

“Develop policy measures to enhance the quality and the linkage of Education and Research in Biosystems Engineering, promote bilateral research cooperation and establish common recognition procedures for the EU and the US relevant programs of studies”

*2<sup>nd</sup> Workshop Proceedings  
Crete, Greece  
June 21-22, 2008*

**POMSEBES**

ISBN 978-960-6806-05-6

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The project has been funded with support from EU.

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Printed in Greece



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Develop a Uniform Structure  
(framework) for Compatible Programs  
of the Biosystems Engineering  
Discipline

## **Objective 1: Develop a uniform structure (framework) for compatible programs of the Biosystems Engineering discipline**

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### **Introduction**

Biosystems Engineering is the more biology-based evolution of the Agricultural Engineering discipline and applies to all living organism systems with the exception of human ones. It integrates engineering science and design with applied biological, environmental and agricultural sciences and can be defined as “*the branch of engineering that prepares students to develop and apply engineering solutions to problems in biological systems*”. In the context of this evolution, Biosystems Engineering should exclude Biomedical Engineering (with human biology background prerequisite), Bioengineering\* and Biotechnology [1].

### **1. Specify the key elements of compatibility of the Biosystems Engineering program of studies in US and EU**

The very basic key element for an emerging EU Biosystems Engineering program of studies to be compatible with those in the US is to ensure that it offers an **essential minimum fundamental engineering knowledge**. The minimum Engineering part of the core-curricula should not be confused with the whole program of studies offered by a particular Department, given that for numerous reasons these programs are not uniform in European countries (i.e. existing needs, educational systems, administrative constraints, etc.) [2]. On this basis, core curricula have been developed in the framework of the USAEE Thematic Network [3] and have been approved by FEANI-EMC [4] in January 2007 to be used as benchmarks for Agricultural and Biosystems Engineering studies in Europe. The core curriculum is structured in two basic levels: a) the Engineering and the Biological/Agricultural Sciences fundamental basis and b) the optional modules (specialisations) related Engineering and Agricultural/Biological parts of the core curricula.

The following courses, defined in terms of contents, learning outcomes and ECTS units compose the Engineering core fundamental basis:

- (1) Engineering Graphics and Design – CAD
- (2) Mechanics-Statics
- (3) Strength of Materials
- (4) Mechanics-Dynamics
- (5) Fluid Mechanics
- (6) Applied Thermodynamics

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\* Bioengineering (also encompasses Biomedical Engineering and Medical Engineering) is an application of engineering principles and design to challenges in human health and medicine [<http://en.wikipedia.org/wiki/Bioengineering>]

- (7) Heat and Mass Transfer
- (8) Electricity and Electronics
- (9) System Dynamics

Thus, these courses should also be expected to comprise the fundamental EU Engineering core basis of Biosystems Engineering programs of studies to achieve compatibility with US programs of studies which usually encompass the following courses (or similar):

- (1) Statics
- (2) Strength of Materials
- (3) Dynamics
- (4) Fluid Mechanics
- (5) Thermodynamics
- (6) Transport Processes
- (7) Engineering Graphics and Design
- (8) Physical Properties of Biological Materials
- (9) Engineering Economics
- (10) Electrical Theory
- (11) Instrumentation
- (12) Foundation of Engineering Design

Another important compatibility key element is the Agricultural/Biological core basis. In the US the Agricultural/Biological core basis competences are usually covered by several general 'Biological Sciences' courses. These courses could include 'Principles of Biology', 'Soil Science', 'Biochemistry', 'Microbiology' and 'Physical Chemistry'. It should however be noticed that more advanced and applied courses in various programs of studies offered in the US build upon the topics addressed within these general courses. Based on the Core Curricula developed by USAEE-TN, the following courses may be considered as comprising the corresponding EU Agricultural/Biological core fundamental basis: (5 courses may be selected out of six depending on the modules offered):

- (1) Plant Biology
- (2) Animal Biology
- (3) Introduction to Soil Science
- (4) Introduction to Agricultural Meteorology and Micro-meteorology
- (5) Understanding the Environment and its interaction with Living Organisms
- (6) Microbiology

*Of major importance is the fact that, based on the approved by FEANI-EMC core curricula specifications, the Agricultural/ Biological core basis should be limited to between 50 and 55.5% of the corresponding Engineering core basis, namely **20-25 ECTS** for the Agricultural/ Biological core fundamental basis **compared to 44-51 ECTS** for the Engineering core fundamental basis, for FEANI to recognize as Engineering any emerging European Biosystems Engineering program of studies.*

The optional (specialisation related) Engineering and Agricultural /Biological science courses included in the Engineering and Agricultural/Biological sciences parts of the core curricula, respectively, are determined for each module or combination of modules of Biosystems Engineering programs of studies and defined as follows:

- Each module may include several Engineering courses and each Biosystems Engineering programme may choose a minimum number of courses from one or several modules, as needed by the individual programme
- Each module may include several Agricultural/Biological science courses and each Biosystems Engineering programme may choose a minimum number of courses from one or several modules, as needed by the individual programme (same as above).

## **2. Indicate the desired minimum competences for the graduates of compatible programs of the Biosystems Engineering discipline**

### ***The EU case***

The first step to be taken is the definition of a minimum of desired competences comprising the Biosystems Engineering core competencies. Core competences refer to the General Competences (i.e. mostly related to math, informatics, sciences like physics and chemistry, etc., and to the generic competencies of the graduate related to communication, cooperation, design ability, etc.) and the core Engineering and Agricultural/Biological Sciences part of the Biosystems Engineering program of studies.

In that respect, the structure of a Biosystems Engineering curriculum should follow the structure of the core curricula developed and proposed by USAEE-TN [3] as it covers a minimum of desired competences that are well-defined and suitable for the new Biosystems Engineering programs of studies in Europe.

### Core competences

#### *General competences: adopted from Thematic Network E4 (activity A1)*

The general competences for Biosystems Engineering are adopted from the corresponding report of activity A1 of the TN: Enhancing Engineering Education in Europe - E4 [5; refer to Appendix A]. The same general competences were adopted and incorporated already in the core curricula developed by the USAEE-TN [3] and approved by FEANI-EMC [4].

#### *Engineering part of core curricula: core basis*

The minimum set of the Engineering part of core curricula should include the contents of fundamental Engineering subjects mandatory for all modules (or specializations) of Biosystems Engineering. These contents are expressed in terms of the well-defined and recognized internationally basic Engineering courses mentioned in the previous section. The corresponding Engineering core competences are given below and are also adopted from the corresponding report of A1 activity of the Thematic Network E4 [5]. Thus:

The 1<sup>st</sup> cycle graduate should be able to:

- Apply knowledge of mathematics, science and engineering and systems approaches appropriate to his or her discipline
- Design and conduct experiments, analyse and interpret data
- Identify, formulate and solve engineering problems
- Recognise the interaction between engineering activities and design, fabrication, marketing, user requirements, and product destruction.
- Communicate information, ideas, problems, and solutions to both specialist and non-specialist audiences

- Adapt to a changing technology and new techniques as part of a life long learning process
- Function efficiently in project groups and teamwork
- Understand the interaction process between people working in teams, and be able to adapt to the requirements of the working environment
- Display an understanding of the influence of engineering activity on all life and the environment, and demonstrate a high moral and ethical approach to engineering tasks
- Apply the learning ability to undertake appropriate further training of a professional or academic nature
- Critically evaluate arguments, assumptions, abstract concepts and data, in order to make judgements and to contribute to the solution of complex issues in a creative process
- Show an appreciation of the uncertainty, ambiguity and limitations of knowledge

The 2<sup>nd</sup> cycle graduate should be able to:

- Demonstrate an in-depth understanding of his/her subject area as part of a general engineering technology
- Demonstrate in-depth knowledge and understanding of a specialised area related to his/her field of study
- Plan, and carry out research in his/her specialised field
- Assume an analytical approach to work based on broad and in-depth scientific knowledge
- Function in leading roles, including management roles, in companies and research organisations, and to contribute to innovation
- Plan, supervise and carry out research and development projects
- Explain ideas and projects to a team of co-workers
- Find a solution of particular technical and human problems arising in the working environment
- Apply skills and qualities necessary for employment requiring personal responsibility and decision-making
- Work in an international environment with appropriate consideration for differences in culture, language, and social and economic factors
- Communicate information, ideas, problems and solutions to both specialists and non specialists
- Accept accountability for related decision-making including use of supervision
- Show awareness and relate to connections with other disciplines and engage in interdisciplinary work

*Agricultural /Biological sciences part of core curricula: core basis*

The minimum set of the Agricultural/Biological sciences part of core curricula [2] is designed in a such way that it includes the required outcome learning of fundamental knowledge of Agricultural / Biological sciences subjects mandatory for all modules (or specializations) of Biosystems Engineering. These subjects should represent Agricultural / Biological sciences related fundamental basic knowledge with a broader biological background for Biosystems Engineering as compared to traditional Agricultural Engineering programs of studies. Therefore, the minimum set of the Agricultural / Biological sciences competences are given defined as follows:

The 1<sup>st</sup> cycle graduate should be able to:

- Understand the fundamental biological mechanisms which govern the life of living organisms in general
- Recognise the interactions between systems of living organisms and their environment

The 2<sup>nd</sup> cycle graduate should be able to:

- Appreciate issues (e.g. techniques used to model and subsequently simulate) related to biological systems and their management
- Understand matters related to environmental protection and sustainability

Developments towards the establishment of a SINGLE European Accreditation procedure for all European Engineering programs of studies are currently under way through the EUR-ACE project (EUROpean ACcredited Engineer [[www.eurace.org/](http://www.eurace.org/)]). Accreditation of Agricultural and Biosystems Engineering programs of studies at the EU level shall comply with the EUR-ACE Standards Framework in the same way as for any other ENGINEERING program of studies in Europe.

The categories of Programme Outcomes specified within the EUR-ACE Framework Standards include:

- a. Knowledge and Understanding
- b. Engineering Analysis
- c. Engineering Design
- d. Investigations
- e. Engineering Practice
- f. Transferable (personal) Skills

For each category, the EUR-ACE Framework Standards list the Programme Outcomes for the First & Second Cycle. In any case, the outcomes should be interpreted to reflect the specific demands of different branches, cycles and profiles

### **The US case**

In the United States, accreditation of programs is conducted by a non-governmental, peer-review process to assure the quality of the postsecondary education students. Educational institutions or programs volunteer to undergo this review periodically to determine if certain criteria are being met. ABET is the organization that accredits programs in applied science, computing, engineering and technology, including the Biological and Agricultural Engineering programs.

To comply with the ABET engineering criteria, a program must first formulate *program educational objectives* (broad goals that describe the career and professional accomplishments that the program is preparing graduates to achieve) that address institutional and program mission statements designed to meet the needs of various groups of program stakeholders. The program must then establish a set of *program outcomes* (knowledge, skills, and attitudes the program graduates are expected to have) that directly address the educational objectives *and* encompass certain specified outcomes. For the core courses of the curriculum, *outcome-related course learning objectives* (statements of ability and skills that students who complete the course should be able to possess) must be written. The program educational objectives and outcomes must be included in a self-study report, which must also include information on how the levels of attaining various outcomes are assessed, and how the assessment results will be used to improve the program [6].

Engineering programs must demonstrate that their students attain the following outcomes:

- (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 multidisciplinary 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 to outcomes (a) through (k) any additional outcomes that may be articulated by the program should be assessed. Program outcomes must demonstrate that the program educational objectives are attained. It must also assure that all students meet the program requirements.

### **3. Present examples of a study program with uniform structure (framework) leading to compatible learning outcomes**

#### ***The EU Case***

Apart from the core competencies, a study program with uniform structure (framework) leading to compatible learning outcomes has to incorporate mid-level competences which refer to the optional specialization (module) part of the core curriculum. Mid-level competences are extended and completed with applied courses on specialised areas of expertise over the 2<sup>nd</sup> cycle programme of studies (or during the last two years of the integrated programmes of studies).

#### Mid-level competences

The EU mid-level competences abide to the core curricula modules developed during the USAEE-TN [2] course and approved by FEANI-EMC [3]. The mid-level competences concern the foundation for the development of more applied competences related to various specialisations. These competences have to be enriched and strengthened (through more specialised / applied courses) so as to end up to the specific expertise to be acquired. The mid-level competences for some classical modules of Agricultural and Biosystems Engineering programs of studies are described as follows:

#### *Water Resources Engineering*

- Understand the biological mechanisms which govern the life of living organisms and their biological and physicochemical characteristics as they are related to various aspects of water resources engineering (design and analysis of hydraulic systems in support of living organisms, related production, etc.)
- Recognise the interactions between water and soils and their affect on the living organisms systems

- Understand matters related to environmental protection and sustainability as related to various aspects of water resources engineering

#### *Mechanical Systems and Mechanisms*

- Understand the biological mechanisms which govern the life of living organisms and their biological, mechanical and physicochemical characteristics as they are related to various aspects of mechanical systems and mechanisms (design and analysis of mechanical systems in support of living organisms, related production, etc.)
- Appreciate matters related to living organisms protection and agro-chemical or other physical and biological means used for this purpose
- Understand matters related to environmental protection and sustainability as related to various aspects of mechanical systems and mechanisms

#### *Structural Systems and Materials*

- Understand the biological mechanisms which govern the life of living organisms and their biological, mechanical and physicochemical characteristics as they are related to various aspects of structural systems and materials (design and analysis of structural systems and bio-materials in support of living organisms, related production, etc.)
- Appreciate matters related to living organisms interaction with controlled or natural micro-environment and the effects of the related physical, chemical and biological factors
- Understand matters related to environmental protection and sustainability as related to various aspects of structural systems and materials

#### *Information Technology and Automation*

- Understand the biological mechanisms which govern the life of living organisms and their biological, mechanical and physicochemical characteristics as they are related to various aspects of information technology and automation (design and analysis of automation systems in support of living organisms, related production, etc.)
- Appreciate matters related to living organisms and systems physical, chemical and biological factors exploitable by information technology (e.g. biosensors, etc).
- Understand matters related to environmental protection and sustainability as related to various aspects of information technology and automation in designing with living organisms and systems

#### *Bioprocessing*

- Understand the biological mechanisms which govern the life of living organisms and their biological, mechanical and physicochemical characteristics as they are related to various aspects of bio-processing (design and analysis of bio-processing systems in support of living organisms, related production, etc.)
- Recognise issues related to post-harvest physiology and food science as related to various aspects of bio-processing
- Comprehend subjects such as food quality and microbiology

#### *Waste Management*

- Understand the biological mechanisms which govern the life of living organisms and their biological, mechanical and physicochemical characteristics as they are related to various aspects of waste management (design and analysis of waste management systems in support of living organisms, related production, etc.)

- Understand matters related to environmental protection and sustainability as related to various aspects of waste management
- Recognise issues related to soil chemistry
- Appreciate the interactions between water and soils and contaminants or pollutants
- Be aware of the biological processes used in waste treatment and management

#### *Energy Supply and Management*

- Understand the biological mechanisms which govern the life of living organisms and their biological, mechanical and physicochemical characteristics as they are related to various aspects of energy supply and management (design and analysis of energy supply systems in support of living organisms, related production, etc.)
- Understand issues related to fossil fuels energy production, transport, distribution; advantages and negative environmental effects
- Comprehend questions related to alternative renewable energy sources and systems; negative and positive environmental impact
- Understand matters related to environmental protection and sustainability as related to various aspects of energy supply management

#### **The US Case**

As stated before, through the ABET assessment process, the development of a clear program mission and program goals that address the program educational objectives and desired attributes of the program graduates (program outcomes) requires the faculty to systematically consider what their program is and what they would like it to be. The final product of this process is a unifying framework for course and curriculum development. When faculty members structure their course syllabi, learning objectives, and teaching and assessment methods to address the program outcomes, it would result in a coherent curriculum in which all courses have well-defined and interconnected roles in achieving the program mission [6]. The course learning objectives which are specific statements of what students in a course should be able to do upon the completion of that course, are critical to the success of this process and would enable the programs to demonstrate how specific program outcomes are addressed in the curriculum. If the outcomes are then assessed continuously and the results are used to improve instruction in the courses that address them, the degree to which the program meets its self-selected goals would improve. Based on the ABET criteria for Biological and similarly named engineering programs, the 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.*” [7]. Thus, the ABET process relies on the programs and institutions to specify the desired competencies for their graduates in any specific field of study. It is upon the programs and institutions to demonstrate the achievement of those competencies prior to getting accreditation.

#### **4. Identify critical points affecting student mobility (i.e. ECTS vs. US credits, prerequisite courses, 2<sup>nd</sup> EU cycle degree vs. M.Sc./M.E. US degree, etc.)**

The past decade has witnessed an unparalleled collaboration among the institutions of higher education in the world. Many institutions have established student exchange programs to meet the needs of the stakeholders. This international collaboration, however, is being

hampered due to the lack of compatibility among programs. However, several other factors impact the student mobility between the EU and US institutions in Biosystems Engineering including:

- a) Incompatibility among curricula. This includes both horizontal compatibility among European as well as vertical transatlantic with the US institutions. Lack of program harmonization among European countries is a major obstacle.
- b) Lack of well-defined entry points to the US graduate programs for graduates of various cycles in Europe by the US institutions such as those graduating from 3+2 or 4+1 programs.
- c) Lack of a uniform understanding of an engineering curriculum among various European institutions. The proliferation of programs that call their graduates “engineers” without really offering an engineering curriculum.
- d) Lack of “biological” content in the current Biosystems Engineering programs in Europe.
- e) There exist no succinct transparent policies and practices across the institutions in the US regarding admission of European students to their programs. This could be alleviated through development of outcome-based assessment process for the European countries to be used as a tool for defining an entry point into their graduate programs.
- f) Insufficient availability of scholarships and fellowships for international students, particularly for European students
- g) Lack of a well-defined process for benchmarking European institutions and programs against their US counterparts.

