ARIZONA STATE UNIVERSITY

GENERAL STUDIES PROGRAM COURSE PROPOSAL COVER FORM

Courses submitted to the GSC between 2/1 and 4/30 if approved, will be effective the following Spring.
Courses submitted between 5/1 and 1/31 if approved, will be effective the following Fall.

(SUBMISSION VIA ADOBE.PDF FILES IS PREFERRED)

DATE 4/13/11

1. ACADEMIC UNIT: Ira A. Fulton Schools of Engineering

2. COURSE PROPOSED: FSE 194 Introduction to Sustainable Engineering: Technological, Social & Sustainable Systems 3 hrs

(prefix) (number) (title) (semester hours)

3. CONTACT PERSON: Name: Ann Zell Phone: 5-8931

Mail Code: 8109 E-Mail: ann.zell@asu.edu

4. ELIGIBILITY: New courses must be approved by the Tempe Campus Curriculum Subcommittee and must have a regular course number. For the rules governing approval of omnibus courses, contact the General Studies Program Office at 965-0739.

5. AREA(S) PROPOSED COURSE WILL SERVE. A single course may be proposed for more than one core or awareness area. A course may satisfy a core area requirement and more than one awareness area requirements concurrently, but may not satisfy requirements in two core areas simultaneously, even if approved for those areas. With departmental consent, an approved General Studies course may be counted toward both the General Studies requirement and the major program of study. (Please submit one designation per proposal)

Core Areas

- Literacy and Critical Inquiry—L
- Mathematical Studies—MA
- Humanities, Fine Arts and Design—HU
- Social and Behavioral Sciences—SB
- Natural Sciences—SQ

Awareness Areas

- Global Awareness—G
- Historical Awareness—H
- Cultural Diversity in the United States—C

6. DOCUMENTATION REQUIRED.

(1) Course Description
(2) Course Syllabus
(3) Criteria Checklist for the area
(4) Table of Contents from the textbook used, if available

7. In the space provided below (or on a separate sheet), please also provide a description of how the course meets the specific criteria in the area for which the course is being proposed.

CROSS-LISTED COURSES: ☑ No ☐ Yes; Please identify courses:

Is this an amultisection course?: ☑ No ☐ Yes; Is it governed by a common syllabus? 

James Collofello
Chair/Director

(Date) 4/18/11

Chair/Director (Signature)

Rev. 1/94, 4/95, 7/98, 4/00, 1/02, 10/08
Rationale and Objectives

**Literacy** is here defined broadly as communicative competence in written and oral discourse. **Critical inquiry** involves the gathering, interpretation, and evaluation of evidence. Any field of university study may require unique critical skills which have little to do with language in the usual sense (words), but the analysis of spoken and written evidence pervades university study and everyday life. Thus, the General Studies requirements assume that all undergraduates should develop the ability to reason critically and communicate using the medium of language.

The requirement in Literacy and Critical Inquiry presumes, first, that training in literacy and critical inquiry must be sustained beyond traditional First Year English in order to create a habitual skill in every student; and, second, that the skills become more expert, as well as more secure, as the student learns challenging subject matter. Thus, the Literacy and Critical Inquiry requirement stipulates two courses beyond First Year English.

Most lower-level [L] courses are devoted primarily to the further development of critical skills in reading, writing, listening, speaking, or analysis of discourse. Upper-division [L] courses generally are courses in a particular discipline into which writing and critical thinking have been fully integrated as means of learning the content and, in most cases, demonstrating that it has been learned.

Students must complete six credit hours from courses designated as [L], at least three credit hours of which must be chosen from approved upper-division courses, preferably in their major. Students must have completed ENG 101, 107, or 105 to take an [L] course.

Notes:

1. ENG 101, 107 or ENG 105 must be prerequisites
2. Honors theses, XXX 493 meet [L] requirements
3. The list of criteria that must be satisfied for designation as a Literacy and Critical Inquiry [L] course is presented on the following page. This list will help you determine whether the current version of your course meets all of these requirements. If you decide to apply, please attach a current syllabus, handouts, or other documentation that will provide sufficient information for the General Studies Council to make an informed decision regarding the status of your proposal.
Proposer: Please complete the following section and attach appropriate documentation.

