American Center for Life Cycle Assessment &
Portland State University
Hatfield School of Government's Executive Leadership Institute

Present

InLCA/LCM 2007

International Life Cycle Assessment & Management 2007

From Measurement to Investment

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October 2007

Welcome to InLCA/LCM 2007!

We are very pleased to be holding this year's conference in Portland, Oregon. Portland is a city renowned for its concern for environmental issues, a leader in land use management and in public transportation.

The spirit of sustainable agriculture is expressed through the many restaurants and boutiques breweries that are located in the city. We have provided a brief listing of some of these locations and invite you to enjoy them during your stay here.

Portland State University is our partner for this year's conference. PSU lies in the heart of Portland, and in many ways the university is the heart of the sustainability movement in the area. The university hosts the Center for Sustainable Design and Innovation (CSDI) and the Center for Sustainable Processes and Practices as well as several degree programs. The university walks the talk, too. Several of the university buildings are LEED certified, and the campus operations focus on sustainability in transportation, energy, food service, landscape and custodial services.

Our conference is being held at University Place, the conference center owned by the university. I am sure we will have many stimulating conversations there and will make and strengthen our professional relationships as well as enjoy the many interesting presentations.

Welcome to Portland!

The Conference Planning Committee

Welcome to Portland, Oregon

Getting Around Portland

Downtown Portland is very easy to get around without a car - take advantage of the public transportation! If you need additional information, speak with the concierge at your hotel.

- **Max**
  This is the way to go. It is free within Fareless Square, which covers 300 city blocks. You can take the Max to go to Washington Park, the zoo, and OMSI. It is also very easy to take to and from the airport. Take note of the fareless zones because you will need to buy a ticket if you are outside this zone.

- **Portland Streetcar/Trolley**
  The Portland Streetcar runs on the street with traffic as a circulator between Portland State University, downtown, the Pearl District, and the Northwest District. It conveniently connects most of the food and attractions in and around downtown. You need to buy pass(es) for the trolley.

- **Taxi**
  Taxis are more difficult in Portland as they are few and far between and cannot be flagged down like NYC. Have the hotel call you one if you need to go anywhere from the hotel. You will be able to get a taxi from the airport. Phone numbers for cabs:
  Radio Cab 503-227-1212
  Broadway Cab 503-227-1234
  Portland Taxi 503-256-5400

What to do in Portland

Washington Park
Washington Park is the US's largest public park, located in SW Portland, which is close to downtown. To get there, take the Max to Goose Hollow Station.

In or near Washington Park:

1) **Japanese Garden**
2) **Hoyt Arboretum** – If the weather is nice, go for a walk or hike through the Hoyt Arboretum which has 10 miles of trails and offers spectacular views. The Hoyt Arboretum starts at the Washington Park MAX Station.
3) Oregon Zoo

Additional Activities
Powell's Books.
1005 W Burnside
You can spend an entire day browsing through this enormous and famous bookstore for used and new books. Visit especially if you are searching for a rare book or one no longer in print

Portland Art Museum
1219 SW Park Ave.

Portland Art Museum's collection includes European and American painting and sculpture, English silver, Asian art, Native American art, Pre-Columbian art, Cameroon and other African art, contemporary art, sculpture, prints and drawings, and photography. Open every day except Monday.

Oregon Museum of Science and Industry (OMSI)
1945 SE Water Ave.
The Oregon Museum of Science and Industry is one of the most popular attractions in Portland. OMSI offers a variety of interactive science displays and includes an OMNIMAX theatre, the Murdock Planetarium, and the USS Blueback Submarine.

Classical Chinese Garden
NW 3rd and Everett
Open 9 a.m. - 6 p.m.
An authentic Suzhou-style garden, the Chinese Garden is little changed from what might have greeted you during the Ming dynasty in China.
The Garden is located between NW 2nd and 3rd and NW Everett and Flanders in Old Town/Chinatown. The garden is also available by MAX or by buses 1, 4, 5, 8, 10, 16, 33, 40, and 77.

Saturday downtown Portland Farmers Market
South Park blocks at Portland State University, downtown Portland
Open Saturdays, 8:30 - 2:00.
If you are still here on the weekend, walk over to the park blocks at OSU and support the "Sustainable" community. Pick up some breakfast or lunch at any one of the artisan bread and pastry stores or local cheese producers and then browse through Oregon's Fall bounty.

Waterfront Park
Along the Willamette River on Front Ave (SW Naito Pkwy)
Great walk along the river and view of the east side of the city.

Places to Eat

Portland is blessed with more than its fair share of exceptional eating establishments across many styles of cuisines – and so many restaurants use sustainable practices. Below are a few. Reservations recommended.

- **Higgins** 1239 SW Broadway (503) 222-9070

Excellent Northwest cuisine. There is a formal dining area (reservation required) but also a more casual and modestly priced bistro area for which no reservation is needed. Largest selection of Belgian beers this side of Brussels.
http://higgins.ypguides.net/

- **Wildwood** 1221 NW 21st Avenue (503) 248-9663

Another excellent restaurant that offers Northwest cuisine. Reservation recommended.
http://wildwoodrestaurant.com/

- **Hot Lips Pizza** Various locations, including 1909 SW Sixth Ave and in the EcoTrust building.

Pizza by the slice. http://www.hotlipspizza.com/

- **Fife** 4440 NE Fremont St (971) 222-3433

Delicious Northwest cuisine located on the East side of town. You will need a car or taxi to get to Fife. http://www.fiferestaurant.com/

❖ **Pazzo Ristorante** 627 SW Washington (503) 228-1515
Excellent Italian food and an outstanding wine list. http://www.pazzo.com/

❖ **Bijou Cafe** 132 SW 3rd Ave (503) 222-3187
Local fresh ingredients. Snapper hash is a trademark favorite. Very popular, so expect to wait (and wait) for weekend breakfast.

<u>Additional Restaurants</u>

<u>Pacific Northwest</u>

❖ **Jakes Famous Crawfish** 401 SW 12th (503) 226-1419
A great place for fresh fish lovers! This 110 year old establishment offers not only lively atmosphere but also excellent food. This is the crown jewel (as wells as the 1st) in the McCormick & Schmicks chain. Note: don't get this mixed up with Jake's Grill (although owned by the same people). Reservation recommended.

❖ **Southpark** 901 SW Salmon (503) 326-1300
Reasonably-priced and excellent Northwest meets Mediterranean cuisine. Eat in the main dining room or go to Southpark's lively wine bar that offers a small-plate menu.

<u>Asian</u>
❖ **Typhoon** 2310 NW Everett St (503) 243-7557
Great Thai food in an entertaining lively atmosphere.

❖ **Sungari Pearl** 1105 NW Lovejoy St (971) 222-7327
Specializes in fresh, authentic elegant Chinese.

❖ **Pho Van Vietnamese Bistro** 1012 NW Glisan St (503) 248-2172
Specializes in fresh, authentic Vietnamese food.

<u>Pizza</u>
❖ **Old Town Pizza** 226 NW Davis (503) 222-9999
This would be a good opportunity to visit Portland's Old Town. Delicious pizza and the restaurant is located in one of the city's oldest remaining buildings (built in 1880). Sits on top of the haunted Portland underground. (http://oldtownpizza.com/)

❖ **Pizzacato** 705 SW Alder St. (corner of Alder and Broadway)
For a quick slice of yummy gourmet pizza. Also one on NW 23rd.

<u>Breakfast/Brunch</u>
❖ **Besaws** 2301 NW Savier St (503) 228-2619
A Portland tradition. Go early or plan to wait.

❖ **Mother's Bistro** 409 SW 2nd Ave (503)464-1122
Great brunch on Sat/Sun and wonderful comfort food the rest of the week. Traditional homemade inspired recipes like mom used to make.

Brew Pubs/Microbreweries

Portland and its surroundings are known as the birthplace & capital for microbrewed beer. Visit one or many to build a pub crawl into your itinerary!

- **Laurelwood NW Public House** – 2327 NW Kearny St. (503) 228-5553 Above average pub food to go along with award winning beers.

- **Rogue Ales Public House** – 1339 NW Flanders St
  This is a must for any & all beer *connoisseurs*. An extensive and impressive list of handcrafted beers. Give the Hazelnut nectar a try… it is delicious and made with Oregon hazelnuts.

- **Portland Brewing Company** - 2730 NW 31ST Ave (503) 228-5269 Another establishment that serves up food better than your average pub- everything from comfort food to tasty fish tacos. Focus on German style beers.

- **The New Old Lompoc** - 1616 NW 23RD Ave (503) 225-1855
  Good homemade beers and ales. Great outdoor patio in the back.

- **Pilsner Room/Full Sail Brewing Company** - 0307 SW Montgomery St (503) 222-5343
  Attached to the Haborside restaurant. Great location over looking the Willamette River. The atmosphere can get hyper in the summer and on weekends.

- **McMenamins Pubs** - McMenamins establishments are all over the Portland and Oregon area. Check out the website for the closest to you: http://www.mcmenamins.com.

Places to Day Trip

These are places that you would definitely need to rent a car to get to. Talk to your concierge about getting a map of these areas or tour options.

Mt. Hood

Located about 1 hour east of Portland, Mt. Hood is a beautiful place to visit. Timberline Lodge on Mt. Hood, used for the outdoor shots in the classic Stanley Kubrick/Jack Nicholson psychological- horror film *The Shining*, offers a spectacular view of the Cascade Mountains and Mt. Hood's glaciers. On your way to Mt. Hood, you can stop at Multnomah Falls (second highest waterfall in the US) and hike up the trail to view the falls. You can leave Mt. Hood by way of the backside and drive through thousands of acres of fruit orchards (aka The Fruitloop). (http://www.pova.org/visitors/daytrips/hood.html)

Columbia River Gorge

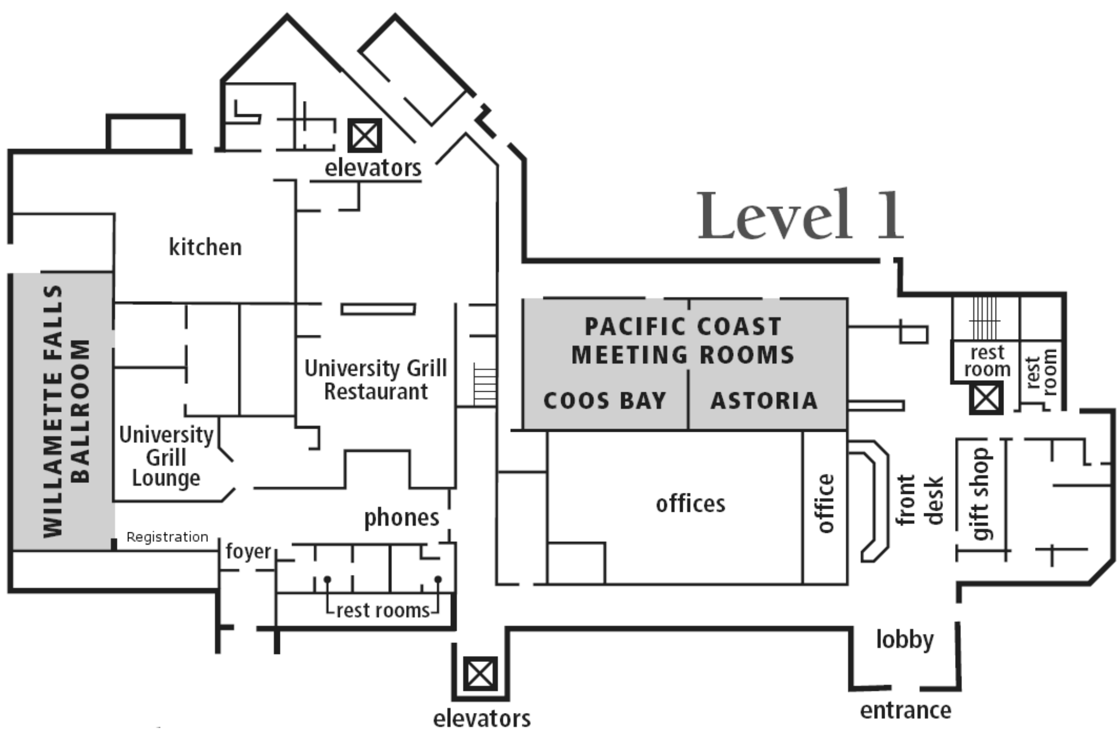
Almost the same drive as Mt. Hood, you can stop at Multnomah Falls on the way. For even better views of the gorge, take the old Gorge Highway and stop at the Vista House for breathtaking views from above. When you reach Columbia River Gorge you can stop in the town of Hood River for lunch and stroll around this water-sporty town. Hood River is also called the "the Aspen of windsurfing," and as the phrase suggests, many worldwide water-sporting events take place here. (http://www.pova.org/visitors/daytrips/hood.html).

The cliffs in the Columbia River Gorge tower 1,500 to 3,000 feet above the river and provide some of the most spectacular views. If you have good shoes and wish to hike to some of these views, there are some amazing hikes on the Washington State side, after you cross Bridge of the Gods.

Mt. St. Helens (Southwest Washington)

Visit Mt. St. Helens National Volcanic Monument and hike around and/or visit one of the several visitor and educational centers. (http://www.fs.fed.us/gpnf/mshnvm). Nearby you can visit Ape Cave and the surrounding parkland. Ape Cave is the longest lava tube in the conterminous United States (about 4 km long). Call or check the website first to be sure these areas are open. (http://vulcan.wr.usgs.gov/Volcanoes/MSH/ApeCave/description_ape_cave.html)

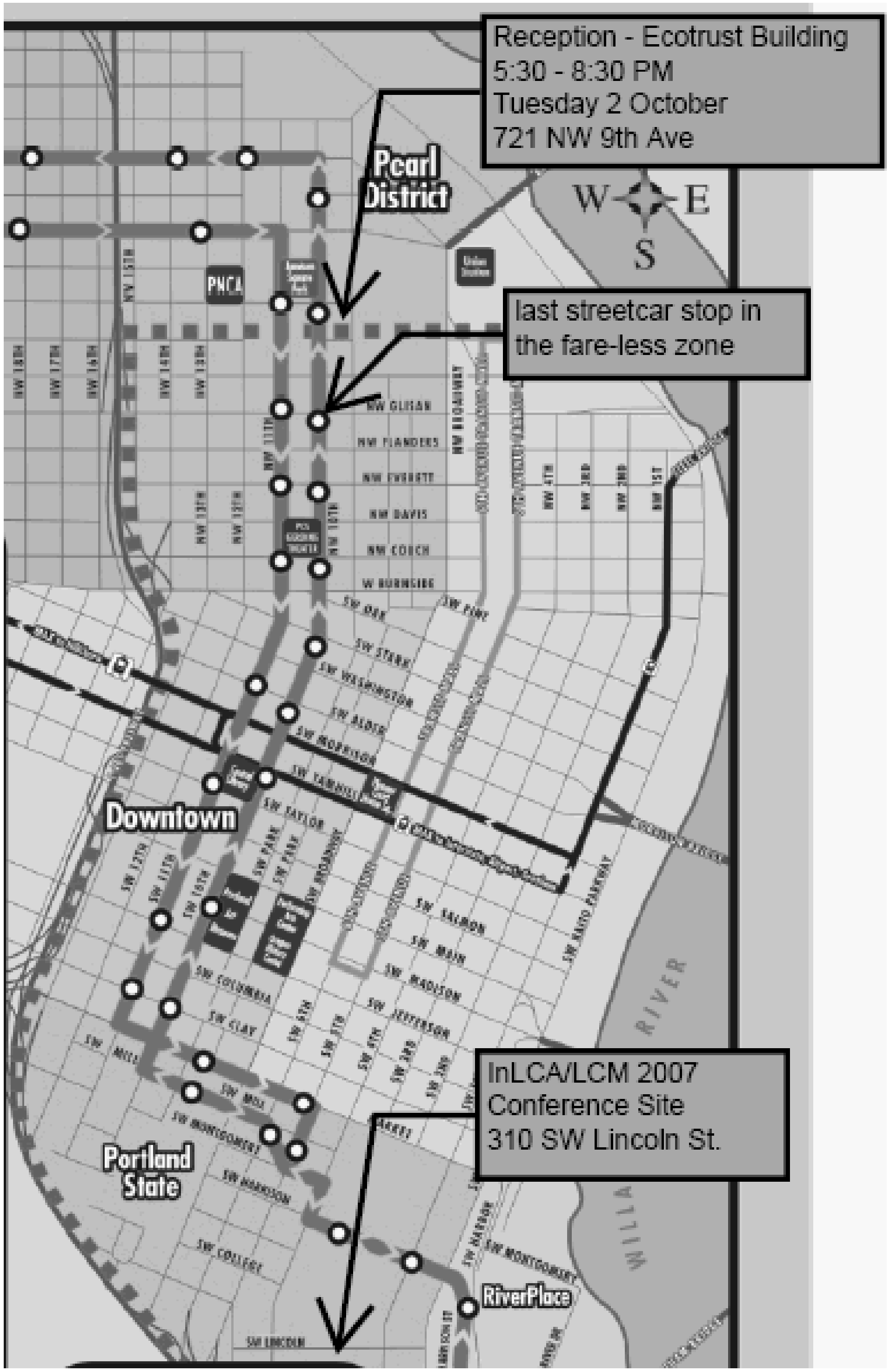
Meeting Rooms



<table>
<tr><td>Start Time</td><td colspan="3">Tuesday, October 2</td></tr>
<tr><td>Room</td><td colspan="3">Willamette Falls</td></tr>
<tr><td>8:30</td><td colspan="3">Registration</td></tr>
<tr><td>10:00</td><td colspan="3">Break</td></tr>
<tr><td>10:30</td><td colspan="3">Opening Plenary
Chair: Langdon Marsh

Jennifer Allen, PSU
Amy Zettlemoyer-Lazar, Sam’s Club
Mark Coffey, Shorebank Pacific
Bob Lilienfeld, The Cygnus Group</td></tr>
<tr><td>12:00</td><td colspan="3">Lunch (on your own)</td></tr>
<tr><td>Room</td><td>Astoria</td><td>Coos Bay</td><td>Willamette Falls</td></tr>
<tr><td>1:30</td><td>Power Generation (p13)</td><td>Green Buildings I (p.18)</td><td>Climate Policy in the Western States (p.23)</td></tr>
<tr><td>3:00</td><td colspan="3">Break</td></tr>
<tr><td>3:30</td><td>Biofuels (p26)</td><td>Green Buildings II (p 31)</td><td>LCA Implications of California’s Low Carbon Fuel Standard (37)</td></tr>
<tr><td>Evening</td><td colspan="3">Reception - Ecotrust Building
5:30 - 8:30 PM (see map on the next page)

Music by 3 Leg Torso</td></tr>
</table>



The closest streetcar stop to the Ecotrust building is just south of NW Johnson street (between Irving and Johnson) is outside the fare-less zone. If you use that stop you should purchase a ticket on board the streetcar ($1.75 – good all day). If you get off at the previous stop, between Flanders and Glisan, no fare is required.

