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Introduction

Human activities result in different types of environmental impacts at different levels. Many decisions made at the design stage determine impacts of the products, structures, services and business units that manifest during production, use and beyond. Assessment of such impacts can be best done using a life cycle perspective. The analytical tool of life cycle assessment (LCA) supports informed decision-making by avoiding problem-shifting and sub-optimization. When dealing with measures of improving environmental performance, problem-shifting occurs between life cycle stages e.g. upstream to downstream parts of the life cycle. It may also occur between medium such as from air to water. Burden is also being shifted in space (e.g. from urban to rural) and in time (e.g. from today to future). LCA provides an opportunity of, at least, minimizing such problem-shifting.

This course on LCA in design, offered for undergraduate and graduate students, helps would-be architects, engineers, business professionals and designers develop the skill of understanding the far-reaching and lasting implications of the decisions they make at different levels of design.

Requirement of Prior Knowledge

There is no formal prior knowledge requirement.

Objectives

The course aims at contributing to the development of an expertise in systems-thinking of environmental implications of design and development of products, structures, services and business units. A basic competence in LCA will be provided by the course. After completing the course, students should be able to:

- Understand the overall purpose and principles of LCA.
- Describe the content and explain the purpose of the different steps of LCA.
- Carry out a complete LCA of a defined system based on the ISO standard for LCA.
- Write an LCA report complying with guidelines and terminologies of the ISO standard.
- Discuss possible applications and limitations of LCA.
- Understand how a third-party critical review of LCA is done.

Teaching Approach

The course will be delivered through Lectures, Case Study Presentation, LCA Lab, Project work (Presentation and Work), and Critical Review.

i) Lectures

The lectures will provide a theoretical background of LCA covering:

1) Methodological

- Identification and delimitation of the system boundary
- Defining and handling of allocation problems

- Selection of characterization method
- Midpoint and endpoint approaches

2) Data

- Identification and use of data from LCA databases
- Collection and use of data from other sources

3) LCA Software Tools

- Tools available
- Use of LCA software tools

4) Results reporting and application

- Contents of an LCA report
- Analysis and interpretation of LCA results

Content: Topic Areas

The main topic areas of the course are covered in the lectures outlined briefly below.

Introduction to LCA and to Project Work

This lecture reflects over how LCA can be used in different fields. It covers basic features of LCA including history of LCA and different phases of LCA. Introduction to the project work will also be given.

LCA Examples– Food, Biofuel, Coffee Machine, Wooden Shed

These will consider issues related to Food, Biofuel, Coffee Machine, Wooden Shed.

Goal and Scope Definition

This will give a basic framework of LCA covering aspects of system boundary, functional units, data quality requirements, etc.

Life Cycle Inventory Analysis

Based on the information from the Goal and Scope Definition, this will deal with the quantitative dimension of LCA including data collection and modeling of the product or service system under consideration.

Data availability and Data Quality in LCA and LCA Software Tools

Data quality and associated issues will be the subject of this lecture. Brief outline of the selected LCA software tools available will be presented.

Life Cycle Impact Assessment, Interpretations, Reporting and Critical Review

The methods and approaches for quantifying the environmental impacts using the data collected will be the focus of this lecture. Implication of the choices that are involved in applying the different methods of aggregating and weighting data will be covered. This will also cover the different aspects of LCA reporting and critical review that are articulated in the ISO Standard for LCA.

ii) LCA LAB

This will be a computer lab with an LCA software tool called SimaPro. Students individually will go through the different parts of the tool from the perspective of carrying out an LCA work that is related to the Project below. **See a separate LCA LAB Instruction.**

iii) Case Study Presentation

Case Study presentation will be done in groups based on published LCA studies (see below). The groups will be maintained to work on a project related to the same product system. The

task here is to **present the content** of the article and add **own reflection on weaknesses and strengths** of the LCA study reported.

Solar Thermal

Koroneos, C., & Nanaki, E. (2012). Life cycle environmental impact assessment of a solar water heater. *Journal of Cleaner Production*, 37, 154-161. doi:10.1016/j.jclepro.2012.07.001

Wind Turbine

Demir, N., & Taskin, A. (2013). Life cycle assessment of wind turbines in pinarbai-kayseri. *Journal of Cleaner Production*, 54, 253-263. doi:10.1016/j.jclepro.2013.04.016

Passenger Car

Koroneos, C., & Nanaki, E. (2012). Life cycle environmental impact assessment of a solar water heater. *Journal of Cleaner Production*, 37, 154-161. doi:10.1016/j.jclepro.2012.07.001