## **5. Proposed policy measures**

In conclusion, the development of an EU-US uniform structure of Biosystems Engineering programs of study could be achieved provided that:

- The emerging Biosystems Engineering discipline is considered as the evolution of the Agricultural Engineering (a consistent definition of Biosystems Engineering should be decided upon and communicated)
- A common definition of student course load is developed to make EU Biosystems curriculum compatible with that of the US
- EU Biosystems Engineering programs have a well defined engineering core (courses/topics) based on the approved by FEANI USAEE TN core curricula, which is already compatible with the corresponding US curricula
- A list of learning outcomes for students in Biosystems Engineering is built-up to assist with the development of the curriculum (this approach will define course/topics for the modules offered by specific programs of study).

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## **Appendix A**

### **(Adopted from the report of Activity 1, of the Thematic Network E4)**

#### ***1<sup>st</sup> cycle graduate***

##### *Computer Science/Informatics*

- ✓ Use common computer tools to produce documents, make presentations, carry out calculations and simulations.
- ✓ Design and maintain an Internet presentation of his/her work.
- ✓ Carry out computer based tasks using object oriented programming and expert systems.
- ✓ Use professional computer codes to prepare data, and obtain reasonable results from calculations.

##### *Mathematics*

- ✓ Construct a mathematical model of a given problem using differential calculus.
- ✓ Apply the technique used for setting up definite integrals.
- ✓ Classify, set up for solution and solve a selection of ordinary differential equations.
- ✓ Use mathematical tools to report the results of his/her work
- ✓ Use intelligent software tools applied to the solution of mathematical problems.
- ✓ Understand and use the concept of sets and classes and be familiar with Boolean algebra.
- ✓ Manipulate complex numbers in Cartesian and polar form.
- ✓ Use Matrix algebra and its application in solving systems of linear equations.
- ✓ Understand the concepts of vectors representing lines and planes in 3-D space.
- ✓ Explain topics like Fourier series and Laplace-transforms and their applications in problem solving.
- ✓ Apply linear transformations.
- ✓ Understand and interpret information in statistical information.
- ✓ Use statistical methods for sampling and measurement, planning, control, interpretation and decisions

##### *Physics*

- ✓ Use the relevant laws of kinematics and dynamics to solve problems of rotational and lateral movement.
- ✓ Explain harmonic oscillations, damped oscillations and forced oscillations and treat such oscillations mathematically.
- ✓ Describe waves mathematically and explain the concept of wave lore
- ✓ Explain the first and second law of thermodynamics and solve problems applying these laws
- ✓ Explain the principles of electric and magnetic fields and apply the basic laws of electric circuits
- ✓ Explain the basic principles of quantum theory

##### *Chemistry*

- ✓ Display basic knowledge of general chemistry, organic and inorganic chemistry
- ✓ Assess the environmental influence and impact on organisms and use this knowledge in solving technical problems.

### *Environment*

- ✓ Understand the influence of technical activities or processes on the environment, and outline possible ways of reducing such influence.
- ✓ Display a clear understanding of the interaction between environmental issues and technological issues and on the basis of this knowledge be able to make independent recommendations on topics of work environment.

### **2<sup>nd</sup> cycle graduate**

#### *Mathematics*

- ✓ Formulate mathematically and to solve practical problems related to designing and exploitation of real technical systems.

#### *Computer Science/Informatics*

- ✓ Understand the algorithms of professional codes, their limitations and requirements, to prepare the data for the code in the proper way and to analyse obtained results of calculations.

Describe the Biological/Biosystems Engineering programs of study in the US and the current trends in EU, focusing on Education and Research

**Objective 2: Describe the Biological / Biosystems Engineering programs of study in the US and the current trends in EU, focusing on education and research**

Prepared by

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**Programs of studies in the emerging field of Biological/Biosystems Engineering**

Typical Biological/Biosystems Engineering programs of study programs of two U.S and two European Universities are presented, indicative of the current trends in US and the EU on Education and Research in the emerging field of Biological/Biosystems Engineering.

**1. Provide information on educational issues from one or two example US Biological/Biosystems engineering academic program(s)**

***Educational information on Biological Engineering at the University of Illinois***

At the University of Illinois, a four-step process has been taken to develop the biological engineering undergraduate educational program. Step 1 was to change the department name from Agricultural Engineering to Agricultural and Biological Engineering while maintaining the undergraduate program name Agricultural Engineering. In Step 2, a specialization of Biological Engineering was created within the Agricultural Engineering degree program (in addition to the existing specializations of Bioenvironmental Engineering, Off-Road Equipment Engineering, and Soil and Water Resources Engineering and concentration of Food and Bioprocess Engineering). A specialization signifies the technical emphasis of the educational experience and will not appear on the student's transcript. A concentration is a formally recognized curriculum within a degree program and will appear on the student's transcript. Step 3 has been initiated to change the degree program name from Agricultural Engineering to Agricultural and Biological Engineering (ABE). Step 4 is to develop a formal concentration of Biological Engineering within the new ABE degree program. The courses of studies of the Specialization in Biological Engineering and the draft Concentration in Biological Engineering are shown in the following.

## CURRICULUM IN AGRICULTURAL ENGINEERING

UNIVERSITY of ILLINOIS at URBANA-CHAMPAIGN

*For the degree of Bachelor of Science in Agricultural Engineering with a  
Specialization in Biological Engineering*

The B.S. Degree in Agricultural Engineering provides a specialization in **Biological Engineering**. This specialization integrates biology and engineering to provide solutions to problems related to living systems (plants, animals, humans, and microorganisms). Engineering biological systems vary widely in scale. At the molecular level, nanometer-scale devices consist of a few biomolecules inside individual cells. At the other extreme, regionally-scaled complex ecosystems depend upon multiple species of interacting living organisms. Such systems are becoming increasingly important in areas such as bioenergy, bioprocessing, alternative energy, nanotechnology, biosensing, bio-informatics, and bioenvironment. Students in this specialization have the opportunity to select courses directly related to **Biological Engineering**. Graduates will earn a 4-year ABET accredited degree from the College of Engineering that will prepare them for productive careers in industry, consulting, government, or research.

### FIRST YEAR

First Semester	Hours	Second Semester	Hours
ABE 100 - Intro to Agr Engineering .....	1	MATH 231 - Calculus II .....	3
ENG 100 - Engineering Lecture.....	0	MATH 225 - Introductory Matrix Theory .....	2
MATH 221 - Calculus I <sup>2</sup> .....	4	CHEM 104 - General Chemistry II* .....	3
CHEM 102 - General Chemistry I .....	3	CHEM 105 - General Chemistry Lab II* .....	1
CHEM 103 - General Chemistry Lab I .....	1	PHYS 211 – Univ Physics, Mechanics .....	4
Humanities or Social Science Elective <sup>3,4</sup> .....	3	RHET 105 - Principles of Composition or .....	
GE 101 - Engineering Graphics & Design or .....		GE 101 - Engineering Graphics & Design <sup>1</sup> .....	4-3
RHET 105 - Principles of Composition <sup>1</sup> .....	3-4	Total	17-16
Total .....	15-16	*Biological Version Recommended	

### SECOND YEAR

ABE 221 - Agr and Bio Engineering I .....	4	ABE 222 - Agr & Bio Engineering II .....	4
MATH 241 - Calculus III .....	4	MATH 385 - Intro Differential Equations .....	3
PHYS 212 - Univ Physics, Elec & Mag.....	4	PHYS 213 - Univ Physics, Thermal Physics .....	2
TAM 210 - Intro to Statics or TAM 211 - Statics <sup>5</sup> .....	2-3	TAM 212 - Introductory Dynamics .....	3
CS 101 - Intro to Computing, Eng & Sci .....	3	Biological and Natural Sciences Elective <sup>6</sup> .....	3-4
Total .....	17-18	Total .....	15-16

### THIRD YEAR

Agricultural Engr Technical Elective <sup>7</sup> .....	3	Agricultural Engineering Technical Elective <sup>7</sup> .....	3
TAM 251 - Introductory Solid Mechanics .....	3	TAM 335 - Introductory Fluid Mechanics or CHBE 421 .....	
ECE 205 - Intro Elec and Electr Circuits.....	3	or ME 310.....	4
ECE 206 - Intro Elec and Electr Ckts Lab .....	1	ME 300 - Thermodynamics or CHBE 321 Thermodynamics <sup>5</sup> ..	3-4
ABE 440 - Applied Statistical Methods I5, CEE 202, STAT 400 / .....		ECON 103 - Macroeconomic Principles <sup>3</sup> .....	3
MATH 4635, or IE 300 .....	3-4	Biological and Natural Sciences Elective <sup>6</sup> .....	3-4
Humanities or Social Science Elective <sup>3,4</sup> .....	3	Total .....	16-18
Total .....	16-17		

**FOURTH YEAR**

ABE 430 - Project Management .....	2	Agricultural Engr Technical Elective <sup>7</sup> .....	3
Agricultural Engr Technical Elective <sup>7</sup> .....	3	Technical Elective <sup>7</sup> .....	4
Technical Elective <sup>7</sup> .....	4	Humanities or Social Sciences Elective <sup>3,4</sup> .....	6
Humanities or Social Science Elective <sup>3,4</sup> .....	3	Free Elective <sup>4</sup> .....	3
Free Elective <sup>4</sup> .....	3	Total .....	16
Total .....	15		

**TOTAL HOURS FOR DEGREE. . . 128**

<sup>1</sup> RHET 105 may be taken in the first or second semester of the first year as authorized. The alternative is GE 101. Students may take SPCM 111 and 112 in place of RHET 105.

<sup>2</sup> Math 220 – Calculus may be substituted, with four of the five credit hours applying toward the degree. Math 220 is appropriate for students with no background in calculus.

<sup>3</sup> Students must satisfy the 18-hour social sciences and humanities requirements of the College of Engineering, including ECON 102, 103 or ACE 100 and the campus general education requirements for social sciences and humanities.

<sup>4</sup> One elective course must satisfy the General Education Advanced Composition requirement.

<sup>5</sup> The extra hour of credit for this course may be used to help meet free elective requirements.

<sup>6</sup> Students must complete at least 7 hours from the Biological and Natural Sciences approved list.

<sup>7</sup> Students must complete 20 hours of technical electives; at least 12 hours must be from ABE courses and the remainder selected from the department approved Technical Electives List.

**Biological and Natural Sciences (7 hours minimum)**

ATMS 421	Earth Systems Modeling .....	4	IB 203*	Ecology .....	4
CHEM 232	Elementary Organic Chemistry I .....	3	IB 452*	Ecosystem Ecology .....	3
CHEM 233	Elementary Organic Chemistry Lab I .....	2	MCB 150	Molecular and Cellular Basis of Life .....	4
CHEM 332*	Elementary Organic Chemistry II .....	3	MCB 151	Molecular and Cellular Laboratory .....	1
CPSC 261	Biotechnology in Agriculture .....	3	MCB 250*	Molecular Genetics .....	3
CPSC 265*	Genetic Engineering Lab .....	3	MCB 250*	Molecular Genetics .....	3
FSHN 274	NonMajors Food Microbiology .....	1	MCB 409*	Bioinformatics and Func Genomics .....	3
FSHN 414*	Food Chemistry .....	3	MCB 426*	Bacterial Pathogenesis .....	3
FSHN 461*	Food Processing I .....	3	MCB 450*	Introductory Biochemistry .....	3
FSHN 462*	Food Processing II .....	3	NRES 219	Principles of Ecosystem Mgmt .....	3
FSHN 471*	Food and Industrial Microbiology .....	3	NRES 419*	Env and Plant Ecosystems .....	4
GEOG 406*	Fluvial Geomorphology .....	4	NRES 420*	Restoration Ecology .....	4
GEOG 468*	Biological Modeling .....	3-4	NRES 427	Modeling Natural Resources .....	4
GEOG 469*	Spatial Ecosystem Modeling .....	3-4	NRES 439*	Env and Sustainable Dev .....	3
IB 203*	Organismal & Evolutionary Biol .....	4	NRES 456*	Integrative Ecosystem Mgmt .....	3

\* Students interested in these courses should be mindful of sequencing the required prerequisites  
Other courses with a strong biological or biotech content may be approved by advisor

**Technical Electives (20 hours minimum)**

**Agricultural Engineering Technical Electives; at least 12 hours from:**

ABE 374	Env Control for Bio Buildings .....	3	ABE 459	Drainage and Water Management .....	3
ABE 397	Independent Study .....	1-4	ABE 469 <sup>x</sup>	Industry-Linked Design Project .....	3
ABE 425 <sup>#</sup>	Eng Measurement Systems .....	4	ABE 476	Indoor Air Quality .....	3
ABE 436	Renewable Energy Systems .....	3	ABE 479	Design of Agr & Bio Structures .....	3
ABE 455	Erosion and Sediment Control .....	2	ABE 485	Food and Process Eng Design .....	2
ABE 456	Land and Water Resources Engineering .....	3	ABE 497	Independent Study .....	1-4
			ABE 498	Special Topics* .....	1-4

\* All students must take this course. Includes major design experience.  
 † This course is strongly recommended.  
 \* Several new biological engineering courses are currently being taught as ABE 498: i.e. ABE 498 LFR Engrg Life Support Systems; ABE 498 KB Engineering Application of Nano-Scale Biology; ABE 498 PK Non-Point Pollution- Processes and Control; ABE 498 MH Landscape Water Management; ABE 498 RC Nonpoint source pollution modeling

**Other Technical Electives; remainder of the 20 hours from list below or any 300 or 400 level engineering course approved by advisor:**

CEE 330	Environmental Engineering .....	3	CHBE 321*	Thermodynamics .....	4
CEE 430*	Ecological Quality Engineering.....	2	CHBE 421*	Momentum and Heat Transfer .....	4
CEE 431*	Biomonitoring.....	3	CHBE 422*	Mass Transfer Operations.....	4
CEE 432*	Stream Ecology.....	3	CHBE 471	Biochemical Engineering.....	3
CEE 437*	Water Quality Engineering .....	3	CHBE 472	Techniques in Biomolecular Engineering...	3
CEE 444*	Env Eng Principles, Biological.....	3	MSE 498	MatSE for Sustainability.....	3
CEE 449*	Environmental Engineering Lab.....	3	TAM461	Cellular Biomechanics .....	4
CHBE 221	Principles of CHE.....	3			

\* Students interested in these courses should be mindful of sequencing the required prerequisites  
 Other courses may be approved with consent of your advisor.

