Agricultural Engineering (now called Biosystems Engineering) obtained the following results:

- increase of crop yield and food production;
- reduction of agricultural and food production costs;
- reduction of crop yield loss;
- improvement of the ergonomics and safety conditions of agricultural and forestry operators, aimed at reducing their effort and accident risk.

As a result of a survey carried out in the framework of the USAEE-TN project, during the last decades research needs were identified in the subject area of Agricultural Engineering to be related to the following interest fields: 1) power and machinery (e.g. tractors, machines for tillage and earth moving; 2) post harvest technology (e.g. drying, product storage, food packaging); 3) soil and water (e.g. soil erosion, irrigation and drainage); 4) structures and environment (e.g. greenhouses, livestock buildings, waste management, production of biomaterials).

Moreover, during the last 10 years, the other following interest fields have been developed within the subject area of Agricultural Engineering and now constitute fundamental components of research activities in many departments of Agricultural Engineering in Europe: 1) information technology and the human interface (e.g. biosystems modelling, ergonomics); 2) automation and emerging technologies (e.g. automatic control, image analysis, biosensors); 3) precision agriculture (e.g. GPS, GIS, soil mapping); 4) animal production technology (e.g. livestock welfare, animal transport); 5) rural development (e.g. renewable energy sources).

Recently, as a consequence of the structural changes of Biosystems Engineering degree study programmes, research activities have been initiated in some emerging highly specialised subjects [2].

4.1.2. Identification of research needs/opportunities

Research papers published in relevant international journals and, above all, current EU funded research projects in Biosystems Engineering can be used to discover research needs/opportunities in this subject area. Among the 10 “activity areas” mentioned by the Community Research and Development Information Service (CORDIS), under the 7th Framework Programme (FP7), the following ones were identified:

- Food, Agriculture and Fisheries, and Biotechnology, aimed at building a European Knowledge Based Bio-Economy or KBBE, including agriculture, food, forestry, fisheries and other bio-based industries, with particular reference to the sustainable production and management of biological resources from land, forest and aquatic environments, food safety, life sciences, biotechnology and biochemistry for sustainable non-food products and processes;
- Energy, aimed at adapting the current energy system into a more sustainable, competitive and secure one, also depending less on imported fuels and using a different mix of energy sources (above all renewable, energy carriers and non-polluting sources);
- Environment, aimed at improving the knowledge about the interactions among climate, biosphere, ecosystems and human activities and building up new technologies, tools and services for the sustainable development of the environment and its resources; this “activity area” will also address policy needs such as the environmental impact assessments of EU policies and the follow up to the Kyoto and post-Kyoto actions on climate change [3].

According to the Strategic Plans 2005-2009 of the two main French Research Centres in agronomy and agricultural/environmental engineering (INRA and Cemagref), the society needs are concerned with the following new subjects for agriculture, industry and environment:

- sustainable development, aimed at allowing economical viability with respect to constrains among environment, society and economy balance;
- climate changes (global warming), leading to manage natural resources and industrial activities (including agriculture);
- water management, aimed at optimising such a limited resource and managing flood and dryness;
- multi-functional agriculture;
- development of a safe society, based on natural risk management, food safety, environmental impact of agriculture (pollutant management).

In France the above new subjects have determined the following new research needs/opportunities in Biosystems Engineering:

- implementation of human and social sciences to the scientific and technological progress, in order to deal with sustainability criteria (taking into account the relationship among environment, society and economy balance) and, therefore, to study the economical and social impact of technological progress on agricultural systems;
- development of the discipline of environmental engineering (also concerned with modelling methods and decision-making tools for the environment);
- limited energy dependence and development of biomass-based energy sources;
- a new spatial and systemic approach to land, i.e. rural spaces (land systems) and water management (water systems), involving the development of less sensitive cultivars, new low input cultivation strategies and new purposes for agricultural products;
- risk management, i.e. machine safety, safe food technology and storage, air pollution management, agricultural pollutants, natural risks (flood/dryness, gravity risks in mountains, fires [4] [5].

In France examples of practical applications of the above new research needs/opportunities are the following:

- new modelling approaches to agricultural systems, i.e. precision agriculture, remote sensing aided decision-making tools (e.g. relationships between wine and soil);
- FARMSTAR program, involving in 2007 300,000 ha for nitrogen management on winter wheat and rape seed, water management on corn, using satellite imagery and ground based modelling;
- development of input less sensitive cultivars and agricultural strategies (for which cultivar certification protocols are envisaged);
- multidisciplinary approaches to agricultural systems, including human and social sciences, in order to understand conditions of acceptation/non acceptation of progress, models and new technologies;
- increase of non-food agricultural production (up to 30%).

Nowadays the subject area of Biosystems Engineering is concerned with the production, processing, storage and distribution of agricultural (food and non-food) products (e.g. plant and animal production, livestock buildings, animal health and welfare, agricultural, forestry and food machines and plants, post harvest technology, process engineering, ergonomics and safety, safe food production), the protection of the natural environment and the preservation of the natural resources (e.g. land planning, soil conservation, rational water management, air pollution control, waste management, preservation of natural habitats) [6].

In Europe the current interest fields in Biosystems Engineering are the following:

1) Power and Machinery;
2) Information Technology and the Human Interface;
3) Automation and Emerging Technologies;
4) Precision Agriculture;
5) Animal Production Technology;
6) Post Harvest Technology;
7) Soil and Water;
8) Rural Development;
9) Structures and Environment [7].

The current research needs and/or opportunities in the subject area of Biosystems Engineering, within each of the above interest fields, are presented in the following paragraphs.

4.1.2.1. Power and machinery

The research needs and/or opportunities are concerned with the following subjects: design of agricultural machinery (i.e. tractors and machines for conventional and minimum tillage, sod seeding and earth moving, for the establishment, protection and harvest of field, protected and orchard crops), modification of the machines offered by the market, certification and/or verification of the related technical specifications of the manufacturer, production of biofuels (non-food production).

4.1.2.2. Information technology and the human interface

The research needs and/or opportunities are concerned with the following subjects: communications and field bus protocols, development and setting up of user-friendly software for the management of farms and agricultural industry processes, risk environmental assessment, ergonomics, operator health, welfare and safety (in terms of his active and passive protection) in agriculture, forestry and food production processes.

4.1.2.3. Automation and emerging technologies

The research needs and/or opportunities are concerned with the following subjects: automation and control of agricultural, animal and food production processes, intelligent machines, robotics for product processing, greenhouses, food industries and milking equipment, remote sensing, positioning systems, image analysis, biosensors, engineering for biotechnology, application of new electronic technologies.