Start Time	Wednesday, October 3		
Room	**Astoria**	**Coos Bay**	**Willamette Falls**
8:30	Social LCA (p. 39)	**Cancelled**: Financing Sustainability I	Energy (p.44)
10:00	Break		
10:30	Corporate Use of LCA (p.49)	Financing Sustainability II (p.55)	LCI (p.56)
12:00	Lunch (on your own)		
1:30	LCA & Consumers (p.61)	Measurement, valuation and pricing of ecosystem services (p.67)	Transport (p.68)
3:00	Break		
3:30	LCA and Regulation (p.74)	Intergenerational Finance and The New Bottom Line (p.80)	Packaging (p.81)
Evening			

Start Time	Thursday, October 4		
Room	**Astoria**	**Coos Bay**	**Willamette Falls**
8:30	LCM & LCA Education (p.89)	Impact Assessment (p.94)	Using the US LCI Database (p. 104)
10:00	Break		
10:30	Agriculture (p. 105)	LCA Methods (p. 109)	Choosing Life Cycle Impact Indicators (p. 115)
12:00	Lunch (on your own)		
1:30	Fisheries (p.116)	LCA Studies (p. 121)	LCA Professional Certification (p.127)
3:00	Break		
3:30	Closing Plenary **Bill Bradbury, Oregon Secretary of State**		
Evening			

Power Generation

Session Chair: Joe Marriott

Life Cycle Assessment of Dendrothermal Power Generation in Thailand including Economic Feasibility Analysis: A Case Study
Natanee Vorayos, Nat Vorayos, Tanongkiat Kiatsiriroat

Moving Towards a Mixed-unit LCA model for Power Generation
Joe Marriott, Troy Hawkins, H. Scott Matthews

Triple Bottom Line Life Cycle Analysis (TBL-LCA) Methodology at BC Hydro
Yasuhiko Ogushi, Cheong Siew, Thomas Mah

Life Cycle Assessment of Distributed Generation Options in California
Margaret K. Mann, Michael Whitaker, Marla Muelle

Power Generation

Life Cycle Assessment of Dendrothermal Power Generation in Thailand including Economic Feasibility Analysis: A Case Study

Natanee Vorayos,* Department of Mechanical Engineering, Chiang Mai University
Nat Vorayos, Department of Mechanical Engineering, Chiang Mai University
Tanongkiat Kiatsiriroat, Department of Mechanical Engineering, Chiang Mai University

The electricity generated from fuel-wood (dendrothermal electricity technology) has become one of the interesting alternatives to support Thailand national policy of which the ultimate goal is to reduce the degree of reliance on energy imports. The technology has been proposed due to the advantages such as its potential to substitute the conventional fossil fuel by the indigenous renewable energy resource, its relatively cheap cost and its benefit on labour employment in rural area. However, since environmental concern has extensively become another important factor for sustainable development during the last two decades, the consideration based on only the economic feasibility and its potential seems not to be adequate. In this study, the life cycle assessment (LCA) of the electricity generated from a pilot dendrothermal power plant using fast growing tree, i.e. acacia, as fuel-wood is carried out to investigate whether the application of dendrothermal technology or the conventional electricity generation system causes more environmental impact. The cost evaluation and the energy analysis during its life cycle are also determined. The result from LCA shows that the environmental impact of the electricity generated from the pilot plant is mainly caused by the greenhouse gas emission related to the fossil fuel and chemical substance consumption during fuel-wood plantation, transportation and steam production following by the impact caused by the other air pollutions. However, when the greenhouse gas emission is ignored due to the carbon dioxide absorbed by the photosynthesis of fuel-wood, the impact of the pilot plant becomes relatively low. Besides the advantage of environmental quality, the results from the cost and energy analysis during the life cycle also confirm that the dendrothermal power plant has high potential to be considered as one of the most suitable technologies for the sustainable development especially when the fuel-wood plantation and the transportation management have been taken into account.

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* corresponding author: natanee@dome.eng.cmu.ac.th

Power Generation

Moving Towards a Mixed-unit LCA model for Power Generation

Joe Marriott,* Civil & Environmental Engineering, Carnegie Mellon University
Troy Hawkins, Civil & Environmental Engineering, Carnegie Mellon University
H. Scott Matthews, Civil & Environmental Engineering, Carnegie Mellon University

Due to the economic and environmental importance of electricity, power generation is the subject of much interest. With supply chains reaching throughout the economy and around the world, electricity has also been the focus of many life-cycle assessments.

In previous work, we built upon the existing Economic Input-Output LCA (EIO-LCA) model by adding detailed electricity industry data. This detail was added by splitting up, or disaggregating, a single sector representing power generation into additional sectors, each representing a specific construction or operation portion of the electricity industry. Improving the resolution of the model in this way allows the user to distinguish among various methods of electricity generation such as wind, solar, coal, natural gas, and nuclear. For each of these disaggregated sectors we created a supply chain – what the sector purchased from the other 500 sectors in the economy in order to produce its output – and a set of emission factors which allowed calculation of the environmental impact of the sector's output.

As we move forward, adding new potential generation technologies and modeling uncertain future generation scenarios we reach the limits of a economic input-output model, such as changing commodity prices and technology advances. Some of these limitations can be overcome by representing output of the electricity sectors explicitly as kilowatt-hours rather than dollars. Such a mixed-unit input-output model reduces the need for price approximations and ties results directly to delivered electricity. This also allows for the calculation of an environmental inventory based on emissions factors rather than economic multipliers.

In this presentation we discuss our mixed-unit input-output model for electricity generation and present case studies demonstrating the usefulness of the mixed-unit input-output approach to modeling electricity generation.

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* corresponding author: marriott@cmu.edu

Power Generation

Triple Bottom Line Life Cycle Analysis (TBL-LCA) Methodology at BC Hydro

Yasuhiko Ogushi,* BC Hydro
Cheong Siew, BC Hydro
Thomas Mah, BC Hydro

BC Hydro is an electric utility company operating in the Province of British Columbia, Canada. The company is committed to meeting the energy needs of the Province with a focus on the environmental, social, and financial bottom lines. This Triple Bottom Line approach is being incorporated in business decisions to lead the way to a path to sustainability. The Triple Bottom Line Life Cycle Analysis (TBL-LCA) Methodology is the assessment framework for distribution assets that embodies the Triple Bottom Line principle.

BC Hydro has 56,000 km of distribution lines, 876,000 poles and 311,000 transformers and many other pieces of equipment and facilities across the Province. These distribution assets typically have an average of 30 to 40 years of life span. The sheer scale and long life span of distribution assets require a prudent, holistic and long-term view in investment decisions as it is costly to reverse the original decisions. Life-cycle thinking is a way of assessing impacts throughout the life cycle of assets and is essential in distribution asset management. The TBL-LCA Methodology is based on life-cycle thinking, and it further integrates a wide range of factors in the assessment framework to fulfil the commitment to Triple Bottom Line. Social and environmental factors, such as safety, waste generation, and greenhouse gas emissions, are incorporated in a consistent and quantitative manner. The goal of developing the TBL-LCA Methodology is to establish a framework that provides an optimum decision with an acceptable level of risk, satisfactory performance, and the lowest life-cycle cost. The TBL-LCA Methodology gives contrast to the traditional approach that tends to focus only on initial financial cost.

BC Hydro formulated the Methodology and piloted 10 assessment projects including distribution pole assessment, transformer selection, and conductor sizing. The outcomes of assessment projects indicate potential benefits and are expected to be reflected in system improvement projects and the development of standards in the following years. Further improvement of the Methodology for the next cycle of assessment is now underway.

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* corresponding author: yasuhiko.ogushi@bchydro.com

Power Generation

Life Cycle Assessment of Distributed Generation Options in California

Margaret K. Mann,* National Renewable Energy Laboratory
Michael Whitaker, Symbiotic Engineering
Marla Mueller, California Energy Commission

The National Renewable Energy Laboratory (NREL) has been funded by the California Energy Commission to conduct a life cycle assessment (LCA) study on distributed generation (DG) options in California. NREL examined the production of electricity by existing and emerging DG technologies compared to typical peaking power plants being built in California, typical natural gas combined cycle power plants, and possible coal-fired combined cycle power plants.

With this study, policy-makers will have a better understanding of the implications of recommending various options to utilize DG technologies to meet the growing demand for electricity in California. This study is not designed to advocate one option over the other, but instead provides additional information as to the life cycle emissions, resource consumption, and energy use of the various choices for DG. The results of this inventory are appropriate for identifying efforts to mitigate negative effects.

The technologies studied are:

- Peaking power plant specific to California
- Natural gas combined cycle power plant
- Integrated coal gasification combined cycle power plant
- Natural-gas simple cycle turbine power plant
- Natural gas-fired microturbines
- Natural gas-fired reciprocating engines
- Natural gas combined cycle
- Photovoltaics (PV)
- Anaerobic digesters located at waste water treatment plants
- Natural gas-fired molten carbonate fuel cells
- Natural gas-fired phosphoric acid fuel cells
- Small-scale biomass gasification
- Advanced ICE diesel-fired engines
- Anaerobic digesters using dairy waste

Important conclusions for this study are in the following categories: prime mover efficiency, natural gas produciton and delivery, local versus global emissions, and total greenhouse gas emissions. Generalized conclusions and example results to support these conclusions will be discussed.

* corresponding author: margaret_mann@nrel.gov

Green Buildings I

Session chair: Michael Deru

Hybrid Life Cycle Assessment Model for Construction Processes: Focus on Commercial Buildings
Melissa M. Bilec, Robert J. Ries, H. Scott Matthews, Aurora L. Sharrard

Automated Building LCA
Delwyn Gloria Jones, Peter Scuderi, Jennifer Rose Tobias

Comparison of the Life Cycle Assessments of Three Houses: Masonry, Insulating Concrete Form, and Wood Frame
Medgar Marceau, Martha VanGeem

Model-Based LCA on Stanford's Green Dorm
Jennifer Tobias, John Haymaker

Hybrid Life Cycle Assessment Model for Construction Processes: Focus on Commercial Buildings

Melissa M. Bilec,* University of Pittsburgh
Robert J. Ries, University of Pittsburgh
H. Scott Matthews, Carnegie Mellon University
Aurora L. Sharrard, Carnegie Mellon University

The design and construction industries have an increasing interest in and responsibility for a building's environmental impacts, which are considerable over a building's entire life cycle (design, raw material extraction and processing, construction, use, and end-of-life). While some existing research has assumed that the impacts of the construction phase are negligible; others have indicated that life cycle assessment (LCA) tends to underestimate the environmental impacts associated with construction. Part of the reason previous assessment of the construction industry's environmental impacts has not advanced is the construction industry's lack of data.

This research qualitatively and quantitatively examined the environmental impacts due to the construction phase of commercial buildings located in the United States. The research, conducted using LCA, also focused on further understanding and developing hybrid LCA modeling. The created process-based hybrid LCA model for construction will be presented, along with life cycle inventory results of PM emissions, GWP, SOx, NOx, CO, Pb, non-methane VOCs, energy usage, and solid and liquid wastes. Life cycle impact assessment results will also be presented for two to three impact assessment methods.

Results indicate that when compared with the entire building life cycle, construction - including service sectors such as design and construction management - is as important as the other life cycle stages of materials and end-of-life scenarios. In terms of hybrid LCA modeling, the process based LCA proved to be effective in modeling the construction phase and allowed for efficiently combining process and input-output inventories. Including input-output results, especially construction service sectors, is critical in construction LCA modeling. One case study's results demonstrated that services had the highest level of methane emissions and were a significant contributor to CO2 emissions. The results were reviewed to contextualize their significance and relationship to the United States Green Building Council's Leadership in Energy and Environmental Design rating system and the United States Non-Road diesel regulations with recommendations for improving both items.

* corresponding author: mbilec@engr.pitt.edu

Green Buildings I

Automated Building LCA

Delwyn Gloria Jones,* Australian CRC for Construction Innovation
Peter Scuderi, Australian CRC for Construction Innovation
Jennifer Rose Tobias, CIFE, Stanford University

Buildings make very significant internal, local and global environmental impacts. But conventional information technology for building Life Cycle Assessment (LCA) to assess such impacts has severe time, cost and communications limitations. These limitations restrict delivery of sufficiently meaningful LCA information to effectively support the broad-ranging practical decision-making needed to enhance building sustainability.

The Australian Cooperative Research Centre for Construction Innovation (CRC CI) has developed and trialled novel decision-support tools for use by Architectural, Engineering and Construction (AEC) practitioners. LCADesign is one such tool that automates building LCA by exploiting global industry foundation class (IFC) data transfer protocols.

The automated take off from IFC compliant 3D CAD models provides real-time LCA of building designs to AEC as well as LCA practitioners aiming for more sustainable project outcomes. The building supply-chain Life Cycle Inventory (LCI) that informs LCADesign was originally developed on top of one compiled by an Australian Government for the Sydney 2000 Olympic Games. To facilitate wide LCA and AEC practitioner acceptance LCADesign will also allow users to plug in other LCI using Simapro software.

The purpose of this paper is to outline LCADesign software:

- Development including its application of IFC protocols;
- Testing to ensure development to AEC professional standards;
- User experiences from testing across 21 CRC CI Industry partners and
- Interactions with practitioners in construction projects in three countries.

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* corresponding author: Delwyn.Jones@publicworks.qld.gov.au

Green Buildings I

Comparison of the Life Cycle Assessments of Three Houses: Masonry, Insulating Concrete Form, and Wood Frame

Medgar Marceau, CTLGroup
Martha VanGeem,* CTLGroup

An environmental life cycle assessment (LCA) was conducted on three single-family houses. Houses were similar except they were modeled with three types of exterior walls: wood framed, masonry, and insulating concrete form (ICF). The LCA was carried out in accordance with ISO 14044, "Environmental management — Life cycle assessment — Requirements and guidelines." The LCA includes the inputs and outputs of energy and materials from (i) extraction and manufacturing of materials, (ii) construction, (iii) occupancy, including heating and cooling energy use, and (iv) maintenance over a 100-year life. The houses were modeled in cities representing a range of U.S. climates. The ICF and wood frame houses were modeled in Miami, Phoenix, Seattle, Washington DC, and Chicago. The masonry and wood frame houses were modeled in Lake Charles, Tucson, St Louis, Denver, and Minneapolis.

The LCA was conducted by first assembling the relevant LCI data from published reports and commercially available databases. The LCA software tool, SimaPro, was then used to perform a life cycle impact assessment. The impact categories include land use, resource use, climate change, ozone layer depletion, human health effects, ecotoxicity, smog, acidification, eutrophication, and solid waste.

The house designs are based on typical houses currently built in the US and have 228 square meters (2450 square feet) of living space, which is close to the 2005 U.S. average of 226 square meters (2434 square feet). Each house is a two-story single-family unit with four bedrooms and an attached two-car garage. The same layout is assumed for the wood-frame, masonry, and ICF houses. The houses are designed to meet the requirements of the 2006 International Energy Conservation Code (2006 IECC) in all locations because the IECC is the most widely used residential energy code in the US. The energy saving features such as the windows and insulation are varied with climate to meet the requirements of the code. The HVAC equipment is sized for each location and for the peak heating and cooling loads of a particular house. Generally wood houses require larger HVAC equipment.

The paper compares, for a given climate, the environmental impacts for the wood, masonry, and ICF houses. The study is one of the most comprehensive available because it considers the same house construction for a wide range of climates and a complete range of impact categories. The most significant environmental impacts are not from building materials but from the production and household use of electricity and natural gas. Since the ICF walls are more highly insulating and energy efficient than the wood-frame and masonry walls (which are usually insulated to minimum code requirements) the ICF house has lower impacts.

* corresponding author: mvangeem@CTLgroup.com

Green Buildings I

Model-Based LCA on Stanford's Green Dorm

Jennifer Tobias,* Stanford University
John Haymaker, Stanford University

Architecture, Engineering and Construction (AEC) professionals want to use Life Cycle Assessment (LCA) as an integral part of design, but are hampered by a complex process, limited data, and insufficient tools. Model-based tools, such as LCADesign developed by the Australian Cooperative Research Centre for Construction Innovation, promise to help AEC professionals more easily perform and communicate LCA. The prototype LCADesign calculates the embodied environmental impacts from a 3D building information model represented in the global standards-based Industry Foundation Classes (IFC) format. Industry case studies are being conducted to evaluate whether such model-based LCA helps make environmental analyses a more integral part of AEC design.

This paper describes the application of LCADesign to determine the impacts of the Stanford Green Dorm, a 47-student residence and living laboratory. Of key interest are the impacts arising from the choice of wood or innovative steel rocking frame structural systems. We explain the analyses of these two design options, including the modeling of 3D geometry, and customization of local supply chains to improve the accuracy of the data. Our initial analyses found wood to be the environmentally preferred choice. However, with the high likelihood of earthquakes in the region, the design team broadened the scope to include likely seismic impacts. The Blume Center for Earthquake Engineering at Stanford University provided the required data to estimate the damages from an earthquake. We modeled the replacement materials, and performed a second assessment. In this iteration, contribution results showed steel to be the environmentally preferred choice. In subsequent design phases, the design team will investigate steel-wood hybrid systems to maximize the contributions from the durability of steel and the low environmental impacts of wood.

We discuss the strengths and weaknesses of the model-based process from the AEC designer's perspective. LCADesign easily allows the modification of building geometry and calculation and visualization of results. This iteration and real-time information enables LCA to become a more integral part of the design process. We address data quality and transparency issues that otherwise would remain an issue that reduces designers' confidence.

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* corresponding author: jtobias@stanford.edu

Climate Policy in the Western States

Session Moderator: Roel Hammerschlag, Stockholm Environment Institute

An overview of recent climate policy developments in the North American west is followed by three short descriptions of specific experiences, and a 30-minute roundtable discussion with audience participation.

Session Description

The Western Climate Initiative is a collaboration launched in February 2007 between the Governors of Arizona, California, New Mexico, Oregon and Washington to meet regional challenges raised by climate change. Since the initial launch, the Governor of Utah and Premiers of British Columbia and Manitoba have also joined the Initiative. WCI is identifying, evaluating and implementing collective and cooperative ways to reduce greenhouse gases in the region. The partners have set a regional goal of achieving aggregate emissions reductions to reach 15% below 1990 levels by 2020. By August 2008 they will also complete design of a market-based mechanism to help achieve that reduction goal.