**ASU - [L] CRITERIA**

TO QUALIFY FOR [L] DESIGNATION, THE COURSE DESIGN MUST PLACE A MAJOR EMPHASIS ON COMPLETING CRITICAL DISCOURSE--AS EVIDENCED BY THE FOLLOWING CRITERIA:

<table>
<thead>
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<th>YES</th>
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<th>Identify Documentation Submitted</th>
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<td><strong>CRITERION 1:</strong> At least 50 percent of the grade in the course should depend upon writing, including prepared essays, speeches, or in-class essay examinations. <em>Group projects are acceptable only if each student gathers, interprets, and evaluates evidence, and prepares a summary report</em>.</td>
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</tbody>
</table>

1. Please describe the assignments that are considered in the computation of course grades--and indicate the proportion of the final grade that is determined by each assignment.

2. **Also:**

   Please circle, underline, or otherwise mark the information presented in the most recent course syllabus (or other material you have submitted) that verifies **this description** of the grading process--and label this information "C-1".

<table>
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<th><strong>CRITERION 2:</strong> The composition tasks involve the gathering, interpretation, and evaluation of evidence</th>
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1. Please describe the way(s) in which this criterion is addressed in the course design

2. **Also:**

   Please circle, underline, or otherwise mark the information presented in the most recent course syllabus (or other material you have submitted) that verifies **this description** of the grading process--and label this information "C-2".

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<th><strong>CRITERION 3:</strong> The syllabus should include a minimum of two substantial writing or speaking tasks, other than or in addition to in-class essay exams</th>
</tr>
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1. Please provide relatively detailed descriptions of two or more substantial writing or speaking tasks that are included in the course requirements

2. **Also:**

   Please circle, underline, or otherwise mark the information presented in the most recent course syllabus (or other material you have submitted) that verifies **this description** of the grading process--and label this information "C-3".
<table>
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<td>CRITERION 4: These substantial writing or speaking assignments should be arranged so that the students will get timely feedback from the instructor on each assignment in time to help them do better on subsequent assignments. <em>Intervention at earlier stages in the writing process is especially welcomed</em> see class organization in syllabus - students are required to participate in seminar discussions every week, and will have each essay critiqued in those sessions.</td>
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1. Please describe the sequence of course assignments--and the nature of the feedback the current (or most recent) course instructor provides to help students do better on subsequent assignments

2. Also: Please circle, underline, or otherwise mark the information presented in the most recent course syllabus (or other material you have submitted) that verifies this description of the grading process--and label this information "C-4".
Explain in detail which student activities correspond to the specific designation criteria. Please use the following organizer to explain how the criteria are being met.

<table>
<thead>
<tr>
<th>Criteria (from checksheet)</th>
<th>How course meets spirit (contextualize specific examples in next column)</th>
<th>Please provide detailed evidence of how course meets criteria (i.e., where in syllabus)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. At least 50% of grade from writing or speeches</td>
<td>Entire course grade depends on homework writing assignments each week, term paper, and participation in class discussion in seminar groups</td>
<td>syllabus - page 2, under grading section, as marked in attached syllabus</td>
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<tr>
<td>2. gathering and evaluation of evidence</td>
<td>Homework essays structured to require evidence based analysis</td>
<td>See, e.g., homework for weeks 1, 3, 4, 5, 6, 11, 12.</td>
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<tr>
<td>3. minimum of two substantial writing or speaking tasks</td>
<td>course is heavily writing oriented: one term paper, and weekly essays for homework. In addition, half of class time is small seminar format, where students are graded on their participation</td>
<td>syllabus, page 2, explains class structure</td>
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FSE 194
Introduction to Sustainable Engineering:
Technological, Social, & Sustainable Systems
Brad Allenby


Discussion (subject to change depending on number of students):
2:00 – 3:15p M (24114) ECG G315
2:00 – 3:15p W (24115) ECG G315
10:30 – 11:45 T (24116) WHALL 267
12:00 – 1:15p Th (24117) ARTS 246

Professor contact (email preferable): brad.allenby@asu.edu
480-727-8594
Brooke Mayer bkmayer@asu.edu

Catalog Description: Course introduces students to the importance and role of technological, social, and sustainable systems in the modern world. The course provides a framework for the theory and practice of sustainable engineering.

