

# **Circular Engineering in the Built Environment:**

## Principles, Practices and Methods

### **INSTRUCTORS**

#### **Sheida Shahi**

OAA, Ph.D.

#### **Professor Carl Haas,**

Department Chair, University Research Chair, Ph.D., PEng, FASCE, FCAE, FNAC

### **COURSE DESCRIPTION**

Building construction and demolition comprise 40% of our waste stream, and buildings account for similar amounts of our embodied energy and resource usage, so moving toward a circular economy in the built environment is necessary for our sustained well-being. The objectives of this course are for participants to gain: (1) an understanding of basic circular engineering principles for the built environment such as closed materials loops, reduced waste and increased reuse, (2) familiarity with prevailing and emerging practices such as LCI (Life Cycle Impact) analysis and adaptive reuse project planning and (3) limited introductory facility with a subset of the most common methods and software tools used for executing those practices such as the Excel-based Sustainability ROI Workbook and One-Click LCA<sup>®</sup>. A significant part of the course will be a project through which the participants can focus on self-study of a toolset of particular interest to them and its application to a problem of interest such as reuse of construction materials, buildings as materials banks, or abiotic resource depletion related to a class of infrastructure assets. On completion of the course, participants should be able to apply a broad circular economy systems perspective to built environment issues, identify knowledge gaps and problems of interest, set the boundaries for a subsystem problem analysis, and be able to select and learn to use appropriate available tools for the analysis.

## COURSE SCHEDULE:

All lecture notes, videos and readings will be posted weekly on LEARN.

Weekly class discussions will be held on Wednesdays from 10 am – 12 pm EST.

	DESCRIPTION	ASSIGNMENTS	DUE DATE
<b>LESSON 1:</b> May 4	<b>Introduction to Definitions and Concepts of Circular Economy</b>	Term Project: Part 1	May 10, 2022 11:59 PM EST
		Assignment 1	May 17, 2022 11:59 PM EST
<b>LESSON 2:</b> May 11	<b>Overview of Embodied Energy and Life Cycle Analysis (LCA)</b>	Term Project: Part 2	June 28, 2022 11:59 PM EST
<b>LESSON 3:</b> May 18	<i>Assignment 1 Presentations</i>	Assignment 2	May 31, 2022 11:59 PM EST
<b>LESSON 4:</b> May 25	<b>Materials and Product Flows</b>		
<b>LESSON 5:</b> June 1	<b>Circular Engineering: Design Concepts and Tools</b>	Assignment 3	June 21, 2022 11:59 PM EST
<b>LESSON 6:</b> June 8	<b>Field Trip to Market Places and Building Adaptation Projects, TBD</b>		
<b>LESSON 7:</b> June 15	<b><u>Part 1:</u> Modules and Disassembly <u>Part 2:</u> Market and Business Models for Circular Economy</b>		
<b>LESSON 8:</b> June 22	<b><u>Part 1:</u> Measuring Circularity and Economic Feasibility of CE in the Built Environment <u>Part 2:</u> Workshop – Sustainability Return on Investment (SROI) Workbook <u>Part 3:</u> Assignment 3 Presentations and Discussion</b>	Term Project Part 3	July 5, 2022 11:59 PM EST

<b>LESSON 9:</b> June 29	<b>Building Adaptation – Case Studies and Methods</b>		
<b>LESSON 10:</b> July 6	<i>Interim Reviews: Term Project</i>	Term Project Part 4	July 19, 2022 11:59 PM EST
<b>LESSON 11:</b> July 13	<b><u>Part 1:</u> Option Appraisal for Building Adaptation</b> <b><u>Part 2:</u> Future of Circular Engineering in Construction</b>		
<b>LESSON 12:</b> July 20	<i>Final Reviews: Term Project</i>	Term Project Part 5	August 3, 2022 11:59 PM EST

**LESSON OVERVIEW**

**Lesson 1: Introduction to Definitions and Concepts of Circular Economy**

Introduction to the definitions and concepts of Circular Economy (CE) will be provided. The focus will be on the resource challenge and why implementation of CE in construction is needed for the future of sustainable development. The potentials of measuring tools in CE will be reviewed.

