



## ISE 576, Industrial Ecology

### *Syllabus*

**Units:** 3

**Term — Day — Time:** Spring 2023 — Monday — 2-4:50 pm

**Location:** OHE 100B & DEN@Viterbi

**Instructor:** Robert O. Vos, PhD GISP

**Office:** AHF B57B

**Regular Office Hours:** Mondays and Fridays 9:30 a.m.-10:30 a.m. PT. Also available by appointment via email.

**Contact Info:** [vos@usc.edu](mailto:vos@usc.edu), 213-821-1311

**Course Producer:** Heesuh Lee

**Office:** Olin Hall 310U

**Regular Office Hours:** Mondays, 11 a.m.- 1 p.m.

**Contact Info:** [heesuhle@usc.edu](mailto:heesuhle@usc.edu)

## Course Scope and Purpose

Industrial ecology (IE) focuses on impacts to the natural world from the sharp increase in the rate and scale of human transformation of the earth following the industrial revolution. Concepts and tools covered in the course identify and measure impacts from the design and operation of the industrial system in categories such as ecological degradation, human health, 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 multidisciplinary field involving science and technology (engineering), public policy, economics, and business operations. The course focuses much less on problem sets than the traditional engineering course. Instead, it aims for understanding of major concepts and the ability to identify and execute a comparative environmental life cycle assessment (LCA) research project that meaningfully aids decision-making with regards to design, operation, or policymaking for green technologies.

### *Learning Outcomes*

On completion of this course, students should be able to:

- Articulate the core philosophy and principles of industrial ecology as it is practiced globally.
- Identify the benefits and limitations of tools like materials flow analysis, design for environment, environmentally extended input-output analysis, and process-based life-cycle assessment.
- Differentiate and choose appropriately among tools for measuring environmental impacts of industrial systems.
- Relate the concepts of reverse logistics, industrial symbiosis, and biomimicry to design solutions for sustainability problems in the industrial system.
- Apply and operate screening-level life cycle assessment tools and software in case studies for product and packaging design.
- Conduct a comparative environmental life cycle assessment (LCA) in support of a decisions with respect to design, operations, or policy making for products, products systems, or infrastructure in the industrial system.

**Prerequisite(s):** Graduate standing or permission of the instructor

**Co-Requisite(s):** None

### **Class Conduct**

**Harassment, sexual misconduct, interpersonal violence, and stalking** are not tolerated by the university. All faculty and most staff are considered Responsible Employees by the university and must forward all information they receive about these types of situations to the Title IX Coordinator. The Title IX Coordinator is responsible for assisting students with supportive accommodations, including academic accommodations, as well as investigating these incidents if the reporting student wants an investigation. The Title IX office is also responsible for

coordinating supportive measures for transgender and nonbinary students such as faculty notifications, and more. If you need supportive accommodations you may contact the Title IX Coordinator directly ([titleix@usc.edu](mailto:titleix@usc.edu) or 213-821-8298) without sharing any personal information with me. If you would like to speak with a confidential counselor, Relationship and Sexual Violence Prevention Services (RSVP) provides 24/7 confidential support for students (213-740-9355 (WELL); press 0 after hours)

## Course Structure

The main ongoing activities in this course comprise readings, attendance at lectures, and participation in discussions during lectures or asynchronously online. 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 environmental life cycle assessment by teams of 3-5 students.

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 covers life-cycle assessment (LCA) methods and tools. The third section of the course looks at industrial ecology practice in the domains of consumer products, sustainable cities, energy, and water.

*Workload* – This is a 3-credit, one semester course. Students should expect to spend on average 9-hours per week completing the work in this course with weeks with heavier time commitment outside of class as the final project unfolds during Weeks 5-15.

## Technological and Communication Requirements

Students will need to be able to competently use Microsoft Excel and Microsoft Office to produce the final project. Other than this, screening LCA modeling programs will be provided by the instructor or as freeware from the Internet. Instructions will be given on how to use this software during lectures, but will require additional self-study. 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. All student will access course materials through the DEN learning content management system called "D2L." The DEN students will access class sessions via D2L and Cisco WebEx.