4.1.2.4. Precision agriculture

The research needs and/or opportunities are concerned with the following subjects: study of the accuracy of global positioning systems useful for agriculture (GPS, DGPS), methods for mapping crop yield and inputs (soil characteristics), Geographic Information Systems (GIS), spatially variable rate crop input application.

4.1.2.5. Animal production technology

The research needs and/or opportunities are concerned with the following subjects: feeding systems, milking equipment and plants, dairies, control of livestock ethology, aimed at its welfare, control of harmful gas, odour, dust and waste emissions in livestock buildings, waste treatment, meat processing, aquaculture plants, etc.

4.1.2.6. Post harvest technology

The research needs and/or opportunities are concerned with the following subjects: crop drying, processing and storage, food packaging and processing, different categories of machines able to process the products, food chain and traceability, aimed at assuring safe food production.

4.1.2.7. Soil and water

The research needs and/or opportunities are concerned with the following subjects: climatology, relationships water-soil, water movements, soil erosion control, irrigation and drainage, water resource management, monitoring and protection of shallow and deep water resources from eutrophication and algae development, treatment of the wastes deriving from animal husbandry, agricultural and food industries (e.g. those for wine and oil production), phyto-depuration, basin hydrological models, etc.

4.1.2.8. Rural development

The research needs and/or opportunities are concerned with the following subjects: rural electrification and viability, transportation network for product commercialisation, alternative and renewable energy sources, agritourism (or rural tourism), etc.

4.1.2.9. Structures and environment

The research needs and/or opportunities are concerned with the following subjects: design of rural buildings, livestock buildings, dust and odour control, climate control and setting up of horticultural and floricultural greenhouses, landscape planning, environmental impact, including the implementation of low agricultural inputs (i.e. chemicals, plastic materials and energy) and outputs, waste management, production of biomaterials (non-food production), vernacular architecture, computational fluid dynamics for optimal building design, etc.

4.1.2.10. Others

Other research needs and/or opportunities in Biosystems Engineering are concerned with the following subjects: multi-functional agriculture, oriented to the health (through the production of neutraceuticals, that are healthy foods produced by food companies in collaboration with sellers of dietary supplements, e.g. vitamins and anti-oxidants), culture, landscape and environment, implementation of Life Cycle Assessment (LCA) in any process, reforestation operations, such as Short Rotation Forestry (SRF), based on wood species with 3-5 year cycle and aimed at producing biomass and adsorbing carbon dioxide, etc.

4.1.3. Trends

Europe is the world leader in the agricultural machinery sector and, generally, Agricultural Engineering and Technologies (AET) are fundamental for cost-efficient production of high quality food, biomaterials and energy crops but need continuous innovations, in order to meet the future needs of the growing global competition among machinery manufacturers. Therefore, recently a European Working Group on Agricultural Engineering and Technologies (AET) was established, in order to maintain the European leadership in AET, by pursuing the following objectives:

- to inform European decision-makers, in order that FP7 “activity areas” will meet the needs of the European industry;
- to provide a European platform that undertakes co-operation Research and Technological Development (RTD) activities in the AET sector.

The strategy followed by this Working Group was the formulation of a vision paper, the identification of research interest fields and the definition of a “roadmap” of RTD subjects under the umbrella of a European Technology Platform [8]. Thus, for the first time the community of Agricultural Engineering formulated a common vision paper on how European agriculture and engineering technologies applied to it could look like in 2020. Moreover, the technological advances needed in order to translate this vision into reality were identified. Thanks to the commitment of individuals from industry, research and other associations, this vision paper shows the future research interest fields on AET. Within these interest fields the first specific subjects for RTD were defined but, during the next years, with growing knowledge further topics will arise and will be continuously added to the first ones [9].

Since AET is strongly linked with other production and manufacturing technologies, it has formed a Working Group under the umbrella of the European Technology Platform “MANUFUTURE”. Therefore, the AET Strategic Research Agenda (SRA) is an independent document that is complementary with the general “MANUFUTURE” one. Moreover, this paper identifies thematic links of this platform with other European Technology Platforms [10].

Not only the USA trends but also the European ones about the research opportunities in the evolving subject area of Biosystems Engineering are shown in the report "Impact Statements 2005 - Biosystems and Agricultural Engineering" by the University of Kentucky [11].

In Europe trends about research needs and/or opportunities in Biosystems Engineering, based on current developments, are concerned with the following interest fields:

1) Power and Machinery (e.g. design and manufacturing of 100% recyclable machines, production of biofuels);
2) Information Technology and the Human Interface (e.g. biosystems modelling, ergonomics in terms of worker safety and equipment design);
3) Automation and Emerging Technologies (e.g. automatic control, implementation of robotics for field and greenhouse operations, animal husbandry, harvest of horticultural, floricultural and orchard products, product storage and packaging, remote control and sensing, land control and monitoring by means of satellite images, image analysis, implementation of biosensors for field and greenhouse crops, implementation of engineering for biotechnology, space agriculture, on orbiting International Space Stations or ISS, and establishment of underground lunar and Mars bases for agricultural production, inside growing chambers, and soil less cultivation);
4) Precision Agriculture (e.g. GPS, GIS, soil mapping);
5) Animal Production Technology (e.g. animal behaviour monitoring, livestock welfare, transport and identification);
6) Post Harvest Technology (e.g. implementation of nanotechnologies for food processing);
7) Soil and Water (e.g. agro-meteorology);
8) Rural Development (e.g. energy systems, renewable energy sources, solar, wind and biofuels, agritourism);
9) Structures and Environment (e.g. land monitoring, protection and recovering, air pollution control, reduction of greenhouse gas emissions, landscape and green planning, reduction of environmental burden, implementation of low agricultural inputs and outputs, production of biomaterials, bioarchitecture);
10) Others (e.g. reforestation of marginal soils).

References:

[1] P. Febo (2003). Agricultural Engineering Curricula: Past, Present and Future. 3rd International Symposium Actual Tasks of Agricultural Engineering, Opatija, Croatia, 24-26 February 2006.

[2] D. Briassoulis, P. Panagakis, E. Nikopoulos (2003). Overview of Research Activities in European Universities of Agricultural Engineering. Proceedings of the 2nd USAEE (Universities Studies of Agricultural Engineering in Europe) Workshop, Palermo, Italy, 26-27 September 2003.

[3] CORDIS (2007). Community Research & Development Information Service. URL: cordis.europa.eu/en/home.html

[4] INRA (2006). Research Strategic Program 2006-2009. URL: www.inra.fr

[5] Cemagref (2006). Research Strategic Program 2005-2009. URL: www.cemagref.fr

[6] A. Comparetti, P. Febo, S. Orlando, G. Scarascia Mugnozza (2006). Tools for Quality Assurance and Assessment of Agricultural Engineering Programmes, Tuning subject-area lines and Disappearing / Rare Knowledge in Italy. Proceedings of the 8th USAEE (Universities Studies of Agricultural Engineering in Europe) Workshop, Bonn, Germany, 7-8 September 2006, pp. 64-73.