**Part 1: Introduction to Circular Economy Concepts**

- Introduction to circular economy in the built environment
- Going from linear to circular
- Opportunities and challenges
- Examples and case studies

**Part 2: Overview of Circularity in the Industry**

- State of circularity in the construction industry
- Circular company success stories

**Part 3: Measuring Circularity**

- Overview of measuring tools for circularity
- Circularity indicator and One-Click LCA

**Part 4: Course Overview**

- Overview of lessons, assignment and term project

**Tasks:**

Assignment 1, Term Project – Part 1

## **Lesson 2: Embodied Energy and Life Cycle Assessment**

### *Term Project Part 1 Due*

Concepts of embodied energy in the built environment and role of life cycle assessment in CE will be reviewed. A detailed understanding of life cycle assessment including inputs and measurement criteria, as well as outputs and comparative criteria, will be presented. Case studies and applications of life cycle assessment for implementing CE in construction will be examined.

#### **Part 1: Introduction to Embodied Energy**

- Embodied environmental impacts in the built environment

#### **Part 2: Introduction to Life Cycle Analysis**

- Understanding life cycle assessment
- Applying and measuring of life cycle assessment

#### **Part 3: One-Click Tutorial**

- LCA Tutorial

**Tasks:** Assignment 1, Term Project – Part 1

## **Lesson 3: Case Study Presentations and Discussion**

### *Assignment 1 Due*

#### **Assignment 1 Presentations**

**Tasks:** Assignment 1, Term Project – Part 1

## **Lesson 4: Materials and Product Flows**

Analysis of the resource challenge, reduction of critical raw materials and waste management in construction will be presented. The applicable concepts of CE to construction will be explored, including recycling, remanufacturing, refurbishment, reuse and repurposing. Reuse and recycling of structural steel will be studied and analyzed in depth.

#### **Part 1: Introduction to Material and Product Flows**

- Introduction to material and product flows in the CE
- Material stocks and flow accounting

#### **Part 2: Material Flows – Case of Transportation Infrastructure**

- In-depth analysis of material accounting for civil projects

#### **Part 3: Recycling, Remanufacturing, Refurbishing, Reuse and Repurposing**

- Introduction to CE principals for waste mitigation

- Strategies for circular waste management and case studies

**Part 4: Material Reuse vs. Recycle - Decision Making Framework Structural Steel**

- In-depth comparison of reuse and recycling of steel

**Tasks:** Assignment 2, Term Project – Part 2

**Lesson 5: Circular Engineering: Design Concepts and Tools**

Review of design concepts for CE various perspectives will be presented. An overview circular thinking and circular design strategies will be presented. Reversible design strategies including adaptability, disassembly and reuse will be explored through case studies and circular design tools such as material passports will be presented.

**Part 1: Circular Thinking**

- Design for circular economy
- Circular design strategies

**Part 2: Reversible Design and Circular Design Tools**

- Adaptability, Disassembly and Reuse
- Buildings as Material Banks (BAMB) and Material Passports

**Part 3: One-Click Tutorial**

- Circularity Tool, Carbon Designer Tool

**Tasks:** Assignment 3, Term Project – Part 2

**Lesson 6: Field Trip to Materials Marketplaces and Building Adaptation Projects**

Visits to local Material Marketplaces and building adaptation project in preparation for Assignment 3.

**Lesson 7:**

**Part 1 - Modules, Interfaces, and Disassembly | Market and Business Models**

**Part 2 - Value of Building Components and Markets in a Circular Economy**

New systems of construction will be explored as strategies for the implementation of CE in the built environment including modular design, design of interfaces, disassembly and deconstruction. The importance of modularity for CE will be reviewed, followed by processes, implementation and case studies. Technologies for improving interfaces and process of disassembly and deconstruction will be studied.

**Part 1:****Modular Construction**

- Modular construction processes

**Disassembly and Deconstruction**

- Deconstruction Project Planning
- Selective Deconstruction Programming
- Disassembly Planning in Adaptive Reuse of Buildings

**Tasks:** Assignment 3, Term Project – Part 2

Circular markets and alternative CE business models will be reviewed at the various regional, national and international scales. Market value of building components for reuse and recycle, etc. will be explored. Alternative business models relating to CE in construction will be presented including sharing platforms, alternative financing and innovative business models.