## Required Readings and Supplementary Materials

The required textbooks for this course are:

- Graedel, T.E., and Allenby, B.R. 2010. *Industrial Ecology and Sustainable Engineering*. Upper Saddle River, New Jersey: Pearson Education. (This book is called "IE" in the course schedule below) (ISBN: hardcover, 978-0136008064; softcover, 978-9332556959)

- Ashby, M.F. 2021. *Materials and the Environment: Eco-Informed Material Choice*. (3rd Edition) Amsterdam: Elsevier Publishers. (We call this book “Mat” in the course schedule below) (ISBN: 978-0128215210)

Supplementary readings will be provided on D2L from various sources including:

- Allenby, B.R. 2006. The ontologies of industrial ecology? *Progress in Industrial Ecology* 3: 28-40.
- Barnosky, A.D., et al. 2012. Approaching a state shift in Earth’s biosphere. *Nature* 486: 52-58.
- Chertow, M.R. 2007. Uncovering industrial symbiosis. *Journal of Industrial Ecology* 11: 11-30.
- European Commission-Joint Research Centre-Institute for Environment and Sustainability. 2010. *International Reference Life Cycle Data System (ILCD) Handbook: General and Detailed Guidance*. (1<sup>st</sup> Edition). EUR 24708 EN. Luxembourg: Publications Office of the European Union.
- Vos, R.O. 2019. The spatially explicit water footprint of blue jeans: Spatial methods in action for sustainable consumer products and corporate management of water. *Case Studies in the Environment*: 1-14. (DOI: <https://doi.org/10.1525/cse.2019.002006>)

For the final project in this course, you will also conduct online library research to find articles that apply LCA methods in ways analogous to your own study or that provide data points for the system you are characterizing.

## **Description and Assessment of Assignments**

### ***Regular Course Assignments and Exams***

*Homework Assignments – 4 worth 20 points.* There are four homework assignments worth five points each. Three of these are a bit like conventional problem sets but require mostly conceptual work and operation of screening LCA software. The last calls on students to use a screening LCA software to evaluate two alternative designs for packaging orange juice.

*Midterm Exam– 1 worth 15 points.* The midterm is a closed book, 90-minute exam given during class in Week 9. It covers all material from reading, lectures, and homework from Weeks 1-8.

*Final Exam– 1 worth 25 points.* The final exam is a closed book, 120-minute exam given during the scheduled final examination period. It covers all material from reading, lectures, and homework from the entire course.

### ***Final Project***

The term project is designed to deepen the student’s knowledge in the application of industrial ecology tools and techniques to technological systems. At the end of the project, students should be able to:

- Organize and structure a set questions for decision-making related to comparing technological systems, particularly on a life-cycle basis.
- Demonstrate creativity and initiative to analyze the interactions among complex technological system components.
- Competently model environmental impacts of the systems under study, including where appropriate on an aggregated, quantitative basis.

The key parts of the final project are as follows:

*Team Formation/Topic Selection - 2 points.* Using the discussion function on D2L, I will give a list of topics to choose from and you should create threads to identify teams. Each team should have at least three and not more than five students. Each team should identify one student to act as “team leader,” who will handle communication with the instructor. The team leader should email the instructor (also with a cc: to the teaching assistant) once the team is formed. This email should name the team members and briefly name and describe the topic in a few sentences. It should also be cc’d to all team members. This all must be accomplished **no later than midnight Pacific Time on Sunday, January 22, 2023**. Two points will be awarded to each student who has been identified as joining a team by the deadline because experience shows that getting an early start on the project is essential to success.

*First Project Presentation – 3 points.* Please find a detailed set of instructions and rubric for the final project on our D2L site. During class in Week 8, teams will give a 10-minute first project presentation with an additional 5-minute discussion period. The first presentation will outline the research question or problem statement related to decision support and give an initial proposal as to the analysis methods to be used. The presentation is graded, but it is worth relatively few points so that it serves primarily as an opportunity for formal feedback from the instructor to keep the team on a productive path. All students are required to be present live or on DEN WebEX for all presentations.

*Final Project Oral Presentation - 15 points.* A comprehensive 15-minute oral presentation of the final project will be given during the final class session in Week 15. It will be evaluated primarily on the effectiveness with which problem statement, methods, results, and limitations are concisely explained. All students are required to be present live or on DEN WebEX for all presentations.

*Final Project Written Report - 20 points.* A written report on your project methodology and outcomes. Detailed instructions are on our D2L site. It will be evaluated both for technical proficiency and its writing quality.

