Maroun Semaan
Faculty of Engineering and Architecture (SFEA)
Mission

We offer world-class educational programs that prepare students for the engineering, architecture, and design professions. Rooted in the liberal education model, our programs also prepare students to be engaged citizens and leaders, entrepreneurs, and researchers who deploy their skills with ingenuity, integrity, and a sense of responsibility towards future generations. Our Faculty produces transformative knowledge and technology through internationally-recognized research and design, and seeks to leverage the special contexts of Lebanon and the region to define highly novel and relevant research programs. We impact policy and practice through our alumni and by directly engaging industry, government, and the public at large.

Graduate Programs

Master’s Degree Programs

The Maroun Semaan Faculty of Engineering and Architecture offers graduate programs of study leading to the degree of Master of Engineering (ME) with majors in civil engineering, environmental and water resources engineering, electrical and computer engineering, mechanical engineering, and chemical engineering. The Faculty also offers the degrees of Master of Engineering Management (MEM), Master of Urban Design (MUD), Master of Urban Planning and Policy (MUPP), Master of Mechanical Engineering with a major in applied energy, and Master of Science (MS) with majors in chemical engineering, biomedical engineering, and energy studies. SFEA also offers a Master of Science program in environmental technology as part of an Interfaculty Graduate Environmental Sciences Program.

In addition, a professional diploma in green technologies with majors in energy, building, and water is offered in the faculty for professionals who wish to enhance their knowledge in the field.

The requirements for admission to the master’s programs are those specified for the master’s degree in the Admissions section of this Catalogue with the following interpretations and additions.

Waiving of Credits

The department or program of the intended major may recommend waiving up to nine credits of course work for students who have completed a Bachelor of Engineering (BE) degree and are applying for admissions to a Master of Engineering (ME) program, which is subject to approval by the advisor, chairperson, and the SFEA Graduate Studies Committee. To apply, the student must have completed advanced engineering courses (600-level and above) that meet the program requirements with a grade of at least 80. In addition, the total number of transferable credits from BE to ME should not exceed 12. This means that if a student has taken a credit overload during his/her undergraduate BE studies, he/she can waive a maximum of 12 credits.
Regulations for Master's Students Taking Undergraduate Courses

Masters level students who are required to take undergraduate courses must obtain a grade of at least 70 in each undergraduate course taken. If a student fails to obtain a grade of 70 in any of these undergraduate courses, the student is allowed to repeat that course only once. Failure to meet the requirements stipulated above will result in the student being dropped from the graduate program.

Curricula and Courses

The curricula and courses offered in each department are presented in the appropriate sections of this Catalogue.

Courses Open to Students from Other Faculties

Students from other Faculties are allowed to take any course for credit offered by the SFEA, provided space is available, the prerequisites are satisfied, and the student has prior approval of both his/her Faculty and the department offering the course.

Doctor of Philosophy (PhD) Programs

The Maroun Semaan Faculty of Engineering and Architecture offers graduate programs leading to the degree of Doctor of Philosophy (PhD) with specializations in biomedical engineering, civil engineering, electrical and computer engineering, environmental and water resources engineering, and mechanical engineering.

Criteria for Regular Admission to PhD Programs

Candidates for a doctoral degree program must hold a master's degree or its equivalent and must demonstrate outstanding academic ability (minimum average of 85 or its equivalent) at the master's level as well as the potential to conduct scholarly research. Additional specific requirements for each program can be found in the departmental sections of this Catalogue. Application to the doctoral program will follow the deadlines set by the Admissions Office. All applicants are required to take the General Exam part of the Graduate Record Examination (GRE) and submit their scores. Students other than AUB graduates and graduates of recognized colleges or universities in North America, Great Britain, Australia, and New Zealand must meet the English language proficiency requirements set for master's students.

Admission to a PhD program requires the recommendation of the department offering the program and the approval of the SFEA Graduate Studies Committee.

Criteria for Admission to the Accelerated PhD Programs

To apply to the accelerated program, students must have an average in their undergraduate work of 85 or above. This applies to the average in the major as well as the cumulative average. In addition to meeting the requirements described in the General University Academic Information Section of the AUB catalogue, there may be specific requirements described in the departmental sections of the catalogue.

RCR Requirement

The Responsible Conduct of Research (RCR) Requirement must be completed by all newly admitted degree seeking graduate students. The requirement consists of a course that must be completed within the first month and is marked by a passing grade. Failure to fulfill the requirement in a timely manner results in a registration hold that is removed once the student has fulfilled the requirement. The specific course/section to be taken is assigned by the student advisor. For more details on the requirement, please refer to page 49. Below is the RCR course listing of SFEA.

RCRE 600 Responsible Conduct of Research for Engineers 0 cr.
Every semester

An online rcr course (Responsible Conduct of Research) from the Collaborative Institutional Training Initiative (CITI Program). Required for all graduate students in the Engineering disciplines. The course “covers core norms, principles, regulations, and rules governing the practice of research.” It consists of the following modules: Research Misconduct, Authorship, Peer Review, Conflicts of Interest, Environmental and Social Dimensions of Engineering Research, Mentoring, Research Involving Human Subjects, Using Animal Subjects in Research, Data Management, and Collaborative Research.

Financial Support Available to Graduate Students

The SFEA offers three types of financial assistance to the most qualified applicants to its graduate programs, which include fellowships, graduate research assistantships (GRA), and graduate teaching assistantships (GA).

The students who receive financial support are expected to maintain a high level of academic performance, satisfactory progress toward a degree, and a satisfactory performance of the work assignments associated with the aid.

These fellowships, GRAs, and GAs covering tuition are available for students at the graduate level in return for assisting faculty members in teaching and/or research for a specified number of hours per week in an academic department. Applicants are selected on the basis of their academic record and the needs of the relevant department. For more information, refer to Full-Time Status for University Graduate Assistants and Graduate Research Assistants, page 51.

Applicants opting for the non-thesis track are normally not offered graduate assistantships.
Biomedical Engineering Graduate Program

Coordinator: Dawy, Zaher (Electrical & Computer Engineering, SFEA)
Co-coordinator: Jaffa, Ayad (Biochemistry & Molecular Genetics, FM)

Coordinating Committee Members:
- Daou, Arij (Biomedical Engineering, SFEA)
- Darwiche, Nadine (Biochemistry & Molecular Genetics, FM)
- Kadara, Humam (Biochemistry & Molecular Genetics, FM)
- Khoueiry, Pierre (Biochemistry & Molecular Genetics, FM)
- Mhanna, Rami (Biomedical Engineering, SFEA)
- Oweis, Ghanem (Mechanical Engineering, SFEA)

Background

The Biomedical Engineering Graduate Program (BMEP) is a joint SFEA and FM interdisciplinary program that offers two degrees that are: Master of Science (MS) in Biomedical Engineering and Doctor of Philosophy (PhD) in Biomedical Engineering. The BMEP is housed in the SFEA and administered by both SFEA and FM via a joint program coordinating committee (JPCC).

