USC Viterbi
School of Engineering
Daniel J. Epstein Department of Industrial and Systems Engineering

ISE 576, Industrial Ecology

Units: 4

Term — Day — Time: Fall 2025 — Mondays and Wednesdays —2-3:50 pm

Location: OHE 120 & DEN@Viterbi

Instructor: Robert O. Vos, PhD GISP
Office: AHF B57B a
Zoom Office: https://usc.zoom.us/my/vosusc
Regular Office Hours: Mondays and Fridays 9:30-10:30 a.m. PT. Also available by appointment via email.

Contact Info: vos@usc.edu, 213-821-1311

Course Description

Concepts and methods to analyze the environmental impacts of industrial systems, including life-cycle assessment, material flow analysis, design for environment and sustainable consumption.

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 sustainability.

Learning Outcomes

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

- Articulate the core philosophy and principles of industrial ecology and sustainable engineering as it is practiced globally.
- Identify the benefits and limitations of tools and methods for sustainability assessment such as materials flow analysis, design for environment, footprint assessment, environmentally extended input-output analysis, and process-based life-cycle assessment.
- Differentiate and choose appropriately among tools and methods for measuring environmental impacts and assessing sustainability of products, processes, and industrial systems.
- Relate the concepts of circular economics, reverse logistics, industrial symbiosis, and biomimicry to design solutions for sustainability problems in the industrial system.
- Apply and operate professional life cycle assessment software in a range of use cases.
- Produce 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, using professional life cycle assessment software as appropriate.

Prerequisite(s): None
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 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)

Diversity and Inclusion – I intend that students from all backgrounds and perspectives will be well served by this course, that students' learning needs will be addressed both in and out of class, and that the diversity that students bring to this class will be viewed as a resource, strength, and benefit. I aim to present materials and activities that are respectful to everyone, and you are also expected to respect others regardless of their race, ethnicity, gender identity and expressions, cultural beliefs, religion, sexual orientation, national origin, age, abilities, ideas and perspectives, or socioeconomic status. Your suggestions are encouraged and appreciated. Feel free to let me know ways to improve the effectiveness of the course for yourself or for other students.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit personal recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Our classes will be recorded on DEN and distributed only to members of the class through D2L. Without express permission of the instructor and announcement to the class, these recordings are not allowed to be distributed outside of D2L. Distribution of recordings can inhibit free discussion, and thus infringe on the academic freedom of other students as well as the instructor. (Living our Unifying Values: The USC Student Handbook, page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study is prohibited. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which has been distributed to students or in any way has been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. (Living our Unifying Values: The USC Student Handbook, page 13).

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 six 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 2-4 students.

The course is designed in three overarching sections. The first section of the course provides an overview of concepts of sustainability and industrial ecology. These include the nature of the sustainability challenge, approaches to sustainability, and systems thinking. The second section of the course covers sustainability assessment with detailed instruction in process-based life-cycle assessment (LCA) and overviews of environmentally-extended input-output analysis and material flows analysis. The third section of the course looks at industrial ecology practice areas in industrial symbiosis, circular economies, design for the environment, footprint methods, sustainable cities, energy, water, and consumption and consumer products.

Workload – This is a 4-credit, one semester course. Students should expect to spend 4-hours per week in class and an average of 4-hours per week completing the work in this course, with a heavier time commitment outside of class for the weeks with homework assignments and work on the final project.

Technological and Communication Requirements

All students 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.

Students will need to be able to competently use Microsoft Excel and Microsoft Office to produce the final project. The course will also provide access to the LCA software Sima Pro Flow, and other cloud-based software. With a good internet connection, students can access this software from any standard computer and most standard (up to date) web browsers. Instructions will be given on how to use this software during lectures but will require additional self-study.

Computer 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. Sessions where we will use the software are marked below, and on those days, you should bring a laptop computer to class. If you need to borrow a laptop for those days, please use USC's laptop loaner program (https://itservices.usc.edu/spaces/laptoploaner/) located at Leavey Library.