Updated: 1/9/2008

Notes to advisors and students:

yellow : ecological engineering

green: nano-scale biological engineering

blue: food and bioprocess engineering → might be good to make this into bioreactor engineering → or life support system engineering

purple: bioenvironmental engineering → related to life support engineering and bioreactor engineering

white: supports more than one of the above

▪ **Biological Engineering (Concentration) under Development in the Department of Agricultural and Biological Engineering, University of Illinois**

First Year						
First Semester			Second Semester			Totals
Course Number	Description	Hours	Course Number	Description	Hours	
ABE 100	Intro to Agricultural & Biological Engineering	1	ABE 141?	Intro to Engineering Biological Systems	2	
ENG 100	Engineering Lecture	0	MATH 231	Calculus II	3	
GE 101 or RHET 105	Engineering Graphics & Design or Principles of Composition	3	CHEM 104	General Chemistry II	3	
MATH 221	Calculus I	4	CHEM 105	General Chemistry Lab II	1	
CHEM 102	General Chemistry I	3	PHYS 211	Univ Physics, Mechanics	4	
CHEM 103	General Chemistry Lab I	1	GE 101 or RHET 105	Engineering Graphics & Design or Principles of Composition	4	

	Humanities or Social Science Elective	3				
TOTAL		15			17	32
<b>Second Year</b>						
First Semester		Hours	Second Semester		Hours	
ABE 221	Agricultural Engineering	4	ABE 222	Biological Engineering	4	
TAM 211	Statics	3	TAM 212	Introductory Dynamics	3	
MATH 241	Calculus III	4	MATH 285	Intro Differential Equations	3	
PHYS 213	Univ Physics - Thermal	2	MATH 225	Matrix Theory	2	
CS 101	Intro to Computing, Eng & Sci	3	PHYS 212	Uni Phys - Elec Mag	4	
TOTAL		16			16	32
<b>Third Year</b>						
Course Number	Description	Hours	Course Number	Description	Hours	
ABE 341?	Heat, Mass Transfer, and Momentum Principles of ABE I	3		Biological Engineering Technical Elective	3	
CHEM 232	Elem. Organic Chem	3	ECE 205	Intro Elec and Elctr Circuits	3	
ECON 103	Macroeconomic Principles	3	CHBE 321	Thermodynamics	4	
MCB 150	Molec & Cellular Basis of Life	4		Humanities or Social Science Elective	3	
	Humanities or Social Science Elective	3		Free Elective	3	
TOTAL		16			16	32
<b>Fourth Year</b>						
Course Number	Description	Hours	Course Number	Description	Hours	
ABE 430	Project Management	2	ABE 469	Capstone Design	4	
	Biological Engineering Technical Elective	3		Biological Engineering Technical Elective	3	
	Technical Elective	2		Technical Elective	3	
	Biological & Natural Sciences Elective	3		Biological & Natural Sciences Elective	3	
	Humanities or Social Science	3		Humanities or Social Science	3	

	Elective			Elective		
	Free Elective	3				
TOTAL		16			16	32
TOTAL						128
	<b>Current requirement</b>	<b>Proposed Requirements</b>	<b>Current Total</b>	<b>Notes</b>		
Humanities and Social Sciences	18	18	18	18 including ECON 103, same as before		
Technical Electives	20	18	18			
BE Technical Electives	12	13	13			
Biological & Natural Science Elective	7	13	13	13 including MCB 150 and CHEM 232		
Free Electives	6	6	6	same as before		
Total Credits	128	128	128			

Course Number	Note
ABE 100/141?	We see significant challenges in first couple of terms, establishment of the learning community is very important. Teach to accept as ex cathedra for some basic science stuff—they have to trust us. (e.g. why do we need orgo.)
ABE 221	possibly need to focus on delivering materials that were clubbed from other courses including, Mass and Heat Transfer, Mechanics of Materials and Statistics
ABE 222	possibly need to focus on delivering materials that were clubbed from other courses including, Mass and Heat Transfer, Mechanics of Materials and Statistics
ABE 141?	possibly need to focus on delivering materials that may be required for upper level science classes
ABE 341?	Clubbed approach to offering heat, mass transfer, and momentum for ABE
ABE 440	currently deleted from compulsory list
ABE 469	Is to be updated to accommodate the capstone needs of all curricula
All technical electives	possibly need to focus on delivering materials that were clubbed from other courses including, Mass and Heat Transfer, Mechanics of Materials and Statistics
TAM 251	Currently deleted from compulsory list
ABE 441?	Advanced clubbed approach to offering heat, mass transfer, and momentum for ABE—such an advanced course could be a technical elective and useful for some ABES

▪ **Educational information on Biological Engineering at Virginia Tech**

Definition/Mission

The mission of the BSE Department is to develop and disseminate engineering knowledge and practices that protect natural resources and improve sustainable production, processing, and utilization of biological materials.

### Program Objectives

The overall educational goal of the BSE program is to graduate biological systems engineers to support sustainable production, processing, and utilization of biological materials and to protect natural resources. The BSE program seeks to prepare its graduates to become successful in the practice of biological systems engineering or in the pursuit of advanced degrees in BSE or other complementary disciplines.

### Career Opportunities

Pharmaceutical firms, energy firms (bioenergy), food processing, biotechnology, Environmental consulting companies, environmental protection agencies, Medical school, veterinary school, graduate school, Peace Corps

### Specialisations/Options

Bioprocess Engineering and Land and Water Resources Engineering

### ▪ Program of studies on Biological Engineering at Virginia Tech

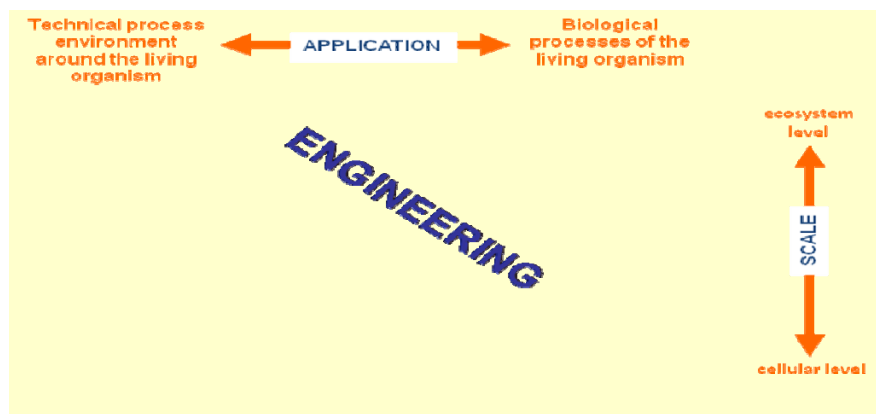
<i>Mathematics</i>	MATH 1205: Calculus I MATH 1114: Elementary Linear Algebra MATH 1206: Calculus II MATH 1224: Vector Geometry MATH 2224: Multivariable Calculus MATH 2214: Differential Equations
<i>Science</i>	CHEM 1074: Chemistry for Engineers CHEM 1084: Chemistry for Engineers Lab PHYS 2305: Foundations of Physics I PHYS 2306: Foundations of Physics I CHEM 2514 or 2565: Organic Chemistry BIOL 1105: Principles of Biology BIOL 1106: Principles of Biology BIOL 2604&2614: General Microbiology & Lab or CSES 3114&3124: Soils & Soils Lab CHEM3615: Physical Chemistry or BSE 3305 Land & Water Res. Engr.
<i>Engineering Science</i>	ESM 2104: Statics ESM 2304: Dynamics ESM 2204: Mechanics of Deformables BSE 3154: Thermodynamics of Biological Systems ESM 3024: Fluid Mechanics ECE 3054: Electrical Theory
<i>Biosystems Engineering/Biological Systems Engineering</i>	BSE 2105-2106: Introduction to BSE BSE 3134: Biological Systems Engineering Seminar BSE 3504: Transport Processes in BSE BSE 4004: Instrumentation & Exp. Mechanics BSE 3524: Unit Operations in BSE or BSE 3306: Land & Water Res. Engr. BSE 4125-4126: Comprehensive Design Project
<i>Specialization: Food and Process Engineering/Bioprocess Engineering</i>	BSE 3524 Unit Operations BSE 4504 Bioprocess Engineering

	BSE 4544 Protein Separation Engineering BSE 4604 Food Process Engineering BSE 4514 Industrial Bioprocessing BSE 4524 Bioprocessing Plant Design
<i>Specialization: Environmental Engineering/Land and Water Resources Engineering</i>	BSE 3305: Land & Water Res. Engr. BSE 3306: Land & Water Res. Engr. BSE 4304: NPS Pollution Modeling & Management BSE 4344 Geographic Information Systems for Engineers CEE 3104 Introduction to Environmental Engineering

## 2. Provide information on current educational development trends of Biological/Biosystems engineering academic program(s) in EU

### ▪ Educational trends of the K.U.Leuven program on Biosystems Engineering

The focus of the courses in Biosystems Engineering at the K.U.Leuven has been shifting the last recent years. Whereas the more classical agricultural engineering courses (e.g. machinery, building constructions, climate control, product handling, etc.) are still taught, there are trends in the courses 1) from studying the technical process environment around the living organisms towards studying the biological processes of the living organism and 2) from studying systems on an ecosystem level towards the cellular level (multi-scale concept) (Fig. 1).



**Figure 1.** Schematic overview of trends in courses of the Biosystems engineering program at the K.U.Leuven.

However, the trend of the program at the K.U.Leuven is not to remove the agricultural engineering, but is rather to extend the courses from agricultural engineering with more biological engineering.

To deepen the understanding of the interaction between technological and biological systems and processes, the importance of quantitative modelling increased dramatically during the last two decades. This can go from black box input-output models derived with systems identification techniques, to detailed mechanistic models based upon (bio)physical laws.

Since biological systems are assembled in different levels of organization which are all interconnected with each other (e.g. a mammal, on the highest level living in an ecological

system, has for example a digestive system composed the following pieces in downscaling order: organs, tissue, cells, cell organells, biomolecules, ...).

To crystallize the importance of the multiscale concepts in biological systems analysis, the K.U.Leuven is investigating the potential of introducing a new module in the curriculum of biosystems/biological engineering encompassing these multiscale modeling concepts.

This module with the provisional title “Biological engineering” will encompass the issues as described in Table 2. Discussions are started about the following issues:

1. how to put this module in a general framework such that more curricula can include it in their education;
2. how to organize these issues in courses: courses per scale or courses encompassing different scales (e.g. multiscale biomechanics, multiscale biophysics, ...)

**Table 2:** Module Biological engineering

Issues	Content
Nanobiophysics	Non-equilibrium thermodynamics, statistical physics
Molecular biophysics	Biopolymers, systems biology
Cellular biophysics	Computational cell biology
Tissue biophysics	Integrative systems physiology

Today the K.U.Leuven is the only university in Flanders organizing an education in Biosystems engineering. The teaching and research staff consist of 9 professors and 14 postdoctoral research engineers represented by two divisions: MeBioS (Mechantronics, Bio-statistics and Senors) and M3BIORES (Measure, Model & Manage Bioresponses), currently housing more than 80 researchers. Both divisions belong to the Department of Biosystems.

The planned extension in the courses from the more classical agricultural engineering towards biological engineering is strongly related with a similar shift in the research activities of the main research groups responsible for organising the courses in Biosystems engineering (cfr. Task 4).

The different courses directly related to the curriculum Biosystems engineering are currently organized into 6 modules which are given in table 3.

▪ **Program of studies of the K.U.Leuven program on Biosystems Engineering**

**Table 3:** Modules and courses in the education Biosystems Engineering

Modules	Courses
Mechanisms	Machine kinematics and dynamics (BSc)
	Precision technology for crop production (MSc)
	Mechanical unit operations (BSc)
	Design and construction techniques incl. CAD/CAE (BSc)
Bio-environment	Sustainability in buildings for production (MSc)
	Bio-omgevingsbeheersing (BSc)
Transport processes	Transport phenomena (BSc)

	Multiscale transport phenomena in biosystems (MSc) Physical processes in handling biological products (MSc)
Systems analysis and design	Systems analysis (MSc) Integration of biological responses in process management (MSc) Mechatronic design of biotechnical processes (MSc) Sensor technology and bio-electronics (MSc) Electronic instrumentation (BSc) Mens en technieken (MSc)
Applied physics and mathematics	Physical properties of biomaterials (BSc) Optics, lasers and acoustics (MSc) Applied thermodynamics (MSc) Strength of materials (BSc) Applied mathematics (MSc) Applied multivariate statistical analysis (MSc)
Management of bio- and agro-systems	Quality control and process and chain management (BSc)

▪ **Educational information on Biological Engineering at University College Dublin**

Definition/Mission

Biosystems Engineering is the 'industry of the 21st century', revolutionising the production, processing and manufacture of biological materials through new engineering technologies.

Program Objectives

The overall objective is to equip you with the analytical skills necessary for you to develop successful professional careers within the bioresource and related industries both at home and abroad.

Career Opportunities

Bioprocess and food companies, Consulting engineering, environmental protection agencies and information technology groups, Typically commence your careers with a strong technological orientation and later progress into a wide diversity of fields

Specialisations/Options

Food and process engineering, Environmental engineering, Mechanisation and renewable energy systems

▪ **Program of studies on Biological Engineering at University College Dublin**

<i>Mathematics</i>	MATH10150 Mathematics for Engineers I MATH10160 Mathematics for Engineers II MATH10170 Mathematics for Engineers III MATH20240 Mathematics for Engineers: Calculus of Several Variables STAT20060 Mathematics for Engineers V
<i>Science</i>	CHEM10030 Chemistry for Engineers PHYC10150 Physics for Engineers I PHYC10160 Physics for Engineers II
Electives	ANSC20030 Principles of Animal Science CPSC20030 Principles of Crop Science FDSC20010 Agricultural Chemistry I INDM20010 Agricultural Microbiology
<i>Engineering Science</i>	EEEN10010 Electronic and Electrical Engineering I MEEN10030 Mechanics for Engineers MEEN10010 Engineering Thermodynamics and Fluid Mechanics MEEN20010 Mechanics of Fluids I MEEN20040 Mechanics of Solids I EEEN30110 Signals and Systems MEEN30100 Engineering Thermodynamics II
<i>Biosystems Engineering/Biological Systems Engineering</i>	BSEN10010 Biosystems Engineering Design Challenge BSEN20060 Food Physics BSEN20040 Literature Research Project BSEN30010 Bioprocess Engineering Principles BSEN30250 Biosystems Engineering Design Project BSEN30270 Biosystems Engineering Major Project
<i>Specialization: Food and Process Engineering/Bioprocess Engineering</i>	BSEN30230 Unit Operations in Bioprocess Engineering BSEN30090 Food Refrigeration Systems BSEN30120 Food Quality and Safety Assurance BSEN30320 Food Process Engineering
<i>Specialization: Environmental Engineering/Land and Water Resources Engineering</i>	BSEN30240 Waste Management BSEN30220 Soil Engineering BSEN30280 Environmental Engineering BSEN30020 Buildings Design and Construction BSEN30030 Buildings Environmental Control
<i>Specialization: Mechanisation and renewable energy systems</i>	BSEN20050 Computer and Manufacturing Technology BSEN30310 Biofuels & Renewable Energies BSEN30190 Power and Machinery Systems BSEN30180 Power and Machinery – Control BSEN30210 Precision Agriculture BSEN30170 Power & Machinery - Advanced Mechanisation

### 3. Provide information on research issues from one or two example US Biological /Biosystems engineering academic program(s)

#### ▪ Research information on Biological Engineering at the University of Illinois

##### Overview

Agricultural Mechanization has been ranked as one of the greatest engineering achievements of the 20<sup>th</sup> 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*.

Domains of ABE (as opposed to human health emphasized biomedical engineering or bioengineering)

The ABE disciplinary relevance and impact areas include:

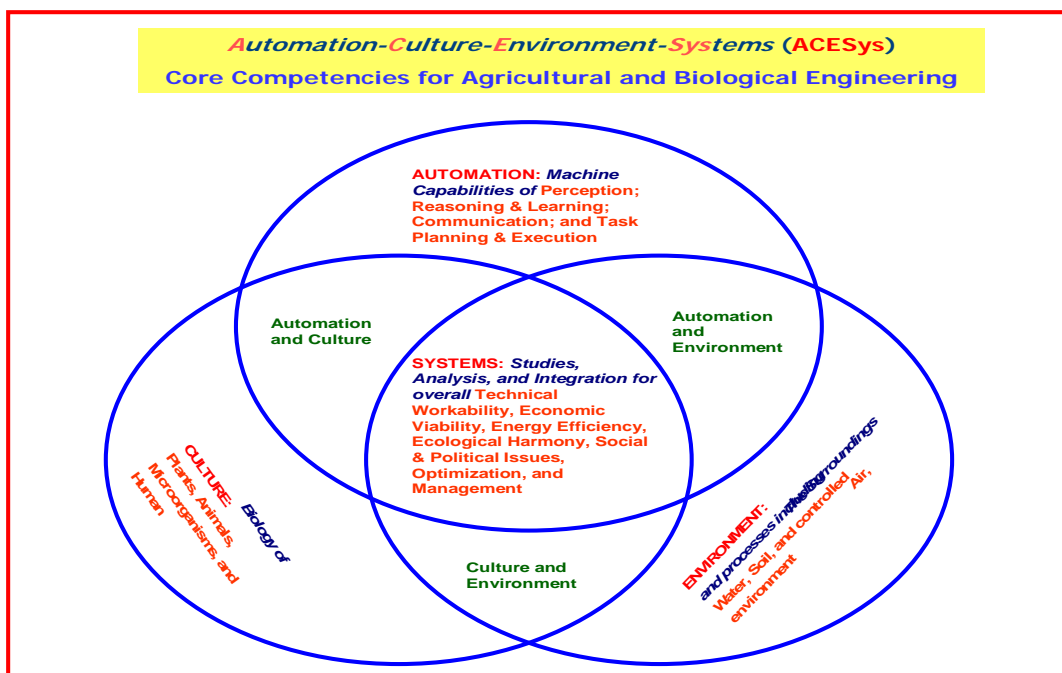
Bio-Based Processing and Production Systems;

- 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; and
- Advanced Life Support Systems.

### 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's 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, modeling, 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.

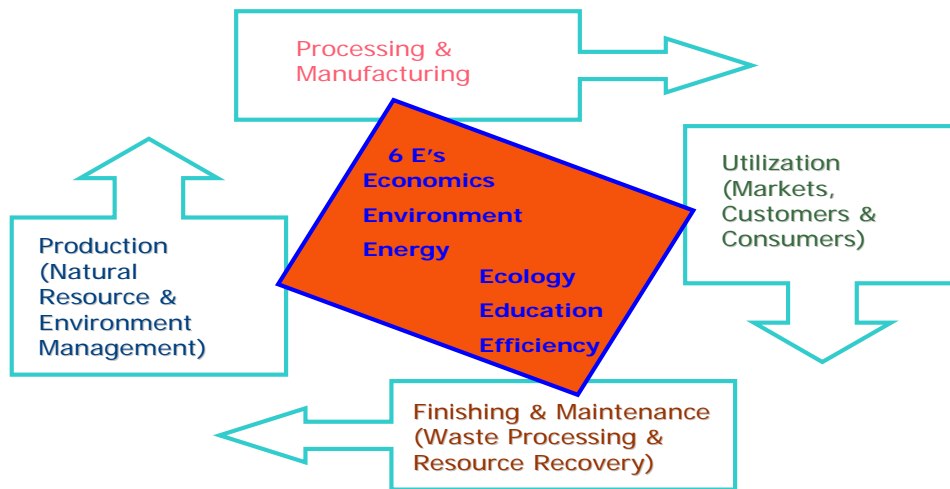
Environment encompasses the surroundings and processes of biological objects, which consist of climatic and nutritional, as well as structural/mechanical conditions. Understanding, delivery, and control of environmental factors have been perceived as a major engineering challenge in agricultural production 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's 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: (1) information about individual system components as well as their interrelationships and (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 studying agriculture has required that the entire food system (including the production of fresh materials to the consumption by end-users), the impact to environment, and effective use of energy be taken into consideration.