Course Objectives: To introduce students to the importance and role of technological, social, and sustainable systems in the modern world, which is increasingly characterized by integrated human/natural/built complex adaptive systems at local, regional and global scales. Emphasis will be on characteristics and fundamentals of technology systems; complex adaptive systems behavior and evolution; and associated cultural, ethical, and managerial behaviors, with a focus on the need for multidisciplinary approaches; and current patterns in technological evolution. The course provides a framework for the theory and practice of sustainable engineering.

At the end of the course, students should be able to:

1. Explain the importance of technology and technological systems;
2. Explain the social and environmental implications of design, construction, operation, and management of technology systems;
3. Identify and explain critical principles of complexity and complex systems; and
4. Be able to use these concepts and principles to explore a topic of their choice in a systemic and integrated way in their term paper.

In addition to domain-specific goals, this course is also intended to help students:

1. Learn to communicate in short essay form and in small group discussions;
2. Understand issues and impacts associated with technology systems and emerging technologies at a broad cultural and geographic scale extending across urban, regional, national and global scales; and
3. Understand the need and develop the capability to participate in lifelong learning.

In terms of ABET criteria, the course will enable students to:

1. Understand professional and ethical issues in the context of engineered and earth systems;
2. Learn to communicate in short essay form;
3. Understand issues and impacts of engineering solutions at a broad cultural and geographic scale extending across urban, regional, national and global scales;
4. Understand the need and develop the capability to participate in lifelong learning; and,
5. Take into consideration contemporary issues and environmental impacts in civil and environmental engineering practices.

Introduction: The Industrial Revolution and continuing dramatic and accelerating changes in economic, technological, and cultural systems has fundamentally changed the way people live, relate to each other, and affect natural and built systems. In fact, many scientists are increasingly referring to our modern period era as the “Anthropocene,” which can be roughly translated as the Age of Humans. Moreover, the accelerating pace of technological evolution – particularly the coming convergence of nanotechnology, biotechnology, robotics, information and communication technology (ICT), and cognitive sciences – will both reinforce the human domination of the dynamics of natural systems, and pose significant challenges to existing cultural and ethical norms and patterns. Thus, it is not possible to understand the modern world, and to make intelligent choices about the future, without some understanding of technological systems and emerging technologies, and the complex systems of which they are a part.

Accordingly, this course will provide students with an introduction to technology and complex systems, and explore some of the implications of technology for sustainability. It will also introduce students to the implications of understanding the Earth as a terraformed planet, and the technological, economic and cultural patterns that have contributed to its evolution. The potential operational, cultural and ethical implications of future evolutionary pathways will be explored, with emphasis on the challenges they pose and the role of technological systems in both creating, and helping to address, such challenges.

The course will consist of 1.5 hours of lecture, and 1.5 hours of discussion in small groups with the TA’s, each week, except where otherwise noted. The course grade will consist of three components: class participation; a homework component which will primarily reflect short essays on class topics; and a term paper.