The mission of the BMEP is to provide excellent education and promote innovative research enabling students to apply knowledge and approaches from the biomedical and clinical sciences in conjunction with design and quantitative principles, methods, and tools from the engineering disciplines, to address human health related challenges of high relevance to Lebanon, the Middle East, and beyond. The program prepares its students to be leaders in their chosen areas of specialization committed to lifelong learning, critical thinking, and intellectual honesty.

The curricula of the MS and PhD degrees are composed of core and elective courses balanced between biomedical sciences and engineering and between fundamental and applied knowledge.

The curricula include the following three research focus areas:

- **Biomedical Systems:** This focus area includes research directions such as devices, instrumentation, biomechanics, biomaterials, drug delivery systems, and tissue engineering.
- **Biomedical Cybernetics:** This focus area includes research directions such as biomedical and health informatics, computational biology, biomedical signal/image processing, and biomedical systems engineering.
- **Cardiovascular and Pulmonary Engineering:** This focus area includes research directions such as fluid mechanics, modeling, simulation, imaging, devices, and implants related to both human cardiovascular and pulmonary systems.

A student may select his/her courses to satisfy the requirements of one of the three focus areas.

The MS and PhD degrees are open to students holding degrees from relevant fields of study including basic sciences, biomedical sciences, computer science, engineering, health sciences, and mathematics. Due to the interdisciplinary nature of the program, remedial undergraduate courses in both sciences and engineering have been identified to cover the needed prerequisite knowledge, customized per student on a case-by-case basis. Remedial undergraduate courses do not count as credit towards the MS or PhD degree completion. Grades on these remedial courses will appear on the transcript as Pass/Fail with a passing grade of 70/100.

Master of Science in Biomedical Engineering

The BMEP offers a Master of Science (MS) degree in Biomedical Engineering with two options: Thesis option and non-thesis option.

Admission Requirements

The application procedures and admission requirements to the MS program follow AUB’s General University Academic Information as documented in the Graduate Catalogue. To be considered for admission, applicants must hold a Bachelor’s degree in a relevant field of study from AUB or its equivalent from a recognized institution of higher learning.

Accepted students in the thesis option are eligible to apply for Graduate Assistantship (GA) and Graduate Research Assistantship (GRA). GA cannot be used to cover the tuition for remedial undergraduate courses.

Course Requirements

The MS program consists of 30 credits. The curriculum design is divided into core courses and elective courses in addition to a master thesis for the thesis option. This program does not provide credit towards New York State licensure.

**Core graduate courses:** 18 credits of core courses from biomedical sciences and engineering.

<table>
<thead>
<tr>
<th>Required core courses (18 cr.)</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMEN 600 Biomedical Engineering Applications</td>
<td>3</td>
</tr>
<tr>
<td>EPHD 310 Basic Biostatistics</td>
<td>3</td>
</tr>
<tr>
<td>HUMR 314 Research Seminar</td>
<td>1</td>
</tr>
<tr>
<td>BMEN 672 Hospital Lab Rotation</td>
<td>0</td>
</tr>
<tr>
<td>BIOC 321 Nucleic Acids and Basic Genetics</td>
<td>1</td>
</tr>
<tr>
<td>BIOC 322 Protein Biochemistry</td>
<td>1</td>
</tr>
<tr>
<td>PHYL 346 Human Physiology</td>
<td>4</td>
</tr>
<tr>
<td>BMEN 601 Computational Modeling of Physiological Systems</td>
<td>3</td>
</tr>
<tr>
<td>BMEN 673L Biomedical Engineering Lab</td>
<td>1</td>
</tr>
<tr>
<td>HUMR 310A Biomedical Research Techniques</td>
<td>1</td>
</tr>
</tbody>
</table>

**Restricted elective graduate courses:** 6 credits restricted elective courses customized per focus area and required by both thesis and non-thesis options.

<table>
<thead>
<tr>
<th>Restricted elective courses (6 cr.)</th>
<th>Credits</th>
<th>Systems</th>
<th>Cybernetics</th>
<th>Cardiovascular</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYL 302 Cardiovascular Physiology</td>
<td>2</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYL 300A Pulmonary Physiology</td>
<td>1</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECE 601 Biomedical Engineering I</td>
<td>3</td>
<td>A1</td>
<td>B1</td>
<td>C1</td>
</tr>
</tbody>
</table>

1. EPHD 310 can be replaced by another advanced level statistics course based on JPCC’s approval.
2. Students in the systems and cybernetics focus areas are required to take two courses from the following groups, respectively: (A1-A6), (B1, B6).
3. Student in the cardiovascular and pulmonary engineering focus area are required to take PHYL302, PHYL300A, and one course from (C1-C5).
Degree Requirements

General requirements for Master's degree holders: Based on AUB's guidelines, a minimum of 48 credit hours beyond those required for the Master's degree, of which a minimum of 18 credit hours must be in graduate level course work and a minimum of 24 credit hours of thesis work. Requirements also allow a maximum of three credit hours out of the 18 credits of course work as tutorial course and include zero credit comprehensive examination preparation course and zero credit thesis proposal preparation course.

General requirements for Bachelor's degree holders: Based on AUB's guidelines, a minimum of 78 credit hours beyond those required for the Bachelor's degree, of which a minimum of 36 credit hours must be in graduate level course work and a minimum of 30 credit hours of thesis work. Requirements also allow a maximum of six credit hours out of the 36 credits of course work as tutorial courses and include zero credit comprehensive examination preparation course and zero credit thesis proposal preparation course.

The following are the graduate level course requirements for students admitted with a Bachelor's degree. The total number of credits is at least 36 credits divided among core, restricted elective, and free elective courses. Students admitted with a Master's degree can waive as many courses as possible without going below the minimum required 18 credits of course work.

Core course work: 21 credits of core courses from biomedical sciences and engineering.

Admission Requirements

The application procedures and admission requirements to the PhD program follow AUB's General University Academic Information as documented in the Graduate Catalogue. To be considered for admission, applicants must hold Bachelor's or Master's degree in a relevant field of study from AUB or its equivalent from a recognized institution of higher learning.

Acceptance into the PhD program is determined by academic performance as well as an assessment of readiness, potential and ability to develop into independent researchers as judged by interviews by faculty members, a written statement, letters of recommendation, GRE scores, and other means of assessment such as publications and industrial experience.