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.

#### 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.** 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 are of particular importance in sustaining and advancing this very large and complex bio-based economic engine.

**Initiative 1: Agricultural Automation** – including machine intelligence of perception, reasoning & learning, communication, and task planning & execution.

**Initiative 2: Bio-Energy and Bio-Products** – including production of bio-fuel, bio-power, and bio-materials. Example research and development activities are ethanol production, bio-diesel properties and engine performance, thermochemical conversion of biomass to crude oil, engineering solutions for biomass feedstock production, and systems integration and analysis.

**Initiative 3: Sustainable Environment** – including information and analytical tools, processes, simulation, and socioeconomic considerations.

**Initiative 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).

**Initiative 5: Systems Informatics and Analysis** – including complex design techniques, decision support, early reliability measurement techniques, holistic agro-ecosystem perspectives, multi-scale modeling, and sustainable development.

All of the above focus areas have biological contents and incorporate systems management and safety/health dimensions. Specific emphases include:

**Indoor air quality**

Air cleaning technologies for indoor environments and reducing emissions  
Characterization of indoor air flows  
Measurement and modeling of airborne pollutants

**Heating, ventilation and air-conditioning (HVAC)**

Volumetric particle tracking velocimetry (VPTV)  
Sensor technology , system simulation and control

**Biofuel conversion**

Thermochemical conversion (TCC) process to produce oil from biomass  
Livestock waste management

**Engine Emission Controls**

Selective catalytic reduction (SCR)  
Control strategies for reducing NOx and PM

**Equipment testing**

Fans, Fume hood, air diffusers,  
Air handling equipment for agricultural, medical and lab animal facilities

**Corn wet milling process**

Enzymatic milling to reduce sulfur dioxide use and control microbial contamination  
Enzymatic milling to reduce steep time

**Dry grind ethanol process modifications**

Quick-germ, quick-fiber  
Quick-protein – protein rich fraction for zein extraction  
Reduction of phosphorous from DDGS to increase value of DDGS  
Membrane filtration to conserve water and recover nutrients  
Effect of milling parameters on fiber removal from DDGS

**Hybrid specific processing**

Hybrid variability and planting location effects on ethanol yields  
Use of transgenic corn with endogenous amylase

**Rapid measurement of starch and grain properties**

RVA viscosity measurements of starch  
Near-infrared reflectance and transmission for extractable and fermentable starch and soybean fatty acids and isoflavones

### **Biofuels and Bioenergy**

Computation of biofuel properties

Biodiesel combustion and emissions modeling

Emissions reducing technologies for biofuels

Engineering solutions for biomass feedstock production

### **Off-road multi-vehicle system optimization**

Decision support system for grain harvesting using wireless data communication

Inter-vehicle data communication for increased system functionality

### **Autonomous vehicle guidance systems**

Stereovision systems

Sensor fusion for vehicle guidance

### **Diagnostic/prognostic systems for off-road machinery**

Fault detection in fluid power circuits

### **Sensor technology and system control**

Granular mass flow measurement devices

Biosensors

### **Robotics for in-field applications**

### **Remote sensing for agricultural applications**

Unmanned Aerial Vehicles

### **Conservation Drainage**

Water Table Management

Drainage System Design

### **Erosion and Sediment Estimation and Control**

Basic Erosion Mechanisms

Rainfall Simulation

### **Water Quality & Land Use**

Effect of Crop Production on Drainage Water Quality

BMP Effectiveness

Cryptosporidium Movement in Surface Runoff

Environmental Assessment of Military Firing Ranges

## Hydrologic Processes

Effect of Drainage Systems on Watershed Response

Partitioning of Streamflow in Drained Watersheds to Flow Sources

## Biosystems; Bioinformatics; Nanobiotechnology; Biosensors; Bioinstrumentation

### 4. Provide information on current research development trends of Biological / Biosystems engineering academic program(s) in EU

#### ▪ Research trends of the K.U.Leuven program in Biosystems Engineering

The research staff in Biosystems Engineering consist of 9 professors and 14 postdoctoral research engineers represented by two divisions: MeBioS (Mechantronics, Bio-statistics and Sensors) and M3-BIORES (Measure, Model & Manage Bioresponses), currently housing more than 80 researchers. Both divisions belong to the Department of Biosystems of the Faculty of Bioscience Engineering.

The research in both divisions has evolved significantly the last few years. Hereafter we describe the main evolutions and trends for MeBioS and M3-BIORES.

#### MeBioS

##### **Mission Statement**

To investigate the interaction between biological systems and physical processes

Emphasis on: (1) Measurement of biomaterial properties and process variables, (2) Analysis of measured signals and (3) Process design and control.

The activities of MEBioS are structured into expertise groups, research groups and valorization groups. Expertise groups bring together those researchers within MeBioS that are active in a research domain. Expertise groups *are supervised by a postdoctoral researcher*

Research groups should contain sufficient critical mass to perform research on top level. Research groups are oriented towards an application domain and their mission is to use the knowledge of the expertise groups in industrial problems of the agro-food industry with a midterm or long term horizon. Research groups are supervised by a professor.

At last, in continuation of the research groups, we have the valorization groups that provide technological advice to companies and search for solutions of short term or midterm problems. Research groups are supervised by a postdoctoral researcher.

##### **Expertise groups**

**Biomaterials science:** The overall aim of this group is to understand the physical properties of agricultural products (vegetable or animal) and the way these properties change during the entire food production chain. The group has specific expertise on optical, transport, mechanical and thermal properties of biological materials and is investigating tomographical methods to quantitatively describe their microstructure. An important aspect is to construct and validate mathematical models, based on physical and biological basic mechanisms, of the mechanical

behaviour of biological materials. Hereto a multiscale approach is followed and mechanical properties of biomaterials are characterised at all appropriate length scales (from nano- to macroscale). The coupling of mechanical properties with transport properties and biological processes is major challenge.

**Biostatistics:** The increasing complexity of signals which are measured by sensors, the increasing acquisition frequency and the inherent biological variability of products and processes causes an increasing complexity of the resulting data structures. In this research group novel advanced techniques for statistical data analysis are developed which account for the particular properties of such datasets and their high dimensionality, such as multivariate statistics for signal analysis (chemometrics) and the analysis of repeated measures or a combination of both. Special emphasis is paid towards a correct description of biological variability. On a larger scale the integration of different sensors, data acquisition and analysis (multivariate statistical process control) leads to a general concept of chain management and control (traceability, integral chain management) for the optimisation of the logistic chain between producer and consumer.

**Biosystems dynamics:** System dynamics involves a structural way of thinking which unifies different principles and laws from several disciplines. It helps to understand the structure in systems and puts the relation between cause and consequence, mostly supported by a mathematical model. An application of system dynamics is bio-mechatronics, in which biological, mechanical, electrical, pneumatic and hydraulic systems are integrated. In the division, bio-system dynamics is mainly applied to model, analyse and control machines and bio-technical installations. The biological product determines the boundary conditions, e.g. forces which may not be exceeded in order to avoid crop damage, maximal machine motions. Actually, a higher degree of integration of the biological factor is pursued, by incorporating the dynamics of biological processes and transport phenomena in the mathematical model. Research activities are located in the area of system identification, parameter estimation, dynamics and control of non-linear and distributed bio-technical systems.

**Sensor technology:** involves the development and application of measurement techniques for physical (pressure, temperature, force, ...) and chemical (pH, soluble solids, vitamins, ...) quantities of biomaterials and –processes. The emphasis is on fast, simple and if possible non-destructive techniques for quality attributes (aroma, taste, firmness, ...) of biological products, that can replace the laborious, time consuming and expensive traditional analysis techniques. The division has expertise in a broad range of measurement principles, such as spectroscopy (UV-VIS, NIR and IR, fluorescence), biomimetic sensors (electronic noses and tongues) and acoustic resonance sensors (firmness).

Special attention is paid to the development of biosensors in which biorecognition elements, such as enzymes, aptamers and antibodies, are immobilized on a transducer surface to translate the biological signal into an electric signal. The latter can be further analysed with the appropriate biostatistical techniques.

**Transport phenomena:** Transport phenomena are a significant aspect of production, preservation and processing of agro-food products. Transport phenomena encompass heat transfer (e.g., cool rooms, ovens), mass transfer (e.g., air and moisture in cool rooms, oxygen uptake in fruits) and particulate mechanics processes (e.g. granular fertilizer spreading, handling

and conveying of grains, tubers and fruits, powder processing). The research group follows a model-based approach to describe transport processes by means of a wide range of available modelling techniques (continuous/discrete simulation, network modelling, finite and discrete element simulation, computational fluid dynamics, Monte Carlo methods). The models are used for understanding the behaviour and performance of products, process design, process optimisation and process control. The group also has expertise in the required measurement techniques including thermometry, velocimetry, gas analysis, and experimental techniques for granular systems and powders. Special emphasis is put on modelling of processes at different spatial scales (multiscale modelling), ranging from nano-features to the full scale of a complete industrial process.

### **Research groups**

**Precision systems in biological engineering:** *the overall aim of this groups is the study of the dynamical behaviour of cellular systems and tissues, the study of the dynamical behaviour of biological products and functional systems in living organisms (human, animal, plant), the study of the dynamical interaction between those biological products and systems and their technical environment (machines and fine-mechanical parts) and the optimization of this interaction process in a bio-mechatronic design.*

**Post harvest technology:** focus on the application of advanced engineering concepts to improve the storage life and quality of fresh fruit and vegetables through appropriate storage technologies and supply chain management.

**Food quality:** development and implementation of sensors to monitor food quality throughout the biological production chain. Research is being conducted with respect to biomimetic sensors (electronic noses and tongues), biosensors (lab-on-a-chips, optical taste sensors, enzymatic biosensorarrays, etc.) and acoustic firmness sensors.

**Food safety:** focuses on the discipline *predictive microbiology that deals with the development of accurate and at the same time versatile mathematical models describing the microbial evolution (growth, survival, inactivation) in food products as a function of intrinsic conditions (like acidity) and environmental conditions (like temperature). Predictive microbiology has interfaces with several food safety management systems: HACCP (Hazard Analysis and Critical Control Points), Risk Analysis/Risk Assessment and, more recently, Food Safety Objectives and Performance Objectives.*

### **Valorization groups**

**Flanders Centre for Postharvest Technology:** The mission of the Centre is to co-ordinate and carry out basic and applied research in the area of storage and quality of fruit and vegetables. The main research topics are: (i) storage physiology, (ii) transport of heat, gasses and moisture during storage, and (iii) quality of horticultural produce. Besides the development of novel measurement techniques and the mathematical modelling of the underlying biophysical and biochemical phenomena, much attention is paid to the practical implementation of the research results.

**CADCracker:** A scientific engineering service for the food and related industries to help solving questions of heat and mass transfer in relation to food quality and safety by means of advanced

Computer Aided Design (CAD) techniques, measurement of process variables and quality attributes and through project management support.

Flanders Network for Particle Technology: The field of particle technology covers a myriad of scientific and engineering subjects. Different types of materials are involved, such as dry particles, colloids and suspensions, as well as a variety of thermo- and physicochemical processes and unit operations. Industrial applications abound in the technology sector, chemical industry, food industry, pharmaceuticals and others. Yet, Flanders was lacking an active forum where cross-fertilization between scientific research and industrial application could take place. To fill in this gap is the ambitious goal of the Flemish Network for Particle technology VNPT wants to constitute a network between industry and academia that effectuates synergies, transgressing the boundaries between industrial sectors, and leads Flanders' companies to innovation and increased competitiveness.

Qualimatrix: Since many years, the development of mechatronic systems, new sensor technologies and advanced statistical techniques form the core business of the MeBioS division. Concerning sensor technologies, a shift towards fast, non destructive and miniaturized sensors can be observed. These sensors are only useful if the information originating from them is optimally used. Qualimatrix therefore aims at combining the knowledge of the Biostatistics and Sensor technology groups in order to excel in industrial quality and process optimization using state-of-the-art sensors and statistics.

M3-BIORES

### ***Mission statement***

M3-BIORES ultimately aims at contributing to an improved welfare of living organisms by integrating on-line measured information of organisms in the monitoring and control of biological processes.

M3-BIORES achieves this goal on the basis of three activities.

**Research**, fundamental as well as applied, on the following activities:

- Measuring and modelling of energy and mass transfers in micro-environmental processes.
- Measuring and modelling of dynamic biological responses of man, animals, plants and products to the micro-environment.
- Integration of biological responses in the monitoring and control of bio-environmental processes.

**Education** in bio-environmental process control to form highly skilled engineers and to attract competent collaborators.

**Public service** by informing and advising stakeholders and translating our scientific results into products for bio-process control and this in close co-operation with industry.

### ***Short history***

The Division Measure, Model & Manage Bioresponses (M3-BIORES) started more than 30 years ago with research in the field of construction and renovation of agricultural buildings (known at that time as the Laboratory for Agricultural Buildings Research, LAB). Quite soon, the research

was extended to the study of climate control inside agricultural constructions (such as stables, greenhouses, storerooms, etc.). From 1991, the study of the micro-environmental processes was coupled with biological responses of the living organisms to their environment. Some years ago, a group on geomatics engineering joined LAB to form the division M3-BIORES. Today the research in M3-BIORES concentrates mainly on three topics, namely 1) modelling, monitoring and controlling of the micro-environment around living organisms, 2) measuring, modelling and management of biological responses of living organisms to their process environment and 3) modelling of effects of solar energy on vegetation systems. For four years, M3-BIORES has also served as a Marie Curie Training site in the field of bioresponse modelling for EU PhD students.

### ***Expertise groups***

**Modelling, monitoring and controlling of the micro-environment around living organisms.** In relation with the first topic, M3-BIORES is for long working on modelling of micro-environmental variables as a function of global control inputs such as ventilation rate, incoming air temperature, and flow direction. Based on previous studies, it has been found out that many physical environmental variables (e.g. air velocity, temperature, relative humidity) are rarely uniformly distributed in confined spaces (such as animal houses, green houses, etc.). In the majority of the applications in practice, although environmental control is achieved using one or limited number of measurement units, online control of 3D micro-environment has never been achieved. In most of the field applications, management of 3D spatial control is based on empirical knowledge and years of hands-on experience. One of the key research activities is to develop model-based control strategies for controlling 3D physical climate variables in processes of different scales (from a volume of 0.072 x 0.026 x 0.020 m until a volume of 12 x 4 x 5 m). These environmental processes are studied in agricultural applications such as animal houses and greenhouses, in incubation processes and food industry, but since five years the trend is to extend this research towards human applications such as monitoring of climate characteristics under safety helmets for cyclists, climate control in cars and controlling of nutrient solutions in perfusion bioreactors for tissue engineering of bone cells.

**Measuring, modelling and management of biological responses of living organisms to their process environment.** In relation with the second topic, the group has specialized in the optimisation of monitoring and control of biological processes by integration of biosignals (signals measured on living organisms which are complex, individually different and time-variant) in process management. M3-BIORES has gained a lot of expertise in the development of so called “Integrated Management Systems” for precision engineering, based on fundamental as well as applied research projects, and is internationally recognized as a pioneer in this domain (e.g. research on Precision Livestock Farming).

Since 2001, M3-BIORES has decided resolutely to extend these research activities also to human applications. This has resulted in recent years in several interdisciplinary projects. The most important today are: 1) the development of safer cycle helmets for young cyclists in collaboration with partners from Biomechanics and Neurosurgery; 2) the development of a monitor system for on-line health status monitoring of individual critical care patients with partners from Critical Care Medicine and Computer Sciences; 3) the development of an on-line pain monitoring system for elderly people suffering from severe dementia with partners from

Biomedical Technology and Medicine; 4) the development of a monitor for sleep quality with partners from Psychology; 5) the development of an on-line fitness monitor for individual cyclists together with professional trainers.

Until now, most of the research has been mainly focusing on biological systems at the organism level, but it is aimed at applying the expertise of modelling of biological systems also on smaller levels (organ, tissue, and cellular level).

**Geomatics Engineering.** The purpose of the Geomatics Engineering group is to develop new methods that contribute to a better quantitative knowledge and modelling of the interaction of solar energy with vegetation systems and the water, carbon and nitrogen cycle of agricultural and forest systems. Methods that are often applied are: numerical techniques such as earth observation, 3D process modelling and statistical procedures.

### *Valorisation*

In 1981, M3-BIORES learned for the first time the trajectory of transforming a research result into a commercial product in collaboration with an industrial partner. Since then, valorisation of scientific knowledge has been an important part in our group's mission.

Patent politics: Protection of developed scientific knowledge has a high priority in our group and this has resulted in eight patents. The patents are owned by Leuven Research & Development (K.U.Leuven) and worldwide licenses are given to complementary industrial partners for specific applications.