**Part 2:****Markets in a Circular Economy**

- Sharing platforms
- Alternative financing
- Innovative business models

**Tasks:** Term Project – Part 2

**Lesson 8:**

**Part 1: Measuring Circularity and Economic Feasibility of CE in the Built Environment**

**Part 2: Workshop – Sustainability Return on Investment (SROI) Workbook**

**Part 2: Assignment 3 Presentation and Discussion**

*Assignment 3 Due*

Tools and methodologies for measuring circularity will be reviewed in depth, and examples from industry will demonstrate application. Strategies for examining economic feasibility of circular strategies in the built environment will be introduced.

**Lesson 9: Building Adaptation – Case Studies and Methods**

Overview and definition of building adaptation systems and importance for CE. Impact and role of building adaptation projects will be explored in detail. The advantages of building adaptive reuse over green-field construction will be investigated. Concepts of planning and designing for building adaptation and CE in construction will be outlined. Concepts of end-of-life planning for building adaptation projects will be explored, including relevant technologies and case studies of their applications.

### **Part 1: Introduction to Building Adaptation**

- Building adaptation definition and scope
- The role of adaptive reuse in the circular economy
- Determining the adaptation potential of buildings

### **Part 2: Adaptation Project Planning**

- Planning and Designing for a Circular Economy in Construction
- The importance of pre-project planning and circular building principles in capital project delivery
- Capital project planning for a circular economy

**Tasks:** Term Project – Part 3

### **Lesson 10: Interim Project Review**

*Term Project Part 3 Due*

**Tasks:** Term Project – Part 4

### **Lesson 11:**

#### **Part 1: Option Appraisal for Building Adaptation**

#### **Part 2: Future of Circular Engineering in Construction**

##### **Part 1:**

Overview of design option appraisal concepts and decision making related to CE will be presented. Challenges and potentials for design in CE will be reviewed with an in-depth case study analysis.

- Design option appraisal and decision-making, methods and case studies
- Review of state-of-the-art tools and case studies of carbon reduction and CE implementation in the built environment

**Tasks:** Term Project – Part 4

##### **Part 2:**

Overview of current research with the Construction Industry Institute and concepts for a future of CE in construction will be reviewed.

**Tasks:** Term Project – Part 5

### **Lesson 12: Final Reviews**

*Term Project Part 4 Due*

**Tasks:** Term Project – Part 5

## ASSIGNMENT AND PROJECT OVERVIEW

### Assignment 1: Case Study of a Circular Project – Presentation to class

Choose a circular building, product, process or service:

- Research, analyze and describe the chosen case study compared to a traditional linear model
- Highlight advantages, challenges and long-term scalability of the chosen approach

### Assignment 2: Circular Strategy Consultation – Report and Discussion

Select an existing building or product or system and demonstrate the impact of implementing circular engineering strategies. Selected strategies must be quantified and analyzed in comparison to existing or status quo conditions to show improvements. A fieldtrip will be organized for exposure to local marketplaces and adaptation projects.

- Provide suggestions for improving the existing building, product or system
- Complete LCA of existing conditions using One-Click LCA
- Select one improvement strategy, implement and compare to existing
- Suggest further circular economy efficiencies
- Evaluate the implemented strategies in terms of circular efficiencies

### Assignment 3: Literature Review on Circular Business Models – Presentation to class

Select a journal article or report on a novel circular business model:

- Research, analyze and describe the business model presented
- Compare the circular economy business model to a traditional alternative
- Highlight advantages, gaps and challenges for large-scale implementation
- Suggest how the business model could be improved for the built environment

### Term Project:

Identify a circular business opportunity related to Martin Luther University College including materials, products, or building components (i.e. re-use of structural steel, adaptive reuse of buildings, design of circular strategies, etc.). Compare a detailed circular strategy to a status-quo base-case (i.e. recycling or disposing of structural steel, demolition of buildings or adaptive reuse design).