[7] A. Comparetti, P. Febo, S. Orlando (2003). Research activities in Italian University Departments and Institutes of Agricultural Engineering. Proceedings of the 2nd USAEE (Universities Studies of Agricultural Engineering in Europe) Workshop, Palermo, Italy, 26-27 September 2003, pp. 70-73.

[8] EU Commission - DG Health and Consumer Protection (2007). Overview - Animal Health and Welfare. URL: ec.europa.eu/food/animal/index_en.htm

[9] MANUFUTURE - EU (2007). Manufuture Platform - Documents. URL: www.manufuture.org/documents.html

[10] MANUFUTURE - EU (2007). MANUFUTURE - Working Group on Agricultural Engineering and Technologies. URL: www.manufuture.org/documents/Manufuture%20Sectoral%20Activities.pdf

[11] University of Kentucky (2007). Impact Statements 2005 - Biosystems and Agricultural Engineering. URL: www.bae.uky.edu/ImpactStatements/PDFs/2005_BAE_Impact_Statements.pdf

4.2. Agricultural and biological engineering research

edited by K.C. Ting

4.2.1. Overview

Agricultural Mechanization has been ranked as one of the greatest engineering achievements of the 20th century by the U.S. National Academy of Engineering. Agricultural engineering played a vital role in that transformation. Many other traditional areas of agricultural engineering, such as soil and water, post-harvest and value-added processing, and structures and environment, have also made remarkable impacts to the agricultural production, the food industry and environmental stewardship. Agricultural Engineering is transforming into a future bio-based engineering and technology mindset and is defining a new culture that will guide our future for many years.

To build on the past success and to further enhance the ability of the "agricultural engineering" discipline in its contribution to an evolving system including agriculture, food, environment and energy, the discipline needs a strategic decision to adopt a more holistic approach as depicted by its new name of "Agricultural and Biological Engineering (ABE)".

In this vision, the land grant functions of teaching, research and extension education as well as the faculty responsibility of service (including economic development) will continue. The overarching mission is to "integrate life and engineering for enhancement of complex living systems". Engineering is a process of design under constraints. The task of design is to systematically and computationally assemble and integrate resources to achieve certain operational and performance goals. Traditionally, engineering design in our discipline has been to enable and facilitate system operations that contain biological processes (this is the task of "bringing engineering to life"). Therefore, the biological processes and the knowledge of life (i.e. biological) sciences have been considered as "constraints" or "requirements". In our new vision, life and engineering sciences are developed, applied and integrated for analyzing and designing bio-based systems (the concept of "integrating life and engineering", i.e., using life sciences as resources for engineering work and vice versa). The overarching goal of agricultural and biological engineering work is to "enhance complex living systems" involving humans, plants, animals and microorganisms within the context of agriculture, food, environment and energy.

4.2.2. Domains of ABE

The ABE (as opposed to human health emphasized biomedical or bio engineering) disciplinary relevance and impact areas include:

- Bio-Based Processing and Production Systems;
- Biomass and Renewable Energy;
- Precision and Information Agriculture;
- Agricultural and Biosystems Management;
- Agricultural Safety and Health;
- Food Quality and Safety;
- Environmental Stewardship;
- Land and Water Resources;
- Spatially Distributed Systems;
- Structure and Facilities for Living Systems;
- Indoor Environmental Control;
- Bio-sensors, Bio-instrumentation, Bio-informatics, and Bio-nanotechnology;
- Intelligent Machinery Systems;
- Automation of Biological Systems;
- Advanced Life Support Systems.

4.2.3. Core competencies of ABE

The key to the successful achievement of this vision lies in faculty expertise, as well as research and educational activities in the areas of automation, culture, environment and systems (i.e. the ACESys paradigm shown in Figure 1). Therefore, an ABE academic unit needs to build a faculty that will provide complete and complementary expertise, as well as conduct research and educational programs following the ACESys paradigm.

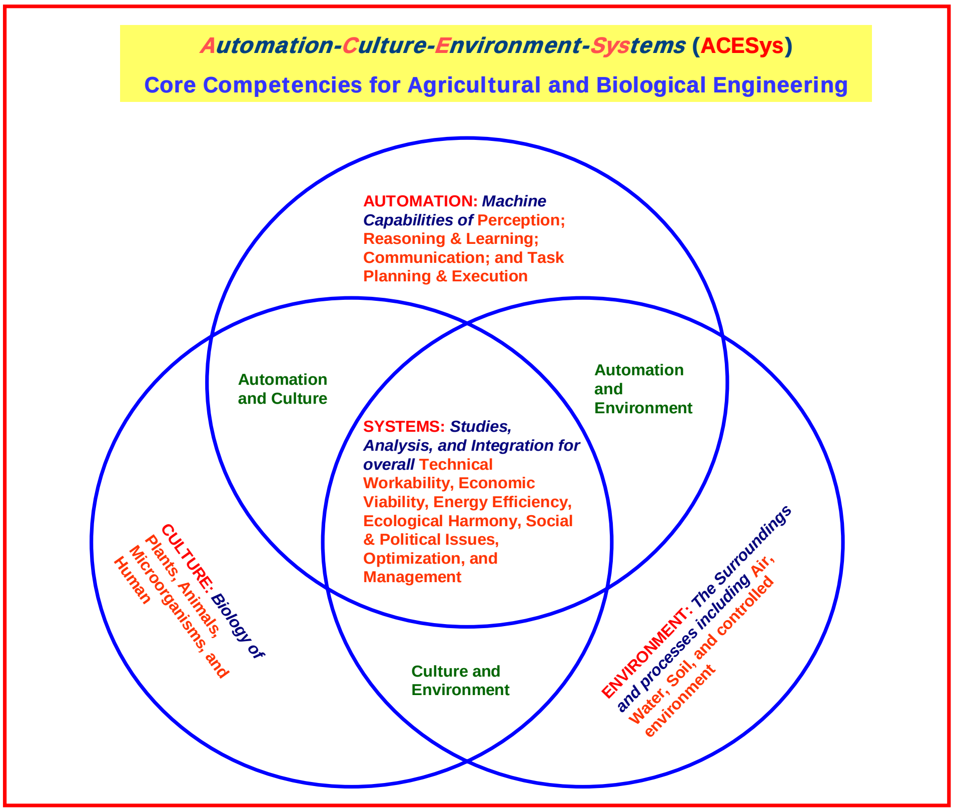

Figure 1. The ACESys core competencies paradigm.

Automation deals with information processing and task execution related to a system operation. The purpose of automation is to equip engineering systems with human-like capabilities of perception, reasoning/learning, communication and task planning/execution. Commonly seen automation topics are instrumentation, control, computerization, mechanization, modelling, machine vision, robotics, artificial intelligence, etc.