Over the coming year, design of the market-based mechanism will need to draw in part upon concepts of LCA; different designs will have different demands on those concepts. LCA may be required explicitly, as in the existing example of California's Low Carbon Fuel Standard; LCA boundary-drawing exercises may appear implicitly when determining additionality and leakage associated with offsets generated outside of allowance markets; familiar but difficult choices surrounding resource allocation may appear in assignment of emissions rates to electricity. This session will be an attempt to explore and catalogue the experience the LCA community has to offer to the WCI process over the coming year.

Introduction to the Western Climate Initiative

Bill Drumheller – Oregon Department of Energy

Besides being a party to the Western Climate Initiative, the State of Oregon has had a greenhouse gas reduction strategy in place since April, 2005. Mr. Drumheller will review the WCI process thus far, and outline the possible consequences it may have for state-level GHG regulation, and GHG trading markets, in the near and medium-term.

Climate Policy in the Western States

Managing Climate Change in California

Alex Farrell

California's Assembly Bill 32, signed into law by Governor Schwarzenegger in September, 2006, requires the California Air Resources Board (CARB) to develop regulations and market mechanisms that will ultimately reduce California's greenhouse gas emissions by 25 percent by 2020. Those regulations will in turn spur specific responses by California citizens and industries, as well as additional government policies to assist in achieving the reduction goals. Professor Farrell will offer an overview of the various GHG-reduction actions likely to occur in California, and their relationships to LCA.

Experience with the Low Carbon Fuel Standard

Roland Hwang

California's Assembly Bill 1007, the Low Carbon Fuel Standard, requires GHG reductions associated with automotive fuels to be measured on a life-cycle basis. Mr. Hwang will review the triumphs and frustrations of the LCA community's experience interfacing with a major piece of GHG regulation.

Lessons from the Open Market

Mike Burnett

In 1997 the state of Oregon enacted the first law in the U.S. aimed at reducing greenhouse gas levels. This law requires new power plants built in Oregon to offset part of their emissions of carbon dioxide, and allows power plants to comply by paying mitigation funds to a non-profit organization that meets certain qualifications. The Climate Trust was chartered as such a qualified organization in 1997, and has since become one of the nation's premier purchasers of project-related greenhouse gas offsets. Mr. Burnett will review the Trust's experience with boundary-setting and other LCA issues arising from the purchase and resale of open-market GHG offsets.

Brainstorming Session

panelists and audience

Following the opening presentations, we will have an open discussion and brainstorming session to identify the areas of LCA expertise available to assist and inform the choices of climate policymakers. The goal will be to produce a draft, one- to two-page resource sheet that InLCA/LCM participants may utilize after the conference as a tool for interacting with the GHG policymaking community

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Climate Policy in the Western States

Presenters

ALEX FARRELL is an Associate Professor in the Energy and Resources Group at the University of California at Berkeley and Director of the UC Berkeley Transportation Sustainability Research Center. He holds a B.S. in Systems Engineering from the U.S. Naval Academy and a Ph.D. in Energy Management and Policy from the University of Pennsylvania.

BILL DRUMHELLER is a senior policy analyst in the Oregon Department of Energy.

ROLAND HWANG is a senior policy analyst in NRDC's energy program and works on transportation energy issues. Prior to joining NRDC, Roland was the director of the Transportation Program for the Union of Concerned Scientists in its Berkeley, California, office. He holds a master's degree in mechanical engineering from the University of California at Davis, as well as a master's in public policy from the University of California at Berkeley.

MIKE BURNETT is the charter Executive Director of Climate Trust, located in Portland, OR, and serves on the Global Warming Advisory Group appointed by Oregon Governor Ted Kulongoski. He earned an M.S. in Environmental Engineering from the University of Florida.

ROEL HAMMERSCHLAG (moderator) is an Associate Scientist in the U.S. Center of the Stockholm Environment Institute. He holds a Master of Public Administration from the University of Washington, and a B.S. in Physics from the Massachusetts Institute of Technology.

Biofuels

Session Chair: Ron Williams

Environmental Implications and Tradeoffs of Biobased Production
Amy E. Landis, Shelie A. Miller, Thomas L. Theis

Eco-Evaluation of Bio-diesel from Used Vegetable Oils in Small Scale Production in Thailand
Sate Sampattagul, Natanee Vorayos, Juntima Rewlayngean, Tanongkiat Kiatsiriroat

Life Cycle Assessment of Emerging Bio-Ethanol Pathways
Sabrina Spatari, Heather L. MacLean

LCA as a decision-supporting tool in production of biodiesel from Waste Cooking Oils (WCO): an industrial perspective
Cécile Querleu

Biofuels

Environmental Implications and Tradeoffs of Biobased Production

Amy E. Landis,* Department of Civil and Environmental Engineering, University of Pittsburgh
Shelie A. Miller, Environmental Engineering and Science, Clemson University
Thomas L. Theis, Institute for Environmental Science and Policy, University of Illinois at Chicago

Biobased products have emerged in today's economy in many forms, from corn-based plastic bottles to soy-based lubricants to fuels from both. In most cases, biomaterials exhibit benefits in the form of fewer greenhouse gases emissions and less nonrenewable fossil fuels usage when compared to their petro-counterparts. Research on the sustainability and environmental implications of these renewable fuels and products has been measured primarily based on reductions in emissions related to the C cycle (greenhouse gases and fossil fuels). Important tradeoffs in the N cycle are being neglected, such as eutrophication and hypoxia caused primarily in the US by agricultural runoff. As society increases its reliance on bio-based feedstocks, it is important to critically examine these non-carbon based environmental stresses and to determine methods for reducing negative effects and alterations to the N cycle. This presentation compares the C and N emissions and resultant impacts for a variety of biobased products (i.e. ethanol, biodiesel, plastics, and lubricants) from a variety of feedstocks (i.e. corn, corn stover, soybeans, switchgrass, sugar cane, rapeseed, kenaf, algae, woody biomass, sorghum) with respect to many environmental impacts of concern, including human health and eutrophication (and global warming). Using a combination of environmental modeling approaches with life cycle methodology and Monte Carlo Analysis, this presentation will explore the tradeoffs involved in transitioning from petro-products to bio-based products.

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* corresponding author: alandis@engr.pitt.edu

Biofuels

Eco-Evaluation of Bio-diesel from Used Vegetable Oils in Small Scale Production in Thailand

Sate Sampattagul,* Faculty of Engineering, Chiang Mai University
Natanee Vorayos, Faculty of Engineering, Chiang Mai University
Juntima Rewlayngean, Thermal System Laboratory, Chiang Mai University
Tanongkiat Kiatsiriroat, Faculty of Engineering, Chiang Mai University

At present, the cost of petroleum fuel is increasing worldwide, so the idea of using alternative fuel in the form of bio-diesel is becoming economically attractive. Bio-diesel can be produced from waste raw material such as from used vegetable oils and in Thailand there is interest in producing bio-diesel from such material at small scale. One can assess its environmental impact from a Life Cycle Assessment (LCA) point of view.

The objectives of this study were to assess life cycle environmental impacts of producing bio-diesel by using the CMU-2 machine with used vegetable oils and make recommendations for improvement. The system boundary of bio-diesel production process starts from material procurement, and includes production and use phases. The Numerical Eco-Load Total Standardization [NETS] model was employed to assess environmental impacts.

The results of the study show that the use phase represents 82.40% of the environmental impacts, followed by 17.45% in the production phase and 0.15% from the material procurement phase. The CMU-2 machine is made of stainless steel that contributes to the problem of natural resources depletion due to the limit of supply, so an alternative material should be sought. In the production phase, the bio-diesel byproduct glycerin should be reused into animal feed instead of disposing it as a waste which approach has been found to be responsible for 36.99% of the system environmental impacts.

Air pollution problem in the use phase was the most significant source of environmental impacts, but these impacts are still lower than found in petrodiesel. Mixing bio-diesel at 25%, 75% and 100% was recommended to reduce environmental impacts by 11.40%, 44.26% and 69.19%, respectively. In parallel, bio-diesel produced by using the CMU-2 machine costs 0.48 US-dollar/liter, comparing with the current diesel cost of 0.85 US-dollar/liter

In conclusion, bio-diesel production by using the CMU-2 machine can support improvements in efficiency in cost, energy, natural resources use and waste reduction. This leads to a more environmentally friendly outcome and supports a more sustainable society.

* corresponding author: sate@eng.cmu.ac.th

Biofuels

Life Cycle Assessment of Emerging Bio-Ethanol Pathways

Sabrina Spatari,* University of Toronto
Heather L. MacLean, University of Toronto

Ethanol derived from biomass (lignocellulose) shows promise as a near-term renewable fuel alternative to gasoline. Ethanol can be domestically produced, requires moderate infrastructure changes, and can reduce life cycle fossil energy consumption and greenhouse gas (GHG) emissions. This paper evaluates different ethanol production pathways considering different ethanol production and vehicle propulsion systems for comparison with reformulated gasoline and corn-based ethanol blended fuels, the standard market alternatives using life cycle assessment.

A set of promising lignocellulosic ethanol conversion technologies are evaluated in combination with different vehicle propulsion systems, including conventional drive and hybrid electric vehicles for near-term (c. 2010) development. The ethanol fuels are analysed as E85 blends (85% ethanol and 15% gasoline) for comparison with gasoline and corn-based E85 alternatives. Detailed material and energy balance models were constructed to characterize different combinations of feedstocks, pre-treatment and hydrolysis-fermentation technologies for the fuel production phase of the life cycle, which were combined with models of vehicle operation for different propulsion systems in order to assess the full life cycle of the lignocellulose-based E85 fuelled vehicles.

We examine the energy resource inputs (fossil energy and petroleum) and GHG emissions for the different lignocellulose-based E85 fuel pathways across the life cycle.

Relative to gasoline and corn-E85 vehicles, there are significant differences in fossil energy inputs and GHG emissions of the bio-ethanol fuel pathways. An explicit analysis of uncertainty using Monte Carlo simulation methods is undertaken and shows that relative to gasoline fuels, lignocellulosic ethanol pathways can reduce fossil energy and GHG emissions by 45%-160% and 25%-150%, respectively per kilometre driven. The importance of co-product allocation accounting procedures is illustrated in this work by showing how the uncertainties in the biomass-based co-products analysed affect the life cycle metrics presented.

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* corresponding author: sabrina.spatari@utoronto.ca

Biofuels

LCA as a decision-supporting tool in production of biodiesel from Waste Cooking Oils (WCO): an industrial perspective

Cécile Querleu,* Veolia Environnement

The perspective of climate change, the high energy prices and the oil supplies have driven a strong interest in alternative transportation fuels. Biofuels have become a hot topic and a large number of environmental studies have been published on the subject. A lot of these studies follow the methodology of the Life Cycle Assessment (LCA), probably the most appropriate method to evaluate the global impact of a biofuel on the environment from well-to-wheel.

But if biofuels present advantages in terms of energy use and emissions of greenhouse gases compared to fossil fuels, one can wonder if additional pressure won't be created on agriculture, biodiversity, water and soil resources with a strong development of the biomass.

In order to optimize the management of waste together with the production of energy, waste cooking oils (WCO) can be used for the production of biodiesel. This biodiesel could then be used in transportation services, like the buses for passengers. Such a project is being carried out by VEOLIA Environnement. The Group offers environmental services like management of waste and public transportation so the biodiesel from WCO could be used in the captive fleet of buses.

LCA is being used to back up the project, in the aim of supporting the stakeholder discussion and decision making during the planning phase of the new technology installation. The goal of the study is also to do a comparative LCA between biodiesel made from WCO with fossil diesel and biodiesel from dedicated energy crops.

This study is internal and still in progress. The system boundaries consider the collection of oils (WCO are collected all over France), the transformation of the WCO in biodiesel and the use of this fuel in the buses of the Group. Results will be available at the end of the year.

* corresponding author: cecile.querleu@veolia.com

Green Buildings II

Session Chair: Michael Deru

Incorporating Life Cycle Analysis into Early Stage Office Furniture Product Development
Caroline Conway, Michael D. Lepech, Gregory A. Keoleian, Denise VanValkenberg, Bradley Youngs

LCA Case Study of Interior Hospital Construction
Liila Woods, Scott Charon, Julie Sless

Evaluating Literature Life Cycle Data: A Case Study for Electrical Metallic Tubing
Steve Barr, Todd Krieger

Life Cycle Performance of Electrical Building Cables: Energy Efficiency and Climate Change Improvement Opportunities
Paola Kistler, Gerald Rebitzer, Ravi Ganatra

Incorporating Life Cycle Analysis into Early Stage Office Furniture Product Development

Caroline Conway, Center for Sustainable Systems, University of Michigan
Michael D. Lepech,* Center for Sustainable Systems, University of Michigan
Gregory A. Keoleian, Center for Sustainable Systems, University of Michigan
Denise VanValkenberg, Steelcase, Inc.
Bradley Youngs, Steelcase, Inc.

Increasing focus is being directed toward improving indoor work environments and the environmental quality of office spaces. Evidence of this is embodied in current USGBC LEED® rating schemes for commercial interiors which aim to “reduce the quantity of indoor air contaminants that are odorous, potentially, irritating and/or harmful to the comfort and well-being of installers and occupants.”

To meet growing demand for environmental product innovations into the workspace, a comprehensive life cycle assessment (LCA) approach is used to examine the environmental impacts of office furniture from raw material extraction through production, distribution, use, and end of life. Because a full LCA requires significant time and resources, many firms perform this analysis after the product is complete, relying instead on qualitative criteria and approximate impacts during development.

However, the decisions that determine a product’s final impacts are most often made in early-stage product development when functions, materials and production methods are identified. The use of LCA methods during this stage can therefore make great strides toward reducing a product’s environmental impacts. In particular, a tool designed for use by product developers and tailored to increasingly incorporate company-specific data as the product is developed can identify a wider range of environmental opportunities and feed into final LCA reports for the product.

Steelcase® has pursued intensive LCAs of six completed office furniture products and is now focused on integrating this analysis into early-stage product development. The completed studies found that most impacts can be addressed through appropriate product design decisions, supply chain management, and manufacturing process choices along with end-of-life management strategies.

To encourage early identification of these improvements, a software tool is being developed for Steelcase that helps product development teams evaluate environmental performance and make informed tradeoffs between product design, material, sourcing, and manufacturing alternatives. The software relies on a unique combination of industry-averaged and firm-specific data to provide a wide selection of design choices while ensuring the results reflect firm-specific innovations. A case study progressing through product development and guided by life cycle analysis metrics is presented, and conclusions related to the tool’s efficacy are drawn from this study.

* corresponding author: mlepech@umich.edu

Green Buildings II

LCA Case Study of Interior Hospital Construction

Liila Woods,* Five Winds International
Scott Charon, Herman Miller Inc.
Julie Sless, Herman Miller Inc.

In this study, the comparative environmental performance of two interior hospital buildout options was examined from a life cycle perspective. The first option involved fixed millwork and conventional wall construction while the second option comprised of Herman Miller's modular casework and movable wall systems. The buildout consisted of interview rooms, exam rooms, nurse stations, nurse reception, pharmacy, laboratory, and interior dividing walls of an entire hospital. GaBi 4 software was used to evaluate the environmental performance of the two buildout options based on global warming potential, primary energy demand, and waste generation. It was found that the modular casework and movable walls have a substantially lower potential to contribute to environmental impact than their fixed millwork equivalents when replacement scenarios considerations were included.

Casework and walls have a high replacement rate in health care applications, therefore three scenarios were developed to capture the additional materials required and waste generated during remodeling and replacement. The three scenarios include a range of replacement rates over a 12-year time span from a conservative to a much more rapid replacement rate typically observed. The 12-year time period and replacement rates and scenarios were chosen to correspond to Herman Miller ROI (Return on Investment) models developed to estimate the cost of replacement and remodeling. These models assume that approximately 2% of casework is replaced every year and between 20% and 100% is replaced every five years due to damage and changing needs of the space within the hospital. Walls are replaced every five years with replacement rates of 15-50%. During each replacement year it was assumed that 5% of new materials are required for remodeling with modular casework while 100% of new materials are required for remodeling of conventional millwork.

As expected, the initial impacts associated with both options were nearly equal at buildout. However, when factoring the renovation and replacement activities over the projected 12-year time span a very different perspective emerged. The life cycle energy used, the greenhouse gas (GHG) emissions, and waste generated were projected to be substantially higher for the fixed millwork hospital buildout.

Hospitals are rapidly changing built environments that require durable and flexible interior spaces. The overall results of this study demonstrate that if one were to consider the environmental burdens associated with only the build-out phase, the substantial differences between conventional construction practices and innovative modular interior systems would not be observed. The consideration of replacement over the life cycle yields dramatically different results and that modular casework and walls contribute less to climate change, primary energy consumption, and waste generation when compared to fixed millwork casework and walls when considering their entire life cycle.

* corresponding author: l.woods@fivewinds.com

Green Buildings II

Evaluating Literature Life Cycle Data: A Case Study for Electrical Metallic Tubing

Steve Barr,* DuPont
Todd Krieger, DuPont

Life cycle analysis often requires data outside the expertise and supply of the company performing the study. Life cycle databases and literature searches are used to fill data gaps as necessary. If the influence on the overall life cycle study of these processes is significant, the data quality must be examined. When multiple data sets are available, there is often added confusion, instead of clarification. Which data set more accurately reflects the impact categories required for the study? Do the literature processes provide adequate data to address all impacts of interest, such as energy consumption, contribution to climate change, and human toxicity? A broader study required the development of a life cycle inventory (LCI) for electrical metallic tubing (EMT). With EMT as a case study, a methodology was developed to generate a comprehensive and representative LCI from life cycle databases, literature sources, and industry reports.

The overall impact from the conduit and other steel pieces is significant within the broader study due to the mass of steel required. Using existing literature models, the results for EMT in certain impact categories were shown to vary greatly. For example, the impact results for greenhouse gas emissions vary by as much as 66% using the different models. Conclusions of the broader study could be affected in some instances. The goal for this portion of the broader study was to develop a credible and representative life cycle model for the manufacture of EMT with particular focus on energy consumption, greenhouse gas emissions, and human toxicity. The model used must be defensible to critics such that the assumptions do not compromise the integrity of the broader study.

For this study, the functional unit is the cradle-to-gate manufacture of 10ft of 2" galvanized EMT. The broader study required various sizes of EMT and assorted galvanized pieces. Secondary steel data available in SimaPro™ life cycle software, including Ecoinvent™ (based on IPPC best available technique (BAT)), Franklin, and ETH-Zurich, were analyzed. Data publicly available from the steel industry, particularly the International Iron and Steel Institute (IISI) "World Steel Life Cycle Inventory Methodology Report 1999/2000" was also evaluated. Eventually, a model was developed that used the IISI LCI data for credibility with that industry. However, certain emissions which were notably omitted in the IISI life cycle inventory (LCI) were included in the accepted model based on the IPPC European BAT data to close the data gaps. Comparisons of the impact assessments for the various models are included.