#### Part 1: Identify a problem in the existing building

- Selection and review of problem, limited literature and precedent review

#### Part 2: Proposal

- Detailed literature review on identified problem and precedents for improvement

#### Part 3: Preliminary solution strategies – Interim Review

- Case study and precedent review
- LCA of existing and new solution



- Provide measurable improvements to base case
- Present a preliminary business case for viability of solution (*Sustainability ROI Workbook*)

**Part 4: Presentation**

- Coherent presentation on problem, precedents for addressing problem
- Present proposed solutions with quantifiable measures and a preliminary business case
- Integrate comments made at interim reviews

**Part 5: Report**

- Consolidate presentation into a report

**GRADE BREAKDOWN**

ACTIVITIES AND ASSIGNMENTS	WEIGHT
<b>Assignment 1: Case Study of a Circular Project</b>	<b>10%</b>
<b>Assignment 2: Circular Strategy Consultation</b>	<b>15%</b>
<b>Assignment 3: Literature Review on Circular Business Models</b>	<b>10%</b>
<b>Term Project: Circular Business Opportunity – Martin Luther University College</b>	<b>55%</b>
Part 1	5%
Part 2	10%
Part 3	15%
Part 4	15%
Part 5	10%
<b>Participation: Peer-review and Discussions*</b>	<b>10%</b>

\*Students are expected to participate in weekly discussions, course surveys and peer-reviews to stay engaged during the on-line Spring term.

**MATERIALS AND READINGS**

There are no required textbooks in this course.  
All reading material will be posted weekly on LEARN.

**CONTACT INFORMATION**

## ANNOUNCEMENTS

Your instructor uses the Announcement widget of the Course Home page to make announcements during the term to communicate new or changing information regarding due dates, instructor absence, etc., as needed. You are expected to read the Announcement on a regular basis.

To ensure you are viewing the complete list of items, you may need to click “Show All Announcements”.

## DISCUSSIONS

A General Discussion topic has also been made available to allow students to communicate with peers in the course. Your instructor may drop in at this discussion topic.

## CONTACT US

WHO AND WHY	CONTACT DETAILS
<p><b>Instructor:</b></p> <p><b>Course-related questions (e.g. course content, deadlines, assignments, etc.)</b></p> <p><b>Personal concerns</b></p>	<p>Post your course-related questions to the Ask the Instructor discussion topic. This allows other students to benefit from your question as well.</p> <p>Questions of a personal nature can be directed to your instructor.</p> <p>Instructor: Sheida Shahi (<a href="mailto:sshahi@uwaterloo.ca">sshahi@uwaterloo.ca</a>)</p> <p>Your instructor checks email and the Ask the Instructor discussion topic frequently and will make every effort to reply to your questions within 24– 48 hours, Monday to Friday.</p>
<p><b>Technical Support, Centre for Extended Learning</b></p> <p><b>Technical Problems with Waterloo LEARN</b></p>	<p><a href="mailto:learnhelp@uwaterloo.ca">learnhelp@uwaterloo.ca</a></p> <p>Include your full name, WatIAM user ID, student number, and course name and number.</p>

## COURSE AND DEPARTMENT POLICIES LATE POLICY

All assignments are due on the date and time indicated (or 11:59 PM on the given date if no time is specified). Late assignments (without penalty) are permitted only when specifically allowed by the instructor. Late assignments will be penalized by 20% for the first week it is late and by 50% if submitted prior to the end of the course. Permission may be obtained in advance for late assignments (with no penalty), but this must occur by email at least 3 days PRIOR to the assignment deadline.

## **UNIVERSITY POLICIES SUBMISSION TIMES**

Please be aware that the University of Waterloo is located in the Eastern Time Zone (GMT or UTC-5 during standard time and UTC-4 during daylight saving time) and, as such, the time that your activities and/or assignments are due is based on this zone.

## **ACCOMMODATION DUE TO ILLNESS**

If your instructor has provided specific procedures for you to follow if you miss assignment due dates, term tests, or a final examination, adhere to those instructions. Otherwise:

## **MISSED ASSIGNMENTS/TESTS/QUIZZES**

**Contact** the instructor as soon as you realize there will be a problem, and preferably within 48 hours, but no more than 72 hours, have a medical practitioner complete a Verification of Illness Form.