Building

Menoufi, K., Chemisana, D., & Rosell, J. (2013). Life cycle assessment of a building integrated concentrated photovoltaic scheme. *Applied Energy*, 111, 505-514. doi:10.1016/j.apenergy.2013.05.037

SmartPhone (if more than four groups are required)

Zink, T., Maker, F., Geyer, R., Amirtharajah, R., & Akella, V. (2014). Comparative life cycle assessment of smartphone reuse: Repurposing vs. refurbishment. *The International Journal of Life Cycle Assessment*, 19(5), 1099-1109. doi:10.1007/s11367-014-0720-7

iv) Project (Presentation and Report)

The project will be done in groups, same as the Caste Study. Students will utilize the knowledge from the lectures and literature and will get an insight into the possibilities and challenges of carrying out an LCA by performing a full LCA of a product system of choice from the list below. SimaPro will be used for the project.

Project Topics:

- Solar Thermal
- Wind Turbine
- Passenger Car
- University Building
- SmartPhone (if more than four groups are required)

For detailed requirements regarding expectations on the project, see a separate Project Description.

v) Critical Review

The task here is to summarize the Critical Review "Peer Review" that starts on Page 91(Addendum 2) of the LCA study report *Franklin Associates (2009) Life Cycle Inventory of Three Single-Serving Soft Drink Containers. Franklin Associates, A Division of ERG, Prairie Village, KS. 6) Critical Review (Max 10 points)*.

For the critical review summary, students are encouraged to use the same structure used in their project to synthesize the Critical Review and reflect on the weakness and strengths of the Critical Review in relation to Goal and Scope Definition, Life Cycle Inventory, Life Cycle Impact Assessment and Interpretation. The Summary should be a maximum of three pages [times new roman 12 points, single spacing, and 0.5 inches margin on all sides].

Means of Evaluation

The basis for final grade of the course will be composed of points achieved in the components of the course namely Case Study Presentation, Project Presentation and Report, Tests (2) and LCA Lab.

The points from the four components will be graded as follows:

1. Project Report	30
2. Project Presentation	10
3. Test 1	15
4. Test 2	15
5. Case Study Presentation	10
6. LCA LAB	10
7. Critical Review	5
8. Class Participation	<u>5</u>
	100

The **Project Report** will be graded according to the marks shown below.

Item	Maximum Points
Goal and Scope Definition	5
Quantitative Part: Life Cycle Inventory and Life Cycle Impact Assessment	15
Interpretation	10

Note that the Goal and Scope Definition part to be submitted on **October 23** will be graded tentatively. For a potential increase in points for this part, a resubmission of a revised version as more knowledge is gained as the Project progress is possible as part of the Final Report.

Case study Presentation (**20 minutes per group**) and Project Presentation (**20 minutes per group**) will be marked based on individual performance during the Presentation and answers to questions asked. Presentations files for both the Case Study and Project are to be submitted before the Presentation time via DropBox in D2L. Project Report will be marked based on group performance except in the case where peer-rating and minutes signed by all members of the group are submitted and imply differential contribution.

For more detail on the project, **refer to a separate Project Description.**

For the LCA Lab, points will be based on answers to written questions for each Lab session. The answers should be submitted before the start of the next LCA LAB session. **See a separate LCA Lab Instruction.**

To get the minimum point of 3 out of 5 **for Class Participation**, an attendance of 75% of the non-Lab classes is enough. To exceed this minimum point, active participation in class is required.

Final grades will be reported as letter grades, with the final grade calculated according to the 4-point range. Correspondence between letter grades and 4-points scale will be based on the following grading scale.

Grade	Grade Point Value	4-Point Range	Percent	Description
A+	4.00	4.00	92.5-100	Outstanding - evaluated by instructor
A	4.00	3.85-4.00	85-92.49	Excellent - superior performance showing comprehensive understanding of the subject matter
A-	3.70	3.50-3.84	80-84.99	Very good performance
B+	3.30	3.15-3.49	76-79.99	Good performance
B	3.00	2.85-3.14	73-75.99	Satisfactory performance
B-	2.70	2.50-2.84	70-72.99	Minimum pass for students in the Faculty of Graduate Studies
C+	2.30	2.15-2.49	66-69.99	All final grades below B- are indicative of failure at the graduate level and cannot be counted toward Faculty of Graduate Studies course requirements.
C	2.00	1.85-2.14	63-65.99	
C-	1.70	1.50-1.84	60-62.99	
D+	1.30	1.15-1.49	56-59.99	
D	1.00	0.50-1.14	50-55.99	
F	0.00	0-0.49	0-49.99	

Notes:

- A student who receives a "C+" or lower in any one course will be required to withdraw regardless of their grade point average (GPA) unless the program recommends otherwise. If the program permits the student to retake a failed course, the second grade will replace the initial grade in the calculation of the GPA, and both grades will appear on the transcript.