Accepted students are eligible to receive scholarships that cover fully their tuition fees and that provide a monthly stipend.
Course Descriptions

**BMEN 600** Biomedical Engineering Applications  3 cr.
Biomedical engineering is an interdisciplinary domain which applies principles of engineering to find solutions for biological and health problems. Biomedical engineering aims to improve our fundamental understanding of biological processes and develop approaches for optimized therapeutic/diagnostic healthcare procedures. The field of biomedical engineering involves the development of materials to replace or enhance the operation of damaged or malfunctioning biological entities, development of diagnostic and therapeutic tools, modeling of biological systems, signal processing and bioinformatics. This course will introduce students to biomedical engineering and will provide insight on the various applications in the biomedical engineering field. The course will be divided into modules and each will be given by a specialist in a certain biomedical engineering area.

**BMEN 601** Computational Modeling of Physiological Systems  3 cr.
This course focuses on the quantitative modeling of different physiological systems. It provides students with current concepts of the mathematical modeling, different quantitative descriptions of cellular and organ physiology. At the subcellular/cellular level, we will examine mechanisms of regulation and homeostasis. At the system level, the course will cover basic aspects of anatomical and pathophysiological features of the nervous, neural, cardiovascular and respiratory systems. Several physiological processes are treated as case studies for increasing complexity in modeling dynamical systems. 
Prerequisite: PHYL 346; or consent of instructor.

**BMEN 602** Computational Modeling of Cardiovascular and Pulmonary Systems  3 cr.
The needs for better understanding of mechanics and the tools for computational modeling of Cardiovascular and Respiratory Systems in healthy and diseased conditions are constantly increasing. This is a result of the enormous advances that have been made in the science and engineering of both surgical and therapeutic medicine. This course covers the modeling and simulation of cardiovascular and respiratory systems. It will provide the students with a thorough understanding of the anatomy, physiology and mechanics of cardiovascular and respiratory systems as well as the computational tools for modeling and simulation of cardiac, circulatory, and respiratory systems in healthy and diseased conditions.

**BMEN 603** Tissue Engineering  3 cr.
In a world of aging population, an ever increasing demand for improvement of healthcare services and need for replacement organs and tissues is arising. The limited pool of donors together with the problem of donor organ rejection is a strong driver for engineering tissues and other body parts. Tissue engineering is an interdisciplinary field that uses cells, biomaterials, biochemical (e.g. growth factors) and physical (e.g. mechanical stimulation) signals, as well as their combination to generate tissue-like structures. The goal of tissue engineering is to provide biological substitutes that can maintain, restore or improve the function of damaged organs in the body. This course will introduce interested students to the new field of tissue engineering and provide insight on cutting edge applications in this area.

**Restricted elective graduate courses**: 9 credits restricted elective courses customized per focus area.

<table>
<thead>
<tr>
<th>Restricted elective courses (9 cr.)</th>
<th>Credits</th>
<th>Systems</th>
<th>Cybernetics</th>
<th>Cardiovascular</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUMR 305  Cell and Tissue Biology</td>
<td>3</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIOC 325  Receptors and Signal Transduction</td>
<td>2</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>BIOC 326A Bioinformatics Tools and Applications in Genomics</td>
<td>1</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>PHYL 302  Cardiovascular Physiology</td>
<td>2</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>PHYL 300A Pulmonary Physiology</td>
<td>1</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>EECE 601  Biomedical Engineering I</td>
<td>3</td>
<td>A1</td>
<td>B1</td>
<td>C1</td>
</tr>
<tr>
<td>BMEN 604  Engineering of Drug Delivery Systems</td>
<td>3</td>
<td>A2</td>
<td></td>
<td>C2</td>
</tr>
<tr>
<td>EECE 603  Biomedical Signal and Image Processing</td>
<td>3</td>
<td></td>
<td>B2</td>
<td>C3</td>
</tr>
<tr>
<td>EECE 663 System Identification or Data Mining or</td>
<td>3</td>
<td></td>
<td>B3</td>
<td></td>
</tr>
<tr>
<td>EECE 693 Neural Networks or</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EECE 667  Pattern Recognition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMEN 607  Biomechanics</td>
<td>3</td>
<td>A3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMEN 603 or Tissue Engineering or Biomaterials &amp; Medical Devices</td>
<td>3</td>
<td>A4</td>
<td></td>
<td>C4</td>
</tr>
<tr>
<td>BMEN 605  Biomedical Imaging</td>
<td>3</td>
<td></td>
<td></td>
<td>B4</td>
</tr>
<tr>
<td>BMEN 609  Introduction to Neuroscience: Experimental, Computational, and Engineering Approaches</td>
<td>3</td>
<td>A5</td>
<td></td>
<td>B5</td>
</tr>
</tbody>
</table>

**Free elective graduate courses**: Students must take at least an additional 6 credits elective courses. These courses should be taken based on the student's specific area of research as approved by the student's advisor.

*Students are required to take two courses from the following groups depending on their focus area: (A1-A5), (B1-B5), and (C1-C5).*
Experts from the medical community will be invited to discuss the various applications of biomaterials and devices in different tissue and organ systems such as orthopedic, cardiovascular, dermatology, and dental applications. The course examines the various applications of biomaterials and devices in different tissue and organ systems such as orthopedic, cardiovascular, dermatology, and dental applications. The students learn the theoretical bases underlying the common forms of medical imaging as well as the limitations and the applicability of such procedures.

This course will focus on recent advances in the development of novel drug delivery systems. The fundamentals of drug delivery are discussed. Various strategies to tune and control the release of active agents for optimized therapeutic outcomes are explored. The course covers polymers and techniques used to produce drug nanoparticles, with specific examples of nanoparticle-based drug delivery systems. Prerequisites: CHEN 314 and CHEN 411; or consent of instructor.

This course will provide students with an overview of the key concepts behind the main imaging modalities used in diagnostic imaging. Focus will be on explaining the physical principles and algorithms underlying X-ray imaging, computed X-ray tomography, magnetic resonance imaging, single-photon emission tomography, positron emission tomography and ultrasound imaging. The students learn the theoretical bases underlying the common forms of medical imaging as well as the limitations and the applicability of such procedures.

This course will allow students to engage with the practical issues in the areas of biomedical instrumentation design and biological signal processing. A particular emphasis will be placed on signal transduction, electronic circuit design for recording and conditioning physiological signals. The lab will introduce hand-on laboratory experiments on biomedical sensors, analog signal amplifiers and filters, digital acquisition and transmission, and basic digital filtering. In addition, some experiments cover topics that demonstrate the various levels of complexity that characterize biological signals. Signal processing tools include spectral and cepstral analysis, de-noising and artifact removal, filter banks and wavelet decompositions, Hilbert transforms, and information-theoretic measures.