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* corresponding author: steve.barr@usa.dupont.com

Life Cycle Performance of Electrical Building Cables: Energy Efficiency and Climate Change Improvement Opportunities

Paola Kistler,* Alcan
Gerald Rebitzer, Alcan
Ravi Ganatra, Alcan

The building industry is one of the most important economic sectors both in industrialized as well as in emerging regions of the world. However, it is also one of the sectors with the highest contribution to man-made environmental impacts. Specifically in regards to actions against climate change and energy resource depletion this sector has to play a major role. The use phase and the resulting energy and greenhouse gas footprints (in addition to other aspects) as well as the complete value chain for the construction and end-of-life phases have to be taken into consideration in order to provide well-founded design recommendations and decision support.

A central element of virtually all modern buildings are electrical cable installations. In order to evaluate the environmental impacts of its products and to identify areas for improvement in sub-sequent decision-making, Alcan Cable has conducted life cycle assessments of different building cable systems. The overall environmental life cycle performance of cable systems based on aluminum and copper has been assessed, taking different design options into account. The results show that life cycle assessment (LCA) is well usable to compare different design options and to support decisions in cable and resulting building designs. Taking into consideration the supply chain impacts, the use phase and the end-of-life aspects, recommendations for specifications are obtained.

The results are then put into the context of the climate change debate and it is discussed how they can be used in the policy discussion, if the bigger picture related to potential market penetration of optimized cable systems is taken into account. A concurrent economic assessment shows how win-win situations can be accomplished, both from an environmental as well as a economic point of view for the cable producer, the building owner and operator and related to the broader societal perspective.

* corresponding author: paola.kistler@alcan.com

Life Cycle Assessment Implications of California's Low Carbon Fuel Standard

Special Session Coordinator: Heather L. MacLean, University of Toronto

Four brief presentations (15 min. each) and a 30 min. moderated roundtable discussion with audience participation. The session and discussion will be chaired by Prof. Heather MacLean, University of Toronto.

Session Description

The California Legislature passed the Global Warming Solutions Act on August 31, 2006 (AB 32 Núñez/Pavley). This law enacted economy-wide greenhouse gas (GHG) emission reduction goals of about 25% below business as usual by 2020. It authorizes the California Air Resources Board (CARB) to identify "discrete early action measures" that can be put into place by 2010. An Executive Order by Governor Schwarzenegger on January 18, 2007 established the Low Carbon Fuel Standard (LCFS) and set a statewide goal to reduce the carbon intensity of California's transportation fuels at least 10% by 2020. The LCFS Executive Order instructed the University of California to study the policy and provide advice on how to implement the policy.

The California LCFS is one of the first policies that will be based on systematic life cycle assessment (LCA), following a similar regulation in the United Kingdom. To implement the regulation, the climate change impacts associated with a large set of different fuel production/vehicle pathways must be investigated though a comprehensive LCA framework. Lessons learned from the implementation of the LCFS will be key for stakeholders in many jurisdictions. Proposals to implement LCFS-type regulations are emerging in the U.S. federal government, several Western U.S. states, Canadian provinces, and in Europe. The presentations in this session discuss the University of California's analyses of the LCFS, focusing on how LCA may be used in this regulatory context, as well as its potential impact on the field of LCA. A focus of several of the session presentations is the development and application of LCA models to evaluate biofuels and heavier fossil fuel feedstocks such as the Canadian oil sands. The potential impacts of California's LCFS on the biofuels and oil sands industries are also addressed.

Comparison of Current Oil Sands Technologies Using Process-based LCA

Alex Charpentier and Heather L. MacLean – University of Toronto

The transportation fuel market in North America increasingly relies on oil supply from the Canadian province of Alberta which possesses the second largest established reserves of oil in the world. Alberta's oil sands consist of a very heavy and viscous bitumen whose development is both highly capital and energy intensive. The California LCFS and other upcoming regulations are increasing interest in inventorying the full set of energy and environmental impacts of this unconventional feedstock for transportation fuels. Process-based LCA is used to estimate the environmental implications of the production of transportation fuels through the two current mainstream oil sands extraction technologies: surface mining and steam-assisted in-situ recovery for shallow and deeper reservoirs, respectively. Life cycle energy use and GHG and air pollutant emissions are compared to results from literature and from two process-based LCA models of oil sands pathways. Finally, potential variation in the carbon intensity of the oil sands-to-gasoline pathway is analysed by examining scenarios such as natural gas substitution for recovering oil sands.

Comparison of Oil Sands Technologies Using Hybrid LCA

Joule Bergerson and David Keith

We apply a hybrid life cycle assessment model to investigate the implications of various oil sands operations. This hybrid approach combines the benefits of the process based framework (including process level data specific to oil sands operations in Alberta) and the economy wide Canadian economic input-output LCA model in order to address the economic and environmental impacts of oil sands operations. This paper presents results of industry surveys and the use of the hybrid LCA framework to demonstrate the magnitude and range of supply chain emissions and the impact the California LCFS will have on this industry. The results of these assessments are then compared to the results from the process model described in the previous talk.

Biomass-based mitigation options for liquid fuel CO_2 emissions within an LCA policy framework

James S. Rhodes and David W. Keith

Increasing biofuels development is a potentially important option for managing anthropogenic CO_2 emissions from liquid fuels. Policy instruments adopting life cycle analytic frameworks, including California's Low Carbon Fuel Standard, are particularly suited to support this option due to the inherent ability of such frameworks to account for CO_2 uptake during biomass feedstock production. Similarly, LCA-based policy instruments could support bio-energy systems that integrate carbon capture and storage systems to produce useful energy products with negative net atmospheric carbon emissions. This presentation will discuss several bio-energy production pathways, each of which have been characterized with engineering-economic models. The relative merits of these pathways will be discussed in terms of their potential contributions toward proximate abatement targets and their likely mitigation costs. The implications of these results for proximate policy development will be discussed and several questions will be raised for consideration by both life cycle analysts and the broader policy community.

Implications of California's Low Carbon Fuel Standard

Alex Farrell

The Low Carbon Fuel Standard is the first significant climate change policy designed specifically to regulate transportation fuels, which account for about a third of U.S. GHG emissions. As proposed, it relies heavily on LCA and will have significant implications for capital investment and technological innovation in the fuels sector. This talk will describe the basic features of the LCFS, what methodological questions it raises for the application of LCA in a regulatory context. The talk will conclude by posing several key questions to the audience based on the above presentations and the experience to date with the LCFS.

Presenters

Joule Bergerson is a Postdoctoral Fellow in the Institute for Sustainable Energy, Environment and Economy at the University of Calgary.

Alex Charpentier is a Doctoral Student in the Department of Civil Engineering at the University of Toronto.

Alex Farrell is an Associate Professor in the Energy and Resources Group at the University of California at Berkeley and Director of the UC Berkeley Transportation Sustainability Research Center.

David Keith is the Canada Research Chair in Energy and the Environment at the University of Calgary.

Heather MacLean is an Associate Professor in the Department of Civil Engineering at the University of Toronto.

James Rhodes recently received a Ph.D. in Engineering and Public Policy from Carnegie Mellon University and is currently exploring post-doc opportunities. His research has focused on the engineering, economic, and policy issues associated with biomass-based strategies for mitigating anthropogenic CO_2 emissions.

Social LCA

Session Chair: Rita Schenck

Social Effects of a Videoconference
Kazue Ichino Takahashi, Masayuki Tsuda, Minako Hara, Yasue Nemoto, Jiro Nakamura, Shiro Nishi

Life Cycle Environmental and Socio-Economic Evaluation of a Glass Bangle Factory in Firozabad (India)
Bastien Roquier, Olivier Jolliet, Pierre Jaboyedoff, Girish Sethi, Sameer Maithel

COMMUNITY - What LCA Ignores
Jeremy Burnham

An Exportable Life Cycle Assessment Tool for Determining Sustainable Viability of Passenger-Only Ferry Routes and Systems
Patrick Richard Vasicek

Social LCA

Social Effects of a Videoconference

Kazue Ichino Takahashi,* NTT Energy and Environment Systems Laboratories
Masayuki Tsuda, NTT Energy and Environement Systems Laboratories
Minako Hara, NTT Energy and Environment Systems Laboratories
Yasue Nemoto, NTT Energy and Environment Systems Laboratories
Jiro Nakamura, NTT Energy and Environment Systems Laboratories
Shiro Nishi, NTT Energy and Environment Systems Laboratories

The environmental impact of videoconferences has been evaluated by LCA and their ecological advantage over the corresponding face-to-face meetings is apparent. However, people do not select a videoconference simply because of its environmental benefits, but rather because it is more cost efficient and/or convenient. Therefore a social impact assessment is needed to evaluate the real impact. We have developed a social impact assessment index, called the Gross Social Feel-good (GSF) index. This index can evaluate quantitatively the contributions of certain factors to the realization of a sustainable society. GSF comprises six component indexes, namely environment, economy, safety, health, comfort and happiness. It is designed to apply to information and communications technology (ICT) services and the results are shown as a monetary value. We applied the GSF index to a videoconference. The component indexes were evaluated from statistical data and questionnaire results. The environmental index was evaluated in terms of the environmental impact of a videoconference by using LIME (a life-cycle impact assessment method based on endpoint modeling), which is an original Japanese life cycle impact indicator. The safety index was evaluated by estimating the number of traffic accidents that could be avoided by people not having to travel. As regards the comfort index, the reduced transportation and meeting times were evaluated and converted to a monetary value. The health index was not evaluated because it does not relate to videoconferences. The economy index was evaluated as the difference between the cost of a videoconference and a business trip. The evaluation of the happiness index, which indicates a person�fs feelings or degree of satisfaction, is now under consideration. As tentative results, the economy index was about U$1,120, the comfort index was about U$90 and the environment index was U$24 and the safety index was less than U$1. These results correspond to the reasons for people using videoconferences. It is important to consider social impact in addition to environmental issues when designing ICT services.

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* corresponding author: ktaka@aecl.ntt.co.jp

Social LCA

Life Cycle Environmental and Socio-Economic Evaluation of a Glass Bangle Factory in Firozabad (India)

Bastien Roquier, Université de Lausanne
Olivier Jolliet,* University of Michigan, School of Public Health
Pierre Jaboyedoff, Sorane SA, Ecublens, Switzerland
Girish Sethi, TERI-The Energy and Resources Institute, New Dehli, India
Sameer Maithel, TERI-The Energy and Resources Institute, New Dehli, India

Conventional life cycle assessment (LCA) methodology has been adapted to take into account social aspects in addition to the environmental impact assessment. This approach aims particularly to provide an operational evaluation methodology for development and cooperation projects taking place in developing countries. The present study proposes to use a hybrid approach (process and economic input-output LCA) for evaluating the socio-economic and environmental effects associated with a product, process or activity over its entire life cycle. The method provides an impact assessment through four environmental damage categories (Human Health, Ecosystem Quality, Global Warming and Resource Depletion) and a selection of socio-economic indicators (Gender Equality, Income Equity, Poverty, Literacy, Child Work, Human Health Impact and Trade-Union Participation). A unique development is the life cycle quantification of environmental impacts, employment and salary structure separated by life cycle stage. The methodology was applied on a case study of glass bangle production in Firozabad (India). The results depict the social and socio-economic issue for some of the Firozabad glass workers, especially from the informal sector. They also show the decrease of the environmental impacts induced by the technology improvements and the shift from coal to natural gas as fuel. This LCA method including both socio-economic and environmental issues provides an effective tool for sustainability assessment. It supplies also valuable information for policy making. However social LCA is still at the beginning and this approach needs further development towards a comprehensive social and environmental assessment methodology.

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* corresponding author: ojolliet@umich.edu

Social LCA

COMMUNITY - What LCA Ignores

Jeremy Burnham,* The Natural Step

Tipping Point - that's where we are on the planet, and we need every discipline to bring its best to the table (metaphor of white-water rafting on rapids with a landslide thrown in) - brief highlights of the current environmental melt-down will be given.

What has caused it is the lack of effective human communication. Many people know what's happening and the remedial steps we should be taking today, but we lack mechanisms to influence those who can take those steps. Our politics and corporates have made themselves immune to responsibility.

What has reduced our ability to communicate effectively is the breakdown of community in this mobile age of fast-food employment and dormitory suburbs. The corporatised global village has turned meaningful craft and work into jobs and careers. Supply chains have become so long that workers no longer have any relationship with their customers.

LCA should factor this effect into its impact analyses. In South Africa we say, "local is lekker". There may be a time (the other end of the rapids) when virtual community replaces real communication, but given our current levels of skills and technology we need to do all in our power to build, not collapse, inter-personal connections and chains of responsibility. It is not good enough for LCA's to measure only inanimate impacts - it is LIFE Cycles we are assessing, and to omit conscious life may make the maths convenient but renders the conclusions meagre.

What is the impact of this or that intervention on vibrant community life? - some examples will be given where this has been taken into account with remarkable results.

We could take this one step further to include the factor of life itself as a quantifiable and highly depletable resource which could/should be included in LCA. If land-based biomass were to include the total living organisms (indirectly photosynthesised product) in the soil, and if maintaining or improving that were considered a vital component of sustainability, then we would be bringing the language and challenge of LCA's closer to what our politicians need to respond to. It is no longer valid to use "cradle to grave" language on a planet whose very survival depends upon our thinking and talking cradle to cradle.

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* corresponding author: jeremy@pes.org.za

Social LCA

An Exportable Life Cycle Assessment Tool for Determining Sustainable Viability of Passenger-Only Ferry Routes and Systems

Patrick Richard Vasicek,* Art Anderson Associates

Waterborne Transit has the potential to transform cities and positively affect the behavior and quality of life of metropolitan residents. The attractiveness of waterborne transit is related to several unique features, including route flexibility, limited infrastructure requirements, a relaxing and pleasant transit experience and utility in emergency situations. A passenger-only ferry (POF) system that is properly integrated into the broader multi-modal transit system could be an important transportation link in the city of the future. A major challenge of establishing and sustaining viable POF routes and systems is the need for significant behavioral changes among the target population. In other words, sustainable success of these systems is highly dependent on many different factors, including certain cultural factors that are difficult to measure. The purpose of this paper is to develop an LCA tool that will facilitate a forward-looking evaluation of the sustainable viability of starting up POF service for a given site or region.

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* corresponding author: pvasicek@artanderson.com

Energy

Session Chair: May Wu

Comparative Life Cycle GHG Emissions of FT-Liquid Fuels from Coal and Natural Gas
Paulina Jaramillo

A Streamlined Life Cycle Analysis of Canadian Wood Pellets
Francesca Magelli, H. Tony Bi

Using the Life Cycle Approach for climate change strategies and voluntary GHG emission offsetting
Marc Binder, Peter Koeberle, Harald Florin, Michael Faltenbacher

LCA of imported agricultural products – impacts due to deforestation and burning of residues
Niels Jungbluth

Comparative Life Cycle GHG Emissions of FT-Liquid Fuels from Coal and Natural Gas

Paulina Jaramillo,* Carnegie Mellon University

By 2030, petroleum demand in the U.S. will be 28 million barrels per day, 72% of which will be used by the transportation sector. By that same year, over 70% of petroleum and petroleum-related products will be imported from oil-rich countries, some of which have highly volatile political and social situations (1). In addition to this dependency on foreign fuel, petroleum combustion from the transportation sector is and will remain one of the largest sources of greenhouse gas (GHG) emissions in the country (2). In addition, emissions also result from the upstream stages (before combustion) of petroleum fuels (3).

As a response to these concerns over our consumption of petroleum, interest in alternative fuel sources for the transportation sector has risen. Transportation fuels produced from coal (CTL) and natural gas (GTL) through the Fischer-Tropsch reaction have been suggested as alternative sources of transportation fuels. The U.S. is rich in coal and the technology to produce CTL has been proven: CTL fuels has been widely used in countries like South Africa. Natural gas is not as abundant in the U.S. as coal, but it is less carbon intensive. Construction of plants to produce GTL fuels for export is being considered in countries like Qatar and Malaysia with support from global oil companies (4).

If CTL and GTL fuels are being considered to be part of our transportation fuel mix, it is important to understand the impacts these fuels would have on our efforts to reduce GHG emissions. Our goal is to perform a life cycle inventory of GHG emissions associated with these fuels, and compare them to life cycle emissions of petroleum fuels. Even though CTL fuels, and to a lesser extent, GTL fuels could reduce our dependency on foreign sources of oil, our estimates suggest that CTL and GTL fuels would not contribute in reducing emissions associated with transportation fuels. In some scenarios analyzed, they could actually increase GHG emissions. This presentation will describe the method used to preform this life cycle comparison as well as the policy implications of our results.

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* corresponding author: pjaramil@andrew.cmu.edu

Energy

A Streamlined Life Cycle Analysis of Canadian Wood Pellets

Francesca Magelli, Department of Chemical and Mineral Engineering (DICMA), University of Bologna, Italy
H. Tony Bi,* Clean Energy Research Centre, University of British Columbia, Vancouver, Canada

There have been increased interests on exporting wood pellets from Canada to Europe to meet the increased demand on biofuels in European countries. The wood pellets industry in Canada, especially in the west coastal region, has grown at a rate of more than 20% averaged over last 5 years due to the steady supply of wood residues. This paper is aimed at analyzing the fuel consumption and air emissions associated with the wood pellets production in British Columbia and export to Sweden based on a streamlined life cycle analysis, starting from tree harvesting for wood residue production to the shipping of wood pellets from Vancouver to Stockholm in Sweden. The results showed that about 8 GJ energy is consumed for each metric tonne wood pellets produced in Canada and then shipped to Europe, representing about 43% of the total energy content of the wood pellets. Among those energies consumed, about 3GJ is associated with long distance ocean transportation. The fossil fuel content for exported wood pellets ranged from 27 to 43%, depending on whether natural gas or wood residues are used for the drying operation during the wood pellet production stage. To reduce the fossil fuel content, wood residues should be used in the drying operation and, if possible, local market should be explored to reduce the energy consumption associated with wood pellet transportation over long distances.

The analysis on environmental and health impact based on smog formation, acid rain formation and health toxicity potential indices showed that most air pollutant emissions and impacts are associated with the ocean transportation of wood pellets, while the raw material acquisition and processing are responsible for the impacts on smog formation. To reduce fuel consumption and wood pellets cost, the energy efficiency for wood pellet processing and transportation needs to be improved in the future. Improvement of the raw material harvesting, pellet production and the transportation is equally important in reducing the environmental and health impacts associated with wood pellets production and export.

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* corresponding author: xbi@chml.ubc.ca

Using the Life Cycle Approach for climate change strategies and voluntary GHG emission offsetting

Marc Binder,* PE Americas
Peter Koeberle, PE International
Harald Florin, PE Americas
Michael Faltenbacher, PE Australia

Confirming the existence of global climate change is no longer the issue. How to counter it – at the global, national and company level – is now rapidly becoming the major issue, and the real challenge for organisations to solve.

