ISE 576 Industrial Ecology: Technology-Environment Interaction
Spring Semester 2017

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Time/Location:
Mondays, 12:30-3:20 p.m., OHE 100B

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.

Learning 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 and corporate sustainability.

Course Notes

The main ongoing activities in this course comprise readings, attendance at lectures, and participation in discussions during lectures. There are also four homework assignments to be completed, one midterm exam in Week 9 covering Weeks 1-8 of the course, and a cumulative final exam.

The major activity of the semester is a final project, performing and reporting on comparative life cycle assessment by teams of 3-5 students, as described below.

Technological Proficiency & Hardware/Software Required

Students will need to be able to competently use Microsoft Excel and Microsoft Office to produce the final project. Other than this, two screening LCA modeling programs will be provided as freeware from the Internet. Instructions will be given on how to use these freeware programs during lectures. These resources can be accessed from student's homes or offices using their own computers and Internet connections or from USC's on campus public (i.e., general) computer labs.

Required Readings & Supplementary Material

- 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" in the course schedule below)
- Ashby, M.F. (2013). *Materials and the Environment: Eco-Informed Material Choice.* (2nd Edition) Elsevier Publishers: Amsterdam. (We call this book "Mat" in the course schedule below)

Description of Assignments

I. HOMEWORK ASSIGNMENTS

There are four homework assignments worth five points each, and there is one, extra-credit homework also worth five points. The homework assignments are listed in the course schedule below and they will be due at the start of the next class following the where they are listed. The detailed assignments are in the textbooks or will be posted on Blackboard.

II. TERM PROJECT

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

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

A. Team Formation & General Rules for Teams

The teams are formed between the first and second class sessions (i.e., between weeks 1 and 3 due to the MLK holiday). Using the Wiki function on DEN Blackboard, I will give the list of topics to choose from and you must sign up before midnight Pacific Time on Sunday, January 15, 2017. Each team should have at least three and not more than five students.

The team members will define the team's activities using the following procedure. A team leader will be selected by each team as the primary conduit between the team and the instructor, but often teams meet in whole or part with the instructor during the semester and any student should feel free to speak with the instructor regarding the project. We follow rules for a semi-autonomous team structure, including:

- Team members must strive in good faith to reach consensus on all major project decisions, including the selection of the team leader.
- All team members must participate in the project paper and presentation process.
- All activities internal to each team are 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.
- The most important norm of team behavior is that all team members carry out their assigned tasks to the best of their ability in a timely fashion. Your reputation within your team is the key here: you do not want to be known as a laggard. If clear laggards are identified, the instructor reserves the right to adjust grades on the final project accordingly.

B. Team Design and Presentations

The instructor will provide a list of topics to choose from. These topics will require additional refinement working with the instructor to further focus and develop approaches for analysis. Students may also propose topics via email to the instructor. If approved, the instructor will post the additional topics to the Wiki. The pre-existing list of topics should prove useful to organize teams early in the semester and prepare for the first presentation. ***Caution:*** experience shows that the teams that postpone the first stage of the project end up performing lower than those who choose to work on the topics early.

After the team formations, each team leader gains the approval of the instructor, and if needed narrows down the topic of the research. After the instructor's final approval, the team will develop a detailed problem statement and generate an outline for the first short presentation.

The first presentation should at a minimum include items in the Introduction section explained in the "Organization of the Paper" (listed below). This presentation is un-graded and provides an opportunity to keep the team project on a productive path. The teams who have moved forward enough to move beyond the introduction and explain the methodology (listed below) will work harder to do so, but will also likely receive more useful feedback from the first presentation. For the first presentation, you do not have to apply the IE tools; just tell us why you are choosing a certain modeling and analysis, and not the others. No paper is required for the first presentation.

The second presentation is scheduled at the end of the semester. This presentation should include the (revised) contents of the first presentation, plus a detailed quantitative assessment of the impacts on a life-cycle basis, and offer solutions to improve the system under study. The instructor's term paper grade is based in part on the presentation effectiveness and technical content of the term paper.