Culture includes the factors and practices that can directly describe and/or modify the growth and development of biological objects. The cultural factors, such as morphological and physiological conditions as well as genetic expressions are important in monitoring growth, development and functions of biological objects. The cultural practices may include operations which directly alter biological states and activities.

Environment encompasses the surroundings and processes of biological objects, which consist of climatic and nutritional, as well as structural/mechanical conditions. Understanding, delivery and control of environmental factors have been perceived as a major engineering challenge in agricultural production and bio-processing.

Systems analysis and integration is a methodology that starts with the definition of a system and its goals, and leads to the conclusion regarding the system workability (i.e. technical feasibility

and practicality), productivity, reliability and other performance indicators for decision support purposes. The success of systems analysis relies on the effective use of information.
Two key resources in systems analysis are the following:

1) information about individual system components as well as their interrelationships;
2) methods of information gathering and processing for creating value-added information.

In the past, agricultural activities mainly included on-farm production of plants and animals. Recently, systems approach to study agriculture has required that the entire food system (including the production of fresh materials and the consumption by end-users), the impact to the environment and the effective use of energy should be taken into consideration. Commonly investigated system level question about the food and agricultural system is the system impact on the 6 E's: Economics, Environment, Energy, Ecology, Efficiency and Education.

The integration of biological, physical and chemical sciences with engineering and technology provides a powerful platform for addressing systems level issues relevant to an increasingly complex agricultural and food system.

4.2.4. ASABE ED-210 Resolution

The membership of our primary professional society, American Society of Agricultural Engineers (ASAE), voted to change its name to the American Society of Agricultural and Biological Engineers (ASABE) in July 2005. ASABE ED-210 (formerly ASAE P-210) is a committee that consists of academic program administrators. During the annual international meeting of ASAE in July 2005, P-210 held a special meeting to discuss the impact of the current proliferation of academic department and program names. It was decided that the names of educational programs would significantly impact five important issues:

1) curriculum and accreditation;
2) student interest and recruiting;
3) placement/industry recognition;
4) ranking and identity;
5) professional engineer licensing and professional society membership.

A list of action items were generated and discussed. They included:

1) select one common program name;
2) develop core elements and common competencies;
3) influence the change of the program names/definition;
4) avoid bioengineering as a name;
5) name programs that are accredited under the ABET agricultural criteria as agricultural engineering and those programs accredited under the proposed biological engineering criteria as biological engineering;
6) continue the discussion on names and how to influence local politics to achieve a common name.

Before the conclusion of the meeting, a motion was passed that P-210 affirms a goal that departments adopt agricultural engineering or biological engineering as their respective accredited undergraduate engineering program names. Our ACESys paradigm will provide a clear vision for future agricultural and biological engineering academic units and programs.

4.2.5. Strategic research initiatives

While the domains and core competencies mentioned above help frame and describe the discipline of Agricultural and Biological Engineering, one key contribution of the discipline is to effectively advance the bio-based economic engine, as shown in Figure 2, by paying special attention to systems level issues of economics, environment, energy, ecology, education and efficiency (i.e. the 6 E's).

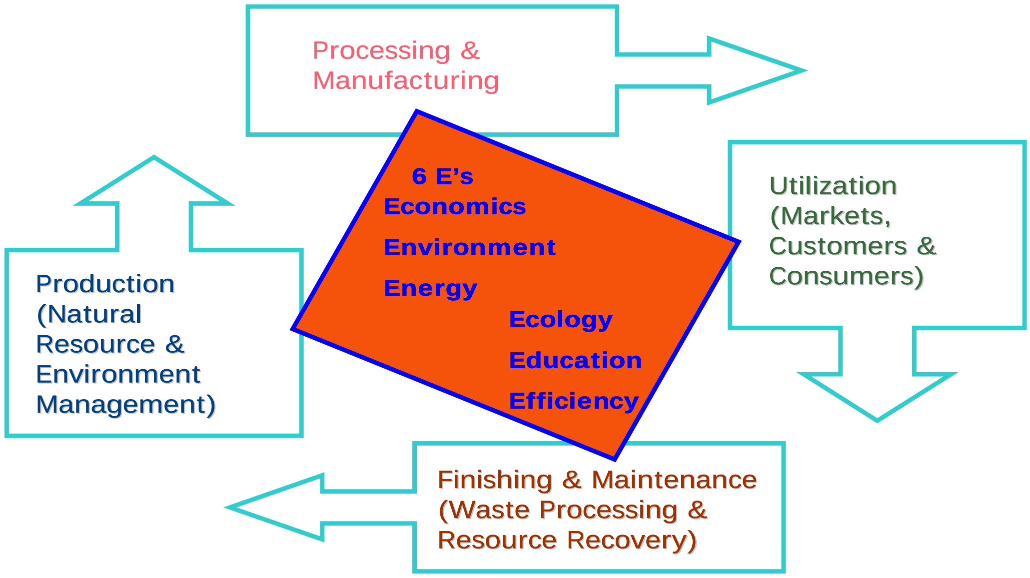

Figure 2. The Bio-Based Economic Engine.

Effectively sustaining the cycle of this economic engine is essential for improving its effectiveness and competitiveness, optimizing its economic return, providing management capabilities, monitoring and ensuring intelligent use of resources, understanding the governing constraints, enabling creative productivity, interfacing with other economic sectors, identifying value-added opportunities and creating new economic activities for wealth and job generation.

The following technical areas or initiatives are of particular importance in sustaining and advancing this very large and complex bio-based economic engine (each focus area incorporates systems management and safety/health dimensions):

1) Agricultural Automation, including machine intelligence of perception, reasoning and learning, communication, and task planning and execution;
2) Bio-Energy and Bio-Products, including production of bio-fuels, bio-power and bio-materials; example research and development activities are ethanol production, bio-diesel properties and engine performance, thermo-chemical conversion of biomass to crude oil, engineering solutions for biomass feedstock production, and systems integration and analysis;
3) Sustainable Environment, including information and analytical tools, processes, simulation and socio-economic considerations;
4) Biological Engineering, including biological nanotechnology (e.g., biosensors, nanotherapeutics with functional biological nanocomponents, etc.), programmable biotechnology (also known as synthetic biology, e.g. whole-cell biosensors, metabolic engineering, tools for molecular biosciences etc.) and biological device design (also involving the development of mathematical and information-based tools on the analysis and simulation of biological systems);
5) Systems Informatics and Analysis, including complex design techniques, decision support, early reliability measurement techniques, holistic agro-ecosystem perspectives, multi-scale modelling and sustainable development.