Communication and Submission

Students are encouraged to contact course administration as follows,

Regarding the course as a whole:

E-mail: gassefa@ucalgary.ca

Phone: 403 220 6961

In person: PF 3191

Regarding LCA Lab:

E-mail: vsnaraya@ucalgary.ca

Submission of assignments (for both Project and LCA Lab) should **ONLY** be **done via Dropbox on D2L**.

Notes:

1. It is the student's responsibility to request academic accommodations. If you are a student with a documented disability who may require academic accommodation and have not registered with the Disability Resource Centre, please contact their office at 220-8237. (<http://www.ucalgary.ca/drc/node/46>) Students who have not registered with the Disability Resource Centre are not eligible for formal academic accommodation. You are also required to discuss your needs with your instructor no later than fourteen (14) days after the start of this course.

2. Plagiarism - Plagiarism involves submitting or presenting work in a course as if it were the student's own work done expressly for that particular course when, in fact, it is not. Most commonly plagiarism exists when:(a) the work submitted or presented was done, in whole or in part, by an individual other than the one submitting or presenting the work (this includes having another impersonate the student or otherwise substituting the work of another for one's own in an examination or test),(b) parts of the work are taken from another source without reference to the original author,(c) the whole work (e.g., an essay) is copied from another source, and/or,(d) a student submits or presents work in one course which has also been submitted in another course(although it may be completely original with that student) without the knowledge of or prior agreement of the instructor involved. While it is recognized that scholarly work often involves reference to the ideas, data and conclusions of other scholars, intellectual honesty requires that such references be explicitly and clearly noted. Plagiarism is an extremely serious academic offence. It is recognized that clause (d) does not prevent a graduate student incorporating work previously done by him or her in a thesis. Any suspicion of plagiarism will be reported to the Dean, and dealt with as per the regulations in the University of Calgary Graduate Calendar.
3. Information regarding the Freedom of Information and Protection of Privacy Act (<http://www.ucalgary.ca/secretariat/privacy>) and how this impacts the receipt and delivery of course material
4. Emergency Evacuation/Assembly Points (<http://www.ucalgary.ca/emergencyplan/assemblypoints>)
5. Safewalk information (<http://www.ucalgary.ca/security/safewalk>)
6. Contact Info for: Student Union (<http://www.su.ucalgary.ca/page/affordability-accessibility/su-structure/contact-info>); Graduate Student representative(<http://www.ucalgary.ca/gsa/>) and Student Ombudsman's Office (<http://www.su.ucalgary.ca/page/quality-education/academic-services/student-rights>).

Readings

Text book (Recommended but not Required)

Baumann, H. and Tillman, A.-M. (2005) The Hitch Hiker's Guide to LCA. An orientation in life cycle assessment methodology and application.

Journal Articles (optional)

Reap J, Roman F, Duncan S, Bras B (2008a) A survey of unresolved problems in life cycle assessment—part 1: goal and scope and inventory analysis. *Int J Life Cycle Assess* 13(4):290–300

Reap J, Roman F, Duncan S, Bras B (2008b) A survey of unresolved problems in life cycle assessment—part 2: impact assessment and interpretation. *Int J Life Cycle Assess* 13(4):374–388

Khasreen ,MM, Banfill. PFG, and . Menzies, G.F. (2009) Life-Cycle Assessment and the Environmental Impact of Buildings: A Review. *Sustainability*, 674-701 28 pages Download from <http://mdpi.com/2071-1050/1/3/674/pdf>

Bare, J. C. and Gloria, T. P. (2006) Critical analysis of the mathematical relationships and comprehensiveness of life cycle impact assessment approaches. *Environmental Science and Technology*, 40(4), 1104-1113.

Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T., Schmidt, W.-P., Suh, S., Weidema, B.P., Pennington, D.W. (2004) Life cycle assessment. Part 1: Framework, goal and scope definition, inventory analysis, and applications. *Environment International*, 30, 701-720.

Pennington, D.W., Potting, J., Finnveden, G., Lindeijer, E., Jolliete, O., Rydberg, T., Rebitzer, G. (2004) Life cycle assessment Part 2: Current impact assessment practice. *Environment International*, 721-739.