Required Readings and Supplementary Materials

The required textbooks for this course are:

- Ashby, M.F. 2021. *Materials and the Environment: Eco-Informed Material Choice.* (3rd Edition) Amsterdam: Elsevier Publishers. (This book is called "MAT" in the course schedule below) (ISBN: 978-0123859716)
- Bakshi, B.R. 2019. *Sustainable Engineering: Principles and Practice*. New York, NY: Cambridge University Press. (This book is called "SE" in the course schedule below) (ISBN: hardcover, 978-1108420457; electronic edition also available through the USC Libraries)

A recommended textbook is as follows:

- Bernstein, J.M. and Vos, R.O. 2021. *Sustainable Consumption and Production: A Revolutionary Challenge for the 21st Century*. Bingley, UK: Emerald Publishing. (This book is called "SCP" in the course schedule below) (ISBN: softcover, 978-1789731026, electronic edition also available)

Recommended supplementary readings provided on D2L include:

- 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*. (1st 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 – 5 homework assignments worth 6 points each. Three of these are a bit like conventional problem sets but require mostly conceptual work and operation of 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 20 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 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, 9/8/24 (just before the start of Week 3).** 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 9, 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. Thus, it serves primarily as an opportunity for formal feedback from the instructor. Residential students are required to present live at the classroom and DEN students synchronously on DEN WebEX for all presentations.

Final Project Oral Presentation - 10 points. A comprehensive 20-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.

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	6	5	30
Midterm Exam	1	15	15
Final Exam	1	20	20
Project Components			
Team Formation/Topic Selection	1	2	2
First Project Presentation	1	3	3
Final Project Oral Presentation	1	10	10
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 that are listed *only* as *"*activity," happen in the class period and are not graded. In-class activities that contribute to a graded homework are also marked "homework."
- 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.

Course Schedule

	Topics	Readings and Assignments	Deliverables
Module 1: Introduction to Industrial Ecology and Sustainable Engineering			
Week 1			
8/25	**Introduction and Status of Ecosystem Services**: Overview of course and key concepts. Are we approaching a state shift in Earth's biosphere?	ISE 576 Syllabus MAT Ch. 1-2 SE Ch. 1-2 Barnosky et al. (2012)	Team Formation
8/27	**Defining Sustainability:** Various perspectives on what it means for society to be sustainable, including an overview of the UN's Sustainable Development Goals (SDGs) *Activity:* Introduction to Homework 1, Descriptions of final project assignment and final project topics, organizing for team formation, and introduction to Homework 1.	SCP Ch. 1	
Week 2			
9/1	**Labor Day, University Holiday, No Class Meeting**		
9/3	**Overview of Industrial Ecology (IE) and Sustainable Engineering (SE):** Key features of the discipline of industrial ecology as a guide for sustainable technologies and materials. *Activity/Homework:* Discussion of Allenby (2006) due at the class session.	Allenby (2006)	Homework 1: Allenby Discussion
Week 3			
9/8	**Systems Thinking in Industrial Ecology:** The role of complex systems, including reductionist vs. holistic engineering approaches and implications in society and business	SE Ch. 3-7 MAT Ch. 14	Homework 2: Complex Systems Identification
9/10	**Sustainability Assessment & Life Cycle Assessment (LCA) Overview:** Overview of sustainability assessment and LCA, including goal definition and functional units.	SE Ch. 8 MAT Ch. 3	

Module 2: Sustainability Assessment and Life Cycle Assessment			
Week 4			
9/15	**Scoping in Life Cycle Assessments (LCA):** Key principles and practice with life cycle scoping. *Activity:* LCA system scope for a T-shirt		
9/17	**Life Cycle Inventory (LCI) Analysis:** Activity data and relationship to life cycle inventories, including common data sources.	SE Ch. 9 & 10 MAT Ch. 6	
Week 5			
9/22	**Life Cycle Inventory (LCI) Analysis (Continued):** Attribution and calculation, including problems of allocation and data quality.		
9/24	**LCI Lab:** Introduction to accessing and choosing LCI data and building a life cycle network using Sima Pro Flow LCA software. *Lab Activity/Homework:* Constructing a product inventory.		
Week 6			
9/29	**Life Cycle Impact Assessment (LCIA):** Structure and content of life cycle impact models and the role of normalization, valuation, and weighting in informing decision-making.	SE Ch. 11 & 15 MAT Ch. 7	Homework 3: LCI Lab Report
10/1	**LCIA Lab**: Choosing and applying LCIA models using Sima Pro Flow software. *Lab Activity/Homework*: Comparing impacts from the inventory based on 2 models.		
Week 7			
10/6	**LCA Interpretation:** How to interpret LCA results including completeness check, consistency check, and uncertainty analysis.	SE Ch. 16 MAT Ch. 8	Homework 4: LCIA Lab Report