This laboratory course aims to introduce students to the practical issues in the areas of biomedical instrumentation design and biological signal processing. A particular emphasis will be placed on signal transduction, electronic circuit design for recording and conditioning physiological signals. The lab will introduce hand-on laboratory experiments on biomedical sensors, analog signal amplifiers and filters, digital acquisition and transmission, and basic digital filtering. In addition, some experiments cover topics that demonstrate the various levels of complexity that characterize biological signals. Signal processing tools include spectral and cepstral analysis, de-noising and artifact removal, filter banks and wavelet decompositions, Hilbert transforms, and information-theoretic measures.

This course will discuss the relationships among sequence, structure, and function in biological networks as well as advances in modeling of quantitative, functional, and comprehensive, genomics analyses. It will assess computational issues arising from high-throughput techniques recently introduced in biomedical sciences, and cover very recent developments in computational genomics, including genome structural variant discovery, epigenome analysis, cancer genomics, and transcriptome analysis.

A course on the study of the biomechanical principles underlying the kinetics and kinematics of normal and abnormal human motion. Emphasis is placed on the interaction between biomechanical and physiologic factors (bone, joint, connective tissue, and muscle physiology and structure) in skeleto-motor function and the application of such in testing and practice in rehabilitation. The course is designed for engineering students with no previous anatomy/physiology. Prerequisite: CIVE 210, MECH 320 or CIVE 310; or consent of instructor.

A course that examines the structure-property relationships for biomaterials and the medical applications of biomaterials and devices. The first part of the course focuses on the main classes of biomaterials, metal, ceramic, polymeric, and composite implant materials, as well as their interactions with the human body (biocompatibility). The second part of the course examines the various applications of biomaterials and devices in different tissue and organ systems such as orthopedic, cardiovascular, dermatology, and dental applications. Experts from the medical community will be invited to discuss the various applications. Prerequisite: MECH 340 or consent of instructor.

A course will examine the various applications of biomaterials and devices in different tissue and organ systems such as orthopedic, cardiovascular, dermatology, and dental applications. Experts from the medical community will be invited to discuss the various applications. Prerequisite: MECH 340 or consent of instructor.

Biomedical Imaging

BMEN 604 / Engineering of Drug Delivery Systems 3 cr.
CHEN 673
This course focuses on recent advances in the development of novel drug delivery systems. The fundamentals of drug delivery are discussed. Various strategies to tune and control the release of active agents for optimized therapeutic outcomes are explored. The course covers polymers and techniques used to produce drug nanoparticles, with specific examples of nanoparticle-based drug delivery systems. Prerequisites: CHEN 314 and CHEN 411; or consent of instructor.

BMEN 605 / Biomedical Imaging 3 cr.
This course will provide students with an overview of the key concepts behind the main imaging modalities used in diagnostic imaging. Focus will be on explaining the physical principles and algorithms underlying X-ray imaging, computed X-ray tomography, magnetic resonance imaging, single-photon emission tomography, positron emission tomography and ultrasound imaging. The students learn the theoretical bases underlying the common forms of medical imaging as well as the limitations and the applicability of such procedures.

BMEN 606 / Computational Genomics 1 cr.
BIOC 326A
This course will discuss the relationships among sequence, structure, and function in biological networks as well as advances in modeling of quantitative, functional, and comprehensive, genomics analyses. It will assess computational issues arising from high-throughput techniques recently introduced in biomedical sciences, and cover very recent developments in computational genomics, including genome structural variant discovery, epigenome analysis, cancer genomics, and transcriptome analysis.

BMEN 607 / Computational Genomics 1 cr.
CHEN 314 and CHEN 411; or consent of instructor.
This course will provide students with an overview of the key concepts behind the main imaging modalities used in diagnostic imaging. Focus will be on explaining the physical principles and algorithms underlying X-ray imaging, computed X-ray tomography, magnetic resonance imaging, single-photon emission tomography, positron emission tomography and ultrasound imaging. The students learn the theoretical bases underlying the common forms of medical imaging as well as the limitations and the applicability of such procedures.

BMEN 608 / Biomaterial and Medical Devices 3 cr.
MECH 320 or CIVE 310; or consent of instructor.
A course that examines the structure-property relationships for biomaterials and the medical applications of biomaterials and devices. The first part of the course focuses on the main classes of biomaterials, metal, ceramic, polymeric, and composite implant materials, as well as their interactions with the human body (biocompatibility). The second part of the course examines the various applications of biomaterials and devices in different tissue and organ systems such as orthopedic, cardiovascular, dermatology, and dental applications. Experts from the medical community will be invited to discuss the various applications. Prerequisite: MECH 340 or consent of instructor.
BMEN 980  Qualifying Exam Part I: Comprehensive Exam  0 cr.  
Every semester.

BMEN 981  Qualifying Exam Part II: Defense of Thesis Proposal  0 cr.  
Every semester. Prerequisite: BMEN 980.

BMEN 982  PhD Thesis  3 cr.  
Every semester. Taken while total required credit hours have been completed.

BMEN 983  PhD Thesis  6 cr.  
Every semester. Taken while total required credit hours have not been completed.

BMEN 984  PhD Thesis  9 cr.  
Every semester. Taken while total required credit hours have not been completed.

BMEN 985  PhD Thesis  12 cr.  
Every semester. Taken while total required credit hours have not been completed.

BMEN 986  PhD Thesis  0 cr.  
Every semester. Taken while total required credit hours have not been completed.

BMEN 987  PhD Thesis Defense  0 cr.  
Every semester. Prerequisite: BMEN 981.

BIOM 326A  Bioinformatics Tools and Applications in Genomics  1 cr.  
This course will discuss the relationships among sequence, structure, and function in biological networks as well as advances in modeling of quantitative, functional, and comprehensive genomics analyses. It will assess computational issues arising from high-throughput techniques recently introduced in biomedical sciences, and cover very recent developments in computational genomics, including genome structural variant discovery, epigenome analysis, cancer genomics, and transcriptome analysis.

BIOM 385  Research Ethics  15.0; 1 cr.  
This course introduces the fundamentals of responsible conduct of research, emphasizing the ethical practice of human research. The course recaps history of ethical principles, the development of research codes of conduct and ethical practices, familiarizes students with the different kinds of ethical issues that they might come across throughout their careers, and allows scholars to reflect critically about what it means to be an ethical and responsible researcher. Summer semester.

EECE 601  Biomedical Engineering I  3 cr.  
This course includes an introduction to: general instrumentation configuration, performance of instrument systems; types and characteristics of transducers; sources and characteristics of bioelectric signals; types and characteristics of electrodes; temperature regulation and measurement; cardiovascular system, measurements, and diagnostic equipment; blood instruments; patient care and monitoring; and electrical safety of medical equipment. Prerequisites: BIOL 210 or BIOL 202 or PHYL 246, and EECE 210; or PHYS 228 and PHYS 228L; or consent of instructor.

