Appendix D. Course Syllabi

28. Future Energy Systems

Cornell University

SUMMARY

Offered by: Mechanical and Aerospace Engineering
Instructor(s): K. Max Zhang

Number of times taught: Three or More
Class size: 30 to 100
Class format: 2.5 hours of lecture per week

Portion of course focused on sustainable engineering: More than 50%

Student Level: Upper division and graduate (3:2)
Students' Major: 80% Mechanical and Aerospace Engineering
20% Other engineering

Department, number, and title of course: Mechanical & Aerospace Engineering 501, Future Energy Systems

Designation as a 'Required' or 'Elective' course: Elective

Course (catalog) description: Spring. 3 credits.

Critically examines the technology of energy systems that will be acceptable in a world faced with global climate change, local pollution, and declining supplies of oil. The focus is on renewable energy sources (wind, solar, biomass), but other non-carbon-emitting sources (nuclear) and lowered-carbon sources (co-generative gas turbine plants, fuel cells) also are studied. Both the devices as well as the overall systems are analyzed.

Prerequisite(s): ENGRD 221 (Thermodynamics) or equivalent. Recommended: M&AE 323 (Introductory Fluid Mechanics), M&AE 324 (Heat Transfer), or equivalents. Open to graduate and upper class students or approval from instructor.

Textbook(s) and/or other required material:

Course Reading Packet.

Course objectives:

Upon completion of this course, students will be:

1. proficient in engineering calculations of the performance and rudimentary design of various energy conversion systems (ABET a and c);
2. familiar with the physics of the environmental issues, including the greenhouse effect and global climate change (ABET a, h and i);
3. adept in the comparative analysis of various energy conversion systems. The comparisons will include cost, social acceptability as well as environmental consequences (ABET c, e and h).

Topics covered:

- Motivation for Studying Future Energy Systems
- Modeling of Global Climate
- Estimation of the Effect of Increased Greenhouse Gases on Global Climate
- Overview of Fossil Fuel Combustion and Plants; Comparison of Fuels
- Cycle Analysis: Brayton, Rankine, Regeneration, Combined Cycles, Cogeneration
- Overall System Efficiency Starting from Well/Mine
- Emerging Sequestration Technologies: Biomass, Oceanic, Mineral Deposition
- Solar Power: Solar Ponds, Solar Towers, Economics of Solar Power
- P-n Junctions, Materials, Photovoltaic Cells
- Wind Power: Formation and Availability; Wind Turbine Theory; Operating Conditions; Land Requirements

- Economics of Wind Energy
- Nuclear Power: Current Reactor Designs, Breeder Reactors, Nuclear Fusion, Waste Disposal
- Transportation: Role of Energy Industry and Renewable Energy Sources
- Advances in ICE Technology
- Hybrid Technology and Fuel Cells; Hydrogen Supplies from Renewable Sources; Infrastructure Requirements
- Battery-powered Vehicles; Distributed Electric Generation from Vehicles
- Issues in Energy for Freight Transportation
- Overview of Other Emerging Future Energy Technologies
- Efficiency and Demand Side Management
- Political and Social Dimensions: the Legislative Process; Interest Groups
- Social Acceptability of New Technologies
- Comparison of Environmental Effects from Fossil Fuel, Wind, Solar, and Nuclear

Class/laboratory schedule, i.e., number of sessions each week and duration of each session: Three 50-minute lectures each week.

Contribution of course to meeting the professional component: This course partially fulfills the requirement to complete three upper level M&AE courses as a Field Approved Elective. It can be used to partially fulfill the requirement to complete two upper level courses within the Thermo-fluids concentration or it can be used to fulfill the Technical Elective requirement.

Relationship of course to program outcomes: This course meets ABET Outcomes a, c, e, h and i and Program Educational Objectives 1, 2, 3 and 4.

Outcome Assessment: Outcomes are assessed by considering grades on specific questions in homeworks, prelims and final, and by analyzing the student end-of-semester survey.

Person(s) who prepared this description and date of preparation:
Francis Vanek
2/23/04

29. Green Engineering Design

University of California Davis

SUMMARY

Offered by: Civil and Environmental Engineering
Instructor(s): Frank Loge

Number of times taught: Three or More
Class size: 30 to 100
Class format: 4 hours of lecture per week

Portion of course focused on sustainable engineering: More than 50%

Student Level: Upper division
Students' Major: ≥90% Civil and Environmental Engineering

ECI-143: Green Engineering Design, Fall, 2006
Department of Civil and Environmental Engineering
University of California Davis

Instructor: Frank Loge
3163 ENG III (754-2297); email: fjloge@ucdavis.edu
Office Hours: M,W 4:30-5:30; T,Th 4:00-5:00; or by appointment.

Location/Schedule: M, W (2:10 – 4:00 p.m.) in Wellman 1
Final exam on Monday, December 11 (1:30 - 3:30)

Textbook:

1. W. McDonough and M. Braugart. 2002. Cradle to Cradle. Northpoint Press. ISBN 0-86547-587-3. (On Reserve)
2. H. Baumann and A. Tillman. 2004. The Hitch Hiker's Guide to LCA: An orientation in life cycle assessment methodology and application. Studentlitteratur AB, Lund, Sweden. ISBN 91-44-02364-2. (On Reserve)
3. S. B. Billatos and N. A. Basaly. 1997. Green Technology and design for the environment. Taylor and Francis Publishers. ISBN 1-56032-460-0. (Available electronically on the course website)

References:

- D. T. Allen and D. A. Shonnard. 2002. Green Engineering, Environmentally conscious design of chemical processes. Prentice Hall. ISBN 0-13-061908-6. (On Reserve)
- Allen, David T. and Kirsten Sinclair Rosselot. 1997. Pollution Prevention for Chemical Processes. John Wiley & Sons, Inc., New York, New York. (On Reserve)
- Ciambrone, David F. 1997. Environmental Life Cycle Analysis. Lewis Publishers, N.Y., NY. (On reserve)
- DeSimone, Livio D. and Frank Popoff. 1997. Eco-Efficiency: The Business Link to Sustainable Development. The MIT Press, Cambridge, MA. (On Reserve)
- Smith, Robin. 1995. Chemical Process Design. McGraw-Hill, Inc. (On Reserve)
- Bishop, Paul L. 2000. Pollution Prevention: Fundamentals and Practice. McGraw Hill, Boston, MA. (On Reserve
- EPA Web site: Office of Pollution Prevention and Toxics, http://www.epa.gov/opptintr/greenengineering/ (Not on Reserve)
- Tchobanoglous, G., F. L. Burton, H. D. Stensel. 2003. Wastewater Engineering: Treatment and Reuse. Metcalf and Eddy. (On Reserve)

Prerequisites Upper division standing. Restricted to Civil Engineering majors (kindof).

Grading Criteria: Option 1

Paper 1	15%
Paper 2	15%
Group Presentation (on paper 2)	10%
Project 1	30%
Project 2	30%
Group evaluation	1 letter grade

Grading Criteria: Option 2

Paper 1	10%
Paper 2	15%
Group Presentation (on paper 2)	10%
Project 1	25%
Project 2	25%
Re-write of Paper 1	15%
Group evaluation	1 letter grade

Final letter grades will be assigned "on the curve", but cutoffs for the various letter grades usually don't drop more than 2 points below the typical "decade" values of 90, 80, 70, etc.

Class Structure: The principal objective of this class is to provide a background and understanding of the principals of sustainability and green engineering. We will specifically focus on life-cycle analyses, waste audit and environmental management systems, economics of pollution prevention and sustainability, and substitute materials for products and processes. I will provide handouts on a periodic basis to supplement information in the textbook. The projects will be completed in groups of 3 individuals. You will have the opportunity to evaluate the performance of your team members at the end of class. I will use these evaluations as part of assigning your overall grade.

