

Life Cycle Analysis for Sustainable Design and Engineering (SIE 466/566)
Spring 2021, Tu/Th 9:30 am – 10:45 am, Live Online
Hongyue Jin, Assistant Professor, Department of Systems and Industrial Engineering
Office Hours: Tu/Th 11 am – 12 pm

Course Description and Overview

This course will provide senior undergraduate and graduate students the conceptual, methodological, and scientific bases to quantify and improve the impact of engineering decisions on the environment, with a focus on applying life cycle analysis (LCA). The course will foster students to assess the environmental sustainability early on in their research to help design and develop more sustainable materials, products, and processes including manufacturing, logistics, and supply chain. Main topics covered include concept of life cycle thinking, computational structure of LCA, process based LCA, economic input-output LCA, LCA software tools and databases, case studies, recent development, and advanced topics in LCA. The students will be able to approach problems with life cycle perspectives, conduct LCA according to the ISO 14040 standards, and understand the strengths and weaknesses of LCA studies.

Course Objectives and Expected Learning Outcomes

The objective of this course is to prepare engineering students with the skills to perform LCA for environmental sustainability. By taking this course, both **undergraduate** and **graduate** students will possess the capability to:

- (i) approach a problem with a systems perspective;
- (ii) conduct LCA using state-of-the-art software tools and databases according to the ISO 14040 standards;
- (iii) identify environmental hotspots of a product life cycle or a process; and
- (iv) interpret LCA results to support decision making.

For **graduate** students, more challenging homework will be assigned for advanced learning outcomes including:

- (i) theoretical underpinnings of LCA principles;
- (ii) ability to conduct LCA without relying on a commercial software;

The above learning outcomes also translate to the following ABET student outcomes:

- (i) Students will learn how to identify, formulate, and solve a design or engineering problem by applying LCA (through a semester-long project);
- (ii) Students will be able to apply engineering design to produce solutions that meet the needs of public health, safety, and environmental welfare (through completing the course assignments and project);
- (iii) Students will enhance their ability to communicate effectively with a range of audiences (through in-class participation and presentations);
- (iv) Students will be able to recognize ethical and professional responsibilities in conducting a reliable and transparent LCA to make informed decisions for environmental sustainability (through LCA case studies and project);
- (v) Students will be able to function effectively on a team to develop leadership, collaboration, and inclusive environment and to establish goals, plan tasks, and meet objectives (through a team project proposal and a final report);

- (vi) Students will be able to analyze and interpret LCA results to draw meaningful conclusions (through a project and case studies);
- (vii) Students will be able to acquire and apply new knowledge in LCA (through case studies and discussions on emerging topics in LCA).

Instructor and Contact Information

Lecture Time: Tu/Th 9:30 am – 10:45 am, Tucson time
Location: Live online
Instructor: Dr. Hongyue Jin, Assistant Professor, Det. of Systems & Industrial Engineering
Email: hjin@arizona.edu
Office Hours: Tu/Th 11 am – 12 pm or by appointment

The instructor will be available to answer questions and/or discuss course materials during the office hours or by appointment.

Join the lecture live online (Tue & Thr 9:30 am – 10:45 am):

- Option 1: Sign in to D2L, select SIE466/566, click on “Upcoming events” on the appropriate date.
- Option 2: Join the zoom meeting each time by clicking xxx; Password: xxx

Watch the lecture video after class:

- Option 1: Sign in to D2L, select SIE 466/566, click “UA Tools”, select “Panopto”.
- Option 2: Sign in to D2L, select SIE 466/566, click “UA Tools”, select “Zoom”, click “Cloud Recordings”.

Join the office hour hosted by the instructor (Tue & Thr 11:00 am – 12:00 pm):

- Option 1: Sign in to D2L, select SIE466/566, click on “Upcoming events” on the appropriate date.
- Option 2: Join the zoom meeting each time by clicking xxx; Password: xxx

Course Prerequisites

Advanced standing is required for undergraduate students. Please visit the webpage for more information on the advanced standing: <https://engineering.arizona.edu/academic-policies/advanced-standing>.

For graduate students, working knowledge of a programming language is required (e.g., MATLAB for matrix operations).

Introductory knowledge on linear algebra, probability, chemistry, and economics are recommended and will be reviewed in class.

Temporary Lecture Schedule:

Lecture	Dates	Topics
1	01/14	Course Overview & Introduction
2	01/19	Life Cycle Thinking
3	01/21	LCA History and ISO Framework
4	01/26	Goal and Scope Definition