References:

[1] Department of Agricultural and Biological Engineering, University of Illinois at Urbana-Champaign (2006). Strategic Plan 2006-2011, Version 1.5, 15 June 2006.

4.3. ACTION STEPS

The action steps concerned with the Objective 4 "Identify research needs/opportunities in Biosystems Engineering" are the following:

1) to identify the domains or applications or enterprises about Biosystems/Agricultural Engineering;
2) to identify the core competencies or knowledge bases or sciences about Biosystems/Agricultural Engineering;
3) to identify the opportunities for integrating the core competencies about Biosystems/Agricultural Engineering, in order to address issues and solve problems in the related domain areas (Table 1).

4.4. FINDINGS/CONCLUSIONS

The research needs and/or opportunities about Biosystems/Agricultural Engineering deal with a series of domains or applications or enterprises, which can be satisfied by core competencies or knowledge bases or sciences (Table 1).

The domains or applications or enterprises include:

- environmental impact assessment;
- risk analysis, ergonomics, health and safety;
- control environmental agriculture;
- post harvest technology;
- product quality;
- product traceability;
- soil erosion and compaction;
- rural development;
- alternative and renewable energy sources;
- biomaterials.

The core competencies or knowledge bases or sciences in Biosystems/Agricultural Engineering include:

- plant and animal biology;
- systems analysis;
- intelligent machines;
- robotics;
- image analysis;
- sensors;
- GPS;
- GIS;
- irrigation systems;
- hydraulic and hydrological models;
- biomass production;
- computational fluid dynamics;
- Life Cycle Assessment (LCA).

Table 1. Example relationships between the domains and the core competencies in Biosystems/Agricultural Engineering.

Domains / **Core competencies**	Environmental impact assessment	Risk analysis, ergonomics, health and safety	Control environmental agriculture	Post harvest technology	Product quality	Product traceability	Soil erosion and compaction	Rural development	Alternative and renewable energy sources	Biomaterials
Plant and animal biology					X	X			X	X
Systems analysis	X	X	X	X	X	X		X	X	X
Intelligent machines	X	X	X	X						
Robotics		X	X	X	X	X			X	
Image analysis	X		X	X	X	X	X			
Sensors		X	X	X	X	X	X		X	X
GPS	X		X		X	X	X	X	X	
GIS	X		X		X	X	X	X	X	
Irrigation systems	X	X	X		X		X	X	X	X
Hydraulic and hydrological models	X	X	X				X	X	X	
Biomass production	X	X			X		X	X	X	X
Computational fluid dynamics			X	X			X			
Life Cycle Assessment (LCA)	X	X	X	X	X	X	X	X	X	X

Accreditations and Professional Licensing Issues; Recognition of Discipline

Objective 5. Developing policy measures and accompanying plans in support of the structural development of the new emerging discipline of Biosystems Engineering

Part V: Accreditation and professional licensing issues; Recognition of discipline/registration issues

Edited by Jean-Paul DOUZALS[1]

Contributions by B. Briassoulis[2], P. Panagakis[2], E. Nikopoulos[2], J. Fehrmann[3], G. Scarascia - Mugnozza[4], P.L. Febo[5], A. Comparetti[5], D. Wulfson[6] and H. Ramon[7]

(1) Dept. of Agricultural Sciences, ENFA Toulouse, France.
(2) Dept. of Natural Resources & Agricultural Engineering, Agricultural University of Athens, Athens, Greece.
(3) Dept. of Agricultural Engineering. Dresden University of Technology, Germany.
(4) Dept. PRO.GE.S.A.., University of Bari, Italy.
(5) Dept. I.T.A.F., University of Palermo, Italy.
(6) Dept. of AgroTechnology, The Royal Veterinary and Agricultural University (KVL), Denmark.
(7) Dept. of Biosystem Engineering, KU Leuven, Belgium.

5.1. Context

European Higher Education in Agricultural/Biological Engineering is historically characterized by a multitude of definitions of course contents and ways of studies. Most of Agricultural Engineering studies curricula are based on an Agricultural Sciences background; sometimes Agricultural Engineering courses concerns only optional. The duality between Agricultural Sciences and Engineering Sciences in conjunction with the disaffection of traditional agricultural sciences for students induce that accreditation and recognition of course (up to the faculty) is a crucial and central problem. These last years, Universities and Higher Education Institutions (almost) systematically implemented the introduction of accreditation process, professional recognition and quality assurance procedures that tend to clarify courses contents and objectives as well as professional outcomes.
At the European level, accreditation and professional licensing issues have been extensively analysed in the framework of the USAEE-TN. The main conclusions describing the European situation may be summarized as follows [1]:

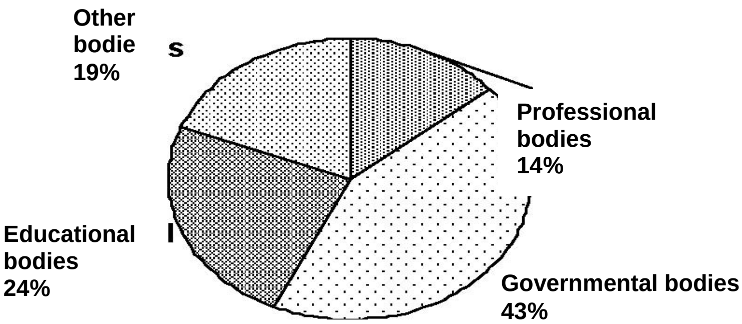

Figure 5.a. Types of organisations and their prevalence in conducting evaluations of Agricultural Engineering curricula in Europe (2006)

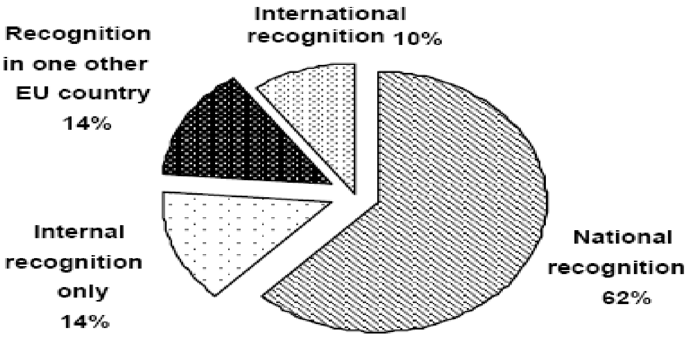

Figure 5.b. Extent to which Agricultural Engineering curricula evaluations conducted in Europe are recognised (2006)

According to previous figures, a large majority of courses are accredited/evaluated under the scope of Government or Educational bodies at a national level of recognition whereas professional recognition is a minority.

Extensive work have been done under the umbrella of the USAEE[1] Thematic Network to propose a core curricula to be recognized by FEANI[2] and/or EurAgeng[3]

5.2. Progress made in Accreditation, professional licensing issues and recognition of the discipline within the USAEE thematic network.