C. Choosing the Project

Take a look at the list of problem statements given. Make sure to choose one that you have familiarity with in the past, think data are available, or you have a deep interest in learning. Groups of students may also pitch the instructor during the first week on topics or problem statements not posed here. Whether you choose among he provided topics or pitch a new topic, you should quickly use Google/Google Scholar to find out the extent to which this topic has been discussed in the open and peer reviewed literature and what materials are available for you to analyze. In particular, make sure that you have an idea about the alternative technologies that you think make the most economic sense, may reduce environmental impacts, and are feasible for you

to study in the period of a semester. Quickly, come up with a concise and well-written description of the technology or product system for this study and share it with your teammates.

D. Suggested Research Approach

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

- Thoroughly research the literature on the product or technology system.
- 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).
- 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? Be very specific, since generality will cause you rework later in the semester.
- Carefully define the functional unit and reference flows of the LCA.
- Define the system scope and boundary with reference to the study goal, and clearly delineate exclusions and inclusions to the system boundary. Justify your selections.
- Develop models of materials and energy inputs and outputs for this system. Begin with simple models and increase their sophistication as you search for new data availability.
- Decide on which industrial ecology tools and techniques you wish to use to analyze this system. Justify your selection.
- Develop data models in terms of inputs and outputs in Excel.
- Collect as much data as available in open and peer reviewed literature, industrial contacts, government web sites, etc. Make sure that you state (as footnotes in your tables) the sources of the data used.
- If a critical set of data is not available, and you cannot move forward without it, estimate a set of data using the best assumptions you can find in literature. Make sure that you state which data is based on what assumptions and tell us how we should go about generating data with greater precision in the future.
- 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 uncertainty in your analysis.
- 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.
- Results are influenced by the assumptions and limitations of the study. As part of your interpretation, state the limitations and assumptions that used and how your findings might change if you used other assumptions.
- 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.
- **Caution: Do not scan and paste pictures and graphs into your paper; it is a violation of copyright laws.** Also, any data used in your tables or graphs from outside sources 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, you may use appendices at the end of the report. Note: *the team members must redraw all figures and tables.*

E. 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. Cover page (Title, Names/affiliations, Date, course name and number)
2. One-page executive summary (for Fleischer Prize submission)
3. Abstract of not more than 250 words followed by a set of 5 keywords for indexing
4. Introduction
    a. defining and motivating the problem
    b. identifying key technologies for the project (use system diagram)
    c. describing the problem in a life-cycle framework
    d. describing the current literature
    e. define system boundary and limitations
    f. writing a set of questions that this study will answer (one sentence each)
5. Methodology
    a. identifying the key methodology for analyzing the system
    b. explain sources of data quality/availability
    c. software applications and associated datasets or methods, if any
6. Analysis
    a. describe data models and analysis
    b. cost/benefit analysis (for Fleischer Prize submission)
    c. data quality, missing data, data gaps, etc.
    d. sensitivity analysis
7. Results and Conclusions
    a. results in both descriptive and tabular/graph forms
    b. conclusions
8. Future Research
    a. future research needs
    b. need for new data or even new approaches to address the questions
9. References (completely spell out names of journals and books with titles and dates). Please use the Chicago Manual of Style (CMS) author-date parenthetical approach to references.
10. In general, include the major tables and figures interspersed in the text rather than an appendix. Use numbers, titles for tables and numbers and captions for figures. Under each table, list the data sources.
11. 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 paper at the final presentation.

Paper length should be no longer than 20 pages, one and a half spaced, at 10-font size, *including* figures, tables, and references but *excluding* the title page, abstract, and, if included executive summary. It will be challenging to meet the assignment criteria effectively at this length. Please plan enough time for your writing to make it possible to accomplish this.

Use electronic submission via DEN Blackboard. You must also submit your modeling file, likely in the format .XLS, using the same file name, except add the word data at the end. Do not email to the instructional team after the deadline.