5	01/28	Life Cycle Inventory Analysis (homework 1)
6	02/02	Developing Process Tree/Table
7	02/04	Understanding a Unit Process
8	02/09	Customizing/Creating a Unit Process (homework 2)
9	02/11	Review of Matrix Algebra
10	02/16	Computational Structure (homework 3)
11	02/18	Sensitivity Analysis
12	02/23	Review on Random Variables and Monte-Carlo Simulation
	02/25	Reading day – No classes
13	03/02	Multi-Function Systems – Disaggregation, Allocation, and Systems Expansion (homework 4)
14	03/04	Project Proposal Presentation
	03/09	Reading day – No classes
15	03/11	Mid-term Exam
16	03/16	Environmental Impact Overview
17	03/18	Impact Assessment Methods
18	03/23	Economic Input-Output LCA (homework 5)
19	03/25	Material Flow Analysis
20	03/30	Process-Based LCA
21	04/01	Process-Based LCA Demo with SimaPro (homework 6)
22	04/06	Consequential LCA
23	04/08	LCA Interpretation
24	04/13	Uncertainty in LCA
25	04/15	LCA Case Studies - Applications and Critics
26	04/20	Design for the Environment
27	04/22	UPLCI, Process Planning, and Optimization
28	04/27	Recent Development in LCA
29	04/29	Final Project Presentation 1
30	05/04	Final Project Presentation 2

The above topics and schedule are subject to change. Revisions in the syllabus may occur as the semester progresses.

Reading Materials



Main: Lecture notes, provided and downloaded from D2L course website

Recommended reference books:

1. H. Scott Matthews, Chris T. Hendrickson, and Deanna Matthews, Life Cycle Assessment: Quantitative Approaches for Decisions that Matter, 2014. Open access textbook, retrieved from <https://www.lcatextbook.com/>.
2. Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach - by Chris T. Hendrickson, Lester B. Lave, and H. Scott Matthews, 2010
3. Environmental Life Cycle Assessment: Measuring the Environmental Performance of Products – by Rita Schenck and Phillip White, 2010
4. The Computational Structure of Life Cycle Assessment – by Reinout Heijungs and Sangwon Suh, 2002

Equipment and Software Requirements

Students will need daily access to the following hardware: laptop or web-enabled device with webcam and microphone; regular access to reliable internet signal; ability to download and run the following software: Microsoft Excel, Word, Power Point, Adobe Acrobat Reader, and programming software of your choice (e.g., MATLAB).

In addition, we will use SimaPro software remotely via <https://arizona.apporto.com/>. Please log in, and click  “Desktop” → double-click on the “SimaPro multi-user” icon on the  desktop. If you have trouble accessing SimaPro, please contact the instructor.



Grading Scale and Grade Policy

I - Grading:

Course Work	Points	Percentage
Homework (6 assignments; 4.17 points each)	25	25%
Mid-term Exam (1)	30	30%
Project Proposal (1 oral and 1 written)	10	10%
Final Project (1 oral and 1 written report)	30	30%
Participation Quiz (6; 1 point each; max 5 points)	5	5%
TOTAL	100	100%

The grading scheme will follow the distribution below. University policy regarding grades and grading systems is available at <http://catalog.arizona.edu/policy/grades-and-grading-system>

Points	Percentage	Letter Grade
90-100	90%-100%	A
80-89	80%-89%	B
70-79	70%-79%	C
60-69	60%-69%	D
<60	<60%	E

The following penalty will be given to late homework, project proposal, and final project, and participation quizzes:

- 1) Submissions delayed by up to 24 hours: -20% (i.e., If you submit within 24 hours from the original deadline, 20% of your score will be taken off).
- 2) Submissions delayed by up to 48 hours: -50% (i.e., If you submit within 48 hours from the original deadline, 50% of your score will be taken off).
- 3) Submissions delayed by more than 48 hours: -100% (i.e., no grade will be given).

The above policy is applied to all the students unless a prior consent has been made with the instructor for medical and job reasons.

Dispute of Grade Policy: Students disputing a grade on any grade item (e.g., homework and exam) must do so within a week of the graded work being returned. Note: unexcused absences will not extend this deadline.

II - Exam

The midterm exam date and time are scheduled based on the course schedule, and all students are required to participate in the exam on time. The only exceptions are medical and job reasons approved by the instructor prior to the exam. Students with disability, please contact the Disability Resource Center (DRC). Students will take the exam through *Examity* or with proctors approved by the instructor.

III – Homework (HW)

Six homework will be assigned throughout the semester, usually given one week of completion time. Homework should be prepared and submitted individually in D2L.

IV – Course Project

Students will work in groups of 3 to 5 with the prior consent of the instructor. The project should (1) contribute to the development of environmentally friendly product, process, or system using a state-of-the-art LCA software tool or (2) systematically review the LCA literature of emerging domain subject to enhance learning. Projects will be graded regarding their potential for impacting research or education. Some examples of projects may include:

- Review of the state-of-the-art LCA on technology, product, or process of interests
- Using LCA to support design/manufacturing/engineering improvement

Students will present the proposal and final project in class at the time specified in the lecture schedule table. For distance learning students whose work schedule conflicts with the class schedule, they may submit videos of presentation to the instructor one day before the scheduled presentation date so that the videos can be played in class.

Project proposal report is expected to be 1 page, summarizing the goal, scope, data, and planned work. Final project report is expected to be 6 pages or longer, describing 5 What (i.e., what is the problem, what has been done, what needs to be done (i.e., research gap), what you have done, what are the results/conclusions), 1 Why (i.e., why it is important), and 1 How (i.e., how you have done it, following the ISO standards on conducting LCA and including detailed life cycle inventory data, if applicable). The grading criteria will include potential impact on the field, creativity, depth of effort, and clarity.

