ISE 576 Industrial Ecology: Technology-Environment Interaction
Spring 2014

Instructors:

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Time/Location:
Fridays, 2-4:50, OHE 120

Note: The syllabus offered here as uploaded to the schedule of classes is for informational purposes only. The readings, general lecture content, and assignments will be as outlined here, but the precise lecture content, field trips, and guest speakers noted in the schedule may change slightly depending on availability.

COURSE DESCRIPTION

Industrial ecology (IE) focuses on impacts to the natural world from the expansion in the rate and scale of human transformation of the earth following the industrial revolution. Concepts and tools trace these impacts relevant to ecological impacts, human toxicity, and resource depletion. IE views these impacts as resulting from the interaction of underlying complex technological, social, economic and legal systems. IE is a heavily interdisciplinary field involving science and technology (engineering), public policy, economics and business operations.

Objectives:
The objectives of this course are to introduce the philosophy and principles of industrial ecology and provide tools to study the impacts in different technology implementations. These approaches and tools are generally used to evaluate products, processes, and systems in their entire life-cycle, including: materials flow analysis, design for environment, environmentally extended input-output analysis, life-cycle assessment, industrial symbiosis, reverse logistics, and sustainable consumption. The course is designed in three overarching sections. The first section of the course provides an overview of concepts and tools in industrial ecology. These include the concepts of systems thinking and industrial symbiosis, as well as an overview of design for the environment (DFE) and materials flow analysis (MFA). The second section of the course provides a more comprehensive coverage of life-cycle assessment (LCA) tools. Students will learn how to use leading models in case exercises on materials selection and product design. The final section of the course relates industrial ecology to a number of current themes and issues in public policy.

Statement for Students with Disabilities
Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. *Scampus,* the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.

COURSE MATERIAL

Required:

- Graedel, T.E., and Allenby, B.R. (2010). *Industrial Ecology and Sustainable Engineering.* Pearson Education: Upper Saddle River, New Jersey. (we call this book "IE")
- Ashby, M.F. (2013). *Materials and the Environment: Eco-Informed Material Choice.* (2nd Edition) Elsevier Publishers: Amsterdam. (we call this book "Mat")
- Other reading materials (see the schedule below) will be placed on the DEN website.

COURSE SCHEDULE

Session #	Topics	Reading/Homework/Slides
#1	• Syllabus, Class Requirements, Expectations, Team Selection • Robinson, Robinson, and Soon (2007) Industrial ecology in the global climate warming debate http://www.oism.org/pproject/s33p36.htm	• Syllabus • Reading: IE Ch 1,2, & 3 and Mat Ch 1 • Slides: Robinson, Robinson, and Soon (2007) • Slides: Barnosky et al. 2012
#2	• Overview to Industrial Ecology • Systems thinking (industrial ecology as the "science and technology of sustainability")	• Slides: Overview of IE 2013 Update • Slides: Spring 2013 Complex System and Sustainability • Reading: Mat Ch 2 & 11 • Reading: IE Ch 15 • Reading: Article by Vos in *JCTBT* • **HW#1: IE 15.1, 15.3** • **Team Formation Deadline**
#3	• Industrial activity, industrial symbiosis, and policy (RV) • Video: Biomimicry: http://www.ted.com/index.php/talks/janine_benyus_shares_nature_s_designs.html (23 min) • Eco-industrial parks and spatial planning	• Reading: Article by McDonough and Braungart in *Interfaces* • Reading: IE Ch 5 & 16 • Reading Mat Ch 4 • Reading: Ehrenfeld and Chertow in *Handbook of IE*

	• End-of-first-life: issues and opportunities	• Reading: Penn and Vos EIP Infrastructure Manual • Slides: Eco-Industrial Symbiosis Spring 2013 • **HW #2: IE 16.4, Mat E4.5**
#4	• LCA overview (Sustainable engineering; Design for Environment) • Life-Cycle Analysis process	• Reading: Mat Ch 3 • IE Chapter 12 • Slides: LCA overview • Slides: LCA Process & LCI Spring 2013 Update

#5	• LCA intro continued • LCA inventory analysis **Mid-term project presentations (5 minutes each)**	• Reading: Mat Ch 3 • Slides: LCA Process & LCI Spring 2013 Update • **HW #3: Mat E3.4, E3.6**
#6	• Guest Lecture from Dr. Sangwon Suh, Bren School of UCSB, "LCA Tools for Green Buildings and Construction" • Infrastructure DfES (Discussion with Guest Speaker)	• Reading: IE Ch 11 • Optional Reading: Paper: on CC versus CMU construction (Rahimi et al.) • (Note: No slide set required for exam.)
#7	• On-Campus Students: Field Trip to GreenPath Recovery in Colton, CA • DEN Students: Video presentation and discussion of the *By-Product Synergy* (BPS) project	• No reading or homework, start reading for Week of 3/8