## Grading Breakdown

Assessment	Number	Points Each	Total Points
Regular Course Assignments and Exams			
Homework Assignments	4	5	20
Midterm Exam	1	15	15
Final Exam	1	25	25
Project Components			
Team Formation/Topic Selection	1	2	2
First Project Presentation	1	3	3
Final Project Oral Presentation	1	15	15
Final Project Written Report	1	20	20
Total	10	-	100 points

## Course Policies

The following are the policies that apply in this course:

- Participate in class discussions and contribute individual or professional experiences when relevant to the topic so that others can benefit and learn.
- Take individual responsibility for completing homework assignments/term project activities and be responsible and collaborative team members for the final project.
- Readings are to be completed **before** the class sessions where they are indicated. Lectures will supplement but not cover readings, and the readings may be needed to effectively participate in exercises given during class time.
- In-class exercises, listed as “*Activity*,” happen in the class period and are not graded.
- Unless otherwise noted, homework assignments are due **at the end of the week** they are listed in the syllabus, allowing for questions or clarification during lectures and assistance during the week, if needed. Deadlines are set as the Sunday before the next class at midnight on D2L. Links on D2L with specific assignment instructions and deadlines 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.

## Schedule

	Topic	Readings and Lecture Slides	Deliverables/Due Dates
<b>Week 1</b> 1/9	<b>Introduction:</b> Syllabus and key concepts. Are we approaching a state shift in Earth's biosphere? <i>Activity:</i> Project descriptions and team formation.	ISE 576 Syllabus IE Ch. 1-3 Mat Ch. 1 & 14 Barnosky et al. (2012) Slide Set: Course Intro	Team Formation due on Sunday, 1/22 at 12 midnight
<b>Week 2</b> 1/16	<b>Martin Luther King Holiday</b> (No regular class meeting)		
<b>Week 3</b> 1/23	<b>Systems Thinking:</b> An overview of industrial ecology with a focus on complex systems and the scope of the field. <i>Activity:</i> Discussion of Allenby (2006)	IE Ch. 15 Mat Ch. 2 Allenby (2006) Slide Deck: Overview of IE Slide Set: Complex Systems	Homework 1: IE 15.1 & 15.3 due on Sunday, 1/29 at 12 midnight
<b>Week 4</b> 1/30	<b>Industrial Symbiosis:</b> Key opportunities and challenges for increased symbiosis, including spatial aspects of systems and design of infrastructure for eco-industrial parks. <i>Activity:</i> Work IE 16.4 together during class.	IE Ch. 5 & 16 Mat Ch. 4 Chertow (2007) Slide Set: Industrial Symbiosis Biomimicry Video (23 minutes): <a href="http://www.ted.com/index.php/talks/janine_benyus_shares_nature_s_designs.html">http://www.ted.com/index.php/talks/janine_benyus_shares_nature_s_designs.html</a>	No deliverables
<b>Week 5</b> 2/6	<b>LCA Applications:</b> A look at specific applications of LCA methods as a prelude to learning detailed LCA methods.  <b>Recorded Lectures and D2L Discussion Forum</b>  (No regular class meeting)	Dr. Sangwon Suh, Bren School of UCSB, "LCA Tools for Green Buildings and Construction" (Recorded Guest Lecture)  Dr. Roland Geyer, Bren School of UCSB, "Spatially Explicit LCA of Sun to Wheels Transportation Pathways in the U.S." (Recorded Guest Lecture)  Vos (2019)	
<b>Week 6</b> 2/13	<b>Life Cycle Assessment (LCA) Overview:</b> LCA process (scoping, activity, and inventory stages.) <i>Activity:</i> LCA system scope for a T-shirt and MAT 3.4 & 3.6	IE Ch. 12 Mat Ch. 3 & 6 Slide Set: LCA Overview Slide Set: LCA Process & Life Cycle Inventory (LCI)	No deliverables
<b>Week 7</b> 2/20	<b>Presidents' Day Holiday</b> (No regular class meeting)		No deliverables