Projects: Project 1. Design a suspended growth biological treatment system and an associated side-stream reactor for the production of PHA applying the 12 principals of Green Engineering. Summarize you design in a technical report with the following sections: (1) Introduction, (2) Methods, (3) Results and Discussion, (4) References, and (5) Appendices. Sections 1-3 should focus on the presentation of your major findings using tables and figures as appropriate. All your design calculations should be placed in appropriate appendices and referenced in the body of the report. The report should be written with 12 pt font, 1 inch margins, and 1.5 line-spacing. There is no page limit on the report. Additional details will be given in a separate handout.

Project 2. Collectively, Projects 1 and 2 are intended to illustrate the underlying processes, steps, and considerations of Green Engineering. Project 1 focused on the detailed design of an activated sludge system for the removal of carbon from wastewater and the concurrent production of PHA. You incorporated one or more of the 12 Principles of Green

Engineering in your specific design. In Project 2, you will focus on (1) a life-cycle assessment of your design in Project 1 relative to conventional methods of plastic production (Cradle to Manufacturing Gate), and (2) a life-cycle assessment of a natural fiber reinforced thermoplastic composite (NFRTC) produced as a deck board relative to timber counterparts (cradle to grave analysis). Additional details will be given in a separate handout.

Papers:

Paper 1. I have provided in class a number of different definitions of Green Engineering and Sustainability, each of which superficially have a different set of goals and objectives. Compare and contrast each conceptual framework, and then synthesize them into one framework that you feel is applicable to the field of Civil and Environmental Engineering. Finally, provide 1 to 3 real-life examples obtained from the literature (e.g., engineering journals or conference proceedings) of engineering designs that meet your criteria. Discuss how these examples meet your criteria. Additional details will be given in a separate handout.

Paper 2. Each group has been assigned a particular topical area either within Green Engineering or that illustrates the application of one or more principles of Green Engineering. Each person will be responsible for writing a 3-5 page double spaced paper excluding tables, figures, and references (page limitation is provided as guidance, and you can deviate from it as appropriate) that presents key aspects of the topical area. Consider the following aspects in your analyses: (1) provide an overview of your topical area; (2) specific aspects of how the topical area works; and (3) a discussion of what aspects of Green Engineering (e.g., one or more of the Principles) are represented by your topical area as reflected in how it works (another way to phrase this is how does the topical area fit within the field of green engineering and reflect one or more of its principles). Although the papers are written individually, you are encouraged to work with your team in generating data. The following criteria will be used in grading the paper: (1) technical writing-20%; (2) content-80%. At the end of the quarter, each team will present a 20 minute Powerpoint presentation on their topical area that represents a compilation of the ideas conveyed in the individual papers.

Listserv:

The listserv for the class is eci143-f06@ucdavis.edu. You will automatically be enrolled on this list if you are registered for the class and have a campus e-mail address. If you don't have a campus e-mail address, you must obtain one. [Go to IT Express, located in room 182 of Shields Library (turn right inside the main entrance and go a few doors down) and bring a photo ID with you.] I will use this to let you know when I post items to the course website, as well as to broadcast questions and answers relevant to the class as a whole. I expect that you will check your email regularly. You are also welcome to send messages to the list yourself.

The software for establishing the class mailing list automatically uses your UC Davis e-mail address. It is not possible to substitute a different address. If you want to receive messages at a different address, you should set up your UCD account to forward to that desired address. See

http://email.ucdavis.edu/forms/mailidredirect.html for instructions on how to do this.

Website: For those registered in the class, the course web site can be accessed through your MyUCDavis portal, http://my.ucdavis.edu. If you are not registered (e.g. auditing, making up a prior Incomplete), go to http://classes.ucdavis.edu/login/CourseManagement/Website/course_search.cfm and browse "Engineering Civil and Environ" (or by instructor) for ECI 143. The following items can be viewed and downloaded online from the course web site: (1) copies of the lecture when powerpoint is used, (2) updated copies of the syllabus (which changes from the most previous version highlighted in red), (3) supplemental reading material, (4) information relevant to the projects, and (5) solutions to the midterm.

Lecture and Reading Schedule

Date	Topic	Reading
10/2	Introduction	Billatos: 1-37 Allen: 1-79
10/4	Introduction	McD: 1-193
10/9	Design Principals of Green Engineering **Paper 1 Assigned (Due 10/18/06)**	McD: 1-193 Handouts Billatos: 39-89
	Natural Fiber Reinforced Thermoplastic Composites	Handouts
10/11	Plastics	Billatos: 91-127
10/16	Wastewater Treatment	Lecture Notes Tchobanoglous
10/18	Wastewater Treatment	Lecture Notes Tchobanoglous
10/23	Wastewater Treatment **Project 1 Assigned (Due 11/22/06)**	
10/25	Natural Fiber Reinforced Thermoplastic Composites	Handouts
10/30	Life-Cycle Assessment	Baumann: 19-41
11/1	Life-Cycle Assessment **Paper 2 Assigned (Due 12/4/06)**	Baumann: 43-68
11/6	Life-Cycle Assessment	Baumann: 73-95
11/8	Life-Cycle Assessment	Bauman: 97-126
11/13	Life-Cycle Assessment	Baumann: 129-172
11/15	Life-Cycle Assessment	Bauman: 175-202
11/20	Life-Cycle Assessment	ISO Handouts
11/22	Movie (McDonough: Next Industrial Revolution) **Project 2 Assigned (Due 12/11/06)**	Baumann: 203-229
11/27	Feasibility of Green Engineering in Practice	
11/29	Feasibility of Green Engineering in Practice	
12/4	Group Presentations of Paper 2 Topical Area	
12/6	Group Presentations of Paper 2 Topical Area	
12/11	**FINAL**	

USEFUL WEBSITES

- http://www.epa.gov/opptintr/greenengineering/
- http://www.libraries.psu.edu/eng/green.htm
- http://www.redo.org/
- http://www.epa.gov/epaoswer/non-hw/muncpl/recycle.htm#Figures
- http://www.epa.gov/epaoswer/non-hw/muncpl/sourcred.htm
- http://www.epa.gov/region02/p2/wastemin.htm
- http://muextension.missouri.edu/xplor/agguides/agengin/g01913.htm
- http://www.chinauscenter.org/purpose/CradleDesign.pdf
- http://hsc.csu.edu.au/chemistry/core/identification/chem921/chem921net.html
- http://www.nrel.gov/lci/database/default.asp
- http://www.epa.gov/ORD/NRMRL/lcaccess/resources.htm
- http://buildingsdatabook.eren.doe.gov/
- http://www.usgbc.org/
- http://www.ciwmb.ca.gov/GreenBuilding/Design/Guidelines.htm
- http://www.ciwmb.ca.gov/GreenBuilding/

30. Hazardous and Solid Waste Minimization

Milwaukee School of Engineering

SUMMARY

Offered by: Architectural Engineering & Building Construction; Environmental Engineering Program
Instructor(s): Carol Diggelman

Number of times taught: Three or More
Class size: Less than 10
Class format: 3 hours of lecture per week

Portion of course focused on sustainable engineering: More than 50%

Student Level: Graduate
Students' Major: ≥90% Architectural Engineering

Winter 2007/2008

EV 730. HAZARDOUS AND SOLID WASTE MINIMIZATION

Carol Diggelman, Ph.D.
Office: CC60A **Telephone: 277-7320** **Email: diggelma@msoe.edu**
Class: Mondays, 6:00 to 9:00 P.M. Room: CC 62
Office Hours: Tu, Th- 4:00 PM; W- 2:00 pm or by appointment.
Texts: USEPA, *An Organizational Guide to Pollution Prevention,* EPA/625/R-01/004; http://www.p2ric.org/CachedPages/printguid.pdf