EECE 603  Biomedical Signal and Image Processing  3 cr.  
Fundamentals of digital signal processing as implemented in biomedical applications. It provides a concise treatment of the tools utilized to describe deterministic and random signals as the basis of analyzing biological signals: data acquisition; imaging; denoising and filtering; feature extraction; modeling. The course is tightly coupled with a practical component through laboratory projects. Examples include the auditory system, speech generation, electrocardiogram, neuronal circuits, and medical imaging. Students should have reasonable software skills in Matlab. Prerequisites: STAT 230 and EECE 340, or equivalent; or consent of instructor.

EECE 633  Data Mining  3 cr.  
This course is an introduction to data mining. Data mining refers to knowledge discovery from huge amounts of data to find non-trivial conclusions. Topics will range from statistics to machine learning to database, with a focus on analysis of large data sets. The course will target at least one new data mining problem involving real data, for which the students will have to find a solution. Prerequisite: EECE 330 or consent of instructor.

EECE 663  System Identification  3 cr.  
This course introduces the basic mathematical tools to fit models into empirical input-output data. General time-series modeling and forecasting, such as stock prices, biological data and others. Topics include nonparametric identification methods; time and frequency response analysis; parametric identification: prediction error, least squares, linear unbiased estimation and maximum likelihood; Convergence, consistency and asymptotic distribution of estimates; properties and practical modeling issues: bias distribution, experiment design and model validation.
EECE 667 Pattern Recognition 3 cr.
The course provides an overview of the algorithms used in machine learning. The course discusses modern concepts for model selection and parameter estimation, decision making and statistical learning. Special emphasis will be given to regression and classification for supervised mode of learning. Students will be assigned typical machine learning problems to investigate as projects.

EECE 693 Neural Networks 3 cr.
The course provides a comprehensive foundation to artificial neural networks and machine learning with applications to pattern recognition and data mining; learning processes: supervised and unsupervised, deterministic and statistical; clustering; single layer and multilayer perceptrons; least-mean-square, back propagation, and Al-Alaoui algorithms; radial-basis function networks; committee machines; principal component analysis; self-organizing maps; and current topics of interest.

EPHD 310 Basic Biostatistics 2.2; 3 cr.
An introductory Biostatistics course that covers basic concepts in statistical methods. The course demonstrates methods of exploring, organizing, and presenting data. The course presents the foundation of statistical inference from estimation, to confidence interval and testing of hypothesis. Applications include comparing population means or proportions via data obtained from paired or independent samples, one-way ANOVA. Also, it introduces simple linear regression, correlations, logistic regression and nonparametric methods for data analysis.

HUMR 305 Cell and Tissue Biology 30.33; 3 cr.
Consists of the first half of Basic Histology, HUMR 209, covering cells and tissues. Open to graduate students outside the department.

HUMR 310A Biomedical Research Techniques 1 cr.
A guided laboratory course in research methods used in cell biology and physiology.

HUMR 314 Research Seminar 0.32; 1 cr.
Presentation and discussion of timely research topics designated by members of the department.

PHYL 302 Cardiovascular Physiology 31.6; 2 cr.
Presents the cardiovascular system with clear reference to pathophysiological and clinical events. Didactic lectures and seminar sessions define physiological concepts and emphasize structure-function relationships. Laboratory sessions familiarize the student with instrumentation and techniques in the cardiovascular field. Open to all graduate students in the department.

PHYL 346 Human Physiology for Paramedical and Undergraduate Students 48; 4 cr.
Outlines fundamental principles of human physiology and the mechanisms governing the function of different body organs. Prerequisites: BIOL 246 and BIOL 201 (or BIOL 210).

Professional Post Graduate Diploma Program in Green Technologies (Pro-Green) General Description of the Pro-Green Program

The Pro-Green Diploma Program is a unique and focused diploma program that caters to professionals aspiring to enhance or complement their technical and decision-making skills in green technologies or progress in green businesses in the areas of energy utilization, building design, construction, and management systems, sustainable and safe water production, water management and waste water treatment.

The American University of Beirut, the Lebanese American University and the American University in Cairo are jointly offering the Professional Post Graduate Diploma in Green Technologies in three specializations:

- Professional Post Graduate Diploma Program in Green Technologies; Major: Energy
- Professional Post Graduate Diploma Program in Green Technologies; Major: Building
- Professional Post Graduate Diploma Program in Green Technologies; Major: Water

Objectives of the Green Technologies Diploma Programs

The Green Technologies Diploma Program is designed to address the trend towards healthier and more socially responsible communities by training professionals on effective ways to develop and advance sustainable energy and water efficiency in production, utilization, storage, and re-use.

The program objectives are:

- to foster problem-solving competencies among professionals pursuing careers in green industries,
- to develop lifelong learning skills among professionals from different disciplines,
- to assist professionals in acquiring the diverse and critical skills needed to advance in their green technology careers,
- and to develop expertise in green technologies related to applications in energy, water, and building.

Upon successful completion of the Green Technology Diploma Program in any area of specialization, students/trainees will be able to:

- acquire an in-depth understanding of green technologies relevant to jobs in planning, design and implementation methods for sustainable energy, building, and water technologies and industries,
- build analysis and hands-on skills needed for development and implementation of green products and processes in the area of specialization (energy, building, or water),
- develop lifelong learning skills in the green technologies field. The pro-green diploma program emphasizes lifelong learning through the establishment of a community of practice and through problem/project-based learning, including case studies related to real life applications from the participants’ own fields of practice,
- and identify how economic analysis, policy and regulatory frameworks can help in expanding green technologies’ market.
Eligibility

The program is intended for professionals and individuals interested in and/or involved in the development and implementation of green technologies in their practice including architects, engineers, facility managers and contractors. The courses are offered at the postgraduate level. Applicants should have a recognized and related bachelor’s degree in natural science, mathematics, engineering, or architecture. Consideration will be given to students who have BA degrees provided that they have completed the prerequisites of the courses offered in the selected specialization.

Admissions Requirements

Applicants to the graduate program, other than AUB graduates and graduates of colleges or universities recognized and located in North America, Great Britain, Australia, and New Zealand, must meet the English Language Proficiency Requirement (ELPR) as explained in the next heading.

Applicants should have a bachelor degree in engineering or science from recognized universities to be enrolled in the diploma program. Professional experience might be considered on case-by-case basis.

The only three documents required for the Diploma in Green are the following:

- A copy of the applicant bachelor degree (diploma) Bachelor of Architecture (BA), Bachelor of Engineering (BE), Bachelor of Science (BS)
- A photocopy of the front page of the applicant's passport or national ID
- TOEFL score, if applicable

Language Requirements

The diploma program is offered in English. The student will follow University policy regarding the English Language Proficiency Requirement (ELPR) for graduate students. Since the students are not graduate degree seekers, the English requirements are determined by requirements of similar diploma programs at recognized institutions.