The report is ideally to be converted to a conference or journal paper. Below are selected journals publishing LCA studies:

1. Journal of Cleaner Production
2. Resources, Conservation, and Recycling
3. The International Journal of Life Cycle Assessment
4. Journal of Industrial Ecology
5. Environmental Research letters
6. ACS Sustainable Chemistry & Engineering
7. Integrated Environmental Assessment and Management
8. Environmental Management
9. Journal of Material Cycles and Waste Management
10. International Journal of Sustainable Manufacturing
11. International Journal of Sustainable Design

V – Teamwork Evaluation

Project team members will be provided a *Teamwork Evaluation Form* to evaluate team members' contributions to the corresponding project components, including proposal, presentations, and final report, with a score scale from 0 to 10 (0 = no contribution; 10 = greatest contribution). The individual's teamwork score for each project component will be calculated as the average evaluation score from all team members excluding him/herself, scaled by 10. For example, the evaluation scores of the project proposal for student A given by all four team members, excluding him/herself, are 10, 9, 8, 7. Then, A's teamwork score is $(10+9+8+7)/4/10 = 0.85$. If the team receives a proposal score of 10, A's adjusted proposal score will be $10 \times 0.85 = 8.5$. The final project score (maximum points: 40) of the student will be calculated as the summation of his/her project proposal and final project (both written and oral).

VI – Participation

There will be 6 pop quizzes, 1 point each, max 5 points in total. The goal is to increase class participation, so students may work in groups for answering the participation questions. However, each student must submit his/her own solution in D2L.

The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at: <http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop>. The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, see: <http://policy.arizona.edu/human-resources/religious-accommodation-policy>. Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: <http://policy.arizona.edu/employmenthuman-resources/attendance>.

Classroom Behavior Policy:

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., chatting, driving, etc.).

The university classroom policy states:

- Not talking with other classmates while the instructor or another student is speaking. If a student has a question or comment, he or she should raise a hand.
- Showing respect and concern for others by not monopolizing class discussion. Students must allow others time to give their input and ask questions. Students should not stray from the topic of class discussion.

Academic Integrity and Code of Academic Integrity:

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: <http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity>. The University Libraries have some excellent tips for avoiding plagiarism, available at <http://new.library.arizona.edu/research/citing/plagiarism>.

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

Instructor will carefully exam all of your homework, reports and exams to prevent plagiarism. For example:

No copy of other people's homework. In grading your homework, the instructor will exam all of your homework carefully and catch anyone who is copying other people's homework. Even if they are from the same software's output, the instructor can still judge whether it is a copy of others or not based on your writing and formatting.

No copy or discussion in the exam. The instructor and other students all will report these behaviors in exams and your exam file will also be checked carefully for any cheating behavior.

Send Your Feedback:

If you have any questions, suggestions or comments related to the class, you are very welcome to contact the instructor. We have several ways for communications:

- 1) In-class feedback
- 2) Office hour
- 3) Email
- 4) Individual appointment (if you cannot come in office hour)
- 5) D2L discussion forum

Threatening Behavior Policy:

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See: <http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students>.

UA Nondiscrimination and Anti-harassment Policy:

The University is committed to creating and maintaining an environment free of discrimination, see: <http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy>.

Inclusive Excellence is a fundamental part of the University of Arizona's strategic plan and culture. As part of this initiative, the institution embraces and practices diversity and inclusiveness. These values are expected, respected and welcomed in this course.

This course supports elective gender pronoun use and self-identification; rosters indicating such choices will be updated throughout the semester, upon student request. As the course includes group work and in-class discussion, it is vitally important for us to create an educational environment of inclusion and mutual respect.

Additional Resources for Students Statement: Office of Diversity (<http://diversity.arizona.edu/>) <http://www.health.arizona.edu/counseling-and-psych-services>

Accessibility and Accommodations (for students with Disability)

At the University of Arizona, we strive to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability or

pregnancy, you are welcome to let the instructor know so that we can discuss options. You are also encouraged to contact Disability Resources (520-621-3268) to explore reasonable accommodation.

If you have reasonable accommodations, please plan to meet with the instructor by appointment or during office hours to discuss accommodations and how the course requirements and activities may impact your ability to fully participate.

If our class meets at a campus location: Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

Their website is <http://drc.arizona.edu/instructors/syllabus-statement>.

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at <http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete> and <http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal> respectively.

Additional Resources for Students

UA Academic policies and procedures are available at <http://catalog.arizona.edu/policies>
Student Assistance and Advocacy information is available at <http://deanofstudents.arizona.edu/student-assistance/students/student-assistance>

Subject to Change Statement

The information contained in the course syllabus, may be subject to change, as deemed appropriate by the instructor, see <http://policy.arizona.edu/faculty-affairs-and-academics/course-syllabus-policy-undergraduate-template>.