FTY 482: Industrial Ecology and Life Cycle Assessment

Fall 2009

## Course Information

FTY 482: Industrial Ecology and Life Cycle Assessment. This course introduces students to the theory and applications of environmental life cycle assessment (LCA) in engineering, corporate and government decision situations. Students will review cases, do problem sets, learn how to use LCA software, and conduct a project in LCA software package.

Number of credit hours: 3 (Lec)

Prerequisites: CHY 121 or BMB207; FTY 104 or MAT215 or MAT 232; INT110 or ECO120 or ECO 100; or permission.

## Faculty Information


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## Instructional Materials and Methods

Course materials will primarily be delivered through class lectures (presentation or workshop format) and computer works, so attendance are mandatory.

There is no required textbook for this course. However, I will use the following reference materials.

Heijungs, R., S. Suh (2002) The Computational Structure of Life Cycle Assessment, Kluwer Academic Publishers: Dordrecht, The Netherlands

Standards: ISO 14040:2006 and ISO 14044:2006

Allenby BR, Industrial Ecology: Policy Framework and Implementation, Prentice Hall, 1999.

Baumann H and Tillman A-M, The Hitch Hiker's Guide to LCA: An Orientation in Life Cycle Assessment Methodology and Application, Studentlitteratur, 2004.

Graedel TE, Streamlined Life-Cycle Assessment, Prentice Hall, 1998.

Guinée JB et al., Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards, Kluwer Academic Publications, 2002.

Hauschild M and Wenzel H, Environmental Assessment of Products. Vol 2 Scientific Background, Chapman & Hall, 1998

Wenzel H, Hauschild M & Alting L, Environmental Assessment of Products Vol 1 Methodology, tools and case studies in product development, Kluwer Academic Publications, 1997.

## Course objectives

The principal objective of this course is to develop basic knowledge and skills necessary to design and implement an LCA project. This course will also help students think critically about decision making that involve products and services.

## Learning Outcomes

At the end of this course, a student will be able to apply the basic concepts and principles of LCA, such as (i) applying the

ISO 14040 series to products and services, (ii) accessing life cycle inventory (LCI) databases, (iii) analyzing the results from a database search, (iv) implementing a LCA project, (v) working as a team, and (vi) communicating with others.

## Grading and Course Expectations

The grading will be based on participation and in-class activities (10%), mid-semester exam (20%), final exam (30%), five problem sets (20%) and a project report (20%).

## In-class activities

In-class activities are exercises (either written works or class discussions ) to strengthen students' understanding of the basic concepts and principles of LCA. These could include topics on comparative assertions, ISO standards and any relevant principles in life cycle thinking. There will be around 3 activities with 3-4% each, for a total of 10%.

## Exams

The first exam will be given half way through the course. The final exam will take place during the scheduled examination period and will be comprehensive. The format of the exams will be a combination of essay questions, short-answer questions, and problem solving.

Make-up exams will only be scheduled for unexpected events such as medical illness supported by a doctor’s note. Students who have no valid excuse will receive a zero for missing exams.

## Problem Sets

There are 5 problem sets with 4% each and will be given every other week. These problem sets are required to be done either in-class or be taken home using LCA software package. The problem sets are related to inventory analysis, allocation

problem, modeling characterization, impact assessment, sensitivity analysis and interpretation.

Late problem sets will be penalized one grade notch (e.g., 1 grade point) for each day it is late. The weekend counts as one day.

## Project Reports

Your project will be an LCA that recommends improvement opportunities within the life cycle of a chosen system. Students should form a group of 3 to 4 members. You need to submit a proposal.

*Details of Proposal*

Your proposal should include (1) an introduction describing the specific system you will evaluate and why you have chosen it (i.e., it is related to your current job or career goals, it is an environmental question you have had for some time, etc.), (2) a list and description of related environmental aspects considered obvious in the news or other literature (be sure to include citations), and (3) a list and description of example process alternatives (both good and bad) throughout the system life cycle.

*Sample Class Projects*

- LCA of PE bottles
- LCA of consumer products
- LCA of bio-ethanol (coming from corn, sugar cane, forest resources and other biomass resources)
- LCA of bio-diesel (coming from animal fats)
- LCA of syngas coming from gasification of municipal solid wastes or other biomass materials
- LCA of agricultural and forest based products (e.g. wood composites)
- LCA of polymer exchange membrane fuel cells

*Details of Project Reports*

Reports should have the following required parts.

*Part 1. Goal and scope definition.* The structure of goal and scope report is described in the ISO Standards. Specifically, you will need to define the goal and scope of the study; define the function, functional unit, and reference flows; define the initial system boundaries (including process flow diagrams depicting major material flows); identify data categories; data quality requirements; and recommendations for critical review. You must also include a brief description of the LCA methodology and a review of existing related LCAs/ environmental assessments.