J. Aldrich, *A Primer for Financial Analysis of Pollution Prevention Projects,* EPA/600/R-93/069. http://www.epa.gov/oppt/ppic/pubs/primerfinancialanalysis.pdf

Grading matrix:

Four assignments:

1.	Waste minimization information assignment	25 pts
2.	Hazardous waste regulation assignment	25 pts
3.	Life cycle environmental inventory assignment	25 pts
4.	Waste/recycling/biodegradation assignment	25 pts

Hazardous/Solid Waste Minimization Project:

Five minute PowerPoint presentation on topic		10 pts
Data search		0 pts
Rough draft	(Due 01/25/08)	50 pts
Final report	(Due 02/22/08)	100 pts
Presentation		30 pts
Handout (1 page summary of findings)		10 pts

Final Examination (Open note/open book)	**100 pts**
Total	**400 pts**

COURSE OBJECTIVES

EV 730 will introduce students to:

- Accessing information of importance to hazardous and solid waste managers from engineering journals, government and Internet sources
- Identifying hazardous wastes as defined by RCRA Subtitle C
- Managing a waste as a hazardous waste
- Using process analysis tools, including process mapping
- Understanding pollution prevention criteria, strategies, programs, project guidelines
- Performing a life-cycle environmental impact inventory
- Evaluating life-cycle costs for a pollution prevention project
- RCRA Subtitle D, the solid waste management hierarchy
- Strategies for minimizing solid waste

- Elements of sustainability
- An opportunity to practice communicating clearly and concisely both in technical reports and presentations

COURSE POLICIES

- Timeliness and attendance
  - The student is expected to be on time for each class.
  - Notify me by email of any absence as soon as possible.
  - There may be a penalty of 5% if you miss more than three hours of class.
- Submitting work/late work:
  - All work must be generated by a word processor, with one inch margins, double-spaced for drafts, single-spaced for final copies and submitted to WebCT in Times New Roman and 12 point size.
  - Proofread for grammar and spelling prior to submission. Obvious failure to do this will result in a "revise and resubmit" grade.
  - Staple all multi-page submissions.
  - Put name and a page number on every page submitted.
  - Avoid excessive use of abbreviations and jargon. Check to make sure all terms are explained. Spell out all abbreviations.
  - All writing must be original to this course; ideas from others must be properly cited.
  - Late work will only be accepted for 48 hours after the due date and will earn a maximum of C.
- Plagiarism- any confirmed act of plagiarism can result in a failing grade.
- Revise & re-submit
  - If a paper is handed back with "revise and resubmit" revisions must be completed and the paper turned in within 3 days for a new grade.
  - If not turned in, the student will receive a grade of D.
- Grading standards
  - A= Consistently exceeded criteria of assignments and work thorough in detail, submitted on time, great improvement in skills, high level of participation and time commitment.
  - B= Work above minimum criteria in amount, quality and thoroughness, submitted on time, shows improvement in skills
  - C= Minimum work, assignments on time and meet criteria, work careless and lacks detailed scope
  - D= Mostly complete work, but quality and/or quantity are significantly below what was expected
  - F= Incomplete work, didn't follow assignment directions, no improvement in skills

EV 730. COURSE SYLLABUS 2007/2008

WEEK/ DATE	**TOPIC/ASSIGNMENTS**
1. 11/26/07	Course overview Introduction- terms, concepts and drivers Environmental regulations **Assignment 1. Information gathering- due 12/03/07.**
2. 12/03/07	Hazardous Waste Management regulations- Sandra Miller, Hazardous Waste Specialist, WDNR **Assignment 2. Hazardous waste regulations- due 12/10/07.**
3. 12/10/07	Pollution prevention planning **EV 730 PROJECT- 5 MINUTE POWERPOINT PRESENTATION ON YOUR TOPIC** **DATA SEARCH DUE**
4. 12/17/07	Life cycle concepts and inventory **Assignment 3. Life cycle environmental inventory assignment due 01/07/08**
5. 01/07/08	Pollution prevention economics: "A Primer for Financial Analysis of Pollution Prevention Projects", EPA/600/R-93/069
6. 01/14/08	Solid waste management- RCRA Subtitle D. Laws and regulations Characterization of solid waste Waste management alternatives- landfill, WTE. **Assignment 4. Waste/recycling/biodegradation problem due 01/21/08.**
7. 01/21/08	Recycling/material recovery Solid waste minimization, recycling, waste exchanges, **PAPER ROUGH DRAFT DUE 01/25/08.**
8. 01/28/08	**Tour GE Renewable Resources facility at 7624 South 10th street, Oak Creek, WI.** **January 30, 2008 SYMPOSIUM 2. EXPLORING SYNERGIES IN MATERIALS' MANAGEMENT, MSOE Todd Wehr Auditorium 7 to 9 pm (6 pm social hour)**
9. 02/04/08	Sustainability and sustainability reporting Design for the environment. National Environmental Performance Track

Wisconsin DNR's Green Tier Program
Chicago Climate Exchange and carbon foot-printing

ROUGH DRAFTS EVALUATED

10. 02/11/08 HAZARDOUS/SOLID WASTE PRESENTATION

* **Length- 10 minutes**
* **Evaluation- peer-evaluated**
* **Handout- one page summary of presentation**

NO ASSIGNMENTS ACCEPTED AFTER 5:00 PM FRIDAY, FEBRUARY 15, 2008.

11. 02/18/08 ONE HOUR FINAL EXAMINATION- OPEN BOOK/OPEN NOTES

FINAL REPORT DUE

PLEASE RETURN ANY MATERIALS LOANED TO YOU SO THEY ARE AVAILABLE FOR LOAN IN THE FUTURE.

EV 730. PROJECT GUIDELINES Winter 2007/2008

Select a hazardous or solid waste stream. Characterize and quantify the waste stream and emissions, using a process map to illustrate. Determine the generator status, the applicable laws and regulations and current costs of hazardous waste disposal. Discuss the potential for Tier 1, 2 and 3 costs. Gather material safety data sheets, exposure and toxicity information for the most toxic chemical. Evaluate the potential for worker exposures and the environmental fate of most toxic chemical, if it were released.

Research the current literature for waste minimization alternatives and propose a cost-effective strategy for minimizing the waste stream. The report should include new process flow diagrams, process descriptions, and recommendations for equipment from vendors and vendor information. Determine life-cycle costs and environmental impacts for the alternate proposed and compare them to current costs and environmental impacts.

The written report should include the following sections and will be evaluated using the matrix below:
Abstract: project definition, methods used and most important results.
Background: including process description, process flow diagram and description, generator status and environmental aspects and impacts.
Objectives:
Methodology:
Literature review: summarize technology alternatives
Proposed alternative: evaluated for performance with process flow diagram
Proposed alternative: evaluated for life-cycle (first, operating and end-of-life) costs
Proposed alternative: evaluated for reductions in life-cycle environmental impacts
Appendices: calculations, vendor information, material safety data sheets, etc.

Give a 10 minute presentation to the class; pass out a one page summary.

EV 730. Solid/hazardous waste Project Evaluation Matrix

Section	Possible Points	Your Points
Abstract	10	
Background, including process description, flow diagram and current regulations	15	
Objectives	5	
Methodology	5	
Literature review/summary of alternatives	15	
Proposed alternative evaluated for performance.	15	
Proposed alternative evaluated for cost	15	
Proposed alternative evaluated for reductions in life cycle environmental impacts.	10	
Conclusions/recommendations	10	
References evaluated for quality (peer-reviewed environmental engineering journals and recent date).	10	
Appendices: calculations, vendor information, MSDS, etc.		