#8	• LCA impact and interpretation stages
	• LCA Protocols: ISO 14000 Series & Carbon Footprints
	• Streamlining LCA
	• DfE Overview
		• Reading: IE Ch 13 & 14
		• Reading IE Ch 8, 9, & 10
		• Slide Sets:
		  • Life Cycle Impact Assessment (LCIA) Spring 2013 Update
		  • Streamlined Life Cycle Assessment (SLCA) Spring 2013 Update
		  • DfX Spring 2013 Update
		• Reading: Also review Mat Ch 3 p 60-66
		• **HW #4: SLCA HW**
		Optional Reading: LCA of high-speed rail: http://www.uctc.net/access/37/access37_assessing_hsr.shtml

#9	• Energy and industrial ecology (Reading Only) • Water and industrial ecology (Reading Only) • Eco-audits (Jae Kim) • Eco-audits tool demonstration (Jae Kim) • Guest Lecture from Dr. Roland Geyer, Bren School of UCSB "Spatially Explicit LCA of Sun to Wheels Transportation Pathways in the U.S."	• IE Ch 19; Mat Ch. 12 • IE Ch 20 • Mat Ch 7 • Mat Ch 15 • Slide Set: Geyer et al. Sun to Wheels LCA • **HW #5: IE 19.6, 20.2 and Eco-Audit HW**
	Spring Break	

#10	• Understanding EIO-LCA
	• *In-Class Exercise*
		• Slides Sets:
		  • EIO-LCA Introduction
		  • EIO-LCA Policy Application
		  • EIO in National Materials Accounts
		• Reading: IE Chap 18
		• Reading: Hendrickson et al. Intro + Ch. 16
		• **HW #6: EIO-LCA Case**

#11	• Guest Lecture from Dr. Brandon Kuczenski, Bren School of UCSB "Auditing U.S. Energy Consumption"
	• Material Flow Analysis (MFA)
	• Industrial Ecology for Sustainable Cities
	  * Urban metabolism
	  * Regional innovation clusters and green jobs
		• Reading: IE Ch. 17
		• Reading: IE Ch. 21
		• Slide Set:
		  • Sustainable Cities and Urban Metabolism Spring 2013 Update

#12	• Consumer Products; Sustainable Packaging: Scorecards, Product Labeling and Beyond • Indicators and Metrics • Sustainable Consumption; Jason Clay TED video: http://www.ted.com/talks/lang/eng/jason_clay_how_big_brands_can_save_biodiversity.html • Case Study: Carbon Footprint of Paper Products (RV) * Brief in class check-in on projects/exam	• Reading: IE 7, 10, & 26 • Reading: JIE Special Issue on Consumption Vol. 14 No. 1 (Columns) • Reading: Mat Ch 5 • Slide Set: Consumption and Consumer Products Spring 2013 Update
#13	• Risk Assessment, Resilience and Technological Change (RV) • Precautionary Principle (RV) • Risk Communication (RV) • Nanotechnology case study (RV) **EXAMINATION**	• Reading: IE Chapter 6 & 27 • Reading: Allenby and Fink, *Science* article • Reading: Allenby and Rejeski, *JIE* article • Reading: Shatkin *JIE* article & Eckleman et al. *JIE* article
#14	Final Project Collaborative Working Session (In Class)	No reading or slide sets
	Final project presentations and term papers due (15	

#15	**minutes each group)**	

Note 1: Readings are to be completed ***before*** the class sessions indicated. Other items may be assigned prior to each session as needed.
Note 2: Materials, lectures and/or task assignments may be revised to accommodate the content and the pace of the class learning process.
Note 3: Generally, homework assignments are due the week *after* they are listed in the syllabus, allowing for questions or clarification during lectures. Links on BlackBoard with specific deadlines will be provided for submission.

COURSE GRADING

Deliverables	*Grade Format*	*Grade Distribution*
Exam	Individual	**40%** (a few exam questions will be provided mid semester to give you a sense of what type of questions to expect from and how to study for this exam)
Term Project	Team	**40%** (40% presentation, 60% final paper)
Homework	Individual	**20%** (Average across 6+ assignments)

General Notes:

- Participate in class discussions, contribute individual experiences when relevant to the topic so that others can benefit and learn.
- Take individual responsibility for completing homework assingments/term project activities
- Students are responsible to make arrangements for audiovisual equipment for their presentations ahead of time.
- Late submissions will not be accepted.
- Laptop policy: you are allowed to use laptops during class to take notes. However, network connections are not allowed and you are not allowed such as email, Internet, social networking, etc. Please download from Blackboard any files you may need before class. The same policy applies to the use of computer workstations in the classroom.