Hochschorner, E. and Finnveden, G. (2003) Evaluation of Two Simplified Life Cycle Assessment Methods. *International Journal of LCA*, 8, 119-128.

Project files

Ardente, F., Beccali, G., Cellura, M., & Lo Brano, V. (2005). Life cycle assessment of a solar thermal collector. *Renewable Energy*, 30(7), 1031-1054. doi:10.1016/j.renene.2004.09.009

Martínez, E., Sanz, F., Pellegrini, S., Jiménez, E., & Blanco, J. (2009). Life-cycle assessment of a 2-MW rated power wind turbine: CML method. *The International Journal of Life Cycle Assessment*, 14(1), 52-63. doi:10.1007/s11367-008-0033-9

Castro, M., Remmerswaal, J., & Reuter, M. (2003). Life cycle impact assessment of the average passenger vehicle in the Netherlands. *International Journal of Life Cycle Assessment*, 8(5), 297-304. doi:10.1065/lca2003.07.127

Scheuer, C., Keoleian, G. A., & Reppe, P. (2003). Life cycle energy and environmental performance of a new university building: Modeling challenges and design implications. *Energy & Buildings*, 35(10), 1049-1064. doi:10.1016/S0378-7788(03)00066-5

If more than four groups are required:

Apple (2012) iPhone 5 - Environmental Report

http://images.apple.com/environment/reports/docs/iPhone5_product_environmental_report_sept2012.pdf

Tentative Schedule

Activity	Topic	Date	Time	Venue	Instructor	Rem.
Lecture 1	Introduction and Project	Thursday, Sept 11	18:30 -21:20	PF2140	GAW	
Lecture 2	LCA Example – Coffee Machine and Food	Thursday, Sept 18	18:30 - 19:40	PF2140	GAW	
Pre-Lab 1	Lab Overview 1: Coffee Machine	Thursday, Sept 18	19:50 - 21:20	PF2170	VN	
Lecture 3	LCA Example – Wooden Shed and Biofuel	Thursday, Sept 25	18:30 - 19:40	PF2140	GAW	
Pre-Lab 2	Lab Overview 2: Wood Shed	Thursday, Sept 25	19:50 - 21:20	PF2170	VN	
Lecture 4	Goal and scope definition	Thursday, Oct 2	18:30 - 19:40	PF2140	GAW	
Lab 1	Goal and scope definition	Thursday, Oct 2	19:50 - 21:20	PF2170	VN	
Lecture 5	Life Cycle Inventory	Thursday, Oct 9	18:30 - 19:40	PF2140	GAW	
Lab 2	Life Cycle Inventory	Thursday, Oct 9	19:50 - 21:20	PF2170	VN	
Lecture 6	Data availability, quality and Databases	Thursday, Oct 16	18:30 - 19:40	PF2140	GAW	
Test	Test 1	Thursday, Oct 16	After lecture	PF2140	GAW	
Lab 3	Databases	Thursday, Oct 16	19:50 -21:20	PF2170	VN	
Lecture 7	Life Cycle Impact Assessment, LCA software and Interpretation	Thursday, Oct 23	18:30 - 19:40	PF2140	GAW	
Lab 4	Life Cycle Impact Assessment and Interpretation	Thursday, Oct 23	19:50 -21:20	PF2170	VN	
Submission	Goal and Scope Definition Part	Thursday, Oct 23	23:59			
Lecture 8	Reporting and Critical Review	Thursday, Oct 30	18:30 - 19:40	PF2140	GAW	
Project	Project Lab: Question and Answer	Thursday, Oct 30	19:50 - 21:20	PF2170	VN	
Presentation	Case Study Presentation	Thursday, Nov 13	18:30 - 19:40	PF2140	GAW, VN	
Presentation	Case Study Presentation	Thursday, Nov 13	19:50 - 21:20	PF2140	GAW, VN	
Lecture 9	Streamlined LCA and LCA in Practice	Thursday, Nov 20	18:30 - 19:40	PF2140	GAW	
Test	Test 2	Thursday, Nov 20	After lecture	PF2140	GAW	
Project	Project Lab: Q & A	Thursday, Nov 20	19:50 - 21:20	PF2170	GAW, VN	
Project	Project Lab: Q & A	Thursday, Nov 27	18:30 - 21:20	PF2170	GAW, VN	
Presentation	Project Presentation	Thursday Dec 4	18:30 -21:20	PF2140	GAW	
Submission	Project Report	Thursday Dec 11	23:59		GAW	
Submission	Summary of Critical Review	Thursday Dec 12	23:59			

GAW: Getachew Assefa Wondimeagegnehu VN: Vrinda Narayan