EV 730. PRESENTATION. **Winter 2007/2008**

PEER EVALUATIONS: Each presentation and presenter will be peer evaluated. Following are the criteria:

1. (15 PTS) **Quality of information.** ___
Clear and concise information on baseline waste stream
(process description, flow diagram, current regulations)
Evidence of research of current peer-reviewed engineering literature
Clear and concise information on alternative
(performance, life-cycle cost and life- cycle environmental inventory)
Evidence of practitioner/vendor contacts
References

2. (5 PTS) **Quality of organization.** ___
Concise opening/overview
Information follows logical sequence
Concise summary and conclusions

3. (10 PTS) **Quality of presentation.** ___
Visuals readable
Good eye contact and interaction with each member of audience
Good voice projection
Interesting
Stays within time constraints

4. (30 pts) **Total** ___

5. (10 pts) **Quality of handout.** ___
Summary of most important findings
Well organized

Constructive comments for presenter:

31. Industrial Ecology

Dartmouth College

SUMMARY

Offered by: Engineering
Instructor(s): Benoit Cushman-Roisin, Peter Robbie and Karolina Kawiaka

Number of times taught: Three or More
Class size: 10 to 30
Class format: 3 hours per week

Portion of course focused on sustainable engineering: Less than 10%, 10 to 25%, 25 to 50%, More than 50%

Student Level: Upper division and graduate (1:1)
Students' Major: ≥90% Engineering

ENGS 171
Spring 2008

INDUSTRIAL ECOLOGY

Course Description:

By studying the flow of materials and energy through industrial systems, industrial ecology identifies economic ways to lessen negative environmental impacts, chiefly by reducing pollution at the source, minimizing energy consumption, designing for the environment, and promoting sustainability.

The objective of this course is to examine the extent to which environmental concerns have affected specific industries, to evaluate the benefits of prevention over compliance, and to discern where additional progress can be made. With the emphasis on technology as a source of both problems and solutions, a broad spectrum of industrial activities is reviewed, ranging from low-design high-volume commodities to high-design low-volume products.

Student activities include a critical review of various articles, participation in class discussions, and a term project in design for the environment.

Prerequisites: ENGS-21 (Introduction to Engineering) and ENGS-37 (Introduction to Environmental Engineering), or permission.

Instructor & Assistants:

Benoit Cushman-Roisin
134 Cummings Hall
Tel: 646-3248

Teaching Assistants: Lauren Busby
Chris Polashenski (?)
TBA

Course Format:

1. Readings (as class preparation)
2. Lectures (leading to informed discussions)
3. Occasional homework sets
4. Occasional guest lecturers and video presentations
5. Term project (in groups of 3 or 4 students)
6. Mid-term and final project reports, and oral presentation

Class Preparation:

The instructor assumes that each student is committed to achieving the highest educational value from the course. Therefore, every student is required to attend all classes and to be actively involved in and a contributor to class activities, by being prepared to raise questions and engage in profitable discussion over the pre-assigned readings.

Primary Text (recommended but not required):

Pollution Prevention: Fundamentals and Practice
by Paul L. Bishop, McGraw-Hill, 2000
reprinted by Waveland Press, 2004

Other Text:

Product Design for the Environment – A Life Cycle Approach
by Fabio Giudice, Guido La Rosa and Antonino Risitano
CRC – Taylor & Francis, 2006

Course objectives:

1. Knowledge of fundamental ways by which industry can make progress in the direction of sustainability;
2. Understanding of principles of pollution prevention and design for environment;
3. Ability to perform limited life-cycle assessments;
4. Knowledge of current, 'green' technological initiatives in the auto industry;
5. Ability to decide in the face of incomparable quantities.

Honor Code:

As always, students are expected to observe all aspects of Dartmouth's Honor Principle, described on pages 44–46 of the Organization, Regulations & Courses. Dartmouth College policy requires that any apparent violation of the Honor Principle be reported to the Committee on Standards. The professor does not have any other choice, however uncomfortable he/she may feel.

Grading:

30% Literature critiques
15% Homeworks
15% Class participation
20% Term project - Phase 1
20% Term project - Phase 2

32. Industrial Ecology

Rochester Institute of Technology

SUMMARY

Offered by: Golisano Institute for Sustainability
Instructor(s): information not provided

Number of times taught: not yet taught
Class size: not yet taught
Class format: not yet taught

Portion of course focused on sustainable engineering: More than 50%

Student Level: not yet taught
Students' Major: not yet taught

Rochester Institute of Technology
Rochester, New York

GOLISANO INSTITUTE FOR SUSTAINABILITY

NEW COURSE PROPOSAL
Industrial Ecology (5001-XXX)

1.0 **Title**: Industrial Ecology **Date**: Oct. 3, 2007
Credit Hours: 4
Prerequisite(s): A minimum of four credits in calculus (or higher), economics, and any one of the following: physics, chemistry or biology. Research experience and graduate standing recommended. Exceptions are by permission of Instructor.
Corequisite(s): none
Course proposed by: Dr. Thomas P. Seager

2.0 **Course information:**

	Contact hours	Maximum students/section
Classroom	4	30
Lab	0	NA
Studio	0	NA
Other (specify _____)	0	NA

Quarter(s) offered (check)
_____ **Fall** __X__ **Winter** _____ **Spring** _____ **Summer**

Students required to take this course: (by program and year, as appropriate)
None

Students who might elect to take the course:
Students who are interested in sustainability and the environmental aspects of manufacturing, production and other industrial activities will take this course. Several different types of students are expected to enroll, including:

- Graduate students and exceptional undergraduate students throughout RIT seeking electives in sustainability or preparing to participate in research related to sustainability; and
- Qualified employees of area manufacturing, engineering, or environmental services firms, as well as government employees, seeking additional education related to sustainability and environmental management, engineering and/or design.

For Curriculum Committee Review Only

3.0 Goals of the course (including rationale for the course, when appropriate):
This course will enhance students' understanding of the interaction between industrial and environmental/ecological systems by providing them with the analytical tools necessary to quantify material and energy exchanges and the adverse environmental consequences of those. Students who successfully complete this course will be able to:

- Describe the similarities and differences that characterize industrial and ecological systems that relate to sustainability and understand the implications of the eco-industrial analogue.
- Draw process and life cycle diagrams that define the boundaries of production systems and the points of contact with ecological systems.
- Define critical design and/or decision variables at multiple points of intervention within the system.
- Compile life cycle inventories from existing databases or using existing software tools, including characterization and normalization of inventory data for multiple impact categories.
- Conduct multi-criteria life cycle impact comparisons, including uncertainty and sensitivity analyses.

4.0 Course description (as it will appear in the RIT Catalog, including pre- and co-requisites, quarters offered)

5001-XXX **Industrial Ecology**
Industrial ecology is the study of the interaction between industrial and ecological systems. Students in this course learn to assess the impact and dependency of production systems on the natural environment by mastering life-cycle assessment tools, concepts in biomimicry and principles of sustainability. This is a core course within the Sustainability M.S. and Ph.D. programs. (Enrollment in the Sustainable Production Systems program or permission of instructor) Class 4, Credit 4 (W)

5.0 Possible resources (texts, references, computer packages, etc.)
There are a number of reading assignments that will strengthen the intellectual foundation of the course, as referenced in the end notes. Some software programs (and user manuals) that are freely available will be distributed and are listed below:

5.1 Building for Environment and Economic Sustainability
http://www.bfrl.nist.gov/oae/software/bees.html

5.2 Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET)
http://www.transportation.anl.gov/software/GREET/greet_2-7_download_form.html