Homework will be a one page, 1.5 spaced, essay each week on the topic assigned for that week. It will be due the second class of each week at the beginning of class, where it will be collected by the TA and cross-edited by the students. The reading assignment for each week includes reviewing the slide package for the next week’s class prior to class.
Grading:

- Class participation: 30%
- Homework: 35%
  - Each missing or late paper is minus 5%
  - Failure to meet minimum quality standards is minus 3%
- Term paper: 35%, of which
  - Grasp and use of course concepts (e.g., complexity, technology systems): 30%
  - Organization, structure, and persuasiveness 30%
  - Proper format 20%
  - Presentation (e.g., no typos, complete sentences): 20%

Primary Texts:
1. Grubler, *Technology and Global Change*
2. Allenby, *Theory and Practice of Sustainable Engineering*
3. Card, *Ender’s Game*
4. Florman, *The Existential Pleasure of Engineering*

Weekly Schedule (note that the topic of the week’s lecture is given for each week; the second session of each week will consist of a small seminar where a) the weekly essays will be collected by the TA and handed out randomly for cross grading, with students commenting on style and substantive content of each essay in a mutually supportive learning environment; b) additional open discussion of issues raised by the weekly lecture; and c) additional instruction in writing, speaking, and learning skills).

Week 1: Welcome to the Anthropocene: a discussion of the increasing impact of humans on the world, including information on demographic trends (urbanization, population growth, per capita material, energy, and water consumption), global economic history, natural cycles (especially C and N), and how they interact in various systems, such as biofuels as response to global climate change.

  - Reading: Chapter 1, Allenby; slide package (in this and all subsequent weeks).
  - Homework (to be handed in at TA session on week 1): Essay. In what major ways does the world we live in now differ from the world 200 years ago?

Week 2: Important Themes of the Human Earth: A number of general themes are important for understanding the world as it now exists, and as providing context for engineering and managing technology today. These include the criticality of technology as a contributor to, and shaper of, accelerating economic, environmental, social, and cultural evolution; the increasing information density and complexity of the world as many physical domains are re-defined into information structures (e.g., genetics and bioengineering); and the growth of active information functionality within built environments (e.g., the “cognitive city” is a complex of “smart” materials, “smart”...
buildings, “smart” infrastructure, and “smart” integrated infrastructures). Moreover, natural systems are increasingly integrated with human and built systems, and thus become subject to their dynamics (e.g., reflexivity, intentionality); examples might include genetic engineering and its commoditization through intellectual property law, or carbon cycle and sulfur cycle management. Institutionally, the rapidly evolving technological frontier creates significant social pressures; fundamentalism as a response to modernity becomes increasingly powerful, and professionals and firms are being charged by society with responsibility not just for their actions, but for their technology systems (cf. Monsanto and genetically modified organisms). It thus becomes increasingly possible that technological evolution will become discontinuous in terms of cultural ability to adapt, especially with NBRIC evolution continuing to accelerate. This is especially true as technological evolution functions to redefine what it means to be human, and begins to reframe the human as a design space. Adaptation will be much more difficult as well because foundational values and cultural constructs continue to become contingent over much shorter time frames (swamp/wetlands; jungle/rainforest; wilderness evil to good; natural/supernatural to natural/human). From a cultural and political perspective, the bipolar order imposed by the Cold War has destabilized global power relationships and, rather than being the “end of history” has unleashed even more powerful conflict between, e.g., fundamentalism and modernity in Islam, Christianity, Judaism, environmentalism, Hinduism, and elsewhere, and, some fear, potentially a “clash of civilizations.” At the same time, the role of nation-state is changing profoundly, leading to more diffuse power structures, different and more varied forms of community (e.g., online social networks), and a loss of the traditional monopoly of the state on military power (e.g., technologies of mass destruction have been democratized).

Reading: Chapter 2, Allenby; Grubler, chapters 1 and 2.

Homework: Essay. Why do you think scientists increasingly refer to our modern era as the “Anthropocene”?

Week 3: Complexity, Contingency, and Accelerating Change: There are very important differences between complex and simple systems. Simple systems are generally intuitively understandable, and their dynamics, such as “cause and effect,” are relatively easy to understand. The anthropogenic Earth, however, is characterized by complexity, which can be thought of as including four forms of complexity: static complexity (number of components and links among them); dynamic complexity (introduced by features such as lag times and feedback loops that operate as a system moves through time); “wicked” complexity, which comes into play as humans and their institutions get involved; and scale complexity, as humans increasingly operate at the scale of regional and global natural and built systems. These operate together to create radical contingency in the modern world, as it becomes difficult to determine what assumptions and institutions will remain valid over time. An important aspect of this contingency is that it undermines many traditional ethical systems: ethical structures (macroethics) appropriate for complex adaptive systems have not yet been developed.