F. Fleischer Prize for Green Technologies: Dr. Fleischer, an Emiritus Professor at the Epstein Department of Industrial Engineering, has given a gift to the Viterbi School of Engineering for this prize. This prize will be awarded to the best paper submitted by a team of students with at least one member from Viterbi, based on their work closely associated with green technologies, so anticipate competition from across the Viterbi School and USC. In 2014, a team whose project originated in this course won the award ($1,000).

Details can be found at: http://viterbi.usc.edu/news/news/2016/the-fleischer-prize-2016-2017.htm

For 2017, the award committee has established the following criteria for this prize:

- The paper submitted as an application for The Fleischer Prize In Green Technology must clearly define the societal implication and significance of the green engineering that is addressed. It must also address the professional ethics that are implicit to the addressed problem.
- The paper must submit a realistic economic cost analysis that serves to assess the reality and pragmatic viability of the addressed project.
- The paper must clarify the materials, processes, applications, and technologies that are required to establish project viability.
- A one (1) page Executive Summary, which is divorced of acronyms and engineering slang, must be included with each submission. This summary should provide a succinct, but illuminating, overview of project intentions. It is specifically intended to give the reader/evaluator a concise and clear indication of the significance, relevance, creativity, and economic value of the green undertaking.
- The submitted document that accompanies the Executive Summary can be no more than twenty (20) pages in length. Its textual lines must subscribe to space and half spacing. This twenty-page limit includes all text, figures and diagrams, photographs, and references.
- An applicant's document must be submitted online as a PDF file by no later than **30 April 2017.** (See the URL above for an electronic submission link.)

H. Final Project Grading Rubric

Metric	Points Possible
Clearly written abstract	5
One-page executive summary (for Fleischer Prize submission)	(-)
Introduction Clear definition and motivation of the problem Study objectives Definition of system components and their relation to an ecosystem Literature review Social relevance A well-defined hypothesis or questions to be answered	15
Methodology	15
Analysis (Cost/benefit analysis has a bonus (extra credit) for the Fleischer Prize submission)	15 (5)
Results and conclusions	15
Future research	5
References	5
Good writing that is free of typographical errors	5
Demonstrated ability to analyze and synthesize complex systems; revealed insights that demonstrated the ability to go beyond the obvious Overall quality	20
Raw Total:	100

I. Some General Resources for the Final Project:

- 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.

Grading Breakdown

Assignment	Format	Number	Points Per Assignment	Total Points (% of Grade)
Mid-Term Exam	Individual	1	20	20
Final Project Written	Team	1	24	24
Final Project Presentation	Team	1	16	16
Homework Assignments (HW)	Individual	4	5	20
Final Exam	Individual	1	20	20
Totals	**-**	**8**	**-**	**100**

Additional Policies

- 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 assignments/term project activities
- Laptop policy: you are encouraged to use laptops during class to take notes. However, network connections are not allowed and you are not allowed 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.
- Readings are to be completed ***before*** the class sessions where they are indicated. Other items may be assigned prior to each session as needed.
- Materials, lectures and/or specific assignments may be revised to accommodate the content and the pace of the class learning process.
- 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, usually just before the start of class, will be provided for submission.
- Late homework submissions or final project submissions will not be accepted and will receive a grade of F.
- Make-up examinations will only be offered in case of valid medical excuses, otherwise a missed examination will result in a grade of F.