International collaboration with complementary scientific partners: We are convinced that a research group of our scale (around 40 people) can only do high level scientific research when there is a strong focus in research objectives. As a consequence of this focus, all our research activities are in close collaboration with complementary scientific partners, such as: ethologists, mathematicians, physiologists, medical doctors, veterinarians, etc. With these partners we share work, funding, publications, patents, royalties, etc.

Product development in collaboration with industrial partners: Since we worked on the first product in 1982 in collaboration with an industrial partner, we developed in total 9 products with several industrial partners. Besides the development of new products, we try to set up long term collaboration agreements with these partners. At the moment we have 2 such agreements and we are negotiating a third one.

Spin-off company: BIORICS N.V.: The higher mentioned long term agreements with companies are very interesting for knowledge valorisation and for keeping enough critical mass in the research group because such agreements allow to pay postdoctoral researchers. At the other side, we learned after 1982 that is not always easy to introduce really innovative products in the traditional market of the agriculture (our first application area). In addition, the last 5 years we are focusing more and more on human applications and therefore we decided to start a spin-off company: BioRICS n.v.

## **5. Compare pedagogical and scholarly emphases between US and EU Biological / Biosystems engineering academic programs**

Pedagogical and scholarly emphasis is given in the emerging Biological/Biosystems engineering academic programs in U.S. and EU in the guiding concepts and subject areas of Biological/Biosystems Engineering. In other words, understand the “what”. The core of the discipline is defined as: *“empowering human capacity with knowledge and wisdom”*.

The current key issue is defining Biological/Biosystems engineering. At the University of Illinois, for example, biological engineering is defined as “integrating life and engineering for enhancement of complex living systems (involving agriculture, food, environment, and energy).” As a learning community the major importance is placed on the quality: know how to evaluate and appreciate quality.

Emphasising quality in the pedagogical and scholar policy of the emerging Biological/Biosystems engineering academic programs in U.S. and EU is in agreement with the corresponding priorities set by the European Commission in the framework of the recent developments of the HEA of Europe.

## **6. Outline the common framework and complementary strengths for Biological/Biosystems engineering academic programs in the US and EU**

Both UIUC and KUL plan to develop within their undergraduate programs of studies a concentration/module of Biological Engineering which seems to perfectly abide to the 2008-2009 ABET criteria for 'Biological and Similarly Named Engineering Programs'.

The undergraduate degree programs in Biosystems Engineering at UCD and in Biological Systems Engineering at Virginia Tech are quite similar. The programs define Biosystems and Biological Systems Engineering similarly. As conveyed by the published program objectives and lists of potential employers, both programs are preparing their graduates for careers in the bioprocessing industry (widely defined) and environmental consulting and protection agencies.

The terminology used in analysing the example cases is a little bit confusing. The term “Agricultural and Biological Engineering” is very broad as it covers various programs of studies. It is as if we are talking about the following three sets of different programs of studies:

- a) Programs of studies in Agricultural Engineering and the emerging from these Biosystems Engineering programs of studies
- b) Programs of studies in Biological Engineering which is based on a mixture of Biotechnology and Engineering
- c) Programs of studies in Biomedical Engineering

Assuming that an Institution offers all three programs of studies then we might talk about a school or a college of Biological Engineering within a University, with three Departments (this of course may vary a lot depending on the administrative structure of each University). But, in any case, we cannot mix-up all these programs of studies in one, or talk about one discipline, meaning that it covers all subjects of the three different programs of studies.

Proposing policy measures towards the development of a common *“Agricultural and Biological Engineering”* framework in the form of one discipline with a common curricula basis covering all

three programs of studies (Agricultural Engineering, Biotechnology plus Engineering and Biomedical Engineering) will create a chaotic situation. On the top of this, we should also consider seriously that Biotechnology is a well-established discipline and Bio-medical Engineering is already offered by classical Engineering Departments which will not allow, for reasons of professional competitiveness and expected conflicts, to be developed by the former Agricultural Engineering Departments.

Of course the possibilities, the competences and the abilities of graduates of the emerging discipline of Biosystems Engineering (meant as the transition from Agricultural Engineering, including as the main core Agricultural Engineering) to work as professionals or researchers in areas of Biotechnology or Biomedical Engineering is very much welcome, expected and should be encouraged. This professional or research attitude happens all the times with all graduates of all disciplines world-wide. The borders of the programs of studies and the disciplines are fuzzy, especially when we are talking about research. However, this is a completely different issue from the issue of establishing well recognised and coherent modern programs of studies in the emerging field of Biosystems Engineering (which are also, naturally, expected to differ from country to country from institution to institution). Such programs of studies should however have a clear professional orientation that is not very fuzzy and does not promise the graduate that he will be able to compete with Biotechnologists, biomedical engineers and agricultural engineers, knowing “nothing of everything”...

A Biosystems Engineering graduate should be able to extend the engineering sciences beyond traditional agricultural applications to all living organisms (except human) applications including agriculture. Biosystems engineers must be involved in the new areas of bio-based materials, agro-fuels, biomechatronics, and assessment of food traceability, quality and safety and in the design of environmentally friendly and sustainable systems for plants, animals and natural resources.

Obviously, any Institution is free to also develop, in parallel to Biosystems Engineering, or without any Agricultural or Biosystems Engineering, other programs of studies, which could be an independent Biomedical Engineering program of studies or an independent Biological Engineering program of studies (meaning Biotechnology and all associated conflicts) but it would be a terrible confusion to talk about Biological Engineering program of studies and there to include everything: Agricultural Engineering, Biotechnology and Biomedical Engineering...

## **7. Proposed policy measures for Biological/Biosystems engineering academic programs in the US and EU**

In conclusion, the policy measures concerning the common framework should be to:

- Encourage every Biosystems Engineering educational and research program to develop a list of domains and a list of core competencies
- Promote the concept that Biosystems Engineering emphasizes “integration of life and engineering, including bringing engineering to life and bringing life to engineering”.
- Request every Biosystems Engineering program to describe its contents in biological sciences
- Explore the opportunity for Biosystems Engineering programs to engage in educating biological sciences students engineering concepts

Identify needs of industry  
(current and future employers)

### **Objective 3. Identify needs of industry (current and future employers)**

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#### **Introduction**

Both in EU and US the image of Biosystems Engineering is not yet very well known by all the stakeholders involved in this discipline, such as employers and the general public, so that the accuracy of this image needs to be improved.

This fact doesn't reflect the increasing relevance of the recent subjects of Biosystems Engineering, i.e. food supply (production, storage, processing, etc.), the significant increase of food prices, also of the fundamental products, and the development of the sectors of bioenergies and biomaterials, which became strategic in an energetic and environmental perspective.

Objective 3 of POMSEBES "Identify needs of industry (current and future employers)" requires to collect information from the current and future employers of Biosystems Engineers, that are, above all, industry representatives, in order to determine which competences Biosystems Engineering graduates require to meet the needs of industry.

Therefore, a questionnaire entitled "University - Enterprise Cooperation" was prepared and sent to several EU industries involved in Biosystems Engineering. The replies of some EU industries to this questionnaire are summarised in paragraph 3, together with the information about US employers of Biosystems/Biological Engineers and job positions that US Engineering graduates obtain upon graduation.

Generally, US "Biological Systems Engineering" departments have an external advisory committee, including several industrial members, in order to provide guidance about the needs of industry. Thus, US University staff has a good understanding of the required competences, in order to prepare their students according to the needs of industry. Unfortunately, some non-traditional industries, which could benefit from Biosystems Engineering graduates, are not aware of these ones. This fact could also imply that Universities are not appropriately designing their degree study programmes in order to meet the needs of these industries.

However, both in EU and US Biosystems Engineers are also requested by public sector, i.e. public institutions (Ministries of agriculture, environment, industry, education and foreign

affairs), local governments (regions, municipalities and national parks), for carrying out tasks related to territory monitoring, land planning, agricultural politics, co-operation with developing countries. This last employability sector must be promoted, because EU and US Biosystems Engineering graduates can provide developing countries with a significant contribution to their progress and, at the same time, citizens of these countries can be taught at EU and US Universities on the most important subjects such as irrigation, mechanisation, rural buildings, etc. [1].

Therefore, within the objective 3 the following three tasks have to be accomplished:

1. to identify ways for enhancing the visibility and the recognition of future graduates in Biosystems Engineering in US (also for EU students) and EU (also for US students);
2. to propose possible research projects in collaboration between Universities and industries or professionals or public sector, including those sectors different from Biosystems Engineering, but interacting with it;
3. to ask questions about the above first two tasks to Universities offering degree study programmes in Biosystems Engineering and to the current and future employers of each country involved in POMSEBES, such as industries, professional organisations and public sector, including those sectors different from Biosystems Engineering, but interacting with it.

### **1. Identify ways for enhancing the visibility and the recognition of future graduates in Biosystems Engineering**

The following ways for enhancing the visibility and the recognition of future graduates in Biosystems Engineering in US (also for EU students) and in EU (also for US students) were identified:

- practical training of EU students in US and US students in EU;
- publication of “curricula vitae et studiorum” of Biosystems Engineering graduates, on the web-sites of EurAgEng (European Society of Agricultural Engineers) and ASABE (American Society of Agricultural and Biological Engineers);
- preparation of a database including the most recent EU and US Biosystems Engineering research projects, both joint ones, involving more than one research institution, and international ones; this database could be used to suggest subjects of Bachelor, Master and Ph.D. thesis to EU and US Biosystems Engineering students and to transfer knowledge to enterprises (for start-up and spin-off projects);
- publication of competences, conversion tables regarding both credits and marks, on the web-sites of EU and US University institutions offering Biosystems Engineering degree study programmes, or their inclusion in a database, which can be prepared by both EurAgEng and ASABE.

Therefore, to stimulate both EU and US students to carry out practical training in different countries will be a major challenge. Hopefully, EU and US Universities can develop "international" degree study programmes within their curricula, in order to strongly encourage

students to obtain significant international experiences, by studying courses and/or carrying out practical training abroad.

Once EU and US Universities agree on core and mid-level competences for Biosystems Engineering discipline, they will need to publicise this information in all the sectors interested, using every form of communication available, and to be persistent in advertising it also in the future.

With reference to the need for EU and US Universities of developing conversion tables for comparisons among degree study programmes offered by different countries/Universities, it can be possible to use the experience that some EU Universities (e.g. Bari and Palermo) obtained within the Socrates-Erasmus programme for EU students, where it is essential to compare course contents, marks, credits, etc., of degree study programmes offered by different countries/Universities.

## **2. Propose possible research projects in collaboration between Universities and industries or professionals or public sector**

In both EU and US there is already a large amount of research collaboration between departments in Biosystems Engineering discipline and industries.

In US there is also a good amount of collaboration between Universities and industries in teaching fundamental design courses during the final year of the degree study programmes.

However, it would be relevant to encourage more collaboration between Universities and industries or professionals or public sector, including those sectors different from Biosystems Engineering, but interacting with it.

Research projects in collaboration between Universities and industries or professionals or public sector, including those sectors different from Biosystems Engineering, but interacting with it, can be proposed on the following subjects:

- bioenergies;
- biomaterials;
- implementation of Computational Fluid Dynamics (CFD), for design and control of climate conditions of agricultural buildings;
- Life Cycle Assessment (LCA);
- image analysis and automation of field operations and food processing;
- precision agriculture;
- planning of green areas and parks;
- water saving and irrigation efficiency;
- animal health and indoor environment in animal housing;
- dust and gas emissions from agricultural activities;
- land planning for forest fire prevention.

### **3. Ask questions about the first two tasks to Universities offering degree study programmes in Biosystems Engineering and to the current and future employers of each country involved in POMSEBES**

The third task of objective 3 of POMSEBES is to ask Universities offering Biosystems Engineering degree study programmes and the current and future employers of each country involved in this project, such as industries, professional organisations or public sector, including those sectors different from Biosystems Engineering, but interacting with it, the following questions about the first two tasks :

- “Which are the ways to enhance visibility and recognition of future graduates in US (also for EU students) and EU (also for US students)?
- “Which are the possible research projects in collaboration between Universities and industries or professionals or public sector, including those sectors different from Biosystems Engineering, but interacting with it?”

This task is aimed at emphasizing the need to advertise the Biosystems Engineering discipline in industry and the public sector but, above all, the need to improve the image of Biosystems Engineers and to provide the general public with an accurate image of Biosystems Engineering itself.

#### **3.1. The EU case**

In EU, in order to improve the image of Biosystems Engineers and to provide the general public with an accurate image of Biosystems Engineering itself, a questionnaire entitled “University - Enterprise Cooperation” was prepared and sent to 28 EU industries involved in Biosystems Engineering, which are current and could be future employers of Biosystems Engineers.

Among these industries, 17 produce agricultural machines, three are food processing industries, five produce structures and equipment for rural buildings, one is a company of GPS services, one is a company of services for agriculture, forestry, environment, aquaculture and fisheries, and one is a company of services for bioenergy/biogas, agriculture and livestock. Unfortunately, only 14 industries, which however constitute an almost significant sample, sent back the questionnaire filled-in. Among these “co-operating” industries, six produce agricultural machines, two are food processing industries, three produce building materials for greenhouses, animal farms and equipment, one is a company of GPS services for agriculture, topography, public works and instruction, one is a company of services for agriculture, forestry, environment, aquaculture and fisheries and one is a company of services for bioenergy/biogas from animal production, field agriculture, livestock engineering, horticulture technology and sensors, as shown in Appendix Q.2.

The graphic display of the replies to the questionnaire “University - Enterprise Cooperation” constitute the last part of this report.

In the majority (64%) of the above industries there are career options relevant to Agricultural/Biological or Biosystems Engineering.

In order to satisfy the needs of these industries the following learning outcomes and/or competences are required :

- technical ones (concerning with R&D or manufacturing or programming and electronics or mechatronics);
- agronomic ones (concerning with farming practices or the integrated management of vineyards);
- mechanical ones (concerning with agricultural machines);
- commercial ones (concerning with marketing and sales);
- administrative ones.

About the 34% of these industries prefers B.Sc. degrees, the 33% prefers M.Sc. ones, only the 8% prefers Ph.D., the 17% indifferently does B.Sc. or M.Sc., and only the 8% does indifferently M.Sc. or Ph.D.

The 38% of these industries intends to recruit more graduates with the classical Agricultural Engineering background, while the 40% of these industries prefers a change from the classical Agricultural Engineering background into the modern Biosystems Engineering one.

The majority (64%) of these industries has a defined and comprehensive policy regarding University - enterprise co-operation and has also run at least one funded co-operation project with a University or institution or research group (89% of which were successful in the past).

According to the majority (85%) of the above industries, for the integration of Biosystems Engineering graduates into the job market, industry and job market itself should be more involved in the curriculum developments/restructuring of studies.

Moreover, according to the 92% of the above industries, for the above aim, it is needed to improve the entrepreneurial spirit at University and also to develop continuing education programs in co-operation with industry so as to meet the market needs.

Furthermore, the 100% of the above industries reckon that it is needed to facilitate and accelerate transfer of knowledge from University to industry and vice versa, and also to implement permanent routes of dialogue between Universities and enterprises; the 85% suggest the need of developing joint education (through research thesis projects) and/or training projects; the 69% favour the need of developing transnational programmes of student mobility for research thesis projects and/or training projects with the support of industry.

Even if only the 50% of the contacted industries sent back the questionnaire filled-in, the given replies are rather homogeneous and show a common policy: a great interest for Biosystems Engineering discipline can be drawn and, at the same time, a good employability for the related graduates and a profitable University - enterprise co-operation can be foreseen in EU.

### **3.2. The US case**

The information about US employers of Biosystems/Biological Engineers and job positions that US Engineering graduates obtain upon graduation can be summarised in the following points, with reference to Iowa State University and Texas A&M University.

#### **▪ Iowa State University**

- a) Iowa State University offers a B.Sc. degree study programme in Agricultural Engineering, but from autumn 2008 a new B.Sc. degree study programme in Biosystems Engineering will be offered.

- b) Students upon graduation in Biosystems Engineering find very high paying jobs in the three major industries: food and bioprocess engineering industry such as General Mills, CARGILL, ADM, CongAgra, meat process industry, etc.; biofuels and bioproduct industry (ethanol, biodiesel, bioplastic, biomaterials, bioproducts, etc.) such as ADM, CARGILL and several ethanol plants in Iowa; pharmaceutical industry. Moreover, major farm equipment industries such as John Deere and AGCO are recruiting biomanufacturing engineers to design harvesting equipment for emerging biofuel crops. In addition, several state and federal governmental agencies are beginning to recognise Biosystems Engineers, primarily in the environmental and bioremediation areas.
- c) Typical job positions offered to Biosystems Engineering graduates are: bioproducts engineer, biomanufacturing engineer, quality control engineer, design engineer, process engineer, bioremediation engineer, environmental manager/engineer, drug delivery/packaging design engineer, research engineer.

- **Texas A&M University**

- a) The students of the Biological and Agricultural Engineering Department of Texas A&M University have been very successful in finding employment upon graduation, in the following enterprises: engineering and environmental consulting firms (such as Dannenbaum Engineering Corporation, Pape Dawson Engineering, Vickrey Associates and URS Corporation); oil, gas and energy industries (such as Halliburton, Exxon Mobile, FMC Tech, Panda Ethanol, Lynntech and TXU Power); agricultural and construction equipment manufacturers (such as John Deere, Alamo Group and CNH Global); food industry (such as Frito-Lay and Kraft Foods). They also find job positions in a wide variety of small firms, in teaching and in government and public sectors such as the Texas Commission on Environmental Quality (the State environmental regulatory agency), the Texas Department of Transportation, and municipal and utility management positions.
- b) Job positions offered to the above graduates include: consulting engineer, systems engineer, civil engineer, plant engineer, field engineer, customer support marketing representative and environmental specialist. In addition, many graduates move rapidly to management positions.