From 2002 to 2006 a Socrates-Erasmus Thematic Network, funded by the DG for Education and Culture, entitled "University Studies of Agricultural Engineering in Europe (USAEE-TN)", was initiated with the fundamental goal of improving and harmonizing the Engineering content of Agricultural Engineering curricula in European universities. The USAEE-TN (http://www.eurageng.org/usaee-tn.htm), composed of 31 partner Universities from 27 European countries, worked towards the restructuring of the University Studies of Agricultural Engineering in Europe through the development of a basic core curriculum in Agricultural Engineering. For the first time a critical mass of human resources and European Institutions/Universities offering such programs of studies has been mobilized in a systematic way, carrying out a coordinated intensive work in an effort to establish basic core curricula to be used as benchmark and recognised/accredited at a European level.

USAEE-TN developed a *Guidance report* as a benchmark core curriculum that established a set of minimum requirements against which any curriculum can be tested and evaluated with regards to meeting the criteria for its admission as a particular program of Agricultural Engineering studies. Currently in most of the departments of Agricultural Engineering in Europe, Agronomy and Agricultural Sciences prevail the program of studies and "'engineering" is a very weak, mostly application oriented, component, whereas the Biosystems Engineering curriculum is an Engineering curriculum and the biological and agricultural sciences components are only supporting this

[1] University Studies on Agricultural Engineering in Europe 2002 – 2006.

[2] Fédération Européenne d'Associations Nationales d'Ingénieurs (European Federation of National Engineering Associations). http://www.feani.org/

[3] European Society of Agricultural Engineers. http://www.eurageng.net/

curriculum in terms of some basic science-based knowledge (UK for example).

The final report was submitted to the FEANI in order for the European Monitoring Board (EMC) to decide on the proposed curriculum. In parallel, the European Society of Agricultural Engineers (EurAgEng) decided to formulate, in cooperation with USAEE-TN, an exciting recognition initiative in which it will formally recognize those university level curricula that adhere to the Guidance report contents. The final reply-decision from FEANI received stated that "*the submitted USAEE-TN Guidance report combined with the FEANI criteria provides guidance to the schools in order to design an agricultural engineering programme to be included in the FEANI INDEX, if the conditions previously mentioned in this letter are fulfilled"*. This means that when a programme of study complies with the approved by FEANI,/USAEE-TN core-curricula requirements, it can be included as an Engineeering programme of studies in the FEANI index and in parallel may seek to be recognised by EurAgEng. This development is considered to be a historic step forward for the area of Agricultural Engineering University studies in Europe.

Under the USAEE-TN framework two Agricultural Engineering Departments from the University of Leon (Spain) and the Lithuanian University of Agriculture, respectively

participated in two trial accreditations conducted by EUR-ACE. No definite conclusions have been reached yet. However, through this synergy between USAEE TN and EUR-ACE, it has been established that Agricultural Engineering programmes of studies would be accredited as a branch of Higher Engineering Education should they follow the basic scheme that was finally approved by FEANI.

5.3. Trends and strategies.

As discussed above, currently traditional Agricultural Engineering studies are not considered as engineering programs of studies in several European countries. Implementation of the time-demanding recognition procedure (already under development) by EurAgEng and FEANI would add value to any Agricultural Engineering program of studies, as it is foreseen to open the way for :

a) Registration to the FEANI index (become Professional Engineers at European level) and

b) Accreditation (i.e. become accredited at the European level Engineering graduates) through the European Accreditation scheme (EUR-ACE) already under development.

5.3.1. Recognition by EurAgEng

An underlying objective of the USAEE-TN was to enhance the comparability and quality of agricultural (and similar) engineering programmes of University studies. Through a survey of Universities across Europe that offer Agricultural Engineering curricula, it was determined that a formal, independently conducted process that recognised those programmes meeting a certain benchmark would be a useful quality assurance mechanism that would ultimately enhance both student mobility and employment opportunities for graduates. EurAgEng has decided to serve the profession by being the entity that conducts the "formal, independent" recognition process envisioned by USAEE-TN.

"Recognition" in this context of the EurAgEng process means that EurAgEng has compared the content of a given programme of study against the benchmark criteria established by USAEE-TN, and recognises the programme of study as satisfying the benchmark criteria. First of all, the EurAgEng recognition process evaluates the "1st cycle" (i.e., 180 European Credit Transfer Systems [ECTS] credits) of a so-called "pivot point" degree programme, as well as the initial 180 ECTS credits of a Long Cycle degree programme.

The recognition process begins with a written request to EurAgEng from the educational institution desiring for its programme of study (or studies) to be evaluated. Once this request is received, EurAgEng in cooperation with the members of the USAEE Steering Committee acting on a voluntarily basis, begins assembling a panel of experts, primarily from its membership, that will evaluate the programme of study. EurAgEng also returns to the applicant information the formal application that will be evaluated. Applications that are complete in form are then forwarded to the evaluation panel for review. Programmes that are recognised as having satisfied the benchmark criteria established by USAEE-TN will be so notified by EurAgEng and the name of the programme and the university will be placed prominently on the EurAgEng website. Additional detail about the EurAgEng recognition process can be found in the short document "EurAgEng Recognition Procedure", available from the EurAgEng Secretariat.

Recognition of a programme of study by EurAgEng is valid for a period of 5 years. Recognised programmes and their university affiliations will be kept in a EurAgEng register and shown on the EurAgEng website for this period. At the end of 4 years, programmes desiring continuing recognition must reapply.

5.3.2 FEANI Index

An Agricultural Engineering programme will be included in the FEANI Index, if all conditions set in the *Guidance report* submitted by USAEE-TN are fulfilled.

First of all, before FEANI takes a decision on the inclusion of a specific study programme in its INDEX of engineering programmes, the following conditions must be fulfilled:

- The application must be submitted to the EMC via the National Member of FEANI representing the school offering the programme
- The programme has produced the first graduates
- An evaluation form (downloaded from the FEANI website) must be completed
- The school must provide a brief description of the academic and professional qualifications of the teaching staff
- The school must provide a description of the laboratorial facilities used by the programme
- The EMC, in cases of doubt, may require further information or a visit to the school

5.3.2. EUR-ACE Implementation

USAEE-TN participates currently in the project board of the EUR-ACE Implementation project aiming to the accreditation of Agricultural and the evolving Biosystems Engineering programs of studies, both established as engineering programs complying with the EURACE Standards Framework in the same way as for any other engineering program of studies in Europe.

References:

[1] Proceedings of the 8th USAEE Workshop. 2006. Tools for Quality Assurance and Assessment of Agricultural Engineering programmes, TUNING lines & Disappearing rare knowledge. Bonn, Germany. Ed. D. Briassoulis and P. Panagakis, AUA, Greece.