Email a scanned copy of the Verification of Illness Form to your instructor. In your email to the instructor, provide your name, student ID number, and exactly what course activity you missed.

Further information regarding Management of Requests for Accommodation Due to Illness can be found on the Accommodation due to illness page.

## **MISSED FINAL EXAMINATIONS**

If you are unable to write a final examination due to illness, seek medical treatment and have a medical practitioner complete a Verification of Illness Form. Email a scanned copy to the Centre for Extended Learning (CEL) at [extendedlearning@uwaterloo.ca](mailto:extendedlearning@uwaterloo.ca) within 48 hours of your missed exam. Make sure you include your name, student ID number, and the exam(s) missed. You will be REQUIRED to hand in the original completed form before you write the make-up examination.

After your completed Verification of Illness Form has been received and processed, you will be emailed your alternate exam date and time. This can take up to 2 business days. If you are within 150 km of Waterloo, you should be prepared to write in Waterloo on the additional CEL exam dates. If you live outside the 150 km radius, CEL will work with you to make suitable arrangements.

Further information about Examination Accommodation Due to Illness regulations is available in the Undergraduate Calendar.

## **ACADEMIC INTEGRITY**

In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect, and responsibility. If you have not already completed the online tutorial regarding academic integrity you should do so as soon as possible. Undergraduate students should see the Academic Integrity Tutorial and graduate students should see the Graduate Students and Academic Integrity website.

Proper citations are part of academic integrity. Citations in CEL course materials usually follow CEL style, which is based on APA style. Your course may follow a different style. If you are uncertain which style to use for an assignment, please confirm with your instructor or TA.

For further information on academic integrity, please visit the Office of Academic Integrity. Discipline

A student is expected to know what constitutes academic integrity to avoid committing an academic offence, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about “rules” for group work/collaboration, should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to Policy 71 - Student Discipline. For typical penalties, check Guidelines for the Assessment of Penalties.

### **APPEALS**

A decision made, or penalty imposed under Policy 70 - Student Petitions and Grievances, (other than a petition) or Policy 71 - Student Discipline, may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 - Student Appeals.

### **GRIEVANCE**

A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70 - Student Petitions and Grievances, Section 4. When in doubt please be certain to contact the department’s administrative assistant who will provide further assistance.

### **FINAL GRADES**

In accordance with Policy 46, Appendix A - Access to and Release of Student Information, the Centre for Extended Learning does not release final examination grades or final course grades to students. Students must go to Quest to see all final grades. Any grades posted in Waterloo LEARN are unofficial.

### **ACCESSABILITY SERVICES**

AccessAbility Services, located in Needles Hall, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodation to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term and for each course.

### **COPYRIGHT INFORMATION**

#### **UWATERLOO’S WEB PAGES**

All rights, including copyright, images, slides, audio, and video components, of the content of this course are owned by the course author, unless otherwise stated. These web pages are owned or controlled by the University of Waterloo, Centre for Extended Learning. By accessing the web pages, you agree that you may only download the content for your own personal, non-commercial use. You are not permitted to copy, broadcast, download, store (in any medium), transmit, show or play in public, adapt, or change in any way the content of these web pages for any other purpose whatsoever without the prior written permission of the course author and the University of Waterloo, Centre for Extended Learning.

#### **OTHER SOURCES**

Respect the copyright of others and abide by all copyright notices and regulations when using the computing facilities provided for your course of study by the University of Waterloo. No material on the Internet or World Wide Web may be reproduced or distributed in any material form or in any medium, without permission from copyright holders or their assignees. To support your course of study, the University of Waterloo has provided hypertext links to relevant websites, resources, and services on the

web. These resources must be used in accordance with any registration requirements or conditions which may be specified. You must be aware that in providing such hypertext links, the University of Waterloo has not authorized any acts (including reproduction or distribution) which, if undertaken without permission of copyright owners or their assignees, may be infringement of copyright. Permission for such acts can only be granted by copyright owners or their assignees.

If there are any questions about this notice, please contact the University of Waterloo, Centre for Extended Learning, Waterloo, Ontario, Canada, N2L 3G1 or [extendedlearning@uwaterloo.ca](mailto:extendedlearning@uwaterloo.ca).