Therefore, on the other side of Atlantic Ocean the demand for Biosystems Engineering graduates by industry seems much more than US Universities can train. Thus, the future for Biosystems/Biological Engineering graduates looks very bright in US.

#### **4. Proposed policy measures**

In conclusion, the anticipated needs of the European and international industry in the broader area of Biosystems Engineering (current and future employers) have been identified and could be satisfied provided that :

- the visibility and the recognition of future graduates in Biosystems Engineering is enhanced, through the practical training of EU and US students, the publication of “curricula vitae et studiorum” of these graduates on the web-sites of EurAgEng (European Society of Agricultural Engineers) and ASABE (American Society of Agricultural and Biological Engineers), the preparation of a database including the most recent EU and US Biosystems

Engineering research projects, and the publication of competences and conversion tables (regarding both credits and marks) on the web-sites of EU and US University institutions offering Biosystems Engineering degree study programmes or their inclusion in a database (which can be prepared by both EurAgEng and ASABE);

- in both EU and US efficient collaboration between University programs of studies in Biosystems Engineering is established incorporating research work at various levels, (e.g. in US, during the final year of the degree study programmes through the undergraduate thesis), and a good collaboration between Universities and industries in teaching fundamental design courses.

In EU, along with a great interest for Biosystems Engineering discipline, a good employability for the related graduates and a profitable University - enterprise co-operation can be foreseen; in US the demand for these graduates by industry seems much more than Universities can train and, therefore, the future for Biosystems/Biological Engineering graduates looks very bright.

**References:**

- [1] G. Scarascia Mugnozza, A. Comparetti, P. Febo (2007). Identify research needs/opportunities in Biosystems Engineering. Proceedings of the 1<sup>st</sup> POMSEBES (Policy Oriented Measures in Support of the Evolving Biosystems Engineering Studies in USA - EU) Workshop, Minneapolis, Minnesota (U.S.A.), 14-15 June 2007.

Develop a pilot accreditation program  
for the Biosystems Engineering  
discipline,  
in conformity to the  
accreditation process conducted  
by ABET & by EUR-ACE

**Objective 4: Develop a pilot accreditation program**  
**(in terms of policy/strategy) for the Biosystems Engineering discipline, in conformity to the existing accreditation process conducted by ABET in the US and by EUR-ACE in EU**

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### **1. Introduction: principles of Accreditation processes**

A tentative proposition for an accreditation strategy concerning the Biosystems Engineering discipline is given based on existing accreditation for engineering programs (EUR ACE<sup>2</sup>, ABET<sup>3</sup>, Washington Accord). The first part concerns the identification of common program outcome descriptors based on a comparative study of 3 accreditations processes cited previously. The second part concerns the proposal of an implementation process based on EQF<sup>4</sup> scheme and Quality Assurance principles. Then, strategic recommendations are proposed based on EQF implementation with possible application in case of new programs set up or program renewal.

#### EUR ACE

The EUR ACE accreditation framework consists of the fulfillment of 6 major program outcomes (Annex 1) that are specific to the First and Second Cycle programs of study in Engineering. This scheme is adopted now by 14 European countries.

#### ABET

ABET provides accrediting criteria standards for all engineering or engineering technology programs at baccalaureate level (1st cycle) corresponding to 4 years study programs (Annex 2). No generic program outcome is given for 2nd cycle programs (Master level) which generally correspond to a specialization with in-depth investigation in the branch of engineering.

#### Washington & Sydney Accords

Washington Accord / Sydney Accord / Dublin Accord were established under the umbrella of the International Engineering Alliance. The Washington Accord signed in 1989 was the first - it recognizes substantial equivalence in the accreditation of qualifications in professional engineering, normally of four years duration. The Sydney Accord was commenced in 2001 and recognizes substantial equivalence in the accreditation of qualifications in engineering technology, normally of three years duration.

The Dublin Accord is an agreement for substantial equivalence in the accreditation of tertiary qualifications in technician engineering, normally of two years duration. It commenced in 2002.

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<sup>2</sup> EUR ACE : Accreditation of European Engineering Programmes

<sup>3</sup> ABET : Accreditation Board for Engineering and Technology

<sup>4</sup> European Qualification Framework

Each program can be described using Eng. programs outcome descriptors (called Graduate Attribute Profiles), but 2 main common ranges will allow to define the typology of program (Annex 3 & 4).

### **1. Focusing on Program/Learning outcomes?**

Accordingly to European Qualification Framework (EQF) a program or learning outcome corresponds to an integration of competences including knowledge-based and practice-based skills. The global acquisition of learning outcomes takes part of the qualification. Tables 1a, 1b and 1c introduce a comparison of EUR ACE, ABET and Washington Accord program outcomes as sorted after individual analysis (see annexes 1 to 3) into 4 main categories:

#### **Context and the branch of Engineering**

Multidisciplinary context  
Science and mathematical principles  
The branch of engineering and forefronts  
Systemic approach

#### **The engineering activities and expertise**

Problem solving  
Engineering design  
Engineering analysis  
Engineering practice

#### **Investigation skills**

Experiments  
Data analysis

#### **Attitudes**

Ethics and Responsibility  
Quality  
Project management  
Business practices  
Communication  
Individual / team Work  
Global context  
Life-long learning

**Table 1a:** Analytical comparison of program outcomes - Synthesis of main graduate attribute profiles according to ABET, EUR ACE, WA and SA

Domain	Criteria	ABET Eng. (1 <sup>st</sup> cycle)	ABET Eng. Tech. (1 <sup>st</sup> cycle)	EUR ACE (1 <sup>st</sup> cycle)	EUR-ACE (2 <sup>nd</sup> cycle)	Washington Accord	Sydney Accord
<b>Context &amp; the Branch of Engineering</b>	Multidisciplinary context	U global (...) context to propose adequate eng. solutions	Engineering Technology	Aware of wider...	Multidisciplinary context	Complex problems with X disciplinary issues	Broadly-defined problems with possible X disciplinary issues
	Science and mathematical principles applied to engineering	Apply (...) to solve problems	<i>Apply and adapt current and emerging (...)</i>	<i>K&amp;U and apply...</i> underlying the branch of eng.	Demonstrate in-depth K&U... underlying the branch of eng.	Apply (...) to conceptualize engineering models	Apply (...) to apply engineering procedures, processes, systems and methodologies
	Forefronts of the branch	n.s.	n.s.	<i>K of some forefronts</i>	Critical awareness of forefronts	n.s.	n.s.
	Systemic approach	n.s.	n.s.	<b>U</b> key aspects and concepts	n. s.	n. s.	n. s.

*K : knowledge; U : Understanding; H&S : Health and Safety; pb. : Problem; Eng. : Engineering; X : Multi; n.s. : not (explicitly) specified*

Table 1b: continued

Domain	Criteria	ABET Eng. (1 <sup>st</sup> cycle)	ABET Eng. Tech. (1 <sup>st</sup> cycle)	EUR ACE (1 <sup>st</sup> cycle)	EUR-ACE (2 <sup>nd</sup> cycle)	Washington Accord	Sydney Accord
Engineering Activities	Problem Solving	Apply Eng. methods and K to solve pb.	Identify, analyze and solve technical problems	Identify, formulate and solve	Solve problems that are unfamiliar, incompletely defined and have competing specifications using Innovative methods	Identify, formulate and solve complex problems	Identify, formulate and solve broadly-defined problems
	Design	Under constraints to satisfy desired needs.	Apply design (...) with creativity to meet program educational objectives	<b>meet</b> desired needs <b>U</b> design methodologies	<b>meet</b> desired needs Unfamiliar problems, complexity, technical uncertainty	Complex engineering to meet desired needs Modeling applied to complex eng.	Broadly-defined engineering technology problems Contribute to design (...)
	Analysis	n.s.	n.s.	relevant analytic and modeling method	Conceptualize eng. models and processes	Related to. solving pb	Related to. solving Eng. Technology pb
	Eng Practice	Modern Eng. tools		To solve problems Aware of non-technical pb.	Comprehensive U of applicable techniques K non-technical pb.	Create, select and apply Modern Eng. tools usage	Modern Eng. tools usage
Investigation	Experiment	Design and Conduct	Design and Conduct	Design and Conduct	and Analytical modeling	Design and Conduct	Design and Conduct
	Data analysis	Analyze and interpret data to draw conclusions	Analyze and interpret data to draw conclusions	Interpret data in order to draw conclusions	Critical evaluation of data	Analyze and interpret data to draw conclusions related to complex problems	Analyze and interpret data to draw conclusions related to broad-defined problems

*K : knowledge; U : Understanding; H&S : Health and Safety; pb. : Problem; Eng. : Engineering; X : Multi; n.s. : not (explicitly) specified*

**Table 1c:** continued

Domain	Criteria	ABET Eng. (1 <sup>st</sup> cycle)	ABET Eng. Tech. 1 <sup>st</sup>	EUR ACE (1 <sup>st</sup> cycle)	EUR-ACE (2 <sup>nd</sup> cycle)	Washington Accord	Sydney Accord
<b>Attitudes</b>	Ethics & responsibility	n.s.	n.s.	Understand	Understand	U and commitment to (...) and norms of eng. practice	U and commitment to (...) and norms of eng. practice
	Quality	n.s.	Quality assessment	n.s.	n.s.	n.s.	n.s.
	Project management	n.s.	n.s.	Aware (...) risk and change management	Demonstrate (...)	n.s.	n.s.
	Business practices	n.s.	n.s.	Aware	Demonstrate	n.s.	n.s.
	Communication	Effectively	Effectively	Effectively inside Eng. community and society	Effectively @ national and international	Effectively inside Eng. community and society Give and receive clear instructions	Effectively inside Eng. community and society Give and receive clear instructions
	Individual / team work	Xdisciplinary team work	Effectively as a team member	Function effectively as individual and team member	Function effectively as individual and team leader (Xdisciplinary)	Function effectively as individual and team member/leader (Xdisciplinary)	Function effectively as individual and team member/leader (Xdisciplinary)
	Global context	Economical, societal, environmental, political, ethical, H&S, manufacturability, sustainability U Contemporary issues	Economical, societal, environmental, political, ethical, H&S, manufacturability, sustainability U Contemporary issues	Aware H&S, economical, legal, societal, environmental issues	Demonstrate Awareness of H&S, economical, legal, societal, environmental issues	H&S, cultural, societal, environmental,	H&S, cultural, societal, environmental,
	Life-long Learning	Recognize and engage	Recognize and engage	n.s.	n.s.	Recognize and engage	Recognize and engage

*K : knowledge; U : Understanding; H&S : Health and Safety; pb. : Problem; Eng. : Engineering; X : Multi; n.s. : not (explicitly) specified*

## Implementation of EQF:

EQF recognizes specific knowledge, skills and competences to degrees in higher education which are specified for the 1<sup>st</sup> and 2<sup>nd</sup> cycle in Table 2.

**Table 2:** EQF standard levels are :

Level	Knowledge	Skills	Competence
Level 6**	Advanced knowledge of a field of work involving critical understanding of theories and principles	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialized field of work	<ul style="list-style-type: none"> <li>• Manage complex technical or professional activities or projects taking responsibility for decision-making in unpredictable work contexts</li> <li>• Take responsibility for managing professional development of individuals and groups</li> </ul>
Level 7***	Highly specialized knowledge with some at the forefront of knowledge in a field of work, as the basis for original thinking and/or research Critical awareness of knowledge issues in a field and at the interface between different fields	Specialized problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	<ul style="list-style-type: none"> <li>• Manage and transform work contexts that are complex, unpredictable and require new strategic approaches</li> <li>• Take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams</li> </ul>

\*\* Level 6: The descriptor for the First Cycle in the Framework for Qualifications of the European Higher Education Area (Bergen 2005)

\*\*\* Level 7: The descriptor for the Second Cycle in the Framework for Qualifications of the European Higher Education Area (Bergen, 2007)

Based on the Table 2 recommendations, the contribution of each criterion (outcome descriptors from Annexes 1 to 3) is proposed as a data base of possible program outcomes. This data base could be possibly used to set up or renew Agricultural/Biosystems Engineering programs of study at 1<sup>st</sup> and 2<sup>nd</sup> cycle).

**Table 3:** Possible implementation of an Agricultural/Biosystems Eng. program (1<sup>st</sup> Cycle)

		<b>Knowledge</b>	<b>Skills</b>	<b>Competence</b>
<b>Level 6 EQF</b> <b>1<sup>st</sup> Cycle</b>		Advanced knowledge of a field of work /study involving critical understanding of theories and principles	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialized field of work	Manage complex technical or professional activities or projects taking responsibility for decision-making in unpredictable work contexts Take responsibility for managing professional development of individuals and groups
<b>Domain</b>	<b>Criteria</b>			
Context	Multidisciplinary context	<input checked="" type="checkbox"/>		
Branch of engineering	Science and mathematical principles applied to engineering	<input checked="" type="checkbox"/>		
	Forefronts of the branch	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
	Systemic approach	<input checked="" type="checkbox"/>		
Engineering activities	Problem Solving		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	Design		<input checked="" type="checkbox"/>	
	Analysis	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
	Eng Practice			<input checked="" type="checkbox"/>
Investigation	Experiment		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
	Data analysis		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Attitudes	Ethics & responsibility			<input checked="" type="checkbox"/>
	Quality			<input checked="" type="checkbox"/>
	Project management			<input checked="" type="checkbox"/>
	Business practices			<input checked="" type="checkbox"/>
	Communication			<input checked="" type="checkbox"/>
	Individual / team work			<input checked="" type="checkbox"/>
	Global context			<input checked="" type="checkbox"/>

## **2. Quality assessment and Assurance**

Common principles for quality Assurance in Higher Education and Vocational Education and Training in the context of the European Qualification Framework

- QA should underpin all levels of the EQF
- QA should be an integral part of the internal management of education and training institutions
- QA should include regular evaluation of institutions, their programs or their quality assurance systems by external monitoring bodies or agencies
- External monitoring bodies or agencies carrying out QA should be subject to regular review
- QA should include context, input, process and output dimensions while giving emphasis to output and learning outcomes
- QA systems should include the following elements :
  - clear and measurable objectives and standards
  - guidelines for implementation , including stakeholder involvement
  - appropriate resources
  - consistent evaluation methods, associating self-assessment and external review
  - feedback mechanisms and procedures for improvements
  - widely accessible evaluation results
- QA initiatives at international, national and regional levels should be coordinated in order to ensure overview, coherence, synergy and system-wide analysis
- QA should be a cooperative process across education and training levels and systems, involving all relevant stakeholders , within Member States and across the Community
- QA orientations at Community level may provide reference points for evaluations and peer learning.

## **3. Consequences on the development of Biosystems Engineering program in Europe**

- Apply EQF recommendations on Qualification levels and Quality Assurance in establishing the emerging discipline in Europe so that the new programs of studies are based on quality
- Follow EUR ACE recommendations on Program outcomes regarding engineering that can be also inspired by ABET and WA/SA principles, ensuring in that way that the new discipline of Biosystems Engineering in Europe is internationally recognized as an accredited branch of Engineering.
- Promote the national development of Biosystem Engineering programs (1<sup>st</sup> and 2<sup>nd</sup> cycles) with a cooperative action with national accreditation agencies under the umbrella of EUR ACE principle to ensure European and international compatibility and recognition.