While regulatory government measures such as caps can have a significant impact, there are additional measures, many of them voluntary, which are being implemented internationally with great success. With regard to the life cycle of a product the operations of a specific company may only cover single phases, most likely during the manufacturing. Therefore it only contributes to a certain amount to the product life cycle GHG emissions.

To avoid shift of GHG emissions between life cycle phases and business decisions which may result in trade offs with regard to other environmental impacts, the life cycle approach is used to assess the overall emissions to ensure that the up- and downstream processes and its emissions are considered putting the specific GHG emissions of a company into perspective.

This approach also ensures a coherent GHG reporting according to the different scopes (direct, energy production and indirect) as defined in the World Business Council for Sustainable Development "A corporate accounting and reporting standard" and in the new ISO standard 14064 "Green House Gases".

The first part of presentation will show a modular, flexible approach which can be tailored for corporations of all sizes, private individuals, single processes or products as well as public and private events to not only assess and offset GHG but also how this approach can be used for the identification of GHG reduction potentials. It features a staged procedure containing the following steps

- Status quo using the life cycle approach
- Optimization of the own operations

  - Analyzing, balancing and monitoring of material and process emissions using the life cycle approach which include upstream emissions,
  - Benchmarking to reduce the energy consumption as well as reduce the in-house and up stream emissions (material and process).

- Approach/ strategies how to compensate the remaining GHG emissions

The second part will show how this approach can be realized in an efficient way using existing tools like LCA in combination with tools supporting EMS systems and internal documentation systems which are already in place.
The third part will then discuss how these tools complement each other by presenting selected examples.

* corresponding author: m.binder@pe-international.com

Energy

LCA of imported agricultural products – impacts due to deforestation and burning of residues

Niels Jungbluth,* ESU-services Ltd.

Life cycle assessment (LCA) of imported oil plants life soybeans or plant oils, e.g. palm oil, is an important issue in many LCA studies for food products and animal production. Quite often imported products are assessed with the same data as national products. Country specific aspects for the location of production might thus be forgotten.

In an ecoinvent project for the investigation of biofuels several such agricultural products have been investigated. The aim of this project is to investigate data for biomass production, conversion to biofuels and use for transport services. The production of fuels like ethanol, rape seed methyl ether, BTL (biomass-to-liquid), etc. is investigated in a way consistent with the existing ecoinvent datasets. The findings from this project are quite interesting also for studies on food products. The presentation highlights methodological issues relevant for global biofuel production, like accounting for CO2 emissions due to land transformation and clear cutting of tropical rain forests. Results from the LCA study for soybeans and oil produced in Brazil and the US, sugar produced in Brazil as well as for palm oil production in Malaysia is presented. The assessment shows that CO2 and particle emissions due to deforestation and burning of harvesting residues might form an important part of environmental impacts throughout the life cycle. Especially the issue of deforestation should be taken into account for countries with increasing agricultural production area.

* corresponding author: jungbluth@esu-services.ch

Corporate Use of LCA

Session Chair: Margaret Mann

LCA as a Tool for Supporting Sustainability
Valerie Bone

Using Total Business Cost Assessment to Link Sustainability to the Bottom Line
Dickson de la Haye, Lise Laurin

A new LCA approach to assess company's environmental performances for a strategic environmental management
Renée Michaud, Julie-Anne Chayer, Edouard Clement, Manuele Margni, Réjean Samson

Quantifying and Benchmarking Environmental Performance of Companies: LCA for Socially Responsible Investments
Damien Friot, Josef Kaenzig, Myriam Saadé, Manuele Margni, Olivier Jolliet

Economic and environmental assessment of processes and investments using LCA and LCC
Malgorzata Góralczyk

Corporate Use of LCA

LCA as a Tool for Supporting Sustainability

Valerie Bone,* Pacific Market International

PMI has been engaged in Corporate Social Responsibility since the founding of our company in 1983. Our journey began with philanthropic and community involvement. As we increased our factory base in Asia, we published our first Code of Conduct in 1998 and have grown in this work steadily since. In 2006 PMI was awarded the American Chamber of Commerce in Shanghai Award for advancement in Corporate Social Responsibility (CSR).

As part of building a sustainable company, we built upon the environmental requirements in our Code of Conduct by launching our Environmental Sustainability Plan in 2006. Our Sustainability Plan includes both eco-efficient goals and eco-effective goals. Our eco-efficiency goals focus on continuous environmental management improvement at our factories and offices. We have water recycling and waste material recyling programs established in our core factories that reduce our environmental impact while improving costs.

We engaged Iere and other NGO's with environmental expertise to help us complete our first LCA in June 2006. Our LCA experience has opened up new ideas for environmental improvement at our factories and in our products. The LCA has provided the base-line information we need as we engage in eco-effective product development. Before perfoming the LCA at our largest JV factory, we thought that our biggest environmental impact was in the manufacturing process. It our scoping for the LCA, we set the system boundary at the maximum scope from raw material suppliers through end of expected consumer use of the product. The results of the LCA surprised us because the analysis showed that our manufacturing process was only responsible for 3% of the environmental impact. The largest opportunity to make a difference is in our upstream raw material supplier choices, and in our downstream variables such as freight choices. The materials we choose to use to make our products and the material suppliers we choose to source the raw materials from is now a focus for our company. We now understand that supplier location in addition to level of supplier commitment to sustainability in their operations may have a significant impact on our product's environmental impact.

LCA has provided a platform for us to link B2B with our (upstream) supply chain and our (downstream) clients. The LCA showed us that the real opportunity for improvement was in material sourcing, product and packaging design and downstream actions in addition to the manufacturing process at 1% to 3% impact. This was a surprise to us. It has provided a new way to look at our sustainable business opportunities.

There is a popular myth currently circulating that says LCA is "old" eco-efficiency thinking. We see LCA as a viable tool that should be used in conjunction with other sustainability tools. From the LCA we understand what to focus on and where we can make the most impactful improvements. We see LCA as a sustainability tool we will continue to use as we move forward in our sustainability plan. We intend to perform another LCA in 2007. We are currently talking with several of our clients to engage them in this process.

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* corresponding author: valerie.bone@pmi-worldwide.com

Corporate Use of LCA

Using Total Business Cost Assessment to Link Sustainability to the Bottom Line

Dickson de la Haye, The Dow Chemical Company
Lise Laurin,* EarthShift

For many, protecting the environment, employees, and communities has been considered an expense, requiring equivalent return on investment to any other expense taken on by a company. In the last few years, this approach has been recognized to be unsustainable. While shareholders have begun demanding sustainable actions from corporations, they have not reduced the pressure on profitability. So how does a company justify expenditures toward more sustainable management practices when traditional cost accounting shows a negative return on investment? Total Business Cost Assessment (TBCA) successfully shows return on investment in areas not considered in traditional cost accounting: areas such as potential legal liabilities, employee morale, community and regulator relations, and brand value--areas that affect profitability, even if the effects are difficult to measure.

The Dow Chemical Company has been using TBCA to evaluate its EH&S goals and to enable better decision making Utilizing the TBCA methodology, Dow estimated a total value of $950 million generated from the EH&S 2005 incident reduction goals. Furthermore, Dow estimated spending close to $1 billion on the resource productivity goals and achieved an overall value of over $5 billion. The TBCA process and the results of the analyses are opening the eyes of participants and reviewers to new ways of approaching decisions, business, and the marketplace.

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* corresponding author: llaurin@earthshift.com

A new LCA approach to assess company's environmental performances for a strategic environmental management

Renée Michaud, CIRAIG
Julie-Anne Chayer, CIRAIG
Edouard Clement, CIRAIG
Manuele Margni,* CIRAIG
Réjean Samson, CIRAIG

This paper present a methodology aiming to identify companies environmental priorities based on a life cycle approach. Using data provided by and collected at the company an overall evaluation of quantitative and qualitative aspects is performed. Quantitative aspects such as purchased goods and services, on-site direct emissions, distribution and transport, sales and product requirements at the use phase and the end of life scenarios are evaluated with the Green-E LCA software (www.green-e.ch). Environmental performance indicators are obtained combining such flows with generic life cycle inventory databases and impact assessment methods. A semi-quantitative matrix analysis, adapted from Graedel (1), is used to evaluate environmental practices that cannot be directly quantified, such as working procedures, green purchasing, pollution emission control practices, etc. Both quantitative and semi-quantitative results are used to identify improvement actions and business opportunities.

Two case studies on furniture manufacturing and diary products companies are presented, where it is demonstrated that the LCA approach enabled to identify environmental hot-spots and proper trade-offs between the life cycle stages, such as material supply versus production phases or transportation. The furniture manufacturing company obtained a better evaluation for onsite environmental management activities compared to upstream and downstream activities and this because of the ISO 14001 certification already obtained in November 2003. Primary material supply was clearly the key point to adress in term of environmental impacts (linked to the use of resources and emission). The diary product producing company showed equal improvement opportunities along all the life cycle chain in terms of environmental management, whereas the quantitative analysis identified the packaging and transportation activities dominating the overall life cycle chain, i.e. more important compared to the onsite energy use and emissions.

The results of such an analysis can be directly used for the implementation or the amelioration of an EMS according ISO 14001. The integration of upstream and downstream processes results in tremendous impacts on the perception of environmental performance realigning priorities of the EMS, especially defining new priorities, such as procurement policies or eco-design. LCA on a company basis is therefore a useful tool for a strategic EMS enabling the decision maker identifying the right priorities, which are not necessarily within the classical company burdens.

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* corresponding author: manuele.margni@polymtl.ca

Corporate Use of LCA

Quantifying and Benchmarking Environmental Performance of Companies: LCA for Socially Responsible Investments

Damien Friot, University of Geneva, Applied economics
Josef Kaenzig, University of St-Gallen
Myriam Saadé, Ecointesys-Life Cycle Systems
Manuele Margni, CIRAIG-Ecole Polytechnique de Montreal
Olivier Jolliet,* University of Michigan, School of Public Health

Interest for socially responsible investment is growing. Social and environmental performances assessments are becoming additional requirements for a growing number of mutual funds. There is however a large gap between the financial side of the selection process, where complex valuation procedures are usual and the sustainable side, mostly relying on qualitative and heterogeneous information. Thanks to the number of companies publishing environmental data (energy and water use, CO_2 emissions), it becomes possible to evaluate the feasibility of a quantitative approach. First studies at EPFL have however shown that the data published in environmental reports are currently not adequate for a proper benchmarking with obvious mistakes in units, lack of homogeneity or incomplete geographical coverage. A quantitative approach requires therefore to establish verification strategies and data completion with other sources. In addition to these data issues, some conceptual issues have to be taken into consideration: environmental reports are describing direct emissions, on site, but do not consider induced emissions, either upstream (suppliers) or downstream (customers). It seems therefore clear that direct emission need to be complemented by evaluating emissions in a life cycle perspective. Selecting the best environmental performers within a sector is therefore only possible, on a quantitative basis, within an overall integrated approach including suppliers and customers. Finally a case study in the automobile sector shows how life cycle thinking and associated approaches (Life Cycle Assessment, Impact Assessment, extended Input-Output Analysis) provide help to define an appropriate to benchmark key impacts.

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* corresponding author: ojolliet@umich.edu

Corporate Use of LCA

Economic and environmental assessment of processes and investments using LCA and LCC

Malgorzata Góralczyk,* Mineral and Energy Economy Research Insitute of the Polish Academy of Sciences

The paper describes the system of environmental and economic assessment of processes based on Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) developed for the purpose of supporting the decision making regarding the choice of equipment used in the process of mining of the copper ore. The assessment system combines the environmental impact assessment performed using LCA with the economic analysis based upon LCC concept.

The development of such system is the response to the difficulties expressed by the decision makers who were facing the problem of meeting the environmental restrictions and economic goals at the same time. The system can be applied both for the strategic planning and for the day-to-day decision making. LCA by itself doesn't include financial matters, but in this area the natural supplement of LCA is the financial analysis done using LCC. That way the life cycle concept is applied to both environmental and economic matters.

Although the system of environmental and economic assessment was developed especially for the copper ore mining it was designed in that way that it can be easily adapted to different processes and also to the extended (i.e. including environmental impact) assessment of the investment projects. The example of application of the system developed to the investment project assessment will also be presented.

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* corresponding author: goralczyk@min-pan.krakow.pl

Financing Sustainability, Part II

"The Challenges of Scaling Up"

Session Coordinator: Stephanie L. McGillivray, Complexity Management, LLC

Many success stories have illustrated that clean and alternative energy and environmental technology businesses or projects can succeed. But most of these are pilot projects, small projects, and companies in highly fragmented markets. The next challenge is going to be to scale these successful projects up from both a technology and business model standpoint to become the new way of doing business. How might larger scale solve pressing environmental problems? Solutions might include large-scale facilities, large-scale production of distributed or on-site equipment, utility-like business models, transportation/transmission solutions, or bringing together the power of personal choice. How are life cycle considerations incorporated into these solutions?

This panel will explore some of the business and financing issues inherent in scaling up sustainable energy and environmental solutions. What are some of the innovative business approaches being commercialized and grown? How have businesses met the challenges of scaling up? Where will the money come from? What do investors need to see to fund these larger-scale solutions? What else is needed to help clean businesses grow dramatically?

Life Cycle Inventory

Session Chair: Masayuki Tsuda

LCI Database Upgrade: Experience and Challenge

Matthias Fischer, Julia Pflieger, Harald Florin

Australian Life Cycle Inventory – Progress and Industry Engagement

Maree Lang

Computational tools for process based life cycle inventory calculations

Evan M Griffing, Michael Overcash

Is this New Life Cycle Information Worth it? A Thermodynamic and Statistical Approach for LCI Reliability Estimation

Hangjoon Kim, Bhavik R. Bakshi, Prem K. Goel

Life Cycle Inventory

LCI Database Upgrade: Experience and Challenge

Matthias Fischer, LBP-GaBi, University of Stuttgart
Julia Pflieger, LBP-GaBi, University of Stuttgart
Harald Florin,* PE International GmbH

With respect to acceptance, use and benefit of Life Cycle Assessment (LCA) information a decisive and determining factor is the availability of high quality Life Cycle Inventory (LCI) data.

The experience and knowledge gained within the upgrade process of the project "GaBi Databases 2006" can be discussed and will be of use in the context of all kind of Life Cycle Inventory data studies, are they project-based or integrated into regional database activities.

The presentation will discuss the main challenges faced and identified, with particular focus on the following topics:

- To keep the balance between several disciplines, methodological questions, software related issues, documentation and technical aspects.
- To combine long term know-how / experience of senior staff with junior employees' manpower bringing along an efficient knowledge transfer as well as set-up of future experts within the team.
- To implement a comprehensive, long-lasting and interlinked knowledge and data management system.

In addition the presentation will illustrate the key principles and approach followed to cope with the described challenges:

- Mobilization of a large interdisciplinary team with long time experience in the requested fields.
- Efficient, target-oriented and sustainable networking within the team as well as with external
- Comprehensive and standardized documentation.
- Involvement in and know-how about ongoing international database related activities to have a harmonized approach and to foresee future requirements.
- Use of generic and variable parameterized LCI models.
- Use of supporting features of the software system, e.g. variable flow properties, GUID identification of objects, etc.

The presentation will provide an insight into the LCI database update activities undertaken by the University of Stuttgart and PE International GmbH – with particular emphasis on the key principles to be applied and considered in any kind of LCI data studies to ensure an accepted and successful outcome of the data project.

* corresponding author: h.florin@pe-international.com

Life Cycle Inventory

Australian Life Cycle Inventory – Progress and Industry Engagement

Maree Lang,* Plastics and Chemicals Industries Association

The Australian LCA Society (ALCAS) and CSIRO (Australian federal science body) have collaborated to develop an Australian Life Cycle Inventory (AusLCI) Database, which was launched at a major Australian LCA Conference in late 2006. AusLCI will be Australia's contribution to a global initiative to promote sustainable consumption and production and will be a demonstration of government and business leadership.

AusLCI has broad support from government and regulators, universities and industries, each recognizing the need for transparent and comprehensive life cycle data. Currently in Australia, inventory data is disparate and not necessarily representative of current local processing or production facilities.

A number of major activities are now underway before AusLCI can go live and move to being fully operational. This includes development and agreement on technical specifications, engaging stakeholders including data users and data providers and development of a business model for the long term and sustained operation of AusLCI.

A range of material groups are also engaged in the process and providing key input to technical specifications and the business case development. For example, with funding support from Environment Protection Authority Victoria, the Plastics and Chemicals Industries Association (PACIA) is reviewing all plastics inventory data for inclusion in AusLCI in a manner consistent with international plastics data sets. This will require considerable effort by the sector to generate new and updated data for AusLCI.

This paper will provide an update on the status of AusLCI, including key technical parameters and the business case approach. The engagement of industry groups will be highlighted, using the Australian plastics sector as a case study, including motivations for involvement in AusLCI and current sector based work.

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* corresponding author: mlang@pacia.org.au

Life Cycle Inventory

Computational tools for process based life cycle inventory calculations

Evan M Griffing,* North Carolina State University
Michael Overcash, North Carolina State University

The process design-based methodology of generating life cycle inventory (LCI) data can be a powerful tool for developing data quickly and transparently. For each chemical process in the supply chain, engineering data are used to create a representative process flow diagram. Model equations (or heuristics) convert the design and engineering data into mass and energy flows into and out of the process. The level of complexity or detail used in such a process-based model is an important decision.

With most engineering models, additional complexity improves accuracy at the cost of increased computational time or model development time. In the context of LCI work, supply chains are typically five to 30 chemical processes, and may include over 100 separate processes. The broad scope of the problem can clearly increase model development time. Complexity over a large life cycle may decrease transparency as it becomes difficult to communicate manifold additional choices. We have been refining process design heuristics to strike a balance of accuracy and simplicity.

Several commercial software packages are available to model processes in the chemical industry. These are typically marketed for designing or modifying plants (that may be built). As such, that level of complexity is inappropriate for LCI work. We have created a set of software tools to facilitate calculation of model equations and display of data with the overarching goals of quickly generating transparent LCI data. The software (1) utilizes unified physical property and unit operation models (2) produces consistent reports that are easy to review (3) allows practitioner to focus on design variables instead of computations (4) allows practitioner to see calculation details and intervene when necessary.

Calculations for each process are performed in Excel with the aid of visual basic for applications (VBA). Excel allows the user to examine and modify the calculations at each step. VBA is used to automate repetitive tasks and create reports. LCI and physical property data are stored in a centralized database to facilitate information sharing between users and improve consistency across the database. The software tools have been shared openly on a limited basis with industrial and academic collaborators.