For students applying to the diploma program, a minimum score of 450 in EEE, TOEFL: CBT 230; PBT 513; IBT 80 or 6.5 IELTS is required for admission. Applicants who are graduates of an English-speaking university are exempted from the English language test. An applicant might also be required to report for an interview with the program coordinator.

Green Technologies Structure and Degree Requirements

The green technologies diploma program shares a set of core courses that can be registered and followed at any of the joint universities. Each major specialization will also include a number of required specialization courses and one or two elective courses depending on the major. The admission procedures, teaching and examination regulations and academic calendars at universities are carefully coordinated. The program will include a major e-learning format through blended and online offering of courses.

Course Requirements

Core Courses

Students are required to complete the following 6 credits of core courses that are common to the three specializations in Energy, Building, and Water:

PRGR 601  Green Economy, Policies and Law  3 cr.
PRGR 602  Green Technologies System Approach to Sustainability and Management  3 cr.
PRGR 698B  Seminar/Webinar  0 cr.

The required core courses of the program provide solid foundation in both technical and economic aspects of green technologies in Energy, Buildings, and Water, allowing the student to simultaneously understand advances in selected green technologies and their interrelations with market economy, policy and energy laws. The specialization courses consist of more in-depth development of expertise in the selected major through a number of specialization courses selected in the major, elective courses, and a graduation project.

The diploma program permits part-time enrollments. To obtain a diploma degree in green technologies in any of the offered specializations, the student must complete a minimum of 18 credits of course work depending on the specialization, including a project in an area related to the selected specialization. The diploma program credit requirement is distributed as follows:

18 credits are required to complete the diploma:

- 6 credits of core courses
- 6 to 8 credits of courses in the area of specialization excluding the project in the area of specialization
- 2 to 4 credits for elective course as approved by project advisor/s from the list of elective courses as well as courses from other specializations that are outside the student declared specialization.
- Project (equivalent to 2 credit hours)
- 0-credit Seminar/Webinar (to be registered twice)

The program is offered online for most courses except for the non-mandatory elective labs (Labs are electives and will be offered face to face. When offered, it is possible to have experiments done intensively over weekends for students who are taking this elective.)

The diploma should be completed in 12-18 months.

The core, specialization, and elective courses are summarized in the following sections.
Specialization Courses
Students are required to complete a minimum of 6 credits from their selected specialization. The courses in the various specializations are as listed below.1

<table>
<thead>
<tr>
<th>Energy Specialization</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRGR 603 Solar Radiation and Energy Conversion</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 604 Solar PV Electricity</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 605 Wind Energy</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 606 Energy Storage</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 609 Renewable Energy Lab</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 615 Biofuels</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 616 Waves, Tidal, and Hydro Energy</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 617 Energy Efficiency in Buildings Evaluation and Design</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 620 Energy Systems and Sustainable Environments</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 621 Waste to Energy Processes and Technologies</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 699 E Project</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building Specialization</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRGR 630 Sustainable preservation and Restoration of Existing Buildings</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 631 Low energy architecture and passive building designs</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 632 Sustainable building materials</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 633 Renewable energy systems and energy efficiency in buildings</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 634 Moisture and control of humidity in buildings</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 637 Green building basics and building rating practices</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 639 Construction and Demolition Waste Management</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 641 HVAC Systems for Energy Efficient Acclimatization</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 643 Heat Pumps and innovative methods to improve performance with direct applications</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 645 Building Energy System Modeling</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 646 Energy management Systems of buildings</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 699 B Project</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Specialization</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRGR 664 Water Instrumentation</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 665* Water Basics</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 666 Water Infrastructure Systems</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 667 Water Treatment and Water Desalination</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 668 Wastewater and Sludge Treatment</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

1 Water Core Course

Elective Courses
The elective courses can be selected from specialization courses outside the chosen area of specialization. In addition, a number of elective course modules can be selected from the following:

<table>
<thead>
<tr>
<th>Elective Courses</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRGR 670 Life Cycle Assessment</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 673 Research Skills Development - General</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 677 Cost-Benefit Analysis</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 679 Project Management, Risk Management and Planning</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PRGR 680 Innovation and Knowledge Transfer</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

Course Loads, Credit Transfer, and Sample Program

Course Loads
Typically the maximum number of credits for the diploma that may be taken in a regular semester is up to 5 or 6 credits, however the student can follow her/his own pace.

Credit Transfer
A maximum of 6 credits can be transferred from other institutions out of the 18 credits for the student to earn the Diploma from the home institution into which the student was originally admitted. This means that two-thirds of the 18-credit requirement for the diploma should be registered at the institution that will grant the degree. Normally, the core courses of the program are duplicated and are offered at each of the partner institutions.

Requirements for Double Specialization
Students may enroll and earn a diploma in two specializations. To fulfill the basic requirement for the double specialization, a student must complete a minimum of 8 credit hours of graduate course work over and above the requirements for the first specialization. This will include 6 credits in the second specialization as well as 2 credit hours for a project. The minimum total credit hours for a double specialization in green technologies diploma would be 26 credit hours.
Requirements for Three Specializations

For a diploma in three specializations, a student must complete a minimum of 8 credit hours of graduate course work over and above the requirements for the two other specializations. This will include 6 credits in the third specialization as well as 2 credit hours for a project. The minimum total credit hours for a triple specialization in green technologies diploma would be 34 credit hours.

Course Descriptions

Core Courses

PRGR 601 Green Economy, Policies and law 3 cr.
The course covers a wide range of topics related policy, law and market economics. Topics include environmental and resource economics and policy; environmental issues and regulations global sustainability and future trends; international environmental law; carbon management for green environment; the science of urban ecology; corporate environmental responsibility; green laws compliance; cost benefit analysis; environmental economics and sustainable development; green tech & finance. International climate change mitigation financing mechanisms (National Appropriate Mitigation Actions and others). Best practices and case studies for successful implementation of climate change mitigation strategies locally and internationally. Introductory statistical and data modeling tools are used as basis of effective decision making or analysis.

PRGR 602 Green Technologies System Approach to Sustainability and Management 3 cr.
The course covers topics related to green technologies applications and system approach to sustainability and management. The first part of the course is related to green tech application including renewable energy sources vs. conventional; solar systems: solarthermal, photovoltaic, solar concentrators, wind; biofuels and biotechnologies; water production and quality; wind; hydrogen cells; low energy architecture and energy efficient buildings; and recycling and reuse of materials, elements and components. The second part of the course covers system approach to sustainability and management including environmental management systems and auditing; environmental impact assessment; sustainability management; sustainable operations; and project and portfolio management.