[2] Proceedings of the 5th USAEE Workshop. 2005. Establishment of an accreditation system in Agricultural Engineering University Studies in Europe, Dresden, Germany. Ed. D. Briassoulis and P. Panagakis, AUA, Greece.

Accreditation of Biological (Biosystems, Biological Systems) Engineering Programs in the United States

prepared by M.L. Wolfe
Biological Systems Engineering Department, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA (mlwolfe@vt.edu)

Introduction

Engineering degree programs in the U.S. are accredited by ABET, Inc., formerly known as the Accreditation Board for Engineering and Technology. ABET is a federation of 28 professional and technical societies and conducts accreditation activities through four accreditation commissions: Applied Science (ASAC), Computing (CAC), Engineering (EAC), and Technology (TAC). Of particular relevance to the developing Biosystems Engineering programs in Europe are the EAC and the international accreditation activities of ABET. As of October 1, 2006, over 1800 programs were accredited through the EAC of ABET [1].

Engineering Accreditation Criteria

The objectives of engineering accreditation by ABET are the following: (1) to assure that graduates of an accredited program are adequately prepared to enter and continue the practice of engineering; (2) to stimulate the improvement of engineering education; (3) to encourage new and innovative approaches to engineering education and its assessment; and (4) to identify accredited programs to the public. ABET is focused on continuous improvement in engineering education to produce well-qualified graduates for the practice of engineering,

Accreditation is based on criteria recommended by ABET member societies, approved by the Engineering Accreditation Commission (EAC) of ABET, and approved by the ABET Board of Directors. The general criteria (included in appendix) for basic level (bachelor) programs include requirements with respect to the following [2]: (1) students, (2) program educational objectives, (3) program outcomes and assessment, (4) professional component, (5) faculty, (6) facilities, (7) institutional support and financial resources, and
(8) program criteria. Criteria (1) through (7) are the same for all basic level engineering programs. Criterion (8) includes specific requirements related to curricular topics and faculty qualifications for specific disciplines. For example, the program criteria for civil engineering require that program graduates have proficiency in a minimum of four recognized major civil engineering areas; and mechanical engineering program graduates must have the ability to work professionally in both thermal and mechanical systems areas including the design and realization of such systems.

Program criteria are recommended by ABET member societies. There is a lead society for each program criteria, as well as cooperating societies for some of the program criteria. As of the 2007-2008 accreditation cycle, program criteria are defined for the following engineering programs [2]: aerospace; agricultural; architectural; bioengineering and biomedical; biological; ceramic; chemical; biochemical, and biomolecular; civil; construction; electrical and computer; engineering management; engineering mechanics; environmental; geological; industrial; manufacturing; materials and metallurgical; mechanical; mining; naval architecture and marine; nuclear and radiological; ocean; petroleum; software; and surveying. The ASABE is the lead society for program criteria for agricultural and similarly named programs, as well as for the program criteria for biological engineering.

The biological program criteria (included in appendix) are effective for the first time for the 2007-2008 accreditation cycle. Prior to 2007-2008, biosystems-related programs were included under the program criteria for agricultural and similarly named program, which indicated that "these program criteria apply to engineering programs including "agricultural", "biological", "biological resources", "biological systems", "bioresources", "biosystems", "food", "forest", and similar modifiers in their titles with the exception of biomedically-based engineering programs". As of October 1, 2006, 48 programs (Table 1) were accredited under the ABET criteria of "agricultural and similarly named programs" [3].

Table 1. Programs accredited under the "Agricultural and Similarly Named" program criteria as of October 1, 2006 [3]

Program Name Number of Programs:

Biological Engineering 9
Biological Systems Engineering 7
Agricultural Engineering 6
Biosystems Engineering 6
Agricultural and Biological Engineering 3
Forest Engineering 3
Agricultural and Biosystems Engineering 2
Biological and Agricultural Engineering 2
Biosystems and Agricultural Engineering 2
Bioengineering 1
Biological and Agricultural Systems Engineering 1
Biological and Food Process Engineering 1
Biological Resources Engineering 1
Bioresource Engineering 1
BioResource and Agricultural Engineering 1
BioResource and Agriculture Engineering 1
Food, Agricultural, and Biological Engineering 1

The program criteria for agricultural and similarly named programs evolved as the programs across the country have evolved over the past fifteen to twenty years. A major change in program criteria occurred in the late 1990's as new general criteria were put into place by ABET. The new criteria, termed "EC2000", were based on a philosophy of continuous improvement and outcomes assessment, as opposed to focusing solely on the inputs to the educational program. ASAE, through its ED-204 committee on accreditation, recommended program criteria for agricultural and similarly named programs that specified curricular topics for specific program names, including "agricultural", "biological", "food", and "forest". In the mid- to late 1990's, ASAE recommended a unified program criteria for agricultural and similarly named programs, not specifying particular program names, that requires programs to demonstrate that graduates have proficiency in biological and engineering sciences consistent with the program educational objectives.

The Criteria Committee of the EAC began discussions at the 2003 EAC meeting relative to accrediting the wide variety of biologically-based engineering programs. Subsequently, in early 2004, the Criteria Committee Chair appointed an ad hoc committee to study "bio-based" engineering programs and resolve how they could be logically and equitably accredited and represented to the public. As a result of the ad hoc committee's work, new program criteria for biological engineering were proposed, along with modified program criteria for agricultural engineering. At the same time, modified program criteria for chemical engineering were proposed that would be applicable to "chemical, biochemical, biomolecular, and similarly named engineering programs". The proposed new and modified program criteria were approved by the EAC in July 2005 and by the ABET Board of Directors in the fall of 2005. The proposed changes were published for one year for public comment. The EAC endorsed the proposed changes again in July 2006 and the Board approved them again in October 2006. The new biological and modified agricultural and chemical program criteria went into effect for the 2007-2008 accreditation cycle.

The modified agricultural criteria apply to programs including "agricultural", "forest" and similar modifiers in their titles. The biological program criteria apply to programs including "biological," "biological systems," and similar modifiers in their titles with the exception of bioengineering and biomedical engineering programs.

A coordinating council is being established to coordinate activities related to the biological engineering program criteria. The council will be responsible for evolution of the criteria over time. Members of the council include the lead society (ASABE) and cooperating societies (AAEE, AIChE, ASCE, ASME, BMES, IEEE, NICE) for the program criteria. Establishment of the council recognizes that there is overlap among disciplines and that cooperation, rather than division, is the appropriate approach in presenting engineering to the public.

International Accreditation

In the past, ABET evaluated programs in countries outside the U.S. that are not signatories to the Washington Accord [4], by institutional request, to determine if they were "substantially equivalent" to ABET-accredited programs. "Substantial equivalency" means a program is comparable in educational outcomes, but may differ in format or method of delivery.