Reading: Chapter 3, Allenby; Grubler, chapter 3.
What do you think are the most important differences between complex and simple systems, and why?

Week 4: Sustainability. “Sustainability” was popularized as “sustainable development by the Brundtland Commission in 1987, and has two basic themes: an emphasis on environmental quality, and a demand for increased equality in wealth distribution within and among generations. Despite its high popularity, it remains an ambiguous and somewhat contentious concept, and difficult to translate into operational terms that are easily translated into design and management of technology or earth systems. The sustainability dialog also tends to be naïve, if not somewhat skeptical, of engineering and technology, which leads to significant potential blind spots given the importance of emerging technologies to the shape and dynamics of future social, economic, and environmental systems. It is clear, however, that engineering and technology management today requires a greater focus on the environmental, social, and cultural dimensions of a design or project. Accordingly, much of sustainable engineering is, in fact, learning to translate the mythic language of sustainability into methods and inputs that can inform better engineering and technocratic decisions.

Reading: Chapter 4, Allenby; handouts on sustainability, Grubler, chapter 4.

Homework: You are the head of a design team that has been asked by your marketing department to create a “sustainable cell phone.” Write a memorandum to your boss explaining how you intend to do that.

Week 5: Homo Faber: Human History and Technology. It is not surprising that periods of human development, such as “Neolithic” or “the Bronze Age,” have referred to the dominant technologies of the time, because humans, their institutions, and their societies have always been coupled, and indeed to some extent defined, by their technologies. Indeed, since the Industrial Revolution economists have used the idea of “long waves” of innovation, characterized by particular technology clusters such as coal and the steam engine, or automobiles, to help understand not just technological evolution, but also economic, social, and cultural evolution as well.

Reading: Chapter 5, Allenby; Grubler, chapters 5 and 6.

Homework: Essay: Why do you think technology clusters have institutional, social and cultural effects, rather than just economic impacts?"
example, if plug in hybrids, and solar and wind renewables are to be introduced into a developed economy, the timing will not be determined by how long it takes to build and design them, but rather how long it will take to rebuild the grid to handle greater variability of supply and a large demand spike. More broadly, many cultures have developed technologies, sometimes independently of each other, but few cultures have successfully made technology a core of their success. Part of the reason is that technology is not just widgets, or software, but is also a social and cultural activity, and thus can be inhibited or encouraged by different cultural patterns.

Reading: Allenby, chapter 6; Grubler, chapters 7 and 8.

Homework: Essay: Why should I need to worry about the grid if all I want to do is buy a plug-in vehicle because it’s good for the environment?

Week 7: Case Studies in Technology Systems: case studies of three major technology systems – automobiles, information and communication technology, and green chemistry – will be presented. In each case, it is apparent that each level within a particular technology offers its own unique challenges and opportunities for the sustainable engineer or technology manager: manufacturing a cell phone has different social and environmental issues associated with it than designing and operating a communications network, which in turn raises different issues than the social implications of the services platformed on the physical system. It is also apparent, however, that each technology, as a system, is more complex and integrated than engineers, businesspeople, and policymakers realize. This marks an important area where sustainable engineering offers insights that can improve professional performance significantly.

Reading: Allenby, chapters 7-9.

Homework: Essay: How would you redefine “green chemistry” so that it would be “sustainable chemistry”?