Energy Specialization Courses

PRGR 603 Solar Radiation and Energy Conversion 2 cr.
Solar Radiation: Components, Geometry of Earth and Sun, angle between collector and sun beam, Effect of Earth’s atmosphere, Measurements of solar radiation. The course provides a comprehensive analysis of solar thermal energy collection and utilization with an emphasis on the design, sizing and selection of solar thermal technologies such as: solar thermal power plants, solar water heaters, solar concentrators, solar ponds, and solar updraft towers.

PRGR 604 Solar PV Electricity 2 cr.
The course covers semi-conductor basics, photovoltaic (PV) module characteristics, efficiency analysis; PV module types: mono-crystalline, polycrystalline, amorphous, multilayer cells, current research; PV module manufacture; grid connection and grid-codes, remote (off-grid) connections; Economics and life-cycle analysis. Pre-requisite: PRGR 603 or equivalent or consent of instructor.

PRGR 605 Wind Energy 2 cr.
The module covers the fundamentals of wind energy and the process and limitations of converting wind kinetic energy to electrical energy. It discusses the efficiency law and the governing equation of the conversion process. The module also covers the various types of wind turbines available in the commercial market along with their characteristics, and implementations’ advantages and disadvantages.

PRGR 606 Energy Storage 2 cr.
In this course various energy technologies will be presented and discussed in terms of their principle of operation, system components, energy density, maintenance, and cost. The different technologies that will be addressed for electrical energy storage are: batteries, compressed air, fly-wheel storage, pumped hydro-power, super-capacitors, and superconducting magnetic energy storage. Thermal and thermo-chemical energy storage technologies will also be covered.

PRGR 609 Renewable Energy Lab 2 cr.

PRGR 615 Biofuels 2 cr.
Course content includes studies of types, sources and processing of biodiesel, biomass, bio-methane and bioethanol, and assessing advantages, problems and principles in biofuel production. Biogas and digester design. Solid biomass processing.

PRGR 616 Waves, Tidal, and Hydro Energy 2 cr.
This course gives an overview of the use of ocean thermal, wave, tidal, and hydro energy. It provides a comprehensive analysis of hydro renewable energy collection and utilization for electric power production and other applications with an emphasis on design, sizing, performance analysis and selection of hydro renewable energy technologies. Mini-hydro systems are also covered. It also discusses variety of designs for devices for extracting energy from waves, the technologies and methods for generating electricity from different ocean temperatures between the warm surface water of the ocean and the cold deep water.

PRGR 617 Energy Efficiency in Buildings Evaluation and Design 2 cr.
The module discusses various schemes of conserving energy in buildings and energy types including, space heating and cooling, water heating and energy for lighting and powering electrical and electronics equipment. It also covers passive and active energy conservation techniques including energy efficient HVAC equipment. Addresses integration of solar energy into boilers and condensing units of building systems and introduces optimized control strategies. The students will be introduced to Visual DOE or E-Quest to perform energy
simulation of buildings. Such tools will then be used to carry out full building simulation taking into consideration occupancy data, equipment, lights, and building envelope. A base case of energy usage will thus be established and energy conservation measures are then applied to deduce possible savings and their economic value.

**PRGR 620  Energy Systems & Sustainable Environments** 2 cr.
This course covers a wide range of topics and for ease of teaching should be divided into three sections. Part 1 Worldwide importance of energy systems including their historical and current energy perspectives, concepts and applications of energy systems. This section will also focus on estimation and evaluation of energy resources. Part 2 Sustainable Energy systems; approaches to energy systems analyses and sustainability metrics. Biological Carbon Capture Storage, including the following processes: soil carbon, CO2 to energy, Forests & forest ecology, Digestate from Anaerobic Digestion (AD) process, Biochar Grassland management, Biomass to oil. Part 3 Comprehensive overview of the principal types of renewable energy-including solar, thermal photovoltaics, bioenergy, hydro, tidal, wind, and wave. In addition the underlying physical and technological principles of renewable energy systems and the future prospects of different energy sources. Energy efficiency analyses including energy balance, cost-benefit analysis and cost-efficiency analysis of various energy scenarios and renewable energy choices.

**Building Specialization Courses**

**PRGR 630  Sustainable preservation and Restoration of Existing Buildings** 2 cr.
Energy audits, upgrade of building envelope, sustainable practices for envelope preservation, electric supplies, lighting, and HVAC system. Hands-on evaluation and experimentation of building envelope materials and systems. Building interaction with the environment and occupants. Interaction of building enclosure with mechanical systems. Urban heat island effect.

**PRGR 631  Low energy architecture and passive building design** 2 cr.
This course centers on issues surrounding the integration of sustainable and passive design principles, into conceptual and practical Building design. Topics will include: solar geometry, climate/regional limitations, natural lighting, passive design and sustainability initiatives, insulating and energy storing material. Bioclimatic design and concepts. Case studies will be used extensively as a vehicle to discuss the success/failure of ideas and their physical applications.

**PRGR 632  Sustainable building materials** 2 cr.
Green and recyclable building material, embodied energy, sustainable construction.

**PRGR 633  Renewable energy systems and energy efficiency in buildings** 2 cr.
The module serves as the main process for a establishing a net zero energy building/architecture by means of enabling a building to generate the electrical energy it needs from its own resources. The module thus delves into the two main building's self-energy sources; wind and solar PV. It covers the implementations of micro or mid-scale wind turbines and solar PV systems for the generation of electrical energy. The module also covers storage and grid connection mechanisms as well. Lighting efficiency and electrical installation issues.

**PRGR 634  Moisture and control of humidity in buildings** 2 cr.
Sources of moisture and factors affecting its entry and build up inside the buildings such as construction practices and choice of building materials and furniture. Impact of moisture on thermal comfort and energy performance of the air-conditioning system. Solid/liquid dehumidification and hybrid air-conditioning systems. Modeling of moisture transport. Industrial need to control indoor humidity. Moisture-caused health issues including mold formation and growth.

**PRGR 637  Green building basics and building rating practices** 2 cr.
Assessment of building design and construction operations: Project rating systems (LEED, BREEAM, QSAS, etc.). Embodied energy, carbon content, and emission of CO2, SO2 and NOx of buildings materials, elements, and construction process. Water conservation, water management systems, water efficient landscaping, green roof, rainwater harvesting, sanitary fixtures and plumbing systems, wastewater treatment and reuse, and process water strategies.

**PRGR 638  Construction and Demolition Waste Management** 2 cr.
Building disposal techniques including deconstruction as well as selective and partial selective demolition. Design and construction for deconstruction and reuse. Waste minimization through prefabrication, preassembly, and modular construction. Sustainable waste management including recycling and reuse of waste materials and components.

