Graduate Minor Field: Sustainable Energy

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Summary: Meeting the energy needs of the present and future global population is a grand challenge for the 21st century. This will hasten an improvement in life styles of those from developing nations, and should be achieved without further impairment of the natural environment and climate. Achievement of the goal of meeting future energy needs requires the participation, ingenuity, and hard work of people from a great range of specialized activities, working collaboratively. Accordingly, this minor is intended to integrate scientific and engineering principles that focus on the creation, analysis and improvement of energy technologies, with knowledge of environmental systems potentially impacted by energy production, and with an understanding of human systems that are intertwined with energy-related decisions. An outcome of the minor should be an understanding of the ways in which those themes interact as a system, all of whose parts need to be understood and successfully integrated in order to progress toward meeting the world’s energy needs.

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Program Requirements:

1. Students have to be enrolled for an MS or PhD degree. Students enrolled in professional Masters students are not, at this time, eligible to participate in the minor.

2. At least one faculty member representing the minor field of Sustainable Energy is required to be a formal member of the student’s Special (Thesis) Committee.

3. Students enrolled in the minor will have to demonstrate, to the satisfaction of the faculty member representing the minor field of Sustainable Energy, that they have an adequate understanding of the area pertaining to Sustainable Energy. For students in a PhD program, this will be demonstrated as part of their Admission to Candidacy examination, typically in the form of an oral examination. For MS students, this mastery will be
demonstrated by completion of coursework (see item 4). The representative of the minor field in Sustainable Energy may also test the student’s knowledge at the final thesis defense examination.

4. All students enrolled in the minor are required to take a minimum of three energy-related courses (at least 9 credit hours), as specified on the Graduate School’s web site. These three (or more) courses must be taken from lists of approved courses in three topical areas:
   (i) at least one foundational core course in sustainable energy systems
   (ii) at least one course related to Energy Sources and Technologies for a Transition to Sustainability
   (iii) at least one course related to environmental, policy, economic, business, political, ethical, and/or social consequences.

As a guide for students and minor field faculty, we have provided below the course numbers and titles of around 40 courses that could provide breadth in sustainable energy that we believe constitutes a firm foundation of comprehension of the area. Our goal in making these course suggestions is to allow a broad range of students from many fields and colleges to obtain a graduate minor in Sustainable Energy. Students are encouraged to take more than the minimum number of courses.

**Approved Courses**

**i. Foundational Core Course in Sustainable Energy Systems**

All students taking the Sustainable Energy minor must take one of the following courses that emphasize an integrated or systems-like approach to the consideration of energy systems analysis.

- AEM 4510 Environmental Economics (pre-req.: intermediate microeconomics)
- BEE 4870 Sustainable Bioenergy Systems (pre-req.: thermodynamics)
- CHE 6660 Analysis of Sustainable Energy Systems (no pre-req.; thermodynamics knowledge recommended)
- EAS 4010/5010 Fundamentals of Energy and Mineral Resources (previous course in geology recommended)
- CHEME 6640 Energy Economics (no pre-req.; thermodynamics knowledge recommended)
- CHEME 6650 Energy Engineering (CHEME 6640 pre-req.)
- MAE 4000 Components and Systems: Engineering in a Social Context (offered alternate years, next expected Fall 2011; pre-req.: two yrs. College physics)
- MAE 5010 Future Energy Systems (pre-req.: thermodynamics; knowledge of fluid mechanics recommended)
- ORIE 4150 Economic Analysis of Engineering Systems (no pre-req.)
- SYSEN 5100 Applied Systems Engineering (no pre-req.)
ii. Energy Sources and Technologies for a Transition to Sustainability

Traditional sources:
CHEME 5204/5207 Turbomachinery / Hydrocarbon Resources (total of three credits, 1+2 respectively)
CHEME 6650 Energy Engineering (pre-req. CHEME 6640)
CHEME 4130 Intro to Nuclear Science and Engineering (also AEP/ ECE/ MAE/ NSE/ TAM 4130)
CHEME 6665, 6666, 6670, 6671 are 1-credit modules associated with CHEME 6660 but which can be taken as stand-alone modules.
   CHEME 6665 Geological Carbon Sequestration Module
   CHEME 6666 Unconventional Natural Gas Development from Shale Formations Module
   CHEME 6670 Fossil Fuels Module
   CHEME 6671 Nuclear Energy Module
EAS 4010/5010 Fundamentals of Energy and Mineral Resources
EAS 6669 (also CHEME 6669) Earth Energy Science and Engineering Module (2 cr.; part of the modules associated with CHEME 6660, but can be taken independently)
MAE 4490 Combustion Engines and Fuel Cells
MAE 4580 Intro to Nuclear Science (also CHEME 4130, ECE 4130, NSE 4130)
MAE 4590 Nuclear Fusion (also NSE 4840)
MAE 5430 Combustion Processes
MAE 6560 Nanoscale Energy Transport & Conversion
MSE 4330 Materials for Energy Production, Storage & Conversion
NSE 6330 Nuclear Reactor Engineering