Week 8: The Power of Technology Systems: The Railroad. It is important to understand how pervasive the changes that a major technology system can introduce really are. Railroads are a good example. To begin with, networks such as railroad require a uniform, precise system of time and a means of communication adequate to the time cycle of the technology; railroad technology called forth “industrial time” and its associated culture, as well as the telegraph. Railroad firms were far bigger than previous commercial firms, and required far more capital; they thus created modern managerial capitalism (modern accounting, planning, and administration systems), as well as modern capital and financial markets. Environmentally, railroads transformed landscapes at all scales: Chicago existed, and structured the Midwest economically and environmentally, because of railroads. Like most major technological systems, railroads fundamentally changed US economic and power structures, restructuring the economy from local/regional business concentrations to trusts and monopolies as railroad infrastructure created the possibility of exploiting scale economies of national markets. Railroads even changed the fundamental worldview behind American culture, changing it from
Jeffersonian agrarianism, an Edenic teleology, to a technology-driven New Jerusalem, a cultural schism that replays itself today in the continuing environmentalist challenge to technology.

Reading: Allenby, Chapter 10; first half of science fiction book.

Homework: Essay: If you had lived in a small village in the United States in the early 1800’s when the first railroad was built in your area, how many of the changes that the railroad subsequently caused do you think you could have predicted?

Week 9: The Five Horsemen: NBRIC. The railroad, a core technological system for a technology cluster, had major impacts even though it was just one technology system. We are currently seeing not one, but five, foundational technology systems in a period of accelerating evolution: nanotechnology, biotechnology, robotics, information and communication technology, and cognitive science. These technologies in some ways are the logical end of the chapter of human history that began with the Greeks 2500 years ago. Nanotechnology extends human will and design to the atomic level. Biotechnology extends it across the biosphere. ICT gives us the ability to create virtual worlds at will, and facilitates a migration of functionality to information rather than physical structures. Robotics and biotechnology merge the biological and technological realms, enabling integration at the level of information systems. Cognitive sciences rationalize cognition, and thus enable ever expanding cognitive networks which increasingly merge human and technology systems. Consider, for example, of the way that Google ™ so dramatically extends human memory, creating a cognitive system that includes not just the human elements, but vast swaths of Net technology, or the way that many militaries are building “augmented cognition” technologies, where technologies intended to scan the battlefield for threats are integrated into each soldier’s cognitive systems. Current accelerating rates of technological evolution are not only unprecedented; they have the effect of dramatically extending the spaces within which humans can, intentionally and unintentionally, impact existing systems and design new ones. In doing so, they not only raise the level of complexity of systems that we must strive to understand. Because they also give us rapidly increasing tools to design the human itself, they render contingent much of what we have taken to be fixed.

Reading: Allenby, chapter 11; second half of science fiction book.

Homework: Essay: Compare *Ender’s Game* with the war in Iraq, with its heavy reliance on robotic ground, sea, and air platforms. Do you still think *Ender’s Game* is science fiction? Why or why not?

Week 10: The Engineer as Ethicist: Macroethics. From the viewpoint of the engineer and the technologist, four important characteristics of the Anthropocene differentiate it from the traditional human systems within which existing ethical structures have developed. The first is that the earth systems characteristics of the Anthropocene are neither “human” nor “natural,” but highly integrated composites of both. The second is that, as a result, the dynamics of such Anthropogenic systems include the reflexivity and,
thus, unpredictability of human systems. Thirdly, these systems are highly interconnected: managing global climate change is difficult precisely because the climate system is tightly coupled to human economic and technological systems and their future paths, to powerful cultural and ideological systems, and to other natural systems such as the carbon and nitrogen cycles. Finally, technology systems are major vehicles by which this complexity, integration, and unpredictability are created. Existing ethical systems and many proposed principles such as the Precautionary Principle (don’t implement a technology until you are sure the risks it poses will be less than the existing risks) are inadequate to this level of unpredictability, requiring the sustainable engineer to be much more sophisticated regarding the culture, ethical systems, and contingency of the frameworks within which he or she operates.

Reading: Allenby, chapter 12, watch The Matrix (first film in series)

Homework: Essay: How do you know either reality in The Matrix is more “real” than the other? And if someone in them can’t tell which is which, what do you think of the morality of Neo’s decision to destroy the Matrix?