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* corresponding author: ehgriffi@unity.ncsu.edu

Life Cycle Inventory

Is this New Life Cycle Information Worth it? A Thermodynamic and Statistical Approach for LCI Reliability Estimation

Hangjoon Kim, Department of Statistics, Ohio State University
Bhavik R. Bakshi,* Dept. of Chemical and Biomol. Eng., Ohio State University
Prem K. Goel, Department of Statistics, Ohio State University

All measured data and models contain errors, and Life Cycle Inventory (LCI) data are no exception, particularly since LCI data are usually collected and combined from diverse sources, which may be unreliable, incomplete or unverifiable. Since the underlying or noise free LCI data must satisfy the laws of conservation, their quality may be improved by imposing these laws on measured data. Such an approach has been popular for improving the quality or rectifying industrial data, and has also been developed for LCI data rectification (1). LCI data are often available at multiple overlapping scales, which include engineering data, process LCA databases and economic data. A multiscale rectification approach has been developed for fusing and improving such data (2). The approach involves solving a constrained optimization problem, where conservation equations form the constraints, combined with statistical hypothesis testing for identifying gross errors.

In this presentation we will first provide an overview of the existing methods developed in our group for rectification of LCI data. Although the use of thermodynamic conservation equations has been suggested by others for improving LCI data quality, our work provides the first approach that solves this problem. In addition, our approach is statistically rigorous and addresses many of the unique challenges posed by LCI data. The main focus of this presentation will be on a recently developed novel approach for determining whether obtaining additional life cycle inventory information is worth the effort or cost.

This approach relies on a statistically rigorous estimate of the expected error in LCI data before and after additional data is included. A reliability index is defined based on the ratio of the variance of the error in the data before and after rectification. Calculating this index for linear systems does not require the actual data, but only relies on information about its uncertainty and any new process specific information such as reactions or network connections, that may become available. This is possible because for linear models, the error estimate obtained by solving the rectification optimization problem only depends on the variance of the errors in the available and new data and the models relating the variables. (Explaining this fact is difficult without showing the relevant equations. I would be happy to send the equations in a pdf file, if necessary.) This relative reliability improvement estimate may be obtained for individual variables, streams or processes, and may help in deciding if the estimated improvement justifies the added cost or effort. Our approach can also be used for deciding the focus of future data collection efforts and the accuracy needed in new data to justify the extra effort. On-going work on estimating the error variance will also be described. Case studies based on data from commercial and free LCI databases will be used to illustrate the approach. This includes LCI data for making sodium hydroxide (chlor-alkali process) from the NREL database, and LCI for making ammonium hydroxide from SimaPro and engineering databases.

Shortcomings of the proposed approach and opportunities for future work will also be identified

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* corresponding author: bakshi.2@osu.edu

LCA & Consumers

Session Chair: Ivor Melmore

Research on the Effect of LOHAS Information on Consumer Behavior and System Demonstration Test at Food Supermarket
Yoshio Iwase, Shinichiro Harano, Mitsukiyo Tani, Mika Takaoka

Washington State Consumer Impacts Assessment (WA-CIA) and Index
Jeffrey Morris, H. Scott Matthews, Frank Ackerman, Ivor Melmore

Consumer perceptions of greenhouse gas emissions and energy use in the food system
Andy Larson, Richard Pirog

Sustainable building design – The use of EPDs in an efficient life cycle based building assessment
Marc Binder, Liila Woods, Johannes Kreissig, Anna Braune

LCA & Consumers

Research on the Effect of LOHAS Information on Consumer Behavior and System Demonstration Test at Food Supermarket

Yoshio Iwase, Hitachi, Ltd.
Shinichiro Harano,* Hitachi, Ltd.
Mitsukiyo Tani, Hitachi, Ltd.
Mika Takaoka, Rikkyo University

We have developed a 'Food Navigation System for LOHAS', which is a prototype model of food information system, would lead consumers to healthy and environmentally conscious life in near ubiquitous and sustainable future days.

We did the system demonstration tests at two food supermarkets in TOKYO and Kanagawa prefecture during each two weeks in the autumn of 2006. We used advanced ubiquitous information equipments, for example, IC cards, ubiquitous display, mirror display and electric paper etc. on the demonstration tests.

And, as our second target, we developed a specific navigation system, which provides sustainable information matching each consumer's preference, and leads to LOHAS lifestyle unconsciously.

We also researched the effect providing consumers LOHAS information on the consumer behavior in the case of food purchase.

We investigated the change of consumer behavior by two times customer survey questionnaires at the timing of before and after the demonstration test in supermarkets. We used RFIDs (IC cards) in order to relate each monitor consumer to the selected food according to each personal preference.

Selecting Bean Curd, Egg, Bean Sprout and Ham as test foods , we made the special navigation score system which evaluates the values of health, environment, freshness and price of the selected foods, and provides monitor consumers related information including LOHAS one .

The navigation score, including 'LOHAS points', refers two factors. The First factor depends on the values of health, environment, freshness and price of the selected foods. The second factor depends on the consumer�fs personal preference concerning them.

We evaluated those personal preferences by the pre-questionnaire's answers, and divided all monitors into four categories.

As the result, monitor consumers are apt to buy the kind of items which were introduced with its LOHAS information, and the two third of them feel such 'Food Navigation System for LOHAS' useful and want to use continuously.

This project has been performed under the support of JST (Japan Science and Technology Agency).

* corresponding author: shinichiro.harano.cy@hitachi.com

Washington State Consumer Impacts Assessment (WA-CIA) and Index

Jeffrey Morris,* Sound Resource Management
H. Scott Matthews, Carnegie Mellon University
Frank Ackerman, Tufts University Global Development and Environment Institute
Ivor Melmore, Washington State Department of Ecology

This presentation will describe the economic and LCA theories, techniques and data used to create an index of environmental impacts based on consumption of goods and services in Washington State. This index was created for the Washington State Department of Ecology and tracks changes over time in public health and ecological harm from the environmental emissions caused by the production, use and disposal of goods and services purchased by Washington State consumers (just as the consumer price index [CPI] tracks changes in the prices consumers pay for those purchases). The index will go down if there are decreases in the toxic substances, pollution and wastes associated with consumer purchases.

The index is based on Washington State consumer expenditures as surveyed annually by the US Department of Labor Bureau of Labor Statistics (BLS). Carnegie-Mellon University's Economic Input-Output Life Cycle Assessment (EIO-LCA) model is used to measure upstream pollutant releases, while process LCA data are used to measure emissions during product use and end-of-life wastes management.

There are numerous theoretical and empirical challenges in the creation of such a comprehensive index. These include how to allocate emissions from products whose useful life spans more than a single year, how to adjust for differences in recycling and recycled content purchases by Washington consumers compared with the US average that is reflected in the EIO-LCA model, what weighting system to use for indexing pollutants and wastes, and whether to roll up potential impacts on climate change, human health and ecosystem health into a single overall index (and if so what weights to use for this final indexing).

Potential indexing systems reviewed for this consumer environmental impacts index include Ecological Footprint, the European Union's EcoIndicators99, EPA's Environmental Preferable Purchasing, EPA's RSEI, and EPA's TRACI. The presentation will outline which one was finally selected and the reasons for its use.

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* corresponding author: jeff.morris@zerowaste.com

LCA & Consumers

Consumer perceptions of greenhouse gas emissions and energy use in the food system

Andy Larson, Iowa State University
Richard Pirog,* Leopold Center - Iowa State University

Researchers interested in studying energy use and greenhouse gas emissions in the food system need to understand consumer understanding and concern about these issues to frame their work. How do consumers interested in purchasing food products where the supply chain has reduced emissions of greenhouse gases value other important environmental and social attributes? What is the level of consumer understanding as to which sectors of the food system and modes of transportation consume the most energy and release the highest levels of greenhouse gases? How do consumers make decisions regarding the ecological footprint of the food item they purchase within the context of food safety and country of origin labeling concerns? Has their awareness of these issues been heightened by increased fuel prices or other food safety concerns raised in the media? These questions will be addressed in an internet survey of U.S. consumers regarding perceptions of greenhouse emissions, food safety, country of origin labeling, food miles, and organic versus local to be administered and analyzed in the summer of 2007.

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* corresponding author: rspirog@iastate.edu

Sustainable building design – The use of EPDs in an efficient life cycle based building assessment

Marc Binder,* PE Americas
Liila Woods, PE Americas
Johannes Kreissig, PE International
Anna Braune, LBP-GaBi University of Stuttgart

The building sector provides long-term products and services with a high socio-economic relevance. This stimulates and increases the interest on information on the sustainability performance of buildings nowadays. The sustainability performance of a building can significantly be enhanced when it is designed under the life cycle perspective. Uncountable numbers of options for sustainable or green design exist for each unique building. But each building design has its very specific requirements by the user, the owner, the building's local conditions and the design team. Therefore there is a need to tailor the sustainability assessment to the building's specific conditions.

Current developments in standardization of frameworks for sustainability building assessment systems build on the use of Environmental Product Declarations (EPD*) to cover environmental aspects of construction, e.g. as foreseen in CEN / TC 350** (Européen de Normalisation (CEN)/ Technical Committee (TC) 350).

Together with building teams, the authors developed a method to efficiently enhance the sustainability performance of buildings focusing on environmental aspects and starting in the early planning phase. The method takes life cycle environmental aspects into account, can be enlarged to economic aspects and is in line with the occurring questions and decisions of the building team within the different planning steps.

The presentation is structured in 2 parts:

Part 1 will give an outline of a comprehensive sustainability assessment system for buildings, focusing on the use and benefits of EPDs in this framework. Requirements on the system itself will be discussed, such as the need to be impact oriented and the need to separate the descriptive part and the valuation and assessment part. The modular approach enables the designer to evaluate different design options, show the relevance in perspective to the overall building and identify elements and design options with the potential for reducing the environmental footprint and life cycle costs.

Part 2 will give an overview and first insight information on the how building assessment scheme which is the core part of the certification system of the GeSBC (German Sustainability Council) will address the life cycle view and LCA and on the rating scheme.

* An EPD provide verified/ reviewed environmental information on materials and products. They meet the requirements on documentation and quality of the ISO standard for Type III environmental declarations (ISO 14025). The environmental indicators shall be created according to the principles, framework, methodologies and practices established by the ISO 14040 series of standards. They are accessible for interested parties for no costs.

** CEN/ TC 350 is working on the development of standardised voluntary approach for the delivery of environmental information on construction products, how to assess the environmental performance of buildings, and more generally the integrated performance of buildings in a framework document. The goal is to cover not only all kinds of building products but also all kinds of buildings, e.g. new and existing buildings, and other construction works in general.

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* corresponding author: m.binder@pe-international.com

Measurement, valuation and pricing of ecosystem services for integrated markets such as intergenerational finance

Special Session Coordinator: Langdon Marsh, National Policy Consensus Center, Portland State University

Existing markets rarely take into account the consequences of economic activity on the ability of natural systems to continue to provide needed ecological services, such as climate regulation, purification of air and water, mitigation of floods and droughts, detoxification and decomposition of wastes, generation and renewal of soil and soil fertility detoxification and decomposition of wastes and maintenance of biodiversity. How can life cycle assessment and the measurement and valuation of ecosystem services be integrated into decisions about investment and purchases of goods and services so that the earth restores and retains its ability to provide services upon which human health, prosperity and community and individual happiness depend? The panel will discuss how the fields of measurement and valuation of ecosystem services and life cycle assessment might be used in transformative economic systems like intergenerational finance to produce long term sustainable outcomes for humans and the environment.

Topics to be addressed by the panel will include: definition of, benefits from and measurement and valuation of ecosystem services, the relationship of valuation of ecosystem services to life cycle assessment, the extent to which life cycle assessment adequately takes into account long term impacts or enhancements of ecosystem services, payment for ecosystem services and integration of ecosystem services into transformative economic systems like intergenerational finance. The panel will discuss one or more case studies which use the payment for ecosystem services to create value in protecting or restoring ecosystems and providing benefits to humans.

Participants

Bobby Cochran, Environmental Marketplace Analyst, Clean Water Services, Hillsboro, Oregon
Langdon Marsh, Fellow, National Policy Consensus Center, Portland State University, Portland, Oregon
David Primozich, Willamette Partnership, Salem, Oregon
Sarah Kruse, Ecotrust, Portland, Oregon

Transport

Session Chair: Matthias Fischer

Opportunities in Sustainable Mobility
Ron Williams, Walt Olson

Modeling Passenger and Freight Transportation in Input-Output Analysis: Challenges and Potential Solutions
Christopher L. Weber, H. Scott Matthews

Life Cycle Assessment of Energy and Greenhouse Gas Emissions of Ground Shipping in the United States: U.S. Postal Service Case Study
Aweewan Mangmeechai, H. Scott Matthews

The Green Fleet Program - Vehicle Lifecycle Environmental/Economic Impact analysis tool powered by Argonne National Lab's GREET Model
Greg Wallace-Reynolds Rock

An Assessment of Mechanical and Thermal Conversion Technologies Used in the Recycling of Shredder Residue based on A Life Cycle Approach
Candace S. Wheeler, Nakia L. Simon, Claudia M. Duranceau

Transport

Opportunities in Sustainable Mobility

Ron Williams,* General Motors, retired
Walt Olson, University of Toledo

The transport of people and materials is one of the key requirements in every vision of a sustainable world. The global automotive industry currently provides for the transport of people and materials by air, land, and sea. However, meeting the needs and wants of a growing global population in a sustainable manner will require major changes in the automotive industry.

This presentation communicates the effort of members of the Society of Automotive Engineers (SAE International) to provide leadership and guidance towards sustainable mobility for all future generations. SAE International has served as the professional society (currently 90,000 members) for automotive engineers for more than 100 years. While the future has always been an important consideration for engineers, the future has taken on increased significance with the intellectual development of the concept of sustainability. In its simplest form, sustainable development is development that provides for the current generation without sacrificing the opportunity for future generations to provide for themselves. Thus the earth's resources of air, water, land, materials, and natural balances must be used in a fashion that maintains these resources as accessible for future generations to similarly use for their well being. The creativity of engineers and the development of technology will generate opportunities for sustainable mobility and the time to focus on these opportunities is now.

The World Business Council for Sustainable Development report "Mobility 2030" provides a guideline for moving towards sustainable mobility. It identifies seven goal areas that offer opportunities to contribute to a sustainable future. The goal areas are: emissions and wastes below health concern levels, greenhouse gas emissions at sustainable levels, lower traffic deaths and serious injuries globally, lower transport-related noise, mitigate congestion globally, narrow the mobility divides internationally, preserve and enhance mobility opportunities. This presentation recommends life cycle based actions to approach these goals that have been proposed by the Sustainable Development Program Committee, a standing committee reporting to the SAE Engineering Meetings Board. A speakers bureau has been established to disseminate this information both inside and outside the SAE International organization. The knowledge base supporting these recommendations includes, LCA, DFE, DFA, DFR, Green Engineering, supply chain management, environmental management systems, and well-to-wheel fuel studies.

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* corresponding author: rlwilliams44@email.sae.org

Transport

Modeling Passenger and Freight Transportation in Input-Output Analysis: Challenges and Potential Solutions

Christopher L. Weber,* Carnegie Mellon University
H. Scott Matthews, Carnegie Mellon University

The past few years have seen a proliferation of the use of economic input-output analysis (IOA) as a tool for life cycle assessment (LCA). While IOA has several advantages for LCA, such as aggregate data availability, cut-off error minimization, and temporal efficiency, its problems are also severe. Perhaps most important are its problems related to price variation of commodities between and within sectors and sectoral aggregation error, two uncertainties which are difficult to quantify but likely very important for most IO modeling. These problems may be pronounced for transportation sectors, for several reasons: freight and passenger price variability, the aggregation of passenger and freight transport together, allocation issues between passengers and freight, and the treatment of international transport and imported transport services are a few.

This study seeks to typify and quantify typical uncertainties in modeling passenger and/or freight transport using input-output based LCA (IO-LCA). National level input-output and transportation data from various US sources, including benchmark input-output accounts, transport and passenger logistics data, and international trade data, are compared systematically to detail uncertainties related to differential pricing and aggregation. We conclude that both types of error are likely very significant in typical IO-LCA approaches, and thus, results for transporation-related LCI studies using IOA should be treated with some degree of caution.

However, IOA does have its advantages for modeling transportation logistics, as it is able to show logistics at every level of a product's supply chain from raw material extraction to final delivery when using detailed IO tables. We propose a mixed-unit input-output approach that may solve some of the above problems while maintaining the advantageous total supply chain delineation of IOA. However, as we discuss, this approach will have its own difficulties in model construction and data uncertainty. As in many cases, a hybrid LCA approach may provide the least uncertainty overall.

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* corresponding author: clweber@andrew.cmu.edu

Transport

Life Cycle Assessment of Energy and Greenhouse Gas Emissions of Ground Shipping in the United States: U.S. Postal Service Case Study

Aweewan Mangmeechai, Carnegie Mellon University
H. Scott Matthews,* Carnegie Mellon University

A significant increase in the use of shipping services has drawn public attention to energy consumption and associated air emissions. Despite the transportation sector being an important contributor to fossil energy consumption and greenhouse gas emissions, few detailed studies on the system-wide impacts of shipping exist. The U.S. Postal Service (USPS), a part of the federal government subject to public reporting requirements, represents a case study that can better inform the energy and emission impacts from shipping. Unlike other previous studies, this study takes both energy consumption and emissions from highway vehicles and support services such as buildings and equipment into account. A life cycle assessment (LCA) of the USPS is quantified in this paper by using a hybrid LCA model involving process and an input-output modeling. Existing vehicle-only shipping emissions and energy use are estimated at 600 to 630 grams of CO2 per ton-mile (8,300 to 8,900 BTU per ton-mile), while the hybrid LCA's emission factor for direct energy consumption is 2,500 to 2,700 grams per ton-mile (21,500 to 23,000 BTU per ton-mile). The hybrid LCA emission factor for the whole supply chain is 7,000 to 7,600 kg per ton-mile (85,700 to 91,600 BTU per ton-mile). These numbers prove that the previous studies, which do not include overall impacts of shipping, greatly underestimate actual emission impacts, by up to a factor of 30. This underestimate is important and relevant for decision makers considering the energy and environmental impacts of shipping e.g. purchases of carbon offset. The LCA of USPS shows that USPS's focus should be to decrease electricity consumption in buildings to accomplish CO2 reduction goal.

* corresponding author: hsm@cmu.edu

Transport

The Green Fleet Program - Vehicle Lifecycle Environmental/Economic Impact analysis tool powered by Argonne National Lab's GREET Model

Greg Wallace-Reynolds Rock,* The Green Car Company

The Green Fleet Program is a detailed vehicle environmental and economic impact analysis tool. The program uses quantitative values derived from the GREET model like grams of pollutant per lb of fuel consumed or gallons of fuel consumed per lbs of li-ion batteries manufactured/recycled as quantitative input values. These values power a detailed vehicle simulation tool capable of modeling vehicle's as complex as a tri-fuel vehicle. An example of a tri-fuel vehicle would be a PHEV running on electricity, gasoline and ethanol. The program produces environmental impact reports detailing any specific vehicles impacts on green house gases, regulated emission, and fossil fuel consumption.