5.3 Tool for the Reduction of Chemical and other environmental Impacts (TRACI) http://www.epa.gov/nrmrl/std/sab/traci/

For Curriculum Committee Review Only

5.4 SimaPro 7 LCA software demo http://www.pre.nl/download/default.htm

6.0 Topics (outline):

6.1 Understanding Industrial Ecology
- 6.1.1 The power of metaphor[1 2]
- 6.1.2 Analogies in science
  - 6.1.2.1 Mathematics [3 4]
  - 6.1.2.2 Entropy[5]
  - 6.1.2.3 The biomimicry hypothesis[6 7 8 9]
  - 6.1.2.4 The Gaia hypothesis[10] and earth systems engineering
  - 6.1.2.5 The life cycle[11 12]

6.2 Life Cycle Assessment
- 6.2.1 Scoping[13 14 15 16]
- 6.2.2 Inventory building [17 18 19 20]
- 6.2.3 Characterization factors
- 6.2.4 Normalization[21 22]
- 6.2.5 Impact assessment & environmental scoring[23 24 25 26 27 28]
- 6.2.6 Uncertainty, variability, sensitivity & Monte Carlo analysis[29 30]

6.3 Software & methods studies
- 6.3.1 EIOLCA.net
- 6.3.2 TRACI/BEES[31 32 33]
- 6.3.3 SimaPro
- 6.3.4 IMPACT 2002+[34]
- 6.3.5 GREET[35]

6.4 Student-selected case studies related to supported research projects.
- 6.4.1 Products and Production
- 6.4.2 Energy
- 6.4.3 Sustainable Consumption
- 6.4.4 Policy for Sustainability

7.0 Intended learning outcomes and associated assessment methods of those outcomes

7.1 Understand implications of eco-industrial analogue.
- 7.1.1 Learning activity: Students will complete readings assignments and original papers on the merits and limitations of the eco-industrial analogue at a scale and on a topic relevant to their research area.
- 7.1.2 Assessment: Students must earn a satisfactory grade on their papers. Grading criteria will include orginality, clarity of thought, completeness and quality of written presentation.

7.2 Draw process and life-cycle diagrams.

7.2.1 Learning activity: Draft process and life-cycle diagrams will be drawn by the class (as a group exercise or in small groups) under the supervision of the Instructor. As homework, students will complete individual process and life-cycle diagrams related to their research topics.

7.2.2 Assessment: Students must earn a satisfactory grade on their homework. Grading criteria will include accuracy, clarity and quality of presentation and strength of attribution (i.e., bibliography).

7.3 Define critical design/decision variables

7.3.1 Learning activity: Working with the process and life-cycle diagrams developed in the previous exercise, students will complete a table of independent and dependent variables that characterize the environmental performance of the system. They will present hypotheses about the relation between them and how to investigate or confirm that relation in a business meeting-style roundtable and must moderate the class discussion regarding their presentation.

7.3.2 Assessment: Students must achieve a satisfactory grade based upon their understanding of the system they diagram, the clarity of their hypothesis and the intellectual merit of the discussion they moderate.

7.4 Compile life-cycle inventories using existing software tools

7.4.1 Learning activity: Students will complete reading assignments and participate in classroom discussions. In some case, students will choose one of several similar papers. Additionally, software tools will be distributed and reviewed in class. Students will be assigned to reproduce example inventories in classroom exercises and compare inventories reported by different tools in a small group presentation to the class. To test the hypotheses presented in 7.3, students will complete sensitivity analyses to using existing software tools.

7.4.2 Assessment: Students must earn a satisfactory grade on the group presentation. Grading criteria will include accuracy, originality, clarity and quality of presentation.

7.5 Conduct multi-criteria life cycle impact comparisons

7.5.1 Learning activity: Students will rehearse impact assessment calculations in classroom examples presented by the Instructor. Working in pairs, they will explore the sensitivity of these examples to different approaches in characterization, normalization and aggregation in a homework assignment culminating in a written report.

7.5.2 Assessment: Students must earn a satisfactory grade on their reports. Grading criteria will include accuracy, scope of sensitivities explored, originality, and quality of written presentation. Additionally, students must complete an exam testing their knowledge of the principles of industrial ecology and mathematics of life cycle assessment.

8.0 Program or general education goals supported by this course

This course will support graduate and undergraduate education objectives in programs that relate to the environment, business, production and policy throughout RIT. Furthermore, this course directly supports several program objectives in the proposed Sustainability Institute Ph.D. program.

8.1 Specify quantifiable sustainability objectives and strategies for achieving them.
8.2 Model and improve complex industrial-environmental-social systems with respect to sustainability objectives.
8.3 Define and conduct forward-looking sustainability research.
8.4 Lead multidisciplinary teams working on sustainability issues.
8.5 Conduct life cycle assessments (LCA).
8.6 Create new sustainable production/remanufacturing/recycling methods and to improve existing ones.

9.0 Other relevant information (such as special classroom, studio, or lab needs, special scheduling, media requirements, etc.)

This course frequently relies upon demonstration and interaction with web-based and software resources. The instructor will require a computer with internet access, a projector and screen. The student experience will be enhanced by portable or desktop computer access, although it is not required. Many of the reading topics require a discussion-based format, which will work best in two-hour blocks.

10.0 Supplemental information

None.

11.0 Endnotes.

---

[1] Rosen R. 2005. The machine metaphor in biology, in *Life Itself: A Comprehensive Inquiry into the Nature Origin and Fabrication of Life*. Columbia University Press. pp 20-22, 64-66, 245-247.

[2] Ayres RU. 1989. Industrial metabolism. *Technology and Environment*. National Academy Press.

[3] Ayres RU. 2004. On the life cycle metaphor: Where ecology and economics diverge. *Ecological Economics*. 48(4):425-438.

[4] Lambkin M, Day GS. 1989. Evolutionary processes in competitive markets: Beyond the product life cycle. *Journal of Marketing*. 53(3):4-20.
[5] Ayres RU. 1998. Ecothermodynamics: Economics and the second law. *Ecological Economics*. 26(2):189-209.
[6] Benyus J. 1998. *Biomimicry: Innovation Inspired by Nature*. Harper-Collins. (select chapters)
[7] Gertler N, Ehrenfeld J. 1997. Industrial ecology in practice: The evolution of interdependence at Kalundborg. *Journal of Industrial Ecology*. 1(1):67-79.
[8] Chertow M. 2000. Industrial symbiosis: Literature and taxonomy. *Annual Review of Energy and the Environment*. 25:313-337.
[9] Korhonen J. 2001. Four ecosystem principles for an industrial ecosystem. *Journal of Cleaner Production*. 9: 253–259.
[10] Lovelock JE. 1990. Hands up for the Gaia hypothesis. *Nature*. 344(6262):101-102.
[11] Ayres RU. 1997. The Kuznets curve and the life cycle analogy. *Structural Change and Economic Dynamics*. 8(4):413-426.
[12] Levine S. 2003. Comparing products and production in ecological and industrial systems. *J. Industrial Ecology*. 7(2):33-42.
[13] Curran MA. 2007. Co-product and input allocation approaches for creating life cycle inventory data: A literature review. International Journal of Life Cycle Assessment. 12(2):65-78.
[14] Ekvall T, Finnveden G. 2001. Allocation in ISO 14041— a critical review. *Journal of Cleaner Production*. 9:197–208.
[15] Cleveland CJ, Kaufmann RK, Stern DI. Aggregation and the role of energy in the economy. *Ecological Economics*. 32:301–317.
[16] Kim S, Overcash M. 2000. Allocation procedure in multi-output process: An illustration of ISO 14041. *International Journal of Life Cycle Assessment*. 5(4):221-228.
[17] Miller SA, Theis TL. 2006. Comparison of life-cycle inventory databases: A case study using soybean production. *Journal of Industrial Ecology*. 10(1-2):133-147.
[18] Duchin F. 1992. Industrial input-output analysis: Implications for industrial ecology *Proceedings of the National Academy of Sciences*. 89:851-855.
[19] Joshi S. 2000. Product environmental life cycle assessment using input-output techniques, *J of Industrial Ecology*. 3(2):95-120.
[20] Williams E. 2004. Energy intensity of computer manufacturing: hybrid assessment combining process and economic input-output methods. *Environmental Science and Technology*. 38:6166-6174.
[21] Heijungs R. 2007. Bias in normalization: Causes, consequences, detection and remedies. *The International Journal of Life Cycle Assessment*. 12(4):211-216.
[22] Bare JC, Gloria TP, et al. 2006. Development of the method and U.S. normalization database for life cycle impact assessment and sustainability metrics. *Environmental Science and Technology*. 40:5108-5115.
[23] Bare JC, Gloria TP. 2006. Critical analysis of the mathematical relationships and comprehensiveness of life cycle impact assessment approaches. *Environmental Science and Technology* 40(4): 1104-1113.
[24] Hertwich EG, Hammitt JK, et al. 2000. A theoretical foundation for life-cycle

assessment: Recognizing the role of values in environmental decision making. *Journal of Industrial Ecology* 4(1):13-28.