*Part 1A Data gap analysis*. Develop a table listing the unit processes in the life cycle and the data sources available for each.

*Part 2. Inventory analysis.* Using the ISO Standards as a guide, your inventory analysis should include unit process data keyed to your process flow diagrams and quantifying relevant material and energy flows. Your inventory analysis must include a quantitative analysis of relevant life cycle stages. Data sources should be cited very carefully.

*Part 3. Impact assessment.* Using TRACI as a guide, your impact assessment must include characterization and normalization and may also include valuation.

*Part 4. Interpretation.* The findings from your inventory analysis and impact assessment should be evaluated on the basis of completeness, sensitivity, and consistency of the data.

*Part 5. Recommendations.* The conclusion of your report should support recommendations for resource conservation and pollution prevention.

*Report Requirements*

You're are expected to do database search, literature searches, etc.) outside of class.

Your project report should not exceed 25 pages of text, figures, and tables (not including appendices). Text should be 12-point and text in tables and figures should not be smaller than 10-point. Figures and tables should be integrated within the text of the description unless they are clearly part of an appendix. All citations should be complete.

The first page of report should have the course number (with section number), title, and student ID. Reports that lack any of this information will be penalized.

The project report contributes 20% of your grade and will be graded as follows:

Proposal 5%
Final Report and Oral Presentation 15%

## Tentative Location and Time

Lecture/Computer Work: Tue (am) 9:30 – 11:00 Nutting
Thu (am) 9:30 – 11:00 Nutting

## WebCT

Students may find additional course material such as course outline, announcements, project report details and related articles in the course WebCT at https://webct.umaine.edu/webct/urw/lc9140001.tp0/cobaltMainFrame.dowebct. However, some materials taught in class or the labs may NOT be posted on WebCT. These materials will NOT be provided to students with unexcused absences.

## Accommodation for Students with Disabilities

If you have a disability for which you may be requesting an accommodation, please contact Disability Support Services (**East Annex**, 581-2319) as early as possible in the term.

## Cell Phones

To extend professional courtesy to fellow students and guest speakers, turn off cell phones and other related electronic devices while in class.

## Academic Honesty

Academic dishonesty includes cheating, plagiarism and all forms of misrepresentation in academic work, and is unacceptable at The University of Maine. As stated in the University of Maine's online undergraduate "Student Handbook," plagiarism (the submission of another's work without appropriate attribution) and cheating are violations of The University of Maine Student Conduct Code. An instructor who has probable cause or reason to believe a student has cheated may act upon such evidence, and should report the case to the supervising faculty member or the Department Chair for appropriate action.

## Computer Labs in SimaPro/CMCLCA

Occasional labs dealing with the use of CMCLA/SIMAPRO software package for environmental life cycle analysis of products will be facilitated by the instructor or teaching assistant.

## Tentative Schedule of Topics

| | Discussion Topics, and Lecture Notes | Resources |
|---|---|---|
| Week 1 | Introduction<br><br>Goal and scope definition | Heijungs & Suh chapter 1<br><br>ISO 14040:2006 and ISO 14044:2006<br><br>Cooper, J.S. "Specifying Functional Units and Reference Flows for Comparable Alternatives," International Journal of Life Cycle Assessment, 8, 337-349 (2003)<br><br>Sheehan, et al. (1998) Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus. Prepared for the National Renewable Energy Laboratory, NREL/SR-580-24089. Available at www.nrel.gov/docs/legosti/fy98/24089.pdf |
| Weeks 2-3 | The basic model for inventory analysis<br><br>Computer Lab session<br><br>Project proposal due (2/4) | Heijungs & Suh chapter 2<br><br>Boustead, I. (1999) Eco-Profiles of Plastics and Related Intermediates. Prepared for the European Centre for Plastics in the Environment of the Association of Plastics Manufacturers in Europe (APME). |
| Week 4 | Inventory data sources<br><br>EcoInvent Laboratory | Jiménez-González, C., S. Kim, M.R. Overcash (2000) "Methodology for Developing Gate-to-Gate Life Cycle Inventory Information," International Journal of Life Cycle Assessment, 5(3) 153-159. |
| Weeks 5-6 | The refined model for inventory analysis | Heijungs & Suh chapters 3, 4, 6, and 7<br><br>Field, F., R. Kirchain, J. Clark (2001) "Life-Cycle Assessment and Temporal Distributions of Emissions: Developing a Fleet-Based Analysis," Journal of Industrial Ecology 4 (2) 71-91. |
| Week 7 | Impact | Heijungs & Suh chapter 8 |