**PRGR 641  HVAC systems for energy efficient acclimatization** 2 cr.
Energy conservation measures in the built in environment to enhance the building's energy efficiency while maintaining space thermal comfort and indoor air quality requirement. Overall and segmental thermal comfort models with localized air quality. Fundamentals of ventilation, indoor air-quality, infiltration and natural and mechanical ventilation, importance and impact of indoor air quality on human health and performance of the building air conditioning system. ASHRAE requirements for ventilation. Personalized ventilation and personalized cooling deives.

**PRGR 643  Heat pumps and innovative methods to improve performance with direct applications** 2 cr.
Heat pumps in low energy and passive buildings. Ground source Heat Pump fundamentals, loop Systems, open Systems, soil/rock classification and conductivity, grouting procedures, performance of ground source heat pumps in housing units. Water loop heat pumps, inside the building, bore holes, design and optimization of heat pump plants, including heat sources for such plants are considered in detail. Cost effective design options.

**Can be counted as Energy concentration course.**
**Water Core Course**

Water Crisis, and New Trends.

The course covers basic information about the water and sewer utility operating environment and water sources, as well as the key issues in water demand planning. Students will learn about the history of drinking water regulations and current regulations including the Safe Drinking Water Act and the Clean Water Act. Topics include: today's water crisis, management and best practices, an introduction to regulatory affairs and restrictions, water sources in the region and globally, commercial and domestic water use, our water footprint, responding to the water crisis, and new trends.

**Energy Management Systems of Buildings**

This course offers an introduction to the instrumentation trade as it applies to the day-to-day operation of water/wastewater treatment plants. Topics discussed include types of instruments and control equipment, process measurement and control principles, terminology, design and control systems documentation, operators training and troubleshooting techniques. It is important to note that this course is not aimed to create tradespersons, but is designed from the viewpoint of plant operators, so they can develop more awareness of the plant staff and allow them to effectively monitor and control the plant and major equipment, the treatment process, water production and plant wastes.

**Water Basics**

Analysis and design using commercially available software: wastewater treatment units: screens; sedimentation, coagulation/flocculation processes, filtration, and disinfection. This course will also survey the commonly used thermal and membrane based desalination technologies. Environmental, sustainability and economic factors which may influence the performance, affordability and more widespread use of desalination systems for fresh water production and reuse will be highlighted.

**Green Agriculture and Irrigation Systems**


**Sustainable Water Resources Management**

Strategies for water management at the project and field scale including water shortage management, irrigation strategies, water harvesting, non-conventional water sources for agriculture, groundwater recharge, catastrophe protection, flood management; techniques, methods, and strategies for agricultural, domestic, industrial, and municipal water conservation and sustainable use in dry lands. The module focuses on the operations of various wastewater disposal systems and their implications for health and the environment.

**Life Cycle Assessment**

This module introduces the principles and methods of life cycle thinking and life-cycle assessment (LCA) with specific reference to agricultural and energy systems using attributional LCA. The module will be based around the ISO 14040 methodology and will involve developing a LCA model common software packages such as MS-Excel. It will focus on the four common stages of LCA: (i) definition of the goal and scope; (ii) life cycle inventory analysis; (iii) life cycle impact assessment; and (iv) interpretation with a specific focus on carbon footprint, water footprint and energy audit. Case studies will consider LCA studies of agricultural systems, energy systems and selected industrial processes and products.

---

* Water Core Course
** Can be counted as Energy concentration course.

---

**Building Energy System Modeling**

Indoor space thermal models. Analysis and modeling of building energy systems involving applications of thermodynamics, economics, heat transfer, fluid flow and optimization. The use of modern computational tools to model thermal performance characteristics of components of HVAC systems including chillers, recovery systems, flow control devices, heat exchanges, solar panels, dehumidification systems, boilers, condensers, cooling towers, fans, duct systems, piping systems and pumps.

**Energy Management Systems of Buildings**

The Building Management Systems course provides the necessary tools to control, monitor and optimize the building's facilities, mechanical and electrical equipment for comfort, safety, and efficiency. It covers the principles of the building automation systems (BAS) applied to commercial HVAC equipment, lighting systems, fire and security systems; with keen emphasis on the control routine for energy efficiency.

**Water Basics**

Analysis and design using commercially available software: water distribution systems including pipes, reservoir, pumps and losses. Results visualizations and assessment: pressure, velocity, head losses. Analysis and design using commercially available software: wastewater collection systems including pipes, manholes, drop manholes, wet wells, and other appurtenances. Results visualizations and assessment. Maintenance & Safety; Sampling, Sampling Methods and Parameters; Analysis & Data Handling; Management & Supervision.
PRGR 673  Research skills development - General  2 cr.
Objective of this module is to enable learners to develop critical research skills, including requisite skills for clear and concise communication of research plans, research progress and findings to experts in their respective area thought more efficient use of software and commonly used resources. Focus is on structured inquiry from experiments and/or data collection and analysis, rather than hypothesis or theory to be tested. The module processes will integrate knowledge gained from all other modules in the program, to develop the rationale for research, set out research objectives and methods, analyze and interrogate data, and draw validated conclusions.

PRGR 680  Innovation and Knowledge Transfer  2cr.
The aim of this module is to help students understand theory and practice for investing in and managing green ventures while exercising corporate social responsibility. Sustainability within the organization and in the external environment. It will develop knowledge and exposure to sustainable business concepts. Students will learn how to initiate, manage and implement a sustainable innovative project by collaboratively working on a venture which will be written up and presented at the end of the semester. The course will cover the management process required to transform an innovative idea into a commercial opportunity or business proposition. It will detail the stages and processes involved in the management and commercialization of intellectual property (IP). Students from all disciplines will be involved in the creation of knowledge in the form of intellectual property. Students will be provided with a fundamental understanding of how to manage the development of IP and transfer this asset to the Knowledge Economy. The module will examine some success stories and then addresses the requirements to manage and protect intellectual property rights (IPR) in areas such as ICT, Life Sciences, Engineering, Food and Energy. The potential routes to commercialization and the key business feasibility questions will be considered: can the product be made, will someone buy it and is it possible to make a profit? This module will provide an essential grounding in matters relating to the exploitation of IP, for students interested in both academic and industrial careers. The deliverables of this module will require team projects and participants will graded via continuous assessment.

PRGR 677  Cost-Benefit Analysis  2 cr.

PRGR 679  Project Management, Risk Management and Planning  2 cr.
The abilities to propose, plan, execute and close a project are essential qualities of every manager. This proposal aims to help the student to develop the skill required from every project manager. It will also address common risk management and contingency planning. This should be delivered in accordance with internationally recognized global project management standard bodies, such as PMI, to aid the students who wish to become certified project managers.