[25] Landis AE, Theis TL. 2007. Comparison of impact assessment tools: TRACI, CML and IMPACT 2002+." *Journal of Industrial Ecology*. Under review.

[26] Pennington DW, Potting J, et al. (2004). Life cycle assessment part 2: Current impact assesment practice. *Environment International.* 30:721-739.

[27] Pennington DW, Norris G, et al. 2000. Environmental comparison metrics for life cycle impact assessment. *Environmental Progress*. 19(2):83-91.

[28] Bengtsson, M. and B. Steen, Weighting in LCA – approaches and applications, *Env. Progress*. 19(2):101- 109, 2000

[29] Miller SA, Landis AE, Theis TL. 2007. Use of Monte Carlo analysis to characterize nitrogen fluxes in ag roecosystems. *Environmental Science & Technology.* 41(4):1457-1464.

[30] Landis AE, Miller SA, Theis TL. 2007. Life cycle of the corn-soybean agroecosystem for biobased production. *Environmental Science and Technology.* 41(4):1457-1464.

[31] Bare JC, Norris GA, Pennington DW, McKone T. 2002. TRACI: The tool for the reduction and assessment of chemical and other environmental impacts. *Journal of Industrial Ecology.* 6(3/4):49-78.

[32] Norris GA. 2003. Impact characterization in the Tool for the Reduction and Assessment of Chemical and other environmental Impacts. *Journal of Industrial Ecology* 6(3-4): 79-101.

[33] Lippiatt B, Boyles AS. 2001. Using BEES to select cost-effective green products. *International Journal of Life Cycle Assessment.* 6(2):76-80.

[34] Jolliet O, Margni M, et al. 2003. IMPACT 2002+: A new life cycle impact assessment methodology. *International Journal of Life Cycle Assessment*. 8(6):324-330.

[35] Wang M. 2002. Fuel choices for fuel-cell vehicles: Well-to-wheels energy and emissions impacts. *Journal of Power Sources*. 112:307-321.

33. Industrial Ecology

University of Delaware

SUMMARY

Offered by: Civil and Environmental Engineering
Instructor(s): C. P. Huang

Number of times taught: Once
Class size: 10 to 30
Class format: 3 hours of lecture plus per week

Portion of course focused on sustainable engineering: More than 50%

Student Level: Upper division and graduate (1:1)
Students' Major: ≥90% Civil and Environmental Engineering

CIEG 467/CIEG667 Industrial Ecology

Date	Lecture	Category	Topics	G&A	Activity	Reports
6-Feb	1	Introduction	Objectives, definitation, current issues	Ch.1, 2	Organization	
8-Feb	2	Material processing	Metals minerals; Al; Cu; Co, As, Ag, Cr, Zn, Cd	Ch.4,4		
13-Feb	3		Metals minerals; Al; Co; co, As, Ag, Cr, Zn, Cd	Ch.4,5		
15-Feb	4		Non-metals minerals; S, N, Cl, Si	Ch.4,6		
20-Feb	5		Non-metals minerals; S, N, Cl, Si	Ch.4,7		
22-Feb	6	Energy resources	Principles of energy and thermodynamics			
27-Feb	7		Forms of energy			
	8		Forms of energy			
1-Mar	9	Environmental Management	The ISO 14000 series	Ch.7	Term project proposal	
6-Mar	10		Implementing and applications			
8-Mar	11		Auditing/acounting			Weekly report
13-Mar	12	Life-cycle Assessment	Overview	Ch.15,18		
15-Mar	13		Methodologies	Ch.15,19		Weekly report
20-Mar	14		Applications	Ch.15,20		
22-Mar	15	Design for Environment	Green chemistry	Ch.8,14		Weekly report
27-Mar			Spring recess			
29-Mar			Spring recess			
3-Apr	16		Assembly/demanufacturing	Ch.8,14		
5-Apr	17		Mid-term Exam	Ch.8,14		Weekly report
10-Apr	18		Packing	Ch.8,14		
12-Apr	19	Pollution prevention	Properties and Fates of contaminants			Weekly report
17-Apr	20		Improing manufacturing operations			
19-Apr	21		Planning			Weekly report
24-Apr	22		Energy conservation			
26-Apr	23		Residues management		Project presentation #1	
1-May	24	Sustainability	Sustainable water environment		Project presentation #2	
3-May	25		Sustainable construction systems		Project presentation #3	
8-May	26		Sustainable transportation systems		Project presentation #4	
10-May	27		Sustainability in the world		Project presentation #5	
15-May	28		Sustainability in the world		Project presentation #6	
18-May						Final project

Requiremtnts:
1. Homework: 15%
2. Mid-term exam: 25%
3. Term project: 60%

34. Industrial Ecology and Natural Systems

Georgia Institute of Technology

SUMMARY

Offered by: Industrial and Systems Engineering, and Public Policy (cross-listed)
Instructor(s): Valerie Thomas

Number of times taught: Twice
Class size: 10 to 30
Class format: 3 hours of lecture per week

Portion of course focused on sustainable engineering: More than 50%

Student Level: Graduate
Students' Major: 30% Industrial and Systems Engineering or Public Policy
50% Other engineering
20% Other non engineering

Industrial Ecology and Natural Systems
ISYE 8813B, Fall 2007
Instructor: Valerie Thomas

This course will provide students with the analytical skills to address global energy and environmental problems. The course examines the use of material and energy on the industrial, national, and global scale, the interaction of technological and natural systems, and the potential for reducing impacts through new technology and approaches.

There are no prerequisites.

Section I. Global Change and the Technological Challenge

Week 1 August 22. Overview: Status of Human Development and Natural Systems

Week 2 August 29. IIistory of Technology and Effects on Natural Systems

Week 3 September 5. Climate Change

Week 4 September 12. Energy: The Technological Challenge

Week 5 September 19. Population, Food, Waste, and Depletion of Resources

Section II. Industry and Products

Week 6 September 26. Sustainability Metrics for Industry

Week 7 October 3. Midterm

Week 8 October 10. Environmental Life Cycle Analysis

Week 9 October 17. Pollutant Risk Assessment

Week 10 October 24. Environmental Cost-Benefit Analysis:
Cost of Saved Energy. Cost-Benefit Analysis of Air Pollution Control. Valuing Ecosystem Services

Week 11 October 31. Industrial Symbiosis

Section III. Regions and People

Week 12 November 7. Case Study: State of Georgia

Week 13 November 14. Case Study: Africa

Week 14 November 21. Reducing Energy Use in Transportation. Environmental Implications of Globalization.