10/8	**LCA Interpretation (Continued):** Reporting of significant issues, limitations, and recommendations, including the critical review process. *Lab Activity:* Interpreting models by creating parameters and comparing results.		
Week 8			
10/13	**Sustainability Assessment and LCA Deep Dive:** A look at Techno-Economic Sustainability (TES) LCA through a case study of spatially explicit product water footprints.	Vos (2019) SE 11 (Review 11.2-11.3)	
10/15	**Preliminary Presentations**: Teams present on goal, scope, and proposed methods for final projects. *Activity:* Midterm review workshop including sample questions.		Preliminary Presentation
Week 9			
10/20	**Midterm Exam**		
10/22	**Streamlined Life Cycle Assessment**: A look at an older LCA assessment method for use when data is limited.	MAT Ch. 3 (Review 3.5)	
Module 3: Solutions and Practice Areas			
Week 10			
10/27	**Environmentally Extended Input-Output Models (EEIO)**: An overview of the economic input-output method for constructing LCIs, including hybrid LCA. *Activity: EIO-LCA group simulation*	SE Ch. 10 (Review 10.2-10.3)	Homework 5: Hybrid LCA
10/29	**Energy and Material Flow Analysis (MFA)**: Linking input-output analysis, energy modeling, MFA methods and the development of national and global materials accounts in the context of SDG 12.	SE Ch. 12-14	

Week 11			
11/3	**Design for the Environment (DfE):** Strategies to design more sustainable products and processes, including alternative materials and design heuristics	SE Ch. 17 Mat Ch. 9-12	
11/5	**Sustainable Packaging:** A look at the problem of designing sustainable approaches to packaging. *Activity:* Exploration of product packaging LCA software tools, including introduction to Homework 5.		
Week 12			
11/10	**Final Project Working Session:** Collaborative work of project teams and check-in with the instructor on data and model development		Homework 6: Packaging LCA
11/12	**Eco-Industrial Symbiosis and Circular Economies:** Natural and industrial ecosystems, biomimicry, and eco-industrial symbiosis. Key opportunities and challenges for increased circularity and eco-industrial symbiosis.	SE Ch. 18-19 MAT Ch. 4 & 13 SCP Ch. 4 Chertow (2007)	
Week 13			
11/17	**Consumption and Consumer Products:** The interaction of products and eco-efficiency with aggregate consumption and the implications for sustainability. The roles of sustainable commodity procurement systems and ecolabelling, including product category rules (PCRs) and environmental product declarations (EPDs).	SCP Ch. 2-3	
11/19	**Sustainable Cities and Ecological Engineering**: Concepts and tools related to sustainable cities and nature-based solutions.	SE Ch. 20	
Week 14			
11/24	**Concluding Lecture:** Assessing and managing risks of technological development in industrial ecology and sustainable engineering.	SE Ch. 21-22 MAT Ch. 5 SCP Ch. 5	

11/26	**USC Thanksgiving Break, No Class Meeting**		
Week 15			
12/1	**Final Project Presentations I**		Final Project Presentation Written Project Report
12/3	**Final Project Presentations II**		
12/12	**Final Exam: 2-4 p.m. on Friday, December 12, 2025**		

Statement on Academic Conduct and Support Systems

Academic Integrity

The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others (including AI generated) or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

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. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call

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

988 Suicide and Crisis Lifeline - 988 for both calls and text messages – 24/7 on call

The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL) – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086

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

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 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) 740-0411

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

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

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) 442-1200 – 24/7 on call

Non-emergency assistance or information.

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

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) 442-2850 or otfp@med.usc.edu

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