TEAM FORMATION

General Rules for Teams

The teams are formed during the first session. The team members will define the team's activities using the following procedure. The team leader will perform the negotiations between the team and the instructor. We follow the rules for a semi-autonomous team structure. This includes:

- All team members must participate in the project paper and presentation process.
- All activities internal to each team is assigned, performed and managed by the team members. The instructor will only intervene when one or more of the team members deviate from acceptable norms of team behavior.

Team Effort Grading Policy

To encourage equal contribution by each team member, a "team effort" grading will be enforced. This grading policy is directed at preventing "freeriders" from causing team conflicts. Students in a team do not necessarily have to receive the same grade. Depending on the outcome, some may receive more and some less. At the end of the semester, each student is required to submit a confidential review that states how much each team member has contributed to the team. This can be done by assigning points across the team member such that the mean value is 100. For example, if John gets 80, Amy gets 120, and Scott gets 100, then John will receive 80% of the project grade, Amy will get 120%, and Scott will get 80%. ANY DEVIATION FROM A SCORE OF 100 MUST BE ACCOMPANIED BY AN EXPLANATION. See the sample review below and the scoring explanation.

NOTE: The course instructors expect everyone to contribute significantly to their team projects; therefore, everyone should receive a grade of 100 on all reviews. An explanation is only required if there is any deviation from an assignment of 100. If a team has a case of extreme deviations from 100, then the instructors will determine the grades on their own discretion based on the point totals and explanations.

Example:

Team Member	Score	Explanation
John	80	Did not attend team meetings regularly
Amy	120	Worked significantly more on the project
Scott	100	Contributed equitably to the project

If the project grade was 90%, then John would receive a score of 72, Amy would receive a score of 100% (i.e. maximum), and Scott would receive a score of 90. If there are EXTREME deviations, then the instructors will determine the grades on their own discretion. Minor deviations will be disregarded and all team members will receive the same score.

TERM PROJECT

Introduction

The term project is designed to deepen the student's knowledge in the application of industrial ecology tools and techniques to technology systems. The purpose of this project is to learn how to:

- Organize and structure a set of industrial ecology questions related to technological systems (e.g., energy systems generation, distribution and use on a life-cycle basis).
- Demonstrate creativity and initiative to analyze the interactions among the complex technology system components and quantify their aggregate impacts on the environment.

Team Design and Presentations

After the team formations, each team leader meets with the instructor to narrow down the topic of the research. After the instructor's approval, the team will develop a detailed problem statement and generate an outline for the first short presentation. The first presentation should include items 3a, b, c, and d from the "Organization of the Paper" (listed below). You do not have to apply the IE tools; just tell us why you are choosing a certain approach and not the others. No paper is required. A rating score from 0 to 5 will be given to each presentation as a feedback. The score will not influence your final project grade.

The second presentation is scheduled at the end of the semester. This presentation should include a detailed assessment of the impacts, evaluate the impacts on a quantitative basis, and offer solutions to improve the system under study. The instructor's term paper grade is based on the presentation effectiveness and technical content of the term paper.

The instructional team will provide a list of topics to choose from. These topics will require additional refinement working with the instructional team to further focus and develop approaches for analysis. The pre-existing list of topics should prove useful to organize teams early in the semester and prepare for the first presentation. Our experience shows that the teams that postpone the first stages of the project end up performing lower than those who choose their topics early.

Suggested Research Approach

The following general items are suggested as key components for organizing your LCA-based research activities for this project:

- Select alternative technologies that you think make the most economic sense, may reduce environmental impacts, and are feasible in a relatively short time horizon.
- Include a concise and well-written description of the technology or product system(s)
- As part of the description, clearly state the components of the system and system complexity in terms of the products' or technologies' fit in higher level technological or natural systems (i.e., holoarchies).
- Thoroughly research the literature on the product or technology system.
- Draw a systems diagram showing the elements of the technology in a life-cycle framework.
- Define the goal of your LCA analysis: what questions do you seek to answer?
- Carefully define the functional unit and reference flows of the LCA for comparative purposes
- Define the system scope and boundary with reference to the study goal, and clearly delineate exclusions and inclusions to the system boundary
- Develop models of material and energy inputs and outputs for this system. Begin with simple models and increase their sophistication as you search for new data.
- Decide on which industrial ecology tools and techniques you wish to use to analyze this system.
- Develop data models in Excel or any other software you choose to analyze your data.
- Collect as much data as are available in open literature, industrial contacts, government web sites, etc. Make sure that you state (as footnotes in your tables) the sources of the data used.
- Reduce and integrate your data for a meaningful description of the results.
- Compare the current system results with the proposed new one.
- Discuss uncertainty in the results and use sensitivity analysis as appropriate to explore and delimit uncertainty.
- In IE, the availability and quality of the data are always questioned. Discuss the quality of your data and whether it is adequate to support your findings.
- As part of your interpretation, state the limitations and assumptions that apply to your findings.
- Conclude with recommendations for further study and key steps to reduce environmental impacts in the technology or product system under investigation.