#### 4. How to develop a strategy?

Allow Universities and HEI to set up decision-making tools to implement study programs:

- Coherent program outcomes regarding to the program level (1<sup>st</sup> or 2<sup>nd</sup> cycle)
- Generate common and well-accepted outcome descriptors based on the table
- Provide coherent course content (disciplines, contact hours, activities) related to program outcomes by using the program outcomes simulator
- Develop a QA compatible with EQF recommendations

#### 5. Proposed policy measures

In conclusion, the development of a pilot accreditation program (in terms of policy/strategy) for the Biosystems Engineering discipline could be achieved provided that:

1. Engineering will, as a general trend, be the core of the study program
2. Engineering fundamentals will be included as basic sciences at early stage of the program (following the approved by FEANI USAEE TN core curricula)
3. A comparison among study programs in US and EU will lead to a standard definition of basics and a clarification of application areas
4. Relationships between quality assurance issues of programs of study and learning outcomes or student's core competences should be encouraged

#### References:

- [1] Washington Accord: from Graduate Attributes and Professional Competencies, 13 June 2005, In "IEM Graduates Attributes and Professional Competency Profiles", 11pp. [www.washingtonaccord.org](http://www.washingtonaccord.org)
- [2] ABET: Criteria for accrediting Engineering Programs, effective for Evaluations during the 2008-2009 Accreditation Cycle. 12/4/2007, 19pp. [www.abet.org](http://www.abet.org)
- [3] ABET: Criteria for accrediting Engineering Technology Programs, effective for Evaluations during the 2008-2009 Accreditation Cycle. 11/30/2007, 29pp. [www.abet.org](http://www.abet.org)
- [4] EUR ACE: Framework standards for the Accreditation of Engineering Programmes. 17/11/2005. [www.eurace.org](http://www.eurace.org)
- [5] The European Qualifications Framework for Lifelong Learning (EQF), 2008. 15pp. [www.europa.eu/dgs/education\\_culture/index\\_en.html](http://www.europa.eu/dgs/education_culture/index_en.html)

**ANNEX 1a: EUR-ACE Engineering program: 1<sup>st</sup> cycle Engineering program  
(min. 180 credits)**

*Italic: criteria – Bold : verb, action – underline : performance*

Global Domain	Criteria	Outcome
1- Global Knowledge and Understanding	The branch of engineering	<b>Know, understand and apply</b> science and mathematical principles underlying the branch of engineering <u>Systematic understand</u> of key aspects and concepts <u>Coherent knowledge</u> of the branch of eng. including some forefront of the branch
	<i>The context of engineering</i>	<b>Aware</b> of wider multidisciplinary context of engineering
	Engineering problems	<b>Identify, formulate</b> and <u>solve</u> Eng. problems
2- Engineering Analysis	<i>Eng. Products, processes and methods</i>	<b>Apply, understand</b> and <b>analyze</b> Eng. Products, processes and methods <u>using established methods</u>
	Analytic & Modeling methods	<b>Select</b> and <b>apply</b> <u>relevant</u> analytic and modeling methods
3- Engineering Design/Project	Engineering design	<b>Apply</b> K & U, <b>develop</b> and <b>realize</b> Eng. designs <u>to meet defined and specified requirements</u>
	Design methodologies	<u>Ability to understand</u> design methodologies
4- Investigations	Information resources	Ability to <b>conduct</b> and <b>use</b> searches of literature and data bases
	Experiments	<b>Design, conduct, interpret</b> experimental data <u>in order to draw conclusions</u>
	<i>Practical skills</i>	<b>Select</b> and <b>use</b> <u>appropriate</u> tools, equipments and methods
5- Engineering Practice	Eng. Problems	<u>Ability to solve</u> Eng. Problems with combination of theory and practice
	<i>Eng. Techniques</i>	<b>Aware</b> of applicable techniques and methods and limitations
	<i>Non-technical aspects</i>	<b>Aware</b> of non-technical implications of eng. practices
6- Transferable Skills	Individual/team work	<b>Function</b> <i>effectively</i> as an individual and as a team member
	Communication	<b>Use</b> <u>effectively</u> diverse comm. methods with the eng. community and with society in large
	Global context	<b>Aware</b> of health, safety, legal issues, the impact of eng. solutions, in a societal and environmental context
	Project management	<b>Aware</b> of project management, business practices (risk and change management) and their limitations.

**ANNEX 1b: EUR ACE Engineering program: 2<sup>nd</sup> cycle Engineering program**  
**(min. 240 credits)**

*Italic: criteria – Bold : verb, action – underline : performance*

<b>Global Domain</b>	<b>Criteria</b>	<b>Outcome</b>
<b>1- Global Knowledge and Understanding</b>	The branch of engineering	Demonstrate in-depth knowledge and understanding of science and mathematical principles underlying the branch of engineering
		Critical awareness of the forefront of the branch
<b>2- Engineering Analysis</b>	Engineering problems	Ability to solve problems that are unfamiliar, incompletely defined, and have competing specifications
		Ability to formulate and solve problems in new and emerging areas of their specialization.
		Ability to apply innovative methods in problem solving
	Analytic & Modeling methods	Ability to use their K & U to conceptualize engineering models systems and processes
	Engineering design	Apply K & U, develop and realize Eng. designs to meet defined and specified requirements
<b>3- Engineering Design/Project</b>	Design methodologies	Ability to design solutions to unfamiliar problems
		Ability to develop new and original ideas and methods with creativity
	Manage complexity	Ability to work with complexity, technical uncertainty and incomplete information
<b>4- Investigations</b>	Experiments	Ability Design, conduct, analytical modeling and experimental investigations
	Data mining and analysis	Ability to Identify, locate, and obtain required data, to critically evaluate data and draw conclusions
<b>5- Engineering Practice</b>	Eng. Techniques	A comprehensive understanding of applicable techniques and methods and their limitations
	Non-technical aspects	A knowledge of non-technical implications of eng. practices
	Eng. problems	Ability to integrate knowledge from different branches, and handle complexity

<b>6- Transferable Skills</b>	Individual/team work	Function effectively as an individual and as a team leader with teams composed of different disciplines and levels
	Communication	Work and communicate effectively at national and International context
	Global context	Demonstrate awareness of health, safety, legal issues, the impact of eng. solutions, in a societal and environmental context
	Project management	Demonstrate awareness of project management, business practices (risk and change management) and their limitations.

## **ANNEX 1: EUR-ACE Engineering program First Cycle**

EUR ACE accreditation framework consists of the fulfillment of 6 major program outcomes  
Those 6 major outcomes can be sorted in 3 main categories:

- The Engineering expertise :
  - o Global knowledge and understanding of the branch and context of Engineering by using science and mathematical principles.
  - o Engineering Analysis : Eng. problems, Eng. Products, processes and methods, Analytic and modeling methods
  - o Eng. Design : Eng. design, design methodologies
  - o Engineering practice : Eng. problems, Eng. techniques, non technical aspects
- Investigations abilities :
  - o Information resources
  - o Experiments
  - o Practical skills
- Transferable skills
  - o Individual & team work
  - o Communication abilities : inside eng. community and with society in large
  - o Global context : legal, societal, environmental, H&S issues
  - o Project management : project management, business practices (risk and change management)

Prior statements are based on an **application** process:

- a defined context of the engineering (science, application)
- a defined knowledge of the branch (with few forefronts of the branch)
- Eng. Problem solving is based on the use of (well-) known methods
- Experiments are defined in the context of the branch
- Individual and team work deal mainly with engineering
- Global context is known (H&S, environmental, societal, economical, sustainable issues)

As a comparison, second cycle outcomes can be described with the same descriptors but generally 2<sup>nd</sup> cycle program outcomes are detailed (Annex 2).

In this case, outcomes are based on **transferability and creativity**:

Prior statements are:

- a wider context of engineering (including new and emerging areas of the specialization)
- an in-depth knowledge of the branch
- Eng. Problems are unfamiliar, incompletely defined and can have competing specifications.
- Eng. Models, systems or processes are conceptualized
- Creativity, new and emerging ideas are required
- Critical analysis of experiments are required
- Teams are generally multidisciplinary and own different levels
- Global context is a part of specifications (H&S, environmental, societal, economical, sustainable issues)

## **ANNEX 2c: ABET Engineering program: 1st cycle**

*Italic: criteria* – **Bold : verb, action** – underline : performance

<b>Global domain</b>	<b>Outcome</b>	
<b>1- Engineering methods and knowledge</b>	<b>Apply</b> Engineering methods and knowledge <u>to solve problems</u>	
<b>2- Design under Constraints</b>	<b>Design</b> systems, components or process <u>to satisfy desired needs with realistic constraints</u> (economical, societal, environmental, political, ethical, health and safety, manufacturability and sustainability)	
<b>3- Experiments and data analysis</b>	<i>Experiments</i>	<b>Design</b> and <b>conduct</b> experiments
	<i>Data analysis</i>	<b>Analyze</b> and <b>interpret</b> data <u>to draw conclusions</u>
<b>4- Team Work</b>	<b>Function</b> <u>effectively</u> in multidisciplinary team work	
<b>5- Engineering Problems</b>	<b>Identify, formulate</b> and <b>solve</b> engineering problems in order <u>give a global response</u>	
<b>6- Ethics</b>	<b>Understand</b> professional and ethical responsibility <u>regarding to the prescription applied</u>	
<b>7- Communication</b>	<b>Communicate</b> <u>effectively</u>	
<b>8- Global context</b>	<b>Understand</b> global, economical, environmental, societal context to propose <u>adequate engineering solutions</u> .	
<b>9- Life-Long Learning</b>	<u>Ability</u> to <b>recognize</b> and <b>engage</b> in a life-long learning process	
<b>10- Contemporary issues</b>	<u>Ability</u> to <b>Understand</b> and <b>consider</b> contemporary issues	
<b>11- Modern engineering</b>	<u>Ability</u> to <b>Use</b> techniques, skills and modern tools in the practice of engineering	

## **ANNEX 2: ABET Engineering Technology program: 1<sup>st</sup> cycle**

*Italic: criteria – Bold : verb, action – underline : performance*

<b>Global Domain</b>	<b>Criteria</b>	<b>Outcome</b>
<b>1- Engineering Technology</b>	<u>Appropriate mastery</u> of knowledge, techniques, skills and modern tools in Engineering technology	
<b>2- Domains of application</b>	<u>Ability to apply</u> and <b>adapt</b> current knowledge, emerging applications of mathematics sciences, engineering and technology	
<b>3- Experiments</b>	<b>Conduct experiments</b>	<b>Conduct</b> experiments and <b>apply</b> results <u>to improve processes</u>
	<i>Data analysis</i>	<b>Analyze, interpret</b> data <u>to draw conclusions</u>
<b>4- Design</b>	<b>Apply</b> design of systems, components and processes <u>with creativity to meet program educational objectives</u>	
<b>5- Team work</b>	<b>Function</b> <u>effectively</u> as a team member	
<b>6- technical problems</b>	<u>Ability to Identify, analyze</u> and <b>solve</b> technical problems	
<b>7- Communication</b>	<b>Communicate</b> <u>effectively</u>	
<b>8- Life-long Learning</b>	<u>Ability to recognize</u> and <b>engage</b> a life-long learning process	
<b>9- Responsibility</b>	<u>Ability to understand</u> professional, ethical, social responsibility	
<b>10- Consider our world</b>	<b>Respect</b> diversity and <b>know</b> contemporary professional societal and global issues	
<b>11- Quality assessment</b>	<b>Commitment to</b> quality, timeliness, continuous improvement	

ABET provides accrediting criteria standards for all engineering or engineering technology programs at baccalaureate level (1<sup>st</sup> cycle) corresponding to 4 years study programs. No generic program outcome is given for 2<sup>nd</sup> cycle programs (Master level) which generally correspond to a specialization with in-depth investigation in the branch of engineering.

### **a. ABET Engineering program Outcomes – 1<sup>st</sup> cycle**

Each Eng. program is described by using 11 descriptors that can be sorted in 3 categories:

- The engineering expertise:

- Engineering Methods and Knowledge : to solve problems
- Design and constraints : design systems, components or processes to satisfy desired needs with realistic constraints (economical, societal, environmental, political, ethical, H&S, manufacturability and sustainability)
- Engineering problems : give a global response
- Modern Engineering tools

- Experiments and data analysis abilities:

- design and conduct experiments
- analyze and interpret data to draw conclusions

- Transferable skills
  - o Team Work
  - o Professional ethics and responsibility
  - o Communication
  - o Global context
  - o Life long learning
  - o Contemporary issues

**b. ABET Engineering Technology program Outcomes – 1st cycle**

Each Eng. program is described by using 11 descriptors that can be sorted in 3 categories:

- The engineering expertise:
  - o Engineering Technology : Appropriate mastery of knowledge, techniques, skills and modern tools in Engineering Technology
  - o Domain of application : apply and adapt current knowledge, emerging applications of mathematics, science, engineering and technology
  - o Design : Apply design of systems, components or processes to meet educational objectives with creativity
  - o Technical problems : Solve technical problems
- Experiments and data analysis abilities:
  - o design and conduct experiments to improve processes
  - o analyze and interpret data to draw conclusions
- Transferable skills
  - o Team Work
  - o Quality assessment
  - o Communication
  - o Responsibility
  - o Life long learning
  - o Contemporary issues: respect diversity and know contemporary professional, societal and global issues.

The main difference between Engineering and Engineering Technology Program Outcomes is found on Engineering abilities (analysis, design) which are obviously more Technology-oriented in this last case.

### **ANNEX 3a: Standards for International Recognition**

Washington Accord / Sydney Accord\* / Dublin Accord\* were established under the umbrella of the International Engineering Alliance.

The Washington Accord signed in 1989 was the first - it recognizes substantial equivalence in the accreditation of qualifications in professional engineering, normally of four years duration.

The Sydney Accord commenced in 2001 and recognizes substantial equivalence in the accreditation of qualifications in engineering technology, normally of three years duration.

The Dublin Accord is an agreement for substantial equivalence in the accreditation of tertiary qualifications in technician engineering, normally of two years duration. It commenced in 2002.

Each program can be described using Eng. programs outcome descriptors (called Graduate Attribute Profiles), but 2 main common ranges will allow to define the typology of program.

*(\*) Sydney and Dublin Accords are not applicable to Biosystems Engineering University studies as they concern applications oriented studies in engineering technology (3-year and 2-year programs of studies, respectively)*

### **ANNEX 3b: Range of problem solving**

	<b>Washington Accord</b>	<b>Sydney Accord*</b>
<b>Definition</b>	Complex problem which requires in-depth Eng. K&U	Broadly-defined problem
<b>Range of conflict</b>	Wide ranging or conflicting technical engineering or other issues	Variety of factors with possible conflicting constraints
<b>Depth of analysis</b>	No obvious solution, need abstract thinking, originality to formulate suitable models	Can be solved by well-proven techniques
<b>Depth of knowledge required</b>	In-depth knowledge with fundamental–based first principles analytical approach	Knowledge of principles and applied technologies
<b>Familiarity of issues</b>	Infrequently encountered issues	Familiar problems solved by well-accepted ways
<b>Levels of problems</b>	Outside standards and codes of practice for professional eng.	Partially outside standards and codes of practice
<b>Extent stakeholder involvement and level of conflicting requirements</b>	Diverse groups of stakeholders with varying needs	Several groups of stakeholders with differing/conflicting needs
<b>Consequences</b>	Significant consequences in a range of context	Locally important but ay extent more widely
<b>interdependence</b>	High level of problems including many parts and sub-systems	Part of, or systems within complex engineering problems

*(\*) Sydney Accord in not applicable to Biosystems Engineering University studies as it concerns applications oriented studies in engineering technology (3-year programs of studies)*

### **ANNEX 3c: Range of Engineering Activities**

	<b>Washington Accord</b>	<b>Sydney Accord*</b>
<b>Definition</b>	Complex activities	Broadly-defined activities
<b>Range of resources</b>	Diverse resources (including people, money, equipment, materials, information and technologies)	A variety of resources (including people, money, equipment, materials, information and technologies)
<b>Level of Interactions</b>	Significant problem with interaction between technical, engineering principles and other issues	Occasional interactions between technical, engineering and other issues
<b>Innovation</b>	Creative use of knowledge of engineering principles in novel ways	Use of new materials, techniques or processes in innovative ways
<b>Consequences to society and environment</b>	Significant consequences in a range of context	Consequences mainly local but any extent more widely
<b>Familiarity</b>	Can extend beyond previous experiences by applying principles-based approaches	Normal operating procedures and processes

*(\*) Sydney Accord is not applicable to Biosystems Engineering University studies as it concerns applications oriented studies in engineering technology (3-year programs of studies)*

### **ANNEX 3d: Washington / Sydney Accord**

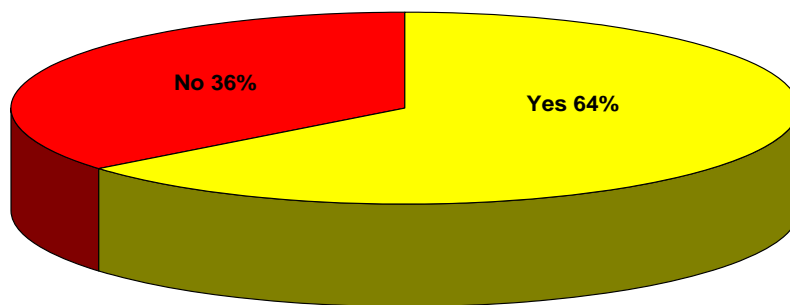
WA/SA\*/DA\* consider 12 program outcomes descriptors with decreasing complexity depending on Higher Education level of study in engineering (4+/3+/2+ years). Those 12 attribute profiles can be sorted in 3 categories.