Week 15 November 28. Presentation of Projects

Week 16 December 7. Review and Synthesis

35. Industrial Ecology and Green Engineering Design

Carnegie Mellon University

SUMMARY

Offered by: Civil and Environmental Engineering
Instructor(s): Cliff Davidson and Scott Matthews

Number of times taught: Three or More
Class size: 10 to 30
Class format: 3 hours of lecture per week

Portion of course focused on sustainable engineering: More than 50%

Student Level: Graduate and upper division (4:1)
Students' Major: 50% Civil and Environmental Engineering
40% Other engineering
10% Non engineering

INDUSTRIAL ECOLOGY AND SUSTAINABLE ENGINEERING DESIGN

12-713

Cross listed as 19-623
Course Syllabus
Fall 2007 Second Mini, 6 units

Cliff Davidson
Professor of Civil and Environmental Engineering/
Engineering and Public Policy

October 22, 2007

Carnegie Mellon University **Dept. of Civil & Environmental Eng.**
CEE 12-713 Fall 2007, Second Mini **Instructor: Cliff Davidson**

INDUSTRIAL ECOLOGY AND SUSTAINABLE ENGINEERING DESIGN

Course meets on Monday and Wednesday, 3:00-4:20 in Porter Hall 7F
Instructor: Cliff Davidson, PH 123E, ext. 8-2951, e-mail: cliff@cmu.edu
Teaching Assistant: Shahzeen Attari, PH A2, ext. 8-6826, e-mail: sza@andrew.cmu.edu

The teaching assistant will establish office hours to help students who have questions about the course material. Students are also encouraged to contact the course instructor if there are questions about the course material or if any other questions or problems arise.

References: There is no textbook for this course. However, the class will use handouts provided by the instructor that summarize journal articles and sections of books. Some of the books from which material has been taken include the following:

Cagan, Jonathan and Craig M. Vogel, *Creating Breakthrough Products: Innovation from Product Planning to Program Approval*, Prentice Hall, Upper Saddle River, NJ, 2002.

Fiksel, Joseph, *Design for Environment*, McGraw-Hill, New York, NY, 1996.

Gould, James L. and William T. Keeton, *Biological Science*, Sixth edition, W.W. Norton and Company, New York, 1996.

Graedel, Thomas E. and Brad R. Allenby, *Industrial Ecology, Second Edition*, Prentice Hall, Upper Saddle River, NJ, 2003.

Kormondy, Edward J., *Concepts of Ecology*, Fourth edition, Prentice Hall, Upper Saddle River, NJ, 1996.

Lovelock, J.E., *Gaia, A New Look at Life on Earth*, Oxford University Press, New York, 1979.

Odum, Eugene P., *Ecology and Our Endangered Life Support Systems*, Sinauer Associates, Inc., Sunderland, Massachusetts, 1989.

Course Objective:

As a follow-up to the course Introduction to Sustainable Engineering, which examined human impacts on global systems and the need for change, this course focuses on solutions to the problems. The student successfully completing this course will understand some of the ways in which human development can be altered to be in harmony with natural earth systems. Specifically, he or she will be able to solve problems in engineering design that can help development while minimizing long-term damage to the environment. The student will also be able to discuss trade-offs in considering different types of solutions.

Course Structure:

Homework assignments are due at the beginning of class. Late homework assignments will have scores reduced by 10% for each 24-hour period following the beginning of class on the due date. Homework assignments received after the graded papers are returned cannot receive credit but may be turned in for grading to obtain feedback.

If you are absent from class, it is your responsibility to obtain copies of the material and any assigned work. If you are dissatisfied with the grade you have received on any material for this course, you should initiate discussion with the teaching assistant within one week after receiving the graded material. The teaching assistant will then discuss the issue with the course instructor. Changes of grade will be granted only in exceptional circumstances, such as a math error in totaling points or work that was overlooked by the grader.

You are allowed to discuss homework problems with your classmates, but all written work must be individual efforts. Copying of assignments is not allowed; any evidence of cheating or plagiarism will be dealt with according to university policies.

Grade Allocation:

Class Participation	10%
Homework	40%
Research Report	15%
Final Exam	35%

Note that each student is required to complete a short research report on a topic of his or her choosing related to sustainability. Details of what is expected in the report will be given in class.

Tentative Course Outline:

1. Introduction

2. UNIT 1: The Earth's Life Support Systems: Global Cycles
    a. Carbon chemistry related to combustion and photosynthesis
    b. Single cell chemistry

3. UNIT 1: The Earth's Life Support Systems: Photosynthesis
    a. Energy flow through the ecosystem
    b. Efficiencies of energy transfer
    c. Biological mutualism

4. UNIT 1: The Earth's Life Support Systems: Ecosystems
    a. Cycling of nutrients in the ecosystem
    b. Examples of ecosystems
    c. Embodied energy, energy diagrams

5. UNIT 2: Industrial Ecology: Definitions and Principles
    a. Links between ecosystems and industrial ecosystems
    b. Concept of embodied energy in natural systems and in industrial products
    c. Natural capitalism

6. UNIT 2: Industrial Ecology: Energy Flow in Industrial Systems
    a. Electric power plant, Biofuels
    b. Industries in Kalundborg, Denmark

7. UNIT 2: Industrial Ecology: Material Flow Analysis
    a. The flows of metals
    b. Aluminum as an example

8. UNIT 2: Industrial Ecology: Deterministic Queueing
    a. Use of a spreadsheet for discrete populations
    b. Integration for continuous populations

9. UNIT 2: Industrial Ecology: Deterministic Queueing
    a. Examples in deterministic queueing
    b. Comparison of discrete and continuous result

10. UNIT 3: Entropy: Definition and Use
    a. Entropy as an indicator of a sustainable process
    b. Derivation of the entropy law

11. UNIT 3: Entropy: Examples
    a. Copper flow in Europe
    b. Municipal Solid Waste in Allegheny County

12. UNIT 3: Design for the Environment
    a. Principles of DfE
    b. DfE as a subset of general design principles

13. Course Review

36. Introduction to Solar Energy Utilization

University of Nevada, Las Vegas

SUMMARY

Offered by: Engineering
Instructor(s): Robert Boehm

Number of times taught: Three or More
Class size: 10 to 30
Class format: 3 hours of lecture per week

Portion of course focused on sustainable engineering: More than 50%

Student Level: Undergraduate, lower and upper division (1:1)
Students' Major: 90% Non engineering