Renewable sources:
BEE 6870 Science and Engineering challenges to the development of sustainable bio-based industries (1 credit)
CEE 6200 Water-Resources Systems Engineering
CHEME 6661-6664 are 1-credit modules associated with CHEME 6660 but which can be taken as stand-alone modules.
   CHEME 6661 Bioenergy and Biofuels Module
   CHEME 6662 Solar Energy Module
   CHEME 6663 Geothermal Energy Module
   CHEME 6664 Wind Energy Module
BEE/EAS 4940 Geoengineering of climate warming
ECE 4510 Electric Power Systems I
ECE 4520 Electric Power Systems II
ECE 4840 Intro to Controlled Fusion
MAE 5020 Wind Power
MAE 4040 Materials Selection for Clean Mechanical Designs
MAE 4140 Mechanics of Lightweight Vehicles
SYSEN 4100 Applied Systems Engineering
SYSEN 4200 Systems Analysis Architecture, Behavior and Optimization
iii Environmental and Social Impacts

AEM 4510 Environmental Economics
AEM 6510 Environmental and Resource Economics
BEE 4870 Sustainable Bioenergy Systems
BEE 7540 The Right to Water
BEE 6740 Ecohydrology
BIOEE/NTRES 4560 Stream Ecology
CEE 4320 Hydrology
CEE 6200 Water resources
CEE 5970 Risk Analysis and Management
CHME 6610 Air Pollution Control
CHME 6640 Energy Economics
CHME 666x are a set of 1-credit modules associated with CHME 6660, but which can be
taken as a stand-alone module. All of these modules are acceptable to fulfill this category.
DEA4220 Ecological Literacy and Design
EAS 4570 Atmospheric Air Pollution
EAS 4800 Our Changing Atmosphere: Global Change and Atmospheric Chemistry
EAS 5051 Climate Dynamics
EAS/MAE 6480 Air Quality and Atmospheric Chemistry
MAE 4000 Components and Systems: Engineering in a Social Context
SYSEN 4100 Economic Analysis of Engineering Systems

Examples of Typical Student Course Fulfillment of the Minor

Example 1: Typical Student Curriculum (starting the minor in the Fall):
- **Fall (Year 1 of starting the minor):** BEE 4870 Bioenergy Systems
- **Spring (year 1):** CEE 6200 Water Resources.
- **Fall (year 2):** MAE 5430 Combustion Processes

Example 2: Typical Student Curriculum (starting the minor in the Spring):
- **Spring (Year 1 of starting the minor):** AEM 4510 Environmental Economics
- **Fall (year 2):** MAE 5020 Wind Power
- **Spring (year 2):** CHME 6610 Air Pollution Control

Example 3: Typical Student Curriculum (starting the minor in the Fall):
- **Fall (Year 1 of starting the minor):** CHME 6660 Analysis of Sustainable Energy Systems
- **Fall (year 2):** MAE 4020 Wind Power
- **Fall (year 3):** EAS 4400 Climate Science, Impacts and Mitigation
Minor Graduate Field Faculty for Sustainable Energy

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*GFA*: Shelby Clark-Shevalier, Chemical & Biomolec. Engr., 255-4550, sjc14@cornell.edu

List of faculty members of the minor graduate field of Sustainable Energy given in the table below:

<table>
<thead>
<tr>
<th>Minor Field Faculty (alphabetical order)</th>
<th>Primary Field Affiliation</th>
<th>Minor Field Faculty (alphabetical order)</th>
<th>Primary Field Affiliation</th>
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<tbody>
<tr>
<td>Richard Allmendinger</td>
<td>GS</td>
<td>Richard Hennig</td>
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<td>Lars Angenent</td>
<td>BEE</td>
<td>Anthony Ingraffea</td>
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<td>Lynden Archer</td>
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<td>Yong Joo</td>
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<td>A. Brad Anton</td>
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<td>Teresa Jordan</td>
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