In addition, you should include the following:

- A list of hard copy and electronic references that you used for this project, including all the data sources and contact information.
- **Do not scan and paste pictures and graphs into your paper; it is a violation of copyright laws.** Any data used in your tables or graphs must have a source associated with it referenced at the bottom of the table or graph**.** If you have a large set of data or graphs use appendices at the end of the report.

Organization of the Paper: Use the following outline for your term paper. You need to write your paper as if you are submitting it to a refereed journal publication.

1. Title (cover) page
2. Abstract followed by a set of 10 keywords for indexing
3. Body of the paper
    a. defining and motivating the problem

    b. identifying key technologies for the project
    c. describing the problem in a life-cycle framework
    d. identifying the key methodology for analyzing the system
    e. data analysis
    f. data quality, missing data, data gaps, etc.
    g. software applications, if any
    h. results in both descriptive and tabular/graph forms
    i. conclusions
    j. future research needs
4. References (completely spell out names of journals and books with titles and dates)
5. Tables must be numbered with descriptive titles
6. List of Figures (with numbers and captions)
7. Figures drawn in popular drawing software and embedded into the main document
8. Submit the entire file in .doc(x) format (e.g. Microsoft Word)

Each student in the team will define and present his/her own role in developing the specific portions of the article at the article presentations. We strongly recommend that all team members present their sections, but in rare cases the teams may elect to present with less than all members.

Article length should be less than 20 single-spaced pages, *excluding* figures and tables. Other material closely relevant to the topic should be placed in appendix (the appendix does not count in the page requirements). *All figures and tables must be redrawn by the team members because copy-and-paste from other sources is in violation of copyright laws.*

Any paper submissions in this course should list the team number, name of the team members, a title, and date of delivery (on the cover page). Use electronic submission via DEN Blackboard for all submissions.

Grading Matrix for Final Term Paper:

Metric	**Points Possible**
Used correct language, grammar, and spelling; PROOFREAD paper	50
Citation and formatting adheres to an accepted standard (e.g. MLA, Chicago)	50
Demonstrated ability to synthesize complex ideas into a coherent paper	50
Revealed insights that demonstrated the ability to go beyond the obvious and make interesting new connections	100
Overall quality and effectiveness relative to other teams (e.g. stood out from the crowd, above average, average, unacceptable at graduate level).	50
Clear definition (and motivation) of the “problem” and define the goal of your LCA analysis (i.e. what questions do you seek to answer?)	150
Clearly state system components and complexity in terms of the products’ or technologies’ fit in higher level technological or natural systems	100
Thorough research effort on the product or technology system	100
Careful definition of the functional unit and reference flows of the LCA	100
Identification of system scope and boundary in a life-cycle framework with reference to the study goal, delineation of exclusions and inclusions to the system boundary	150
Discussion of uncertainty in the result, quality of data, limitations and	100

assumptions to your findings, and concluding recommendations for future study	
Raw Total:	1000
Scaled Total:	**100%**

Some Resources:

- EPA on LCA: http://www.epa.gov/ord/NRMRL/lcaccess/index.html
- EPA on DfE: http://www.epa.gov/dfe/
- DOE on renewable energy: http://www.nrel.gov/
- Resource Optimization Initiative (case studies): http://www.roi-online.org/case_study.asp
- *Journal of Industrial Ecology*, from the International Society for Industrial Ecology (http://www.is4ie.org/)
- Industrial Ecology links at other universities, for example:
    - Industrial Ecology academic programs list: http://www.is4ie.org/resources/Documents/Academic%20programs.pdf
    - Rutgers: http://policy.rutgers.edu/andrews/links/iepointers.htm
    - Columbia: http://www.seas.columbia.edu/earth/EECIndustrialEcology.html
- Green Design Initiative, Carnegie Mellon University: http://www.ce.cmu.edu/GreenDesign/gd/publicationsMainNew.htm
- Green buildings:
    - www.ciwmb.ca.gov/greenbuilding/
    - www.eere.energy.gov/buildings/high_performance/
    - www.epa.gov/opptintr/greenbuilding/
    - www.usgbc.org
- Servicizing and Extended Producer Responsibility at www.tellus.org.