Teaching LCA to Interdisciplinary Graduate Students

Joyce Smith Cooper

University of Washington

cooperjs@u.washington.edu

LCA Infrastructure at UW

- Research
  - **UWME DFE Lab:** LCA methodological advances and case studies in emerging transportation technologies
  - **College of Forest Resources:** the CORRIM Project is a model for multi-university collaboration in inventory analysis focusing on forest and wood products
- Degree and Certificate Programs
  - **Program on the Environment**
  - **Energy and Environment** in Mechanical Engineering (undergraduate concentration and soon-to-be graduate certificate)
- Courses
  - ME415/CEE495/ENVR415 Sustainability and Design for Environment
  - ME599JC Life Cycle Assessment

LCA at UW

- **ME599JC Life Cycle Assessment**
  - **In 2003, LCA was offered as a stand-alone course**
    - Offered to graduate students only
    - Final set of students represented Mechanical Engineering, the College of Forest Resources, and Public Affairs
  - **The course objectives were**
    - to analyze and apply the computational structure of environmental LCA and
    - to understand the relationship between the product life cycle, environmental impact, resource conservation, and pollution prevention.

Course Resources

- **Textbook:** Heijungs and Suh (2002) *The Computational Structure of LCA*
- ISO standards and articles on each assessment phase, streamlining methods, case studies
- **LCI and LCIA software:**
  - **CMLCA** ("Chain Management by LCA" developed by the textbook's authors and available FREE on-line)
  - **TRACI** ("Tool for the Reduction and Assessment of Chemical and other Environmental Impacts" available FREE on-line)
- **A web-board to facilitate data exchange**
  - a TWiki site designed to exchange inventory data that student's identified from publicly available sources or that they developed themselves

Assignments

- **Readings and participation in discussion**
- **Class project**
  - Each student analyzed a product or process related to:
    - their thesis or dissertation or
    - a personal interest
  - Given the time constraints of a 10-week course, the LCA projects included:
    - a goal and scope definition,
    - a list and impact classification of material and energy use and waste for the life cycle, and
    - an inventory and impact characterization of material and energy use and waste for **at least two life cycle stages**
  - Presentation included written and oral project reports

Results

- **Student Evaluations**
  - Students ranked the LCA class 5 on a scale of 0-5 for the course as a whole, the course content, and aspects of the effectiveness of the instructor
- **Strengths**
  - Combination of the web-based lecture notes, class discussion and project
  - Text provides a systematic method
- **Issues**
  - **Text lacked examples**
  - Web-board “not utilized” or “should be emphasized more”
  - Problems using TRACI

Text: ***The Computational Structure of LCA***

- Heijungs and Suh provide a consistent approach, terminology, and notation previously lacking and only partially addressed by archival literature and standardization efforts
- **Advantages**
  - the method is compatible with current inventory data collection and management practices
  - the computational structure forces the practitioner to account for the full life cycle of material and energy flows and explicitly accounts for “complications”
  - the matrix structure facilitates impact assessment and interpretation as currently applied by LCA practitioners.

Text: ***The Computational Structure of LCA***

- **Issues**
  - the text is designed for the at least somewhat-experienced LCA practitioner or the graduate student with some level of comfort in applying mathematical models to complex systems
  - As highlighted by the students and recognized by the authors, in practice or in the classroom, the text **MUST BE** supplemented by examples, LCA handbooks, standards, and archival literature
- Review in the *Journal of Industrial Ecology* (volume 7, no. 2)

Software

- **CMLCA** was not used
  - students used MSExcel and recognized the need for more powerful software for larger inventories
- **TRACI** was used by some students
  - TRACI includes characterization factors for almost 1,000 material and energy flows
  - TRACI allows the user to add material and energy flows and related characterization factors, however….

TRACI Documentation

- Bare, J., G. Norris, D. Pennington, T. McKone (2003) "TRACI: The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts," Journal of Industrial Ecology, 6 (3-4), 49-78.
  - **Very helpful discussion of mid-points vs. end-points**
  - **Good discussion of the impact assessment methods applied**
    - Because this and other TRACI documentation do not provide enough information to replicate the factors contained in the database, **there is no way to be sure additions are comparable**