UNIVERSITY OF NEVADA, LAS VEGAS

EGG 150/450 **Solar Energy Class** **Fall 2007**

Title: Introduction to Solar Energy Utilization
Course Objectives: To introduce the student to the technologies of a wide range of solar energy applications and other renewable energy sources. Included in the solar coverage will be power generation, thermal applications, and building-related issues. Other technical topics to be discussed will be wind generation, alternative fuels, and hydrogen technologies including fuel cell concepts. Related topics included will cover some public policy issues, as well as economic and environmental considerations that impact the development of these energy approaches. This will be done through lectures, both by regular faculty and some outside experts, films and tapes, student readings, student projects and field trips.
Credits: 3
Prerequisites: None
Course Numbers: EGG 150/450
EGG 450: Students enrolled in 450 will have additional assignments compared to the students enrolled in 150. Typically these will be in the form of papers on some type of renewable energy application assigned by the Instructor. The author of the paper will present to the class the information pertinent to the topic assigned.
Instructor of Record: R. Boehm, 895-4160, boehm@me.unlv.edu
Office Hours: 2:30-3:45 MW, TBE B124.
Course Days, Time, and Place: Mondays and Wednesdays, 4:00-5:15 pm, TBE B176
Syllabus: A detailed syllabus will not be given out initially because not all invited speakers have been secured.
Text: McDaniels, THE SUN, Second Edition, Kreiger, 1991. This book will not be used heavily, but we will select limited portions from it for coverage. The Instructor will give the text out on short-term loan for people who do not wish to buy it.
Field Trips: Several field trips will be organized, some to locations on campus, and some to locations that will require automobile travel. We should be able to ride-share for the latter, so if a student does not have a car, it should not be a problem. The more distant locations will be visited at times other than the regular class hour, and these will be determined. Commensurate class time off will be given to cover the time involved in the field trip.
Small Experiments: A few small experiments will be scheduled to demonstrate some types of information given in the course.
Exams: There will be both a midterm exam and a final exam given on a closed-book, closed-notes basis. A study guide for the exams will be prepared for the students by the Instructor prior to the exam. The purpose of this study guide is to focus on specific issues to be addressed in the exam.
Design Project: Student groups of either 2 or 3 students per group (with attempts to balance backgrounds and experiences as much as possible) will be formed to investigate the feasibility of an energy conservation project (includes renewable energy applications if appropriate) to a facility to be selected later. Possible examples will be supplied in class. A preliminary outline of the problem and the approach to its solution should be handed in on 10/23. The final report will be presented both in oral and written forms, all done by the group on the last day of class. Groups may be called upon to give a brief outline of progress at various times in the course.
Grading: Attendance, 1 point each time the class meets for 25% of the grade. A student will not be penalized for one absence. Project study and report, 25% of the grade; Midterm Exam, 25%; Final Exam, 25%. Bonus points: A 10% bonus will be awarded for assisting with the local version of the National Solar Home tour. This will be discussed in class.
WebCT Vista (WebCampus): All materials for this class will be made available on this web site. You can locate access to this site by going to the UNLV home page (www.unlv.edu) and going to "WebCampus" in the A-Z index or to the same name in the Quick Find pull-down on that page. Follow the instructions given under University of Nevada, Las Vegas hot link on the page given. A username and password are required at that point. Under that, see the "Need Login Help?" to assist in getting set up. For anyone with the familiar with the old WebCT system used prior to this year, WebCampus is an update of that, but it does require new insights compared to the old system. Any electronic class materials will be posted there.
Disability Resource Center (DRC) – UNLV complies with the provisions set forth in Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1990, offering reasonable accommodations to qualified students with documented disabilities. If you have a documented disability that may require accommodations, you will need to contact the DRC for the coordination of services. The DRC is located in the Student Services Complex (SSC), Room 137, and the contact numbers are: VOICE (702) 895-0866, TTY (702) 895-0652, FAX (702) 895-0651. For additional information, please visit: <http://studentlife.unlv.edu/disability/>.
Copyright – The University requires all members of the University Community to familiarize themselves and to follow copyright and fair use requirements. YOU ARE INDIVIDUALLY AND SOLELY RESPONSIBLE FOR VIOLATIONS OF COPYRIGHT AND FAIR USE LAWS. THE UNIVERSITY WILL NEITHER PROTECT NOR DEFEND YOU NOR ASSUME ANY RESPONSIBILITY FOR EMPLOYEE OR STUDENT VIOLATIONS OF FAIR USE LAWS. Violations of copyright laws could subject you to federal and state civil penalties and criminal liability, as well as disciplinary action under University policies. To familiarize yourself with copyright and fair use policies, you are encouraged to visit the following website: <http://www.unlv.edu/committees/copyright/>.

UNIVERSITY OF NEVADA, LAS VEGAS

EGG 150/450 **Solar Energy Class** **Fall 2006**

Modified 10/9/06

Title: Introduction to Solar Energy Utilization **Credit:** 3 **Prerequisites:** None
Course Numbers: EGG 150/450 **Instructor:** Several, see syllabus
In Charge: R. Boehm, 895-4160, boehm@me.unlv.edu **Office Hours:** 1:15-2:15 MW, TBE B124.
Course Days, Time, and Place: Mondays and Wednesdays, 4:00-5:15 pm, TBE B174
Course Objectives: To introduce the student to the technologies of a wide range of solar energy applications and related public policy, economic, and environmental considerations. This will be done through lectures, both by regular faculty and outside experts, student readings, and student projects.
Text: McDaniels, THE SUN, Second Edition, Kreiger, 1991. Some topics discussed in class are covered well in the text, others not at all.

Syllabus (effective 7/30/06):

Week	*Date*	*Topic*	*Lecturer*	*Chapters*
1	8/28	Overview of Course, Solar Applications, and Equipment	Boehm (ME)	1, 2, 3, 4
	8/30	Some Questions about Renewables' Viability, Sun Resource	Boehm (ME)	6
2	9/04	*Labor Day Holiday*		
	9/06	Photovoltaics I—Fundamentals, Components	Baghzouz (EE)	11
3	9/11	Photovoltaics II—Design of a System	Baghzouz (EE)	
	9/13	Photovoltaics III— Electric Utility Aspects	Hargrove (SPPC, NPC)	-
4	9/18	Photovoltaics IV—Installation	Brooks (Bombard)	
	9/20	Architectural Aspects (Wednesday)	Fernan.-Gonz. (Arch)	
5	9/25	Analysis of Building Design Issues	Bailey (Innovative Des)	7
	9/27	Collector Concepts	Boehm (ME)	8, appdx
6	10/02	Field Trip: UNLV Solar Site, Water Heating	Boehm (ME)	9
	10/04	Daylighting	Kroelinger (Arch)	-
	10/07	*(Saturday) National Solar Home Tour*		
7	10/09	Wind Energy I Project, Intro Due (written form)	Pepper (ME)	-
	10/11	Wind Energy II	Pepper (ME)	-
8	10/16	Midterm Exam	--	
	10/18	Application of Renewables in the NPS	Butterworth (USNPS)	
9	10/23	Utility Regulation Implications (Project Preliminary due)	Wagner (PUC)	
	10/25	Utility Perspectives	Wood (Nev Pow, SNWA)	
10	10/30	Thermal Power Generation	Boehm (ME)	10
	11/01	Eldorado Valley 64MWe Trough System	Boehm (ME)	
11	11/06	Environmental Motivations, Sustainability	Rypka (Sustainable)	-
	11/08	Wind Energy III	James (CE)	
12	11/13	Hydrogen	Boehm (ME)	
	11/15	Hydrogen, Fuel Cells	Boehm (ME)	
13	11/20	Environmental Economics	Neill (Env Stu)	-
	11/22	Solar and Conservation in Hospitality Industry	Dominguez (Harrahs)	
14	11/27	Student Project Reports Presented	Students	
	11/29	Student Project Reports Presented	Students	-
15	12/04	Solar Stills	James (CE)	
	12/06	Biomass, Crop Yields	James (CE)	
	12/11	(Monday) Final Exam, 6:00 pm		

Lecturers:

Yahia Baghzouz, Professor, Electrical Engineering, UNLV
Gary Bailey, Principal, Innovative Design
Robert Boehm, Distinguished Professor, Engineering, UNLV

Chris Brooks, Solar Specialist, Licensed Installer, Bombard Electric
Steve Butterworth, Regional Energy Program Coordinator, National Park Service (Seattle)
Eric Dominguez, Director, Energy Services, Harrah's International
Alfredo Fernandez-Gonzalez, Associate Professor, School of Architecture, UNLV
John Hargrove, Solargenerations, Sierra Pacific Power and Nevada Power
David James, Associate Professor, Civil Engineering, UNLV
Michael Kroelinger, Professor and Director, School of Architecture, UNLV
Darrell Pepper, Professor, Mechanical Engineering, UNLV
Helen Neill, Associate Professor, Environmental Studies, UNLV
Steve Rypka, Sustainable Living
Rebecca Wagner, Commissioner, Nevada State Public Utility Commission
Gary Wood, Renewable Energy Specialist, Southern Nevada Water Authority

See 3 companion Word documents for remainder of this Appendix.