The Green Fleet program is used to provide lifecycle vehicle analysis and cost benefit comparisons to municipal, educational, and business fleets purchasing eco-friendly vehicles from The Green Car Company. The program gives the GCC the ability to show fleet managers vehicle to vehicle comparisons, establish baselines, simulate future fleets' environmental impacts, as well as perform dynamic analysis tracking things such as cost to own and operate a vehicle over a range of potential fuel prices.

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* corresponding author: greg@greencarco.com

Transport

An Assessment of Mechanical and Thermal Conversion Technologies Used in the Recycling of Shredder Residue based on A Life Cycle Approach

Dr. Candace S. Wheeler, General Motors/Vehicle Recycling Partnership
Nakia L. Simon,* DaimlerChrysler/Vehicle Recycling Partnership
Dr. Claudia M. Duranceau, Ford/Vehicle Recycling Partnership

A number of new technologies are currently under investigation by the Vehicle Recycling Partnership (VRP) and its partners, which are designed to substantially enhance the recycling of end-of-life vehicles and, in particular, the residue, which remains after the vehicles are shredded, and the metals recovered. These technologies fall primarily in one of two types. They include mechanical separations processes, which are designed to recover materials of value from the shredder residue stream, or thermal conversion technologies designed to convert hydrocarbons and other organic materials into marketable oils and specialty chemicals for potential industrial and commercial use. In this study, we looked at the relative environmental benefits/impacts associated with both of these recycling strategies using a life cycle approach. We found that the thermal conversion technology showed an overall environmental benefit for all considered environmental issues compared to the mechanical recycling process. However, the results were highly dependent on the use of the produced product streams. To increase the benefits of the mechanically recovered fractions, the purity of the recovered fractions would have to be increased enabling the materials to be used in higher value applications. Also,the direct solvent emissions were critical with the greatest share of the output emissions related to the contamination of the residue with diesel and gasoline. Additional research is underway to improvement the environmental performance of both processes.

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* corresponding author: nls8@daimlerchrysler.com

LCA and Regulation

Session Chair: Bob Boughton

Life cycle assessment: Applications to solid waste policy and program development in Oregon
David M. Allaway

Comparative LCA of soft drink containers and their respective waste management system in Hungary and Mexico
Adrienn Buday-Malik, Klára Szita Tóth, Guillermo Encarnación, Sergio Flores, Gábor Kiss, Gustavo Solórzano, Tímea Molnár Sipos, István Zsolt

Life Cycle Approaches to State and Local Regulation – California Case Study Experience
Mike Levy

LCA, LCE and LCI methods in WEEE management
Adrienn Buday-Malik

Life Cycle Environmental and Energy Impacts of Extended Producer Responsibility (EPR) Policy
H. Scott Mathews, Y. Anny Huang

LCA and Regulation

Life cycle assessment: Applications to solid waste policy and program development in Oregon

David M. Allaway,* Oregon Department of Environmental Quality

In the last few years, the United States Environmental Protection Agency has developed several tools that facilitate the evaluation of the energy and greenhouse gas impacts of various solid waste management options, including recycling and composting. The State of Oregon's Department of Environmental Quality (DEQ) has applied these tools, along with other life cycle assessment research and literature, to evaluate a variety of solid waste policy and program options.

This presentation will demonstrate how DEQ has applied - and proposes to continue to apply - life cycle assessment to inform a variety of program and policy decisions. Examples will include: 1) technical evaluation of policy and program options in support of Oregon's Governor's Advisory Group on Global Warming; 2) evaluation of the potential greenhouse gas and energy impacts of reducing the frequency of residential curbside recycling collection; 3) education of solid waste professionals and the general population regarding the benefits of recycling and the relative impacts of "upstream" (resource extraction and manufacturing) vs. "downstream" (disposal) life cycle stages; 4) evaluation of e-commerce order fulfillment packaging options, conducted as part of a larger packaging waste prevention project with business; and 5) development of a Waste Prevention Strategy and the identification of "high impact" materials, wastes, and processes to focus on for environmental improvement.

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* corresponding author: allaway.david@deq.state.or.us

LCA and Regulation

Comparative LCA of soft drink containers and their respective waste management system in Hungary and Mexico

Adrienn Buday-Malik, Department of Regional Economics, University of Miskolc, Hungary
Dr. Klára Szita Tóth*, University of Miskolc
Guillermo Encarnación, National Center of Environmental Research and Training, Mexican National Institute of Ecology
Sergio Flores
Gábor Kiss,
Gustavo Solórzano
Tímea Molnár Sipos
István Zsolt

This paper presents the LCA and waste management systems for different types of packaging in Hungary and Mexico, through a research focused on certain materials and waste fractions, which were analysed earlier with LCA. The study shows the preliminary results of a cooperation between the University of Miskolc (Hungary) and the National Center of Environmental Research and Training of the Mexican National Institute of Ecology, as an introduction to a future research project. In both countries the LCA method is relatively new, and in this project we would like to find the possibilities for further development of LCA application, and to find the points of weakness in waste management. The environmental pressure of different types of packaging (PET, Aluminum can, and glass bottles) has been determined (2) on base of LCA (by manual calculations and using SimaPro7 and Gabi4 software), with the comparison of their corresponding waste treatment systems. The results could be applied in Mexico as a basis for environmental policy (1), as well as in Hungary where the LCA method has not yet been used. Nevertheless, the waste management scheme and its waste flows have been investigated by LCA this year in a domestic LCA project (GVOP-3.1.1-2004-05-0248/3.0) (3)

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* corresponding author: regszita@uni-miskolc.hu

LCA and Regulation

Life Cycle Approaches to State and Local Regulation – California Case Study Experience

Mike Levy,* Director, Life Cycle Management Issues - Plastics Division of the American Chemistry Council (ACC)

Life cycle information can be a powerful tool for local and state legislative and regulatory agencies to utilize as part of their input to craft effective laws and regulations pertaining to products and the environment.

More often than not, LCI information is difficult to understand by local politicians, difficult to assimilate in the political process - and the absence of such information can often lead to poor public policy decisions with unintended consequences.

Using real life examples of LCI information for plastics foodservice products and the challenges in educating key opinion makers and local leaders in California in incorporating LCI thinking into their decisions, this paper will provide a basis for addressing key questions and challenges to the use of life cycle data and life cycle thinking into local (and state) laws and regulation:

- How does LCI data get incorporated into public policy on issues of the environment – for instance, reducing litter and marine debris – when the focus of legislators/regulators focus on specific products?
- When LCI data for specific products and their alternatives (for instance, polystyrene foam foodservice products and polyethylene plastic carry-out bags) provide environment and energy tradeoffs information that are counter to proposed local political bans and solutions for litter reduction, what is the mechanism for bringing a more scientific focus and decision to the political process?
- How can LCI and life cycle thinking be better understand and utilized in the legislative and regulatory process – particularly at the local level where cities grapple with environmental legislation?
- What is the role of perspective stakeholders (governments, industry, NGOs, universities, opinion-makers) to utilize life cycle data and life cycle thinking to achieve sound public policy and make measurable improvements to the environment and society?

This full paper and PowerPoint presentation will provide an overview of specific case studies in California – and seek to improve on the process to incorporate the concepts of sustainable development utilizing the life cycle approach and principles.

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* corresponding author: mike_levy@americanchemistry.com

LCA and Regulation

LCA, LCE and LCI methods in WEEE management

Adrienn Buday-Malik,* Department of Regional Economics, University of Miskolc, Hungary

Several LCA-based projects has been launched for waste management during the past few years, but there is a lack of life cycle-focused methods used in the management of waste electronic and electrical equipments. Though this category is one of the fastest growing waste streams worldwide, neither the endusers nor the distributors are aware of the real environmental impact of discarded equipments.

It is known that LCA gives us a solution to evaluate these products environmentally in each phase of their life cycle, but the methodology still has not been applied for the end-of-life management of WEEE. Life Cycle Inventory and Life Cycle Costing models can help the evaluation and the comparison of different management systems.

Why it is important? Due to the WEEE and RoHS Directives, a positive progress was started in hazardous waste treatment in the EU, but there still are challenges to be managed: problem of historical waste, lack of capacities and methods, bad conditions of disposal sites, high rate of incineration, low ratio of regional/transnational solutions and high ratio of individual collection (instead of "bulk" programs).

The paper's aim is to give an overview on the methods to be used to support decision-making and optimization in the implementation of efficient and sustainable WEEE-systems.

Key factors of the optimization process:

- LCA thinking,
- specialization,
- cost-effectivity,
- energy-effectivity,
- time-effectivity,
- eco-effectivity,
- application of transboundary and regional solutions/systems.

Presenting a case study at Hewlett-Packard Hungary, the study points out that LCA-thinking and transnational cooperation - if applied - may result in more sustainable WEEE-systems and less environmental impact.

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* corresponding author: molbuday@uni-miskolc.hu

LCA and Regulation

Life Cycle Environmental and Energy Impacts of Extended Producer Responsibility (EPR) Policy

H. Scott Mathews, Carnegie Mellon University
Y. Anny Huang,* Carnegie Mellon University

Increased production of goods in modern times has improved people's quality of life and enabled economic growth. However, it has also led to significant increases in resource extraction, environmental degradation, and waste output. Traditionally, municipalities are given the responsibility to manage the increasing amount of waste but have no control of waste generation. In the recent decade, several countries in Europe and Asia have transferred the responsibility of waste management to producers by implementing extended producer responsibility (EPR) policies— policies that require producers to be financially or physically responsible for their products after their useful life. EPR policies give producers strong incentives to redesign their products with more effective end-of-life management (EOLM) in mind. It often results in producers having to "take back" products from customers, requiring the design of reverse logistics systems to handle the large volumes of product. Reverse transportation and recycling of products are two important life cycle phases to consider when comparing EPR policy options with traditional EOLM of waste.

Using the Economic Input-Output Life Cycle Assessment (EIO-LCA) methodology, the authors conducted an economy-wide assessment of the potential impacts of EPR policy scenarios. Using data from the purchaser price input-output model compiled by the U.S. Bureau of Economic Analysis, which provide estimates of transportation expenses resulting from delivery of goods from producers to consumers, life cycle environmental impacts of transporting goods between producers and consumers are calculated and compared to the environmental "credits" of recycling estimated using a modified EIO-LCA model. It is found that although reverse logistics transportation of product take-back contributes to certain environmental burdens in the economy, the energy consumed during delivery of most goods is relatively small compared to the energy embodied in the goods during the manufacturing phase. Improved recycling and resource recovery practices can potentially reduce the total energy consumption of industries in the economy. This presentation provides an overview of the research findings and policy implications.

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* corresponding author: yushanh@andrew.cmu.edu

Intergenerational Finance and the New Bottom Line

Chair: Hank Patton, World Steward

This panel discusses progress toward the development of a standard international market for "collateral outcomes" based on LCA. Panelists will present working examples of investment in the United States and China where strategic intent to deliver positive environmental and social outcomes can add significant non-traditional contractual revenue to the bottom line.

For example Stirling Energy Systems of Phoenix, with $5 billion in contract work underway, is building a 600MW solar thermal power plant in Southern California that will provide fuel-free renewable energy for the Western grid. The project additionally will deliver a range of non-traditional outcomes that include climate, acid rain and health consequences, as well as family wage jobs in a breakthrough clean energy technology. The panel will explore other measurable intergenerational benefits that result from the accelerated commercialization of clean technology, and new ways to get these to the bottom line.

Large-scale integrated green developments unfolding in China have significant potential to reduce and replace the need for new coal thermal plants. The Chinese coal industry, however, still grows at an accelerating pace, in contrast to the situation in Washington State, where the sole remaining coal mine at Centralia is mined out, causing significant economic, political and environmental disruption. Representing the beginning and the end of a coal investment life cycle, the Chinese and Centralia situations illuminate the critical need for a profitable intergenerational market in social and environmental outcomes, without which long-term security and stability are unattainable.

East West College President and Panelist David Slawson will premier a new state-of-the-art $150 million Portland development called the Oregon Tower. By design intent the most advanced sustainable building in the West, and occupying a full city block near the Portland Convention Center, the 23-floor complex will produce its own energy, process its own waste water, and deliver a range of designed benefits to the city and the future of the city. The Oregon Tower project has explicitly set out to create a business framework for radical efficiency and other valuable outcomes that sustainable design delivers to the future by integrating fully across sectors and through the life cycle of the full system.

What services can be incorporated to increase the value in an intergenerational business partnership of this kind? In an interactive dialog with the audience, panelists will discuss existing and planned financial mechanisms for both funding and measuring the environmental and social outcomes of this unprecedented partnership with the future.

Panelists:
David Slawson, Founder, Stirling Energy Systems; President, East-West College
Fritz Paulus, Executive Director, Oregon Water Trust
Greg Acker, Director of Sustainability and China program, Sienna Architecture

Packaging

Session Chair: Doug Huizenga

Australian Plastics and Life Cycle Management– Partnerships and Projects
Maree Lang, Clare Moran

Life Cycle Inventory and the Impact to the Wal-Mart Packaging Sustainable Value Network
Amy Zettlemoyer

Assessing the Sustainability of Packaging Systems for Fruit and Vegetable Transport in Europe based on Life-Cycle-Analysis
Stefan Albrecht, Leif-Patrik Barthel, Martin Baitz, Sabine Deimling, Matthias Fischer, Julia Pflieger

An Approach to Measuring Toxicity for the Wal-Mart Scorecard
Rita Schenck

Use of OSHA Data in an LCI Approach to Develop Safety Indicators for the Production of Selected Packaging Materials
Beverly J. Sauer

Australian Plastics and Life Cycle Management– Partnerships and Projects

Maree Lang,* Plastics and Chemicals Industries Association
Clare Moran, Environment Protection Authority Victoria

The Plastics and Chemicals Industries Association (PACIA) has actively partnered with the Environment Protection Authority Victoria (EPA Victoria) and other key stakeholders to develop life cycle management capability across its membership base.

PACIA is the pre-eminent industry association for plastic and chemical manufacturers, importers and fabricators in Australia. With much of its manufacturing membership base located in Victoria, the state regulator, EPA Victoria, is a key partner for PACIA and its members. EPA Victoria's vision is to see the Victorian community living sustainably, and EPA uses partnerships alongside statutory programs to place itself at the forefront of the sustainability agenda.

EPA Victoria's Sustainability Covenant initiative provides the framework for the partnership with PACIA. Through Sustainability Covenants, the entire life cycle of products and services is considered; to better understand environmental impacts and help focus efforts for improvement, while delivering business benefits.

This paper will discuss the evolution of the industry association's approach to life cycle thinking, the Sustainability Covenant and the formation of a life cycle program for its member companies. The PACIA program has evolved alongside and complemented the development of EPA Victoria's broader life cycle management program for industry.

Activities initially focused on awareness raising and communication and have since developed include LCA training for industry, LCM tool development, project assessment and more recently, participation in the development of an Australian life cycle inventory. The strategic drivers behind the program development from both the industry association's and the regulator's perspective will be outlined and highlighted using current case studies.

* corresponding author: mlang@pacia.org.au

Packaging

Life Cycle Inventory and the Impact to the Wal-Mart Packaging Sustainable Value Network

Amy Zettlemoyer,* SAM'S CLUB

The Wal-Mart Inc. Packaging Sustainable Value Network's goal is to improve the packaging of every product sold at Wal-Mart Stores, Inc. Additionally we hope to universally raise the bar on packaging through our unique position in the marketplace and create a race to the top for new packaging technologies and materials. These efforts coordinate and support Wal-Mart's overall sustainability goals of:

- Being supplied 100 percent by renewable energy;
- Creating zero waste;
- Selling products that sustain our resources and environment.

Through this commitment we believe, we will conserve vast amounts of natural resources, reduce global warming pollution, spark universal innovations and save money for everyone involved. The global packaging industry did more than $465 billon in business in 2005. Packaging is at the nexus of every global supply chain and customer relationship. Small changes to packaging have significant impacts on the use of materials, manufacturing, shipping containers, trucks, storage, refrigeration, waste and the energy used for production, transportation and waste.

The Wal-Mart Inc. Packaging Sustainable Value Network created the Sustainable Packaging Scorecard as a measurement tool. Beginning with our private label products, on November 1, 2007, we introduced the scorecard process which is fully transparent to our more than 2,000 private label suppliers. On February 1st 2007, the Sustainable Packaging Scorecard was made available to Wal-Mart's more than 60,000 suppliers. For 12 months, the Packaging Sustainable Value Network including Product and Packaging suppliers will improve the data behind the scorecard while the Product Suppliers input item level packaging detail. The data behind the scorecard currently being collected is GHG/CO2 equivalents for raw packaging materials as well as Health and Safety information. Both of these data sets are being collected by the Packaging Trade Associations on the Packaging SVN conducting full LCA's to ISO 14000 series standards for each raw material. Converted packaging materials, including blow molding, injection molding, additives, adhesive etc will be included in Phase II to be rolled out by 2010.

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* corresponding author: amy.zettlemoyer@samsclub.com

Packaging

Assessing the Sustainability of Packaging Systems for Fruit and Vegetable Transport in Europe based on Life-Cycle-Analysis

Stefan Albrecht, Department Life Cycle Engineering, University of Stuttgart
Leif-Patrik Barthel, Department Life Cycle Engineering, University of Stuttgart
Martin Baitz, PE International GmbH
Sabine Deimling, PE International GmbH
Matthias Fischer,* Department Life Cycle Engineering, University of Stuttgart
Julia Pflieger, Department Life Cycle Engineering, University of Stuttgart

Every day, thousands of goods make their way from the producer to the consumer. Packaging systems play an essential part in the logistic chain. For packaging fruit or vegetables, wooden boxes, cardboard boxes and plastic crates are most commonly used. While the first two are non-returnable packaging systems and normally disposed of or partly recycled after one use, plastic crates as a rule are returnable packaging, washed and reused many times.

The analysis of the individual ecological performance of the current packaging options over their lifetime and life-cycles is important, in order to identify ecologically favourable packaging system for fruit and vegetables according to specific boundary conditions. Concur-rently, optimisation potentials to further reduce the impacts of packaging can be identified. By covering ecological, economic and social effects of a system, the environmental information is framed by these two important aspects towards an overall sustainability assessment in its broadest sense.

Compared to a "one-point study", which considers fixed sets of boundary conditions and situations, in this study a different approach is pursued: a representative base case is chosen and assessed, relevant parameters influencing environmental impacts, characterised by CML-indicators, in the life cycle are identified, varied and then quantitative changes on the results are discussed.