	Topic	Readings and Lecture Slides	Deliverables/Due Dates
<b>Week 8</b> 2/27	<b>Life Cycle Assessment (Con't):</b> The LCA analysis process, with a focus on life cycle impact assessment models and interpretation stages.	IE Ch. 13 & 8-10 Mat Ch. 7 Slide Set: Life Cycle Impact Assessment	Submit first project presentations to D2L by 3/5 at 12 midnight!
<b>Week 9</b> 3/6	<b>First project presentations and midterm exam review</b>	None	
<b>3/13</b>	<i>Spring Recess 3/13-3/20</i>		
<b>Week 10</b> 3/20	<b>Midterm Exam and Streamlined Life Cycle Assessment (SCLA)</b>	IE Ch. 14 Slide Set: Streamlined LCA	Homework 2 Problem Set on SLCA due on Sunday, 3/26 at 12 midnight
<b>Week 11</b> 3/27	<b>Economic Input-Output LCA:</b> An overview and software demonstration of environmentally extended input-output (EEIO) methods. <i>Activity: EIO-LCA group simulation</i>	IE Ch. 18 Slide Set: EIO-LCA Introduction Slide Set: EIO-LCA Policy Application Slide Set: EEIO for National Materials Accounts	Homework 3: Problem Set on EIO-LCA, due on Sunday, 4/2 at 12 midnight
<b>Week 12</b> 4/3	<b>Design for Environment (DfE) Overview:</b> Discussion of DfE, especially as applied to consumer packaging and packaging LCA software demonstration.	IE Ch. 10 Mat Ch. 9 & 11 Slide Set: Design for X Slide Set: Packaging LCA	No deliverables
<b>Week 13</b> 4/10	<b>Sustainable Consumption:</b> Overview of issues with consumption including circular economies, sustainable commodity procurement and the role of LCA in product labeling	IE Ch. 7 Mat Ch. 5 & 13 Slide Set: Consumption and Consumer Products Slide Set: Carbon Footprint of Paper Products	Homework 4: Packaging LCA Comparison due on Sunday, 4/16 at 12 midnight
<b>Week 14</b> 4/17	<b>Sustainable Cities and Risk:</b> An overview of IE concepts and tools related to the practice area of sustainable cities and a concluding lecture on managing risk in IE	IE 6, 26,21, & 27 Mat 12 Slide Set: Sustainable Cities and Urban Metabolism Slides: Concluding Lecture on Risk and Earth Systems Engineering and Management (ESEM)	No deliverables
<b>Week 15</b> 4/24	<b>Final Project Presentations</b>	No readings or lecture slides	Give presentations at class and submit project papers to D2L at the end of class on 4/24!



	Topic	Readings and Lecture Slides	Deliverables/Due Dates
Final Exam	Monday, May 8 from 2-4 p.m. Location TBD/TBA		

**Statement on Academic Conduct and Support Systems 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 Part B, Section 11, “Behavior Violating University Standards” [policy.usc.edu/scampus-part-b](http://policy.usc.edu/scampus-part-b). Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on [Research and Scholarship Misconduct](#).

**Students and Disability Accommodations**

USC welcomes students with disabilities into all of the University’s educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at [osas.usc.edu](http://osas.usc.edu). You may contact OSAS at (213) 740-0776 or via email at [osasfrontdesk@usc.edu](mailto:osasfrontdesk@usc.edu)

**Support Systems**

*Counseling and Mental Health - (213) 740-9355 – 24/7 on call*  
[studenthealth.usc.edu/counseling](http://studenthealth.usc.edu/counseling)

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

*National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call*  
[suicidepreventionlifeline.org](http://suicidepreventionlifeline.org)

Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

*Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL), press “0” after hours – 24/7 on call*  
[studenthealth.usc.edu/sexual-assault](http://studenthealth.usc.edu/sexual-assault)

Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

*Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086*  
[eetix.usc.edu](http://eetix.usc.edu)

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

*Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298*

[usc-advocate.symlicity.com/care\\_report](http://usc-advocate.symlicity.com/care_report)

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

*The Office of Student Accessibility Services (OSAS) - (213) 740-0776*

[osas.usc.edu](http://osas.usc.edu)

OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

*USC Campus Support and Intervention - (213) 821-4710*

[campussupport.usc.edu](http://campussupport.usc.edu)

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

*Diversity, Equity, and Inclusion - (213) 740-2101*

[diversity.usc.edu](http://diversity.usc.edu)

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

*USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call*

[dps.usc.edu](http://dps.usc.edu), [emergency.usc.edu](http://emergency.usc.edu)

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

*USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call*

[dps.usc.edu](http://dps.usc.edu)

Non-emergency assistance or information.

*Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)*

[ombuds.usc.edu](http://ombuds.usc.edu)

A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

*Occupational Therapy Faculty Practice - (323) 442-3340 or [otfp@med.usc.edu](mailto:otfp@med.usc.edu)*

[chan.usc.edu/otfp](http://chan.usc.edu/otfp)

Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.

### ***Library Resources for DEN Students***

All registered students can access electronic library resources through the link <https://libraries.usc.edu/>. Also, the USC Libraries have many important resources available for distance students through the link: <https://libraries.usc.edu/faculty-students/distance-learners>. These include instructional videos, remote access to university resources, and other key contact information for distance students.