- **Engineering expertise applied to +/- complex problems/activities :**
  - o Knowledge of engineering science
  - o problem analysis
  - o Design/development of solutions
  - o Modern tool usage
  
- **Investigation applied to +/- complex problems/activities :**
  - o Design and Conduct experiments
  - o Analyze and interpret data to provide valid conclusions
  
- **Transferable skills applied to +/- complex problems/activities :**
  - o Individual / Team work
  - o The Engineer and the society : societal, H&S, legal, cultural, issues and consequent responsibilities
  - o Ethics : professional ethic, responsibilities and norms of eng. practice
  - o Environment and sustainability
  - o Project management and finance : Business practices, risk and change management
  - o Long-life learning

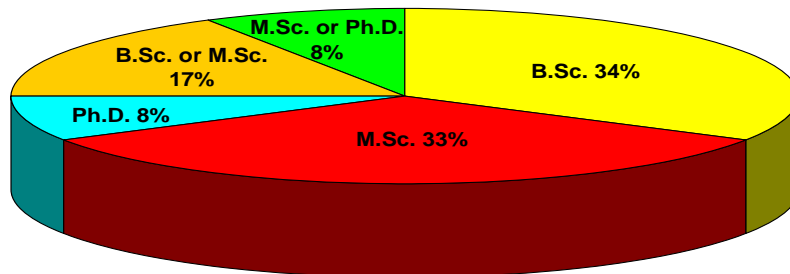
*(\*) Sydney and Dublin Accords are not applicable to Biosystems Engineering University studies as they concern applications oriented studies in engineering technology (3-year and 2-year programs of studies, respectively)*

**Graphic display of the replies to the questionnaire**  
**"University - Enterprise Cooperation"**

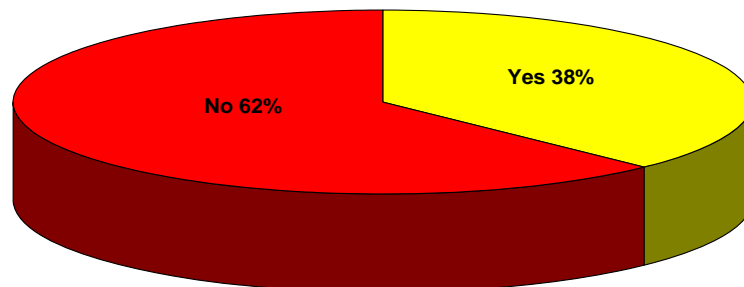
The Guidelines for the 2<sup>nd</sup> Workshop was accompanied by a questionnaire, which tackled the theme on “University – Enterprise Cooperation” (a blank version may be found in Appendix Q.1 below). It was prepared and distributed to several national key-points industry representatives. As expected, the input was relatively poor (fifteen replies). The list of positive replies (please refer to Appendix Q.2) was processed and is presented graphically here-below.



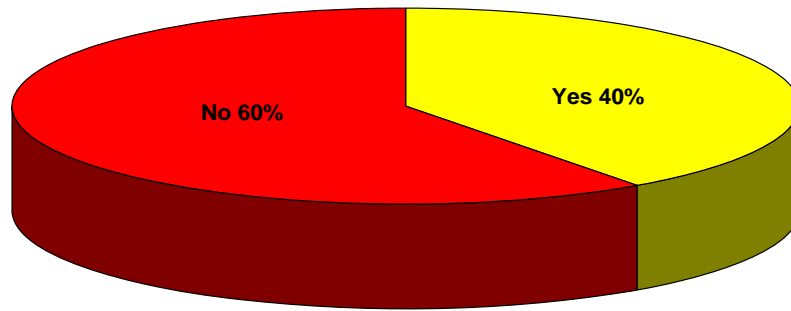
**Figure 1.** Are there career options in your enterprise/company relevant to Agricultural/Biological or Biosystems Engineering?



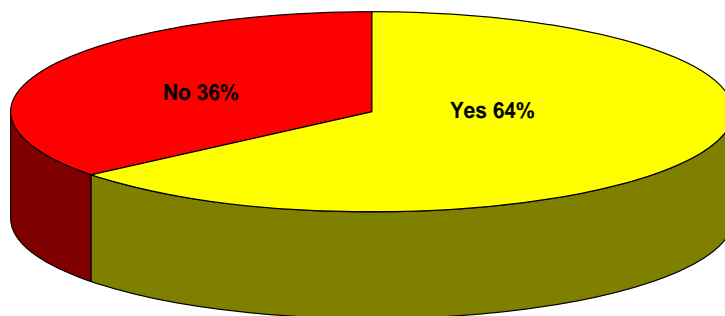
**Figure 2.** Which degrees are preferred (B.Sc., M.Sc., Ph.D.)?



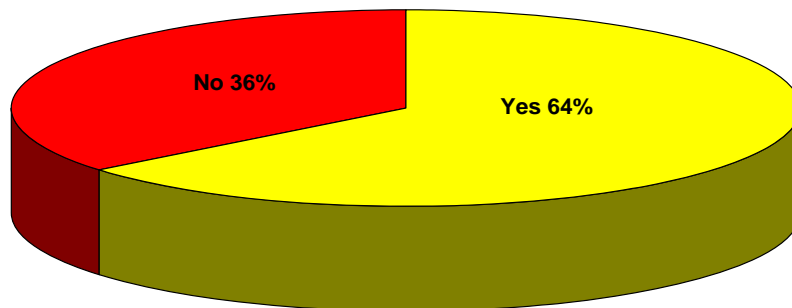
**Figure 3.** Does your enterprise/company intend to recruit more graduates with the classical Agricultural Engineering background?



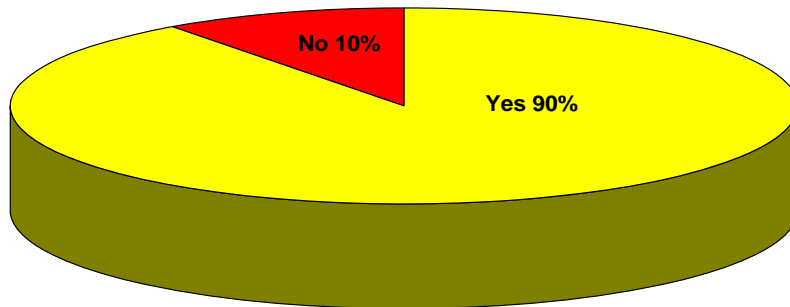
**Figure 4.** Does your enterprise/company prefer a change in that background towards Biosystems Engineering?



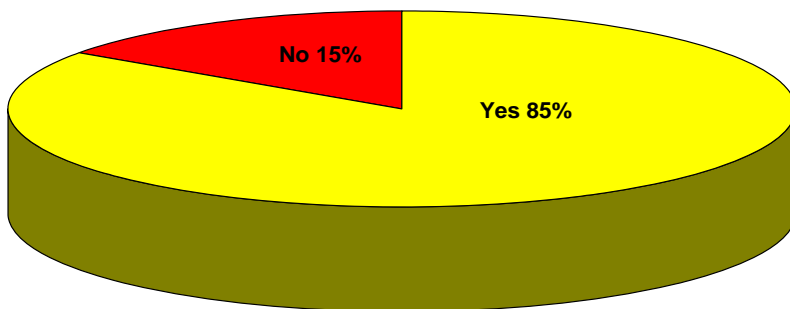
**Figure 5.** Does your enterprise/company have a defined and comprehensive policy regarding University - Enterprise cooperation?



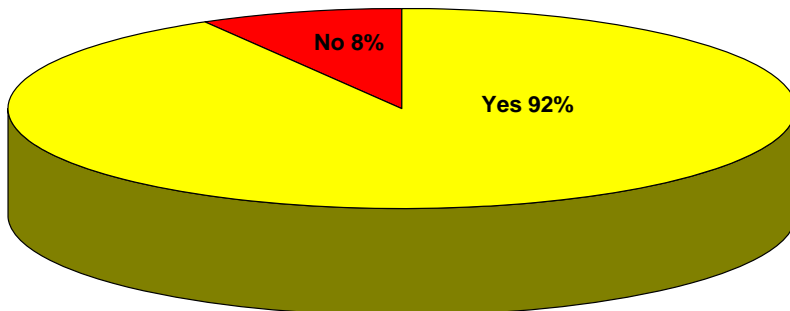
**Figure 6a.** Has your enterprise/company ever run a funded cooperation project with a University/Institution/Research group?



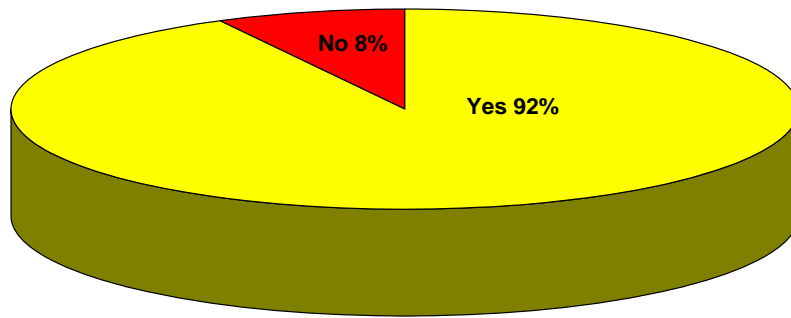
**Figure 6b.** If yes, was it successful (e.g. in terms of implementation of outputs, scientific interaction)?



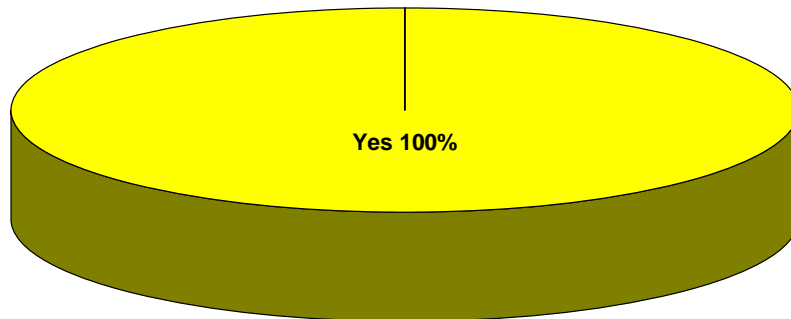
**Figure 7.** Industry and job market should be more involved in the curriculum developments/restructuring of studies?



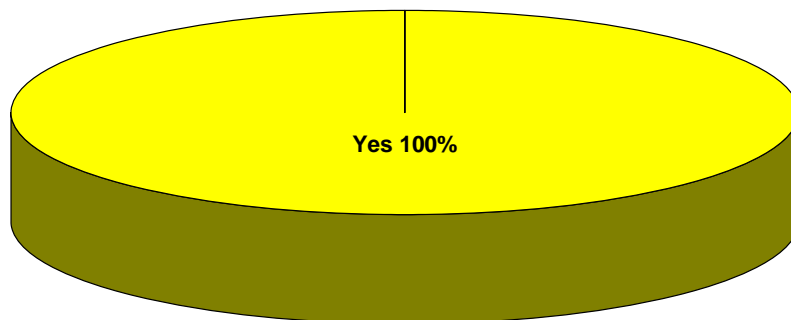
**Figure 8.** Would integration of graduates into the job market improve entrepreneurial spirit at University?



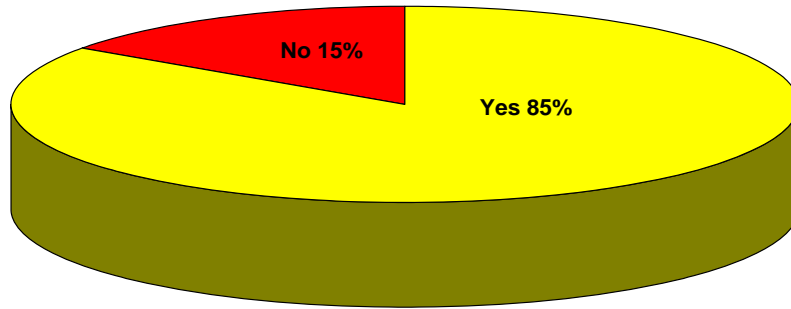
**Figure 9.** Should the development of continuing education programs in cooperation with industry be fostered so as to meet the market needs?



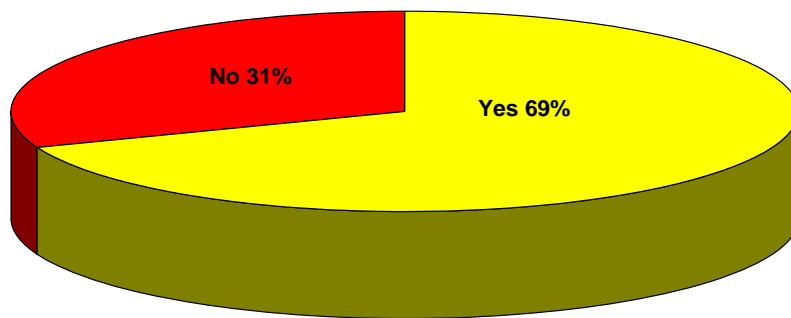
**Figure 10.** Should the transfer of knowledge from University to industry be facilitated and accelerated and vice versa?



**Figure 11.** Should permanent routes of dialogue between Universities and enterprises be implemented?



**Figure 12.** Should joint education (through research thesis projects) and/or training projects be developed?



**Figure 13.** Should transnational programmes of student mobility for research thesis projects and/or training projects with the support of industry be developed?

## Appendix Q.1 : Questionnaire “University - Enterprise Cooperation”

Section 1 (to be filled in by project’s contact person)

Name of enterprise/company	
Country	
Size of enterprise (full-time and part-time employees)	
Name of the respondent	
Position in the enterprise/company	
e-mail address of the respondent	

Section 2 (to be filled in by enterprise /company active in the field of Biosystems Engineering)

Contact person	
Country	
How does your institution sustain partnership with enterprises / institutions (open question)	

Are there career options in your enterprise/company relevant to Agricultural/Biological or Biosystems Engineering?	Y/N
If yes, how many graduates with such background are currently employed?	
What learning outcomes and/or competencies demonstrated required skill potential?	
Which degrees were preferred (B.Sc., M.Sc., Ph.D.)?	
Does your enterprise/company intend to recruit more graduates with the classical Agricultural Engineering background? Or, does it prefer a change in that background towards Biosystems Engineering? If yes, in which direction?	

University-Enterprise Interaction	
Does your enterprise/company have a defined and comprehensive policy regarding University-Enterprise cooperation?	Y/N
If yes, please specify the type of this cooperation / liaison	
Have you ever run a funded cooperation project with a University / Institution / Research group?	Y/N
If yes, please give its title; which was the source of funding?	
If yes, was it successful (e.g. in terms of implementation of outputs, scientific interaction)?	Y/N
Integration of graduates into the job market (opinion of enterprise in the field of Biosystems Engineering)	
Industry and job market should be more involved in the curriculum developments / restructuring of studies; or this might have negative consequences due to the many different and contradictory needs of the industries	Y/N/
Improve entrepreneurial spirit at University	Y/N
Develop continuing education programs in cooperation with industry so as to meet the market needs	Y/N
Facilitate and accelerate transfer of knowledge from University to industry and vice versa	Y/N
Implement permanent routes of dialogue between Universities and enterprises	Y/N
Develop joint education (through research thesis projects) and/or training projects	Y/N
Develop transnational programmes of student mobility for research thesis projects and/or training projects with the support of industry	Y/N
Free comments and suggestions	

I agree that the information submitted can be used for the purpose of the study

## **Appendix Q.2: List of “co-operating” EU industries, which replied to the questionnaire "University - Enterprise Cooperation"**

- 1) De Masi Costruzioni S.r.l. - Gioia Tauro (Reggio Calabria), ITALY, tel. +39 0966 506800-1-2, fax +39 0966 506803, demasi@demasi.it, info@demasi.it (industry of agricultural machines);
- 2) Sicil Zappa S.n.c. di Giardina S.M. & C.- Mussomeli (Caltanissetta), ITALY, tel. +39 0934 952207, fax +39 0934 993164, sicilzappa@ediset.it (industry of agricultural machines);
- 3) Casa Vinicola Calatrasi S.p.A. - San Cipirello (Palermo), ITALY, tel. +39 091 8576767, fax +39 091 8576041, info@calatrasi.it (food processing industry);
- 4) Carlo Pellegrino & C. S.p.A. - Marsala (Trapani), ITALY, tel. +39 0923 719966, +39 0923 719911, fax +39 0923 953542, marketing@carlopedellegrino.it (food processing industry);
- 5) Delta Serre S.P.A. - Castellare di Pescia - Pescia (Pistoia), ITALY, tel. +39 0572 451952, fax +39 0572 453271, info@deltaserre.it (industry of materials for greenhouses);
- 6) P.A.T.I. S.p.A. - Zenone degli Ezzelini (Treviso), ITALY, tel. +39 0423 567326, fax +39 0423 567772, info@pati.it (industry of materials for greenhouses);
- 7) S@T-INFO - Chalon sur Saône (Dijon), FRANCE, tel. +33 03 85420942, fax +33 03 85422130, benoit.gobin@sat-info.fr (company of GPS services for agriculture, topography, public works and instruction);
- 8) Sulky-Burel - Chateaubourg Cedex (Rennes), FRANCE, tel. +33 02 99008484, fax +33 02 99008473, sbillerot@sulky-burel.com (industry of agricultural machines);
- 9) Demeter S.A. - Athens, GREECE, tel. +30 210 5155777, fax +30 210 5155778, ventourakis@demeter.gr (industry of agricultural machines and tyres);
- 10) Geothermiki - Thessaloniki, GREECE, tel. +30 231 0797001/3, fax +30 231 097004, depes@geotherm.gr (industry of materials for greenhouses, animal farms and equipment);
- 11) TRAGSA - Madrid, SPAIN, tel. +34 913 963400, fax +34 913 963488, bberganz@tragsa.es (company of services for agriculture, forestry, environment, aquaculture and fisheries);
- 12) Agrocom Vision - Kvistgaard, DENMARK, tel. +45 49 122424, fax +45 49 138232, madsen@agrocom.com (industry of agricultural machines);
- 13) AgroTech - Aarhus, DENMARK, tel. +45 8743 8400, fax +45 8743 8410, jrp@agrotech.dk (company of services for bioenergy/biogas from animal production, field agriculture, livestock engineering, horticulture technology and sensors);
- 14) Hardi International - Taastrup (Høje-Taastrup), DENMARK, tel. +45 4358 8300, fax +45 4371 3355, min@hardi-international.com (industry of agricultural machines).