Draft Syllabus
Env159: Lifecycle Analysis
UCLA Winter 2012

Time and Location: Tue-Thu 9:30-10:50 AM BOTANY 325

Instructor: Deepak Rajagopal,
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Course description

The public discourse about the implications of current patterns of production and consumption of energy, and goods and services more broadly, suggest such patterns are environmentally and economically unsustainable. How should we then as individuals alter the choices we make and what types of actions should government policy encourage? In addition conservation and efficiency improvements, consider some of the other investment choices we face – gasoline car vs electric car, gasoline vs biofuel, nuclear vs coal electricity, paper vs plastic bags, conventional vs organic farming, concrete vs asphalt pavements, etc. These are complex choices. For instance while a paper bag is biodegradable it may consume more fossil energy, water, and chemicals than non-biodegradable plastic bags made from petroleum. This course is aimed at introducing basic concepts; analytical frameworks and quantitative techniques for systematically and holistically evaluating the environmental trade-offs presented by different alternatives to enable more informed decision-making. In particular, we will focus on the methodology of Lifecycle Analysis or Lifecycle Assessment (LCA), a well-established technique to compute the various material inputs and environmental releases from all activities associated with the lifecycle i.e., raw material extraction, processing, end use, and disposal, of a product or service. We will discuss the different approaches to LCA and their advantages and disadvantages. We will also discuss the strengths and limitations of LCA as a tool for decision-making compared to alternative approaches such as cost-benefit analysis and cost-effectiveness analysis. Students will have the opportunity to perform an LCA of a technology or a product or a service of their choice and present their findings to the class.

Prerequisites:

Basic knowledge of linear algebra - systems of linear equations, matrix algebra

Course website:

https://ccle.ucla.edu/course/view.php?name=12W-ENVIRON159-1

Course Materials and readings

The course material will comprise of lecture notes and readings based on selected published papers, popular articles and technical reports, and chapters from books all of which will all be available electronically through the course website.

Lifecycle Assessment: Principles and Practice. US Environmental Protection Agency Report -EPA/600/R-06/060 May 2006 *Available for download at* http://www.epa.gov/nrmrl/lcaccess/lca101.html

Other useful but not required references

- Life-cycle analysis of energy systems from methodology to applications, by Bent Sorensen, Published by *Royal Society of Chemistry*, June 2011
- Environmental life cycle analysis by David Ciambrone*, CRC-Press* 1997

Some major journals for papers on LCA

- Journal of Industrial Ecology, International Journal of Lifecycle Assessment, Environmental Science and Technology, Journal of Cleaner Production, Journal of Environmental Management, Ecological Economics, Energy.

Grading

The grading will be based on

- Homeworks (10%)
- Term paper (50%) - Due last day of the week instruction ends
- Final exam (40%) - Wednesday, March 21, 2012, 3:00pm-6:00pm
- Class participation (10%)

Term paper

The term paper is a team exercise to be undertaken in groups of 4-5 members. It comprised 50% of your grade. Students will be asked to form teams of four or five members initially and identify a product or service for which they will perform either a Meta-analysis of previous LCAs or perform their own LCA. Since interpretation of LCA is less complex when you used to compare two competing products, processes or services, the project should be a comparison of two such alternatives. Numbers in parentheses denoted the weight of each deliverable in the overall grade for the course.

1. One page proposal identifying the topic, team members (5%)
2. Preliminary outline (10%)
    - Motivation and objective
    - Data sources
    - List of references
3. Class Presentation (15%)
4. Final report (20%)

Each team member will be asked to assess the other members of their team, which will be taken into account in assigning the grades.

Late submissions will be penalized in the following manner:
Late by one day – 15%, Late by 2 days – 30%, Late by 3-5 days 50%, More than 5 days – 75%

Course outline
Part I: The Methodology of LCA

1. Introduction and course overview
Required Reading:
- R. A. Frosch and N. E. Gallopoulos: Strategies for Manufacturing, Scientific American 261 (3), 144-152 1989
- A. Kapur and T.E. Graedel: Industrial Ecology. *Encyclopedia of Energy*, Volume 3, 2004
- *Lifecycle Assessment: Principles and Practice* Chapter 1

Optional reading:
- Why Take A Life Cycle Approach? Report by *United Nations Environment Programme (UNEP) Division of Technology, Industry, and Economics* 2004 http://www.unep.fr/scp/publications/details.asp?id=DTI/0585/PA

2. LCA framework – The Phases of LCA
Reading:
- *Lifecycle Assessment: Principles and Practice* Chapters 1, 2 and 3.
- E. Nieuwlaar Life Cycle Assessment and Energy Systems *Encyclopedia of Energy*, Volume 3, 2004
- Lifecycle Analysis of Energy Systems: From Methodology to Applications by Bent Sorensen Chapter 2

3. Lifecycle Inventory Analysis – Process LCA
Reading:
- J. Bergerson and L. Lave Life Cycle Analysis of Power Generation Systems *Encyclopedia of Energy*, Volume 3, pages 635-645, 2004
- A. Stoppato Life cycle assessment of photovoltaic electricity generation *Energy* 33 (2008) 224–232
- Gloria Zhi Fu, Albert W. Chan and David E. Minns: Life Cycle Assessment of Bio-ethanol Derived from Cellulose, *International Journal of Lifecycle Assessment*, Volume 8, Number 3, 137-141, 2003
- M. B. Hocking Paper Versus Polystyrene: A Complex Choice, Science, Vol 251 1991