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|---|---|---|
| | Assessment and an impact assessment example | Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) website |
| | EXAM 1 | |
| Week 8 | Interpretation<br><br>Computer Lab session | Heijungs, R., R. Kleijn (2001) "Numerical approaches towards life cycle interpretation: five examples," International Journal of Life Cycle Assessment, 6(3) Available at http://www.leidenuniv.nl/cml/ssp/publications/wp2000-001.pdf |
| Week 9 | LCA Applications, Tools, a Case Study, and Status | SETAC North America Streamlined LCA Workgroup (1999) Streamlined Life Cycle Assessment: A Final Report, Prepared for the Society of Environmental Toxicologists and Chemists, Available at http://www.setac.org/files/lca.pdf |
| Week 10 and onwards | Oral reports are given in class. Project reports are due. | |
| Final Exam Week | Final Exam (comprehensive). All work must be completed by the end of the final exam week. | |

## Details of Weekly Learning

*Week 1*

In this lecture we will spend time on conveying what will be taught in this course and how the course is structured. This will be like a planning session before a hiking trip, where we look at the map and show where we are going. We believe it is important for the students to be aware of where we are on the map throughout the course. If you get lost it should be easier to get back on track.

This first lecture will provide an overview of LCA. This includes goal and scope definition, functional unit, reference flows and

drawing a process flow chart. We will use an example of a forest resource based product such as bio-ethanol.

*Week 2 & 3*

In LCA, multiple numbers have to be multiplied simultaneously. To ensure that everyone understands the fundamentals how this is conducted, we will partially devote this session to elementary matrix computations.

We will learn to establish a simple life cycle inventory. The mathematical framework of LCA will be explored to study how we can establish data to describe flows between processes and respective emissions.

*Computer Lab Session*

The laboratory aims to give the students a firsthand experience in performing a simple LCA through a computer exercise where the students perform one of the examples in the CMCLA/SimaPro LCA software. After this session the students should have an overview of the various elements of an LCA.

*Week 4*

We will start with the formulation of a research question and the definition of a functional unit and move on to system border definitions and data gathering. We also present some of the larger LCA databases and discuss cut-off criteria, allocation, time, geographical, marginal and average issues. We will also devote time to find another data source for process interdependence: national accounts and input-output analysis.

*Week 5 & 6*

Combining input- output analysis and LCA into hybrid LCA has shown to be a good method for capturing the better of two

worlds. We present the essentials and the challenges involved in such an approach in this session.

In this lecture on inventory analysis we continue to discuss the combination of multiple data sources of process interdependence and emissions. We look into the operational challenges and among the topics covered are differences in handling capital, nomenclature, data-structures, differences in time and geographical distribution, uncertainty and more.

*Week 7*

We will cover how to perform impact assessment. We will look into how we can convert the large list of various emissions generated by the functional unit into more easily interpretable environmental impacts. We look into integrated methods that combine base indicators into a single indicator or a set of few indicators.

We present common indicators like Eco Indicator 99 and EPS2000. We will go through the basics of establishing the most common base indicators used in LCA, e.g. Global Warming Potential (GWP). GWP is an impact assessment indicator for greenhouse gases. We start with the base physics, identify stressors and their origins, look into the effects and consequences and finally show how the characterization factors can be developed to assess greenhouse gas emissions. We will also cover other impact indicators - acidification and eutrophication, toxicity, human health, particulate matter, ground ozone, abiotic depletion, ozone depletion, and biodiversity.

*Week 8*

In this section of the course we combine all aspects we have been through so far and spend some time on allowing you to perform a complete LCA computation to generate results. Furthermore, we discuss how to analyze the results we get, how

to present them and how to deal with uncertainty and sensitivity of assumptions.

*Computer Lab Session*

We start this section with an in-class computer exercise where the aim is to allow you to put together all pieces of information in the course so far. Working together in small groups, depending on size of available computer facilities, you will be presented with a pre-compiled dataset for you to perform calculations.

*Week 9*

This session is devoted to a project where you will be able to practice and apply what you have learned. Some of the lectures in this section will be converted into consulting sessions for your project work. If necessary, reiteration of LCA principles will be provided to assist you in finishing your project work on time.

*Week 10 and onwards*

It is important to be able to convey your research findings. To give a good presentation requires a fair amount of work. These weeks are scheduled for reporting your LCA projects.

## LCA Professional Certification

This course will help prepare a student to become a LCA certified professional. Global demand for such people is increasing. Even though completing this course does not result in certification, students can obtain certification by (i) meeting the requirements of LCA professional certification and (ii) taking the examination established by the American Centre for Life Cycle Assessment (http://www.aclca.org).