Additional Documentation is Needed

- In the absence of this information, students were encouraged to:
  - **Assume materials not listed in TRACI to have a characterization factor of zero** for ozone depletion, global warming, fossil fuel depletion, acidification, eutrophication, and photochemical smog
  - **End their impact assessment with classification for:**
    - **Land use** (the user in all cases must apply the T&E method and enter the area of land use into TRACI (data sources?))
    - **Human health cancer and noncancer** (the user must ensure comparability among characterization factors in TRACI and as entered into TRACI)
    - **Human health "criteria air pollutants"** (factors are available for nitrogen oxides (NOx), PM10, PM2.5, sulfur dioxide (SO2), and TSP but not for ozone, carbon monoxide, and lead- appears TRACI is using a different definition for criteria air pollutants than EPA)

Web-Board

- A TWiki site is a *collaborative environment* designed to exchange inventory data that student's identified from publicly available sources or that they developed themselves
- **Classification of Data Sources**
  - Electricity production and modes of transportation, mining processes, chemicals and plastics production, …, multiple categories of processes, descriptions of or access to multiple data sources, …
- **Security**
  - Users must be approved to get into the system
  - Some files were password protected
- The web-board is at http://design.me.washington.edu/twiki/bin/view/_ME599jc/WebHome

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Welcome to the home of **TWiki._ME599jc**. This is a web-based collaboration area for ME599JC: LIFE CYCLE ASSESSMENT

This web-board is a TWiki site to be used to exchange inventory data that students identify from publicly available sources or that they develop themselves.

INSTRUCTIONS: Please add data sources (post Excel or Word files, URLS, etc.) and relevant information about the data includi (1) a name for the posting, (2) the developer of the data, (3) a BRIEF listing of the unit processes covered (can be specific as "Hydroelectric Power Production" or general as in "Electricity production"), 4) instructions or warnings about data access or use access, and (5) Your name and the date you added or updated the infromation. Also, feel free to add topics!

WARNING: Consider keeping an electronic list of your postings somewhere else.

ElectricityProductionandModesOfTransportation

MiningProcesses

ChemicalsAndPlasticsProduction

MetalsProduction

ManufacturingProcesses

RecyclingProcesses

WasteTreatmentAndStorageProcesses

OtherProcesses

MultipleCategoriesOfProcesses

DescriptionsOfOrAccessToMultipleDataSources

CaseStudies

Class Projects: goal and scope

- **Projects related to MS theses**
  - DNA chips (used to determine DNA compositions in biological samples)
    - **Goal:** identification and analysis of bio-hazardous materials
    - **Functional Unit:** analysis of 24 samples/hr
    - **Phases modeled:** manufacturing, use, and disposal of samples
  - An automated sonicating machine for pathogen sample testing
    - **Goal:** estimation and assessment of energy requirements
    - **Functional Unit:** “analysis of X samples/day” with no occurrences of cross contamination
    - **Phases modeled:** manufacturing and use

Class Projects: goal and scope

- **Projects related to MS theses (cont')**
  - PFSA as a PEM fuel cell membrane (MS thesis is LCA of PEMFCs)
    - **Goal:** assessment of material use and waste and related NFPA and HMIS hazards
    - **Functional unit:** propulsion of a 1532 kg "generic vehicle" (~4.2 kg PFSA) for 233,000 km over 12 years
    - **Phases modeled:** materials acquisition, materials processing, and membrane fabrication
- **Projects related to a PhD dissertation**
  - Comparison of timber production management intensities (PhD dissertation if LCA of timber production)
    - **Goal:** comparison of global warming and land-use impacts for Douglas fir timber management intensities
    - **Functional unit:** 10,305 ft^3 harvested timber at age 45
    - **Processes modeled:** seedling production, site preparation, planting, growth, and harvesting

Class Projects: goal and scope

- **Projects of a personal interest**
  - Pulp production in Korea
    - **Goal:** comparison of water use and contamination for virgin and recycled pulp
    - **Functional unit:** production of 1,000 kg pulp
    - **Phases modeled:** materials acquisition, materials processing, and membrane fabrication
  - Fuels for camp stoves
    - **Goal:** comparison of air emissions for butane blends, kerosene and white gas
    - **Functional unit:** heating 10L of water from 25 to 100 deg C
    - **Phases modeled:** use and package refilling and disposal

Suggestions for Improvement

- **By the students**
  - Have a continuation or perhaps a seminar on advanced LCA topics
- **By the instructor**
  - Enhance web-board
  - Extend discussion of impact assessment to include estimation of characterization factors already in TRACI

Visit the course website at
http://faculty.washington.edu/cooperjs/Education/ME599JC/ME599%20LCA%20Class.htm