Course Schedule: A Weekly Breakdown

Session Date/ Week	Topics	Reading/Homework
1/9 1	• Syllabus, Class Requirements/Expectations, Team Selection, Project Descriptions • Are we approaching a state shift in Earth's biosphere?	• Syllabus • Reading: IE Ch 1,2, 3 and Mat Ch 1 • Slides: Barnosky et al. (2012)
1/16 2	Martin Luther King Birthday Holiday (no class)	
1/23 3	• Overview of Industrial Ecology • Systems thinking • Industrial ecology as the "science and technology of sustainability"	• Reading: Mat Ch 2, 11 and IE Ch 15 • Slides: Overview of IE • Slides: Complex Systems and Sustainability • HW1 IE 15.1 & 15.3 • **Team formation**
1/30 4	• Industrial Activity and Industrial Symbiosis • Video: Biomimicry: http://www.ted.com/index.php/talks/janine_benyus_shares_nature_s_designs.html (23 min) • Eco-industrial Parks and Spatial Planning • End-of-Life: Issues and Opportunities	• Reading: IE Ch 5, 16 • Reading: Mat Ch 4 • Slides: Eco-Industrial Symbiosis • In Class Exercise, IE 16.4
2/6 5	• LCA Overview (Sustainable Engineering; Design for Environment) • Life-Cycle Analysis process • In-Class Exercise, LCA scope of T-shirt	• Reading: Mat Ch 3 • IE Chapter 12 • Slides: LCA Overview
2/13 6	• LCA Intro Continued • LCA Activity & Inventory stage	• Slides: LCA Process & LCI • In Class Exercise, Mat 3.4 & 3.6
2/20 7	President's Day Holiday (no class)	
2/27 8	• LCA Impact and Interpretation stages • Design for Environment (DfE or DfX) Overview • Exam 1 Review	• Reading: IE Ch 13, 8-10 • Slide Set: Life Cycle Impact Assessment • Slide Set: Design for Environment
3/6 9	**First project presentations (15 minutes each + Q/A)**	Submit presentations to Blackboard *before* class!
3/13 10	• Midterm Exam • Streamlined Life Cycle Assessment (SLCA)	• Reading: IE Ch. 14 • Slide Set: Streamlined LCA • **HW2: SLCA Homework**

-	• Spring Break 3/12-3/19 (no class)	
3/20 11	• Understanding EIO-LCA • EIO-LCA Software Demonstration • In-Class Exercise, EIO-LCA simulation	• Reading: IE Ch 18 • Slides: EIO-LCA Introduction • Slides: EIO-LCA Policy Application • Slides: EIO-LCA in National Materials Accounts • IE Ch 18 • **HW3: EIO-LCA**
3/27 12	• Sustainable Consumption, Consumer Products, and Product Labeling (RV) • Sustainable Commodity Procurement -- 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 • Packaging LCA • Package LCA Software Demonstration	• Slides: Consumption and Consumer Products • Slides: Packaging LCA • Reading: IE 7 • Reading: Mat Ch 5 **Extra Credit HW:** Packaging LCA Comparison
4/3 13	Recorded Guest Lectures (2) (Instructor Absent) • Dr. Sangwon Suh, Bren School of UCSB, "LCA Tools for Green Buildings and Construction" • Dr. Roland Geyer, Bren School of UCSB, "Spatially Explicit LCA of Sun to Wheels Transportation Pathways in the U.S."	• Reading: IE Chapter 11 • Slide Set: Geyer et al. Sun to Wheels LCA • **HW 4: Online discussion of guest lectures (See blackboard)**
4/10 14	• Energy and Industrial Ecology • Water and Industrial Ecology • Sustainable Cities and Urban Metabolism	• Reading: IE 19-21 • Reading: Mat. Ch. 12 • Slide Set: Water Energy Nexus • Slide Set: Sustainable Cities and Urban Metabolism
4/17 15	• Risk Assessment, Resilience, and Technological Change • Teams work on their projects in-class w/ instructor.	• Reading: IE Ch 6, 26, & 27 Slides: Concluding Lecture of ISE 576 on Risk and ESEM
4/24 16	**Final project presentations (15 minutes each) Project papers are due in hard copy at the end of this session.**	
Final Exam	**Friday, May 5 from 2-4 p.m. at OHE 100B**	

Academic Conduct

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Section 11, *Behavior Violating University Standards* https://policy.usc.edu/student/scampus/part-b/. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the *Office of Equity and Diversity* http://equity.usc.edu or to the *Department of Public Safety* http://adminopsnet.usc.edu/department/department-public-safety. This is important for the safety of the whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. *The Relationship and Sexual Violence Prevention Services* http://engemannshc.usc.edu/rsvp/ provides 24/7 confidential support, and the sexual assault resource center webpage http://sarc.usc.edu describes reporting options and other resources.

Support Systems

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information* http://emergency.usc.edu will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.