4. Lifecycle Inventory Analysis - Input Output Analysis I
Reading:
- C. Hendrickson, A. Horvath, S. Joshi and L. Lave: Economic Input-Output Models for Environmental Life-Cycle Assessment**.** *Environmental Science & Technology* **Policy Analysis** April 1, 1998 / Volume 32, Issue 7 / pp. 184 A-191 A
- http://www.eiolca.net/Method/LCAapproaches.html
- http://www.eiolca.net/Method/eio-lca-method.html

5. Lifecycle Inventory Analysis - Tools I

Reading:

- Introduction to LCA of the Smart Grid in GaBI – Lecture by Glenn Sias
- GREET Model - http://greet.es.anl.gov/

6. **Lifecycle Inventory Analysis - Input Output Analysis II**

Reading:

- Horvath and C. Hendrickson: Comparison of Environmental Implications of Asphalt and Steel-Reinforced Concrete Pavements, *Transportation Research Record* 1626 Paper No. 98-0661 105
- Cobas-Flores, E., Hendrickson, C.T.; Lave, L.B. and McMichael, F.C.: Life cycle analysis of batteries using economic input-output analysis *Proceedings of the IEEE International Symposium on Electronics and the Environment*, 1996. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=500411

7. Lifecycle Inventory Analysis- Hybrid Analysis

Reading:

- Limitations of the EIO-LCA and Process LCA model - http://www.eiolca.net/Method/Limitations.html
- S. Suh, M. Lenzen et al. System Boundary Selection in Life-Cycle Inventories Using Hybrid Approaches, *Environmental Science & Technology*, Vol. 38, NO. 3, 2004
- Clark W. Bullard, P.S. Penner and D.A. Pilati: Net Energy Analysis - Handbook for Combining Process and Input-Output Analysis *Resources and Energy* (1978) North-Holland Publishing Company

8. Lifecycle Impact Assessment

Reading:

- *Lifecycle Assessment: Principles and Practice* Chapter 4.
- Jane C. Bare, Gregory A. Norris, David W. Pennington, and Thomas McKone: TRACI **-** The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts *Journal of Industrial Ecology* Volume 6, Number 3–4

9. Uncertainty I – A general introduction

- *Uncertainty* – M. Granger Morgan and M. Henrion
- Should We Risk It *Exploring Environmental, Health, and Technological Problem Solving* by – D. Kammen and , David M. Hassenzahl

10. Uncertainty II – Sources of Uncertainty in LCA

Reading:

- *Lifecycle Assessment: Principles and Practice* Chapter 5.
- EIOLCA – Assumptions and Uncertainty http://www.eiolca.net/Method/assumptions-and-uncertainty.html
- Mark A. J. Huijbregts: A General Framework for the Analysis of Uncertainty and Variability in Life Cycle Assessment, *International Journal of Lifecycle Assessment*, 3 (5) 273 - 280 (1998)

- Mark A. J. Huijbregts: Dealing with Parameter Uncertainty and Uncertainty due to Choices in Life Cycle Assessment, International Journal of Lifecycle Assessment, *International Journal of Lifecycle Assessment* (6) 343-351 (1998)
- Finneveden et al. Recent developments in Life Cycle Assessment, *Journal of Environmental Management* 91 (2009) 1–21 (Section on Uncertainty)

11. Treatment of time and Total Lifecycle cost

Part II: LCA and decision making

12. **From Analysis to Assessment and from past to the future: Attributional versus Consequential LCA**

Reading:

- Tomas Ekvall and Bo P. Weidema: System Boundaries and Input Data in Consequential Life Cycle Inventory Analysis, *International Journal of Lifecycle Assessment*, 9 (3) 161 - 171 (2004)
- Lifecycle Analysis of Energy Systems: From Methodology to Applications by Bent Sorensen Chapter 3

13. **LCA in a policy context: The case of regulation of lifecycle GHG emissions from transportation fuels**

Reading**:**

- TBD

14. **Alternative approaches for sustainability assessment**

Reading**:**

- Goran Finnveden and Asa Moberg: Environmental systems analysis tools - an overview, *Journal of Cleaner Production* 13 (2005) 1165-1173
- Mattias Hojer et al. Scenarios in selected tools for environmental systems analysis *Journal of Cleaner Production* 16 (2008) 1958-1970

15. **Cost Benefit Analysis I – Conceptual foundation**

Reading:

- A.E. Boardman, D.H. Greenberg, A.R. Vining and D. L. Weimer: Cost Benefit Analysis – Concepts and Practice, Chapter 2, 2001

16. **Cost Benefit Analysis II – Valuing the Environment and Full Cost Accounting**

Reading:

- T. Tietenberg: Environmental and Natural Resource Economics, Publisher - Pearson Education 2003 Chapter 3, Valuing the Environment: Methods
- Richard L. Ottinger: Incorporating Externalities – The Wave of the future, Proceedings of Expert Workshop on Lifecycle Analysis of Energy Systems Paris, France, 21st - 22nd May 1992. OECD
- J. Peter Clinch Cost-Benefit Analysis Applied to Energy *Encyclopedia of Energy*, Volume 3, 715-725 2004

17. **Ecolabeling**

18. **Decision making under Uncertainty** – Guest Lecture

19. **Paper presentation**

20. **Paper presentation and Wrap up**

Useful online resources
US EPA LCA Resources:
- http://www.epa.gov/nrmrl/lcaccess/lca101.html
- http://www.epa.gov/nrmrl/lcaccess/resources.html
UNEP SETAC Lifecycle Initiative - http://lcinitiative.unep.fr/
American LCA Center - http://www.lcacenter.org/

Software
- http://www.epa.gov/nrmrl/lcaccess/resources.html#Software
- http://www.eiolca.net/
- http://greet.es.anl.gov/

Databases
- http://www.epa.gov/nrmrl/lcaccess/dataportal.html
- http://www.nrel.gov/lci/