As a result of the ABET Board of Directors unanimous approval in fall 2005 to proceed with developing a plan for international accreditation, substantial equivalency evaluations have been phased out and the first international accreditation pilot visits will be conducted in fall 2007. ABET will continue to honour existing mutual recognition agreements and memoranda of understanding.

References:

1.ABET. 2006 Accreditation Statistics. Available at http://www.abet.org/statistics.shtml. Accessed 10 June 2007.

2. ABET. Criteria for Accrediting Engineering Programs. ABET, Inc., Available at http://www.abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2007-08%20EAC%20Criteria%201115-06.pdf. Accessed 10 June 2007.

3.ABET. Accredited Engineering Programs. Available at http://www.abet.org/schoolareaeac.asp. Accessed 10 June 2007.

4 Signatories to the Washington Accord include ABET, Canada, South Africa, UK, Australia, Ireland, Hong Kong, Singapore, New Zealand, and Japan.

Appendix 5A

Criteria for Accrediting Engineering Programs
Effective for Evaluations during the 2007-2008 Accreditation Cycle

This excerpt of the engineering criteria was obtained from the ABET website on 10 June 2007 from the following Url: http://www.abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2007-08%20EAC%20Criteria%2011-15-06.pdf

These criteria are intended to assure quality and to foster the systematic pursuit of improvement in the quality of engineering education that satisfies the needs of constituencies in a dynamic and competitive environment. It is the responsibility of the institution seeking accreditation of an engineering program to demonstrate clearly that the program meets the following criteria.

I. General criteria for Baccalaureate level programs

Criterion 1. Students

The quality and performance of the students and graduates are important considerations in the evaluation of an engineering program. The institution must evaluate student performance, advise students regarding curricular and career matters, and monitor student's progress to foster their success in achieving program outcomes, thereby enabling them as graduates to attain program objectives.

The institution must have and enforce policies for the acceptance of transfer students and for the validation of courses taken for credit elsewhere. The institution must also have and enforce procedures to assure that all students meet all program requirements.

Criterion 2. Program Educational Objectives

Although institutions may use different terminology, for purposes of Criterion 2, program educational objectives are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve.

Each engineering program for which an institution seeks accreditation or reaccredidation must have in place:

(a) detailed published educational objectives that are consistent with the mission of the institution and these criteria
(b) a process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated
(c) an educational program, including a curriculum that prepares students to attain program outcomes and that fosters accomplishments of graduates that are consistent with these objectives
(d) a process of ongoing evaluation of the extent to which these objectives are attained, the result of which shall be used to develop and improve the program outcomes so that graduates are better prepared to attain the objectives.

Criterion 3. Program Outcomes and Assessment

Although institutions may use different terminology, for purposes of Criterion 3, program outcomes are statements that describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that student acquire in their matriculation through the program.

Each program must formulate program outcomes that foster attainment of the program objectives articulated in satisfaction of Criterion 2 of these criteria. There must be processes to produce these outcomes and an assessment process, with documented results, that demonstrates that these program outcomes are being measured and indicates the degree to which the outcomes are achieved. There must be evidence that the results of this assessment process are applied to the further development of the program.

Engineering programs must demonstrate that their students attain:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. In addition, an engineering program must demonstrate that its students attain any additional outcomes articulated by the program to foster achievement of its education objectives.

Criterion 4. Professional Component

The professional component requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The faculty must ensure that the program curriculum devotes adequate attention and time to each component, consistent with the outcomes and objectives of the program and institution. The professional component must include:

(a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline

(b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study. The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.

(c) a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.

Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.

Criterion 5. Faculty

The faculty is the heart of any educational program. The faculty must be of sufficient number; and must have the competencies to cover all of the curricular areas of the program. There must be sufficient faculty to accommodate adequate levels of student-faculty interaction, student advising and counseling, university service activities, professional development, and interactions with industrial and professional practitioners, as well as employers of students.

The program faculty must have appropriate qualifications and must have and demonstrate sufficient authority to ensure the proper guidance of the program and to develop and implement processes for the evaluation, assessment, and continuing improvement of the program, its educational objectives and outcomes. The overall competence of the faculty may be judged by such factors as education, diversity of backgrounds, engineering experience, teaching experience, ability to communicate, enthusiasm for developing more effective programs, level of scholarship, participation in professional societies, and licensure as Professional Engineers.

Criterion 6. Facilities

Classrooms, laboratories, and associated equipment must be adequate to accomplish the program objectives and provide an atmosphere conducive to learning. Appropriate facilities must be available to foster faculty-student interaction and to create a climate that encourages professional development and professional activities. Programs must provide opportunities for students to learn the use of modern engineering tools. Computing and information infrastructures must be in place to support the scholarly activities of the students and faculty and the educational objectives of the program and institution.

Criterion 7. Institutional Support and Financial Resources

Institutional support, financial resources, and constructive leadership must be adequate to assure the quality and continuity of the engineering program. Resources must be sufficient to attract, retain, and provide for the continued professional development of a well-qualified faculty. Resources also must be sufficient to acquire, maintain, and operate facilities and equipment appropriate for the engineering program. In addition, support personnel and institutional services must be adequate to meet program needs.

Criterion 8. Program Criteria

Each program must satisfy applicable Program Criteria (if any). Program Criteria provide the specificity needed for interpretation of the baccalaureate level criteria as applicable to a given discipline. Requirements stipulated in the Program Criteria are limited to the areas of curricular topics and faculty qualifications. If a program, by virtue of its title, becomes subject to two or more sets of Program Criteria, then that program must satisfy each set of Program Criteria; however, overlapping requirements need to be satisfied only once.

PROGRAM CRITERIA FOR BIOLOGICAL AND SIMILARLY NAMED ENGINEERING PROGRAMS

Lead Society: American Society of Agricultural and Biological Engineers
Cooperating Societies: American Academy of Environmental Engineers, American Institute of Chemical Engineers, American Society of Civil Engineers, American Society of Mechanical Engineers, Biomedical Engineering Society, CSAB, Institute of Electrical and Electronics Engineers, Institute of Industrial Engineers, Minerals, Metals, and Materials Society, National Institute of Ceramic Engineers

These program criteria apply to engineering programs including "biological," "biological systems," and similar modifiers in their titles with the exception of bioengineering and biomedical engineering programs.

1. Curriculum Programs must demonstrate that graduates have proficiency in mathematics through differential equations, a thorough grounding in chemistry and biology and a working knowledge of advanced biological sciences consistent with the program educational objectives. Competence must be demonstrated in the application of engineering to biological systems.

2. Faculty

The program shall demonstrate that those faculty members teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of education and experience or professional licensure.