Week 11: The Engineer as Problem Solver: Systems Engineering. Systems engineering in many cases is highly technical, but when considered at a project management level it forms a structure within which the sustainable engineer or technologist can create solutions that work in the real world. In general, it requires six steps: determine the actual goals of the system, including clients and stakeholders; establish criteria for ranking alternatives (these may be numerical or qualitative); develop alternative solutions (including technological, functional, and long-term structural alternatives); rank the alternatives, including in the process nonperformance and non-quantitative considerations; iterate on both implementation and system response (learning process); and implement, usually as a continuing process in the case of complex system management. Adaptive management, a similar process developed for design and management of complex resource regimes such as fisheries, forests, and watersheds, provides similar guidance, and should be part of the toolbox of the sustainable engineer.

Reading: Allenby, chapter 13; Florman, chapters 1-3.

Homework: You have just been assigned operational responsibility for the Florida Everglades as a regional system. Write a memorandum to the Governor of Florida to identify your goals, clients, and stakeholders.

Week 12: The Engineer and the Environment: Industrial Ecology and Life Cycle Assessment. Industrial ecology, a relatively new field, is the objective, multidisciplinary study of industrial and economic systems and their linkages with fundamental natural systems. It incorporates, among other things, research involving energy supply and use, new materials, new technologies and technological systems, basic sciences, economics, law, management, and social sciences. Although still in the development stage, it provides the theoretical scientific basis upon which understanding, and reasoned improvement, of current practices can be based. Industrial ecology focuses on long term
habitability rather than short term or ad hoc approaches, attempting to understand anthropogenic disruption to fundamental natural systems and cycles rather than just responding to localized perturbations. In general, it focuses on concerns that are of regional and global scope, persistent and difficult to manage, and tend to be long term. Typical industrial ecology approaches include mass-flow analysis to understand energy and material flows through economic and environmental systems, and the linkages among them; popular tools based on this approach include life cycle analysis, or LCA. It is important to recognize that industrial ecology and associated practices in general continues to exhibit a strong bias towards the environmental domain, in part reflecting their origin in environmental engineering and science, and in part reflecting the complexity and strong normative dimensions of social issues, which make them much harder for engineers to quantify and evaluate.

Reading: Allenby, chapter 14 and 15; Florman, chapters 4-6.

Homework: Essay: What is the difference between an industrial ecology and sustainable engineering approach to designing an automobile?

**Term paper due in seminar**

Week 13: Sustainable Engineering Case Studies: Lead in Electronics Solder, Engineering the Everglades, and Running a Mining Megacomplex. Three case studies demonstrate the complexities of sustainable engineering. A study of lead solder use in electronics, compared to alternatives based on bismuth, indium, and a silver/epoxy mixture, raises questions of how additional mining activity should be evaluated from a social perspective. The challenge of engineering the Everglades raises complex problems arising from mutually exclusive stakeholder value systems in the context of a highly valued, unpredictable, and complex resource regime. The mining example demonstrates the difficulty of managing a major operation in a sensitive social and environmental context, and balancing the needs of society as indicated through the market, and the demands of activists.

Reading: Allenby, chapters 16-18.

Homework: You are operating a major mine in a developing country that is managed responsibly but is also causing environmental changes in local ecosystems. Write an op-ed (opinion-editorial) piece for your local newspaper defending your operation against environmental activists who demand that you be shut down.

Week 14: The Engineer as Leader. Sustainable engineering requires many things of professionals: commitment, respect for values and opinions that differ among themselves, and from the ones we may hold, a willingness to understand and work with social, cultural and environmental contexts. But it also requires that, as knowledgeable citizens in an increasingly technological world, engineers function as leaders within their institutions, communities, and society at large.
Reading: Allenby, chapter 19; Florman, chapters 7-11.

Homework: What will you be doing five years from graduation, and what skills will you need to be doing it?