Considered Scenarios: In the conservative scenario (10 years lifetime of the plastic crates assumed, 5 rotations per year), the amount of 66.667 crates leads to 3.333.350 fillings over their life cycle. To fulfil this transportation task with the one-way-systems (wood and cardboard) 3.333.350 crates have to be produced, used and disposed.

In the case of the multi-way scenario, 80.000 plastic crates (13.333 have to be replaced during the assumed lifetime) are produced and disposed, but require other necessities during lifetime such as washing, replacement and return transports.

Selected Results: The results are structured according to the three pillars of sustainability; environment, economy and social effects. They show selected findings of the study.

Packaging

Table 1: Contribution of the crate systems to the annual European emissions total (ppm)

	LC wooden boxes	LC cardboard boxes	LC plastic crates
Eutrophication [ppm]	0,10	0,35	0,07
Ozone Depletion [ppm]	0,003	0,0069	0,005
Summer Smog [ppm]	0,16	0,24	0,13
Global Warming [ppm]	0,20	0,50	0,23
Acidification [ppm]	0,26	0,69	0,21

Table 2: Relative increase of costs due to doubling the transportation task from the conservative scenario to the technical scenario

	LC wooden boxes	LC cardboard boxes	LC plastic crates
Increase [%]	100%	100%	87%

Table 1 shows the contribution to 5 important environmental impact categories in relation to the annual European total emissions. In Table 2 the relative increase of costs due doubling the transportation task of the different systems can be seen and Table 3 shows the amount of human labour for the different stages, which is equivalent to a "job creation potential".

Table 3: Working hours for production and operation per extended functional unit

Total working time [h]	**Wooden boxes**	**Cardboard boxes**	**Plastic crates**
Production	78657	40938	2682
Transport	30294	30294	30294
Washing and Sorting			52748
Regranulation			290

An additional scenario was assessed, assuming an alternative life time of twenty years for the plastic crates, resulting in a tendency to less environmental impact, less cost but not much less work for the plastic crate option in relation to the compared cardboard and wooden boxes.

Conclusions: The current and ongoing discussion about sustainability proofs the necessity to assess and measure sustain-ability. This study shows that it is feasible in a structured methodological way. It is clear that such a study will not be able to cover sustainability exhaustively, but it can be seen that aspects from the field of sustainability complement the environmental life cycle assessment and provide important additional information for decision makers in politics and industry. The use of the same model for the assessment of the different aspects leads to a consistent approach. The utilisation of a consistent database ensures the comparability with later studies.

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* corresponding author: matthias.fischer@lbp.uni-stuttgart.de

Packaging

An Approach to Measuring Toxicity for the Wal-Mart Scorecard

Rita Schenck,* Institute for Environmental Research and Education

The Wal-Mart Sustainability Effort is evaluating the life cycle health and safety of its products. Starting with the packaging Sustainable Value Network, an indicator that can be broadly applicable for the diversity of Wal-Mart's products is needed.

Several available toxicity models and databases were evaluated based on transparency, consensus development and ongoing support, and the PBT Profiler was chosen as the basis of the toxicological data to support the indicator.

The Wal-Mart toxicity model evaluates the persistence, bioaccumulation and toxicity of any organic compound.

Toxicity Indicator = E x L/T x BCF

Where:

E = Life cycle emissions, grams/year (from submitted LCA data)

L = Media weighted lifetime in years (from PBT output)

T = LD-50 of Most sensitive organism, g/L (from PBT output)

BCF = Bioconcentration factor (from PBT output)

The indicator is produced in units of liters, which can be added across unit processes.

The PBT profiler does not produce information on metals, and these data will have to be separately produced, based on literature reviews.

We will present data showing the indicator results for example packaging materials in the U.S. LCI database.

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* corresponding author: rita@iere.org

Packaging

Use of OSHA Data in an LCI Approach to Develop Safety Indicators for the Production of Selected Packaging Materials

Beverly J. Sauer,* Franklin Associates, A Division of ERG

Recently, there has been a proliferation of programs and initiatives that assess the sustainability or preferability of different packaging materials. One of the criteria used in some programs is toxicity.

Traditional toxicology studies assess health issues associated with end-product materials and do not consider the cumulative harmful effects of the “upstream” sequence of processes required to produce the material. Life cycle impact assessment (LCIA) evaluates potential impacts on human health and the environment for the aggregated emissions released over a product’s life cycle; however, aggregated life cycle emissions lack important details. The total release of a substance may reflect a single high-concentration release or multiple low-level releases at different locations and times. These two scenarios would likely have significantly different health impacts. OSHA statistics can supplement LCIA with actual data on worker illnesses that more accurately reflect the impacts of on-the-job exposures in various industry sectors. OSHA data also include injuries relating to occupational hazards (e.g., dangerous equipment) that are not tracked in LCA.

Relying on OSHA data for the industry sector of an end product or material (e.g., plastic resin production or a paperboard mill) neglects the health and safety implications of upstream processes. However, life cycle models provide a framework for evaluating the complete sequence of process steps, resulting in a more complete indication of associated health risks.

The purpose of the project described here was to incorporate published OSHA data into life cycle models at the unit process level to determine cradle-to-material OSHA "scores" for selected packaging materials. Common packaging materials analyzed included several plastic resins, aluminum, and paperboard.

Although a number of assumptions and allocations were required to assign OSHA data to specific unit processes, the approach was sufficient to make some comparative conclusions about cradle-to-material health and safety risks for different materials. The exercise also demonstrated that unit processes with the largest contributions to the total score tended to be raw material extraction steps or steps closest to final material production. Fortunately, these are also the steps for which OSHA data required the fewest allocation assumptions.

* corresponding author: bsauer@fal.com

LCM & LCA Education

Session Chair: Tom Gloria

Building LCA Capacity through Curriculum at Community Colleges
Pinky Dale, Rita Schenck

Making Input-Output Life Cycle Assessment Accessible to General Audiences
Troy Hawkins, H. Scott Matthews, Deanna H. Matthews

Teaching Life Cycle Analysis As An Interdisciplinary Undergraduate Engineering Course
Sean P. McGinnis

Steeluniversity.org: A new Internet E-Learning Resource on Sustainability
J. Pflieger, R. Hambleton

LCM & LCA Education

Building LCA Capacity through Curriculum at Community Colleges

Pinky Dale, South Seattle Community College
Rita Schenck,* Institute for Environmental Research and Education

Most LCA professionals have learned how to perform LCA's in graduate or professional settings, but the concepts of life cycle assessment do not require a bachelor's degree as a basis for comprehension. The existence of software such as GaBi and SimaPro facilitate the creation of LCA studies such that the level of understanding and skill is well within the grasp of a high school student with facility with software.

South Seattle Community College is developing a curriculum for a two year degree to develop LCA professionals. These students will have a basic understanding of environmental science and environmental management, including environmental accounting and statistics. They will spend a year in progressive development of their skills in environmental life cycle assessment. And they will graduate with the skills necessary to measure sustainability and influence organizations towards more sustainable actions.

The project is underway: in winter 2008, the first classes will be offered. Best of all these classes will be available on the internet, and the curriculum will be open source, for other colleges to take up and integrate into their own programs. That will provide for exponential growth in the number of LCA professionals in the United States.

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* corresponding author: rita@iere.org

Making Input-Output Life Cycle Assessment Accessible to General Audiences

Troy Hawkins, Carnegie Mellon University
H. Scott Matthews, Carnegie Mellon University
Deanna H. Matthews,* Carnegie Mellon University

Input-output life cycle assessment is typically a topic for advanced researchers and practitioners. The complex nature of input-output life cycle assessment, especially issues with uncertainty and impact assessment, limit researchers from fully utilizing the concept to provide concrete answers in their research. Yet, teaching the concept of life cycle thinking is essential for future engineers to make decisions that minimize environmental and social impacts. IO-LCA can be a part of this education, but given the complexity and uncertianty, how does one explain the overall concept to non-experts?

We will present a classroom activity suitable for a range of audiences to learn the basic concepts of economic input-output life cycle assessment. The activity involves a simulation of a four-sector economy with transactions between each sector creating a supply chain. Participants determine production functions between the sectors, then given a final demand, calculate the transactions between the industries. The results are determined for physical units, monetary units, and waste units. Discussion of the exercise includes recognition of the circular supply chain, identifying direct versus indirect impacts, and how the results can guide decision makers to target improvements in the system. We then demonstrate how the 4-sector system can be modeled using matrix algebra, which allows extending the system to large numbers of sectors. We will also describe how the activity has been developed over time to improve the delivery of the concepts.

The activity has been used successfully with students from high school through graduate school. Overwhelmingly, the initial reaction to the activity is awareness of the boundless number of resources and transactions required for even a simple product. Even students without knowledge of matrix algebra appreciate the ability to use mathematical techniques to model the system, given the difficulties and errors they encounter during the simulation. The activity has allowed general audiences to comment on our research methods and results with only minimal time spent on relaying background information, and given graduate students a clearer understanding of the mechanics behind the theory they use in course projects and research.

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* corresponding author: dhm@cmu.edu

Teaching Life Cycle Analysis As An Interdisciplinary Undergraduate Engineering Course

Sean P. McGinnis,* Virginia Tech Green Engineering Program

Environmental Life Cycle Analysis (ENGR 3134) is a stand-alone upper level undergraduate class taught as part of the Green Engineering Program at Virginia Tech. This multidisciplinary program strives to work across all 12 College of Engineering departments to expose students to the environmental impacts of engineering practice. Environmental Life Cycle Analysis is one of two required core courses for an 18-credit (6 courses) Green Engineering minor.

The class content covers a wide range of topics including each of the typical life cycle phases and the main steps for completing an LCA for products, processes, or systems. Particular attention is focused on carefully defining the project boundaries and assumptions as well as the collection and assessment of inventory input/output data since most undergraduate engineering students have little practice in these critical skills. LCA concepts which prove difficult for the students to understand clearly include functional units, normalization, and weighting.

Pedagogical challenges in the LCA class content include the following balances: (1) model simplicity vs. complexity; (2) coverage of background material vs. specific examples across disciplines; and (3) individual work vs. group projects. Commercial LCA software and several internet resources are utilized to aid students in working through real LCA examples, but these have a variety of issues which must be addressed to ensure a good environment for students to learn the skills to use LCA appropriately. LCA case studies are interesting and engaging from the students' perspective, but are often either too simple or too complicated for an optimum learning experience. Case studies which show LCA used as an iterative design tool are need to show the power of LCA beyond comparisons, however, few appropriate examples of this use of LCA have been found. Finding ways to collaborate with the LCA community to leverage its experience and expertise has the potential to signficantly improve the teaching and learning of this subject at the college level.

* corresponding author: smcginn@vt.edu

Steeluniversity.org: A new Internet E-Learning Resource on Sustainability

J. Pflieger,* Life Cycle Engineering Dept, LBP, Stuttgart University
R. Hambleton, International Iron and Steel Institute

The International Iron and Steel Institute (IISI – http://www.worldsteel.org) has initiated the development of a comprehensive, freely-available, internet-delivered package of highly interactive e-learning resources for undergraduate students and steel industry employees. The resulting e-learning environment (http://www.steeluniversity.org) creates a ‘one-stop’ shop covering all aspects of steelmaking, steel products and applications, the underlying scientific and engineering principles, industrial and academic collaboration, as well as environmental and sustainability issues relevant to the steel industry.

The module entitled “Sustainability, Steel and the Environment” of the steeluniversity.org provides interactive e-learning resources on the following topics:

- Sustainability
- Principles of Life Cycle Thinking
- Environmental Life Cycle Assessment
- Application of Life Cycle Assessment

The aim of this particular module is to enable the learner to identify relevant environmental parameters over the life cycle of steel products as well as to learn about the resulting environmental effects and impacts. Furthermore he/she will be enabled to explain the basic idea of Life Cycle Thinking and Life Cycle Assessment (LCA) in terms of Goal and Scope definition, System Modelling, Life Cycle Inventory (LCI), Life Cycle Impact Assessment and Interpretation. In addition, the learner can explore selected LCA scenarios facing the steel industry and its customers in the automotive and construction sectors.

* corresponding author: julia.pflieger@lbp.uni-stuttgart.de

Impact Assessment

Session Chair: Martha VanGeem

Okala Impact Factors: North American single-figure process values for product and system impact estimation
Philip White

USEtox: The UNEP-SETAC consensus model for life-cycle impacts on human health and ecosystems
Michael Hauschild, Thomas McKone, Mark Huijbregts, Manuele Margni, Ralph Rosenbaum, Dick Van de Meent, Olivier Jolliet

Life Cycle Impact Assessment of Global Trade on Human Health: T-shirts as a case study
Shanna Shaked, Julia Steinberger, Damien Friot, Stefan Schwarzer, Cedric Wannaz, Manuele Margni, Suren Erkman, Sebastien Humbert, Olivier Jolliet

Note: the following two related abstracts will be presented as a single presentation

An improved method to calculate Land Use effects on endpoint level
An De Schryver, Mark Goedkoop

An improved method to calculate climate change effects on midpoint and endpoint level
An De Schryver, Mark Goedkoop

Impact Assessment

Okala Impact Factors: North American single-figure process values for product and system impact estimation

Philip White,* Arizona State University

This paper reviews the origins and methodological framework of the Okala impact factors. Okala impact factors are single figure values that can be used to estimate overall environmental impacts of materials, processes, and overall lifecycle performance of competing product or service systems. System development teams, professional product designers as well as design, business and engineering students use the Okala impact factors.

The factors have been calculated for 240 materials and processes, including major plastics, metals, packaging materials, transportation methods, electricity and energy sources, incineration, landfill and recycling impacts. The Okala Impact Factors comprise the only usably specific palette of values for a broad range of materials and processes assessed with North American methods that is currently available to designers and system planners. System designers need values for a wide range of materials and processes to compare and refine alternative configurations. Okala Impact Factors were developed to meet these needs. We surveyed 95 working product designers (mostly from North America) who informed us for which processes and processes they currently need environmental impact assessment results (4). This paper also lists the types of materials and processes for which companies and designers currently use, or increasingly want to use, but no inventory data is readily available.

This paper outlines methodological components and considerations used to create the Okala Impact Factors. The impact categories, normalization values and weighting values used for the Okala Impact factors are listed in the table below with the appropriate source. These sources were each selected because they are legitimate centers for LCA expertise in North America. This set of values was consistently applied to assess all processes and materials.

- Characterization impact categories and methodology (the U.S. E.P.A. developed Tool for Reduction and Assessment of Chemicals and other Impacts [TRACI](1))
- Normalization data source (U.S. E.P.A.(2)) and weighting values source (National Institute for Standards and Technology [NIST](3))

Impact Assessment

Table I TRACI Impact categories included in Okala Impact Factors			
TRACI impact category[1]	Normalization[2]	unit	Weight[3]
Acidification	7440	H+ equiv/yr/capita	0.036
Ecotoxicity	73.8	2,4-D equiv/yr/capita	0.091
Fossil fuel depletion	0.0408	MegaJoule/yr/capita	0.117
Global warming (climate change)	24500	Tons CO_2 equiv/yr/capita	0.354
Human cancer	0.258	Benzene equiv/yr/capita	0.092
Human respiratory	76.3	PM2.5 equiv/yr/capita	0.106
Human toxicity	1470	Toluene equiv/yr/capita	0.063
Ozone layer depletion	0.311	CFC-11 equiv/yr/capita	0.024
Photochemical smog	121	NOx equiv/yr/capita	0.042
Water eutrophication	18	N equiv/yr/capita	0.075

- Chemical input/output data sources, including selection and development of inventory data, challenges of dealing with data uncertainties, and strategies for identifying data for crucial materials and processes

Each factor contains the discrete impact values of the ten impact categories prescribed in the TRACI characterization methodology. In a more narrow assessment comparing a few processes, context is essential. But for a palette of process values whose primary function is its ability to be rapidly used in virtually any situation or system, the primary objective is to provide data-derived results based on the best available information.

Normalization values are based on the science from the US EPA. Weighting values are admittedly based on subjective evaluations of NIST. This subjectivity could not be avoided by not weighting. Non-weighting assigns equal weighting of each impact category, which is as subjective as assigning other weighting values. I use the NIST values because NIST is a recognized US authority science and technology; these values are the most legitimate values of which I am aware.

Impact Assessment

The paper considers challenges to developing more accurate factors through higher quality (less uncertain) process flow data. Uncertainty exists in all forms of impact assessment, including both process flow assessment (such as the Okala Impact Factors) and input/output economic correlation (hybrid) assessment. These impact factors were produced with the awareness that uncertainty exists and should be minimized wherever possible.

It also describes how the Okala Impact Factors have been used in classroom settings in terms of what are the proposed and observed learning outcomes, with suggestions on how best to help engineers, designers and design teams use the factors accurately and in the appropriate context.

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* corresponding author: Philip.White.1@asu.edu

Impact Assessment

USEtox: The UNEP-SETAC consensus model for life-cycle impacts on human health and ecosystems

Michael Hauschild, Technical University Denmark/DTU
Thomas McKone, University of California - Berkeley
Mark Huijbregts, Radboud University, Nijmegen
Manuele Margni, CIRAIG-Ecole Polytechnique de Montreal
Ralph Rosenbaum, CIRAIG-Ecole Polytechnique de Montreal
Dick Van de Meent, RIVM, Bilthoven
Olivier Jolliet,* University of Michigan, School of Public Health

Life cycle impact assessment (LCIA) characterizes emissions for the life-cycle assessment (LCA) of a product by translating these emissions into their potential impacts on human health, ecosystems, global climate and other resources. This process requires substance-specific characterization factors (CFs) that represent the relative potential of specific chemical emissions to impact human disease burden and ecosystem health. Within the Life Cycle Initiative, a joint initiative of the United Nations Environment Program (UNEP) and of the Society of Environmental Toxicology and Chemistry (SETAC), a consensus model called USEtox was established to develop internationally harmonized CFs. In 2005 the LCI initiated an international comparison of six models used to make CF calculations. In this paper we describe this model-comparison process and its results_in particular the consensus model. The comparison focused on model differences both in terms of results and model structure. In three workshops, the model comparison participants identified crucial fate, exposure and effect issues for which the models differed. This process identified important sensitivities, differences in assumptions, and model structures that could be harmonized among the different models. Through this process, we were able to reduce inter-model variation. This process also led to the development of a consensus model that contained only the most influential model elements. The consensus model provided a parsimonious and transparent tool for making human health and ecosystem CF estimates. The consensus model has now been used to calculate CFs for several thousand substances and is intended to form the basis of the recommendations from UNEP-SETAC's Life Cycle Initiative regarding characterization of toxic impacts in Life Cycle Assessment.

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* corresponding author: ojolliet@umich.edu

Impact Assessment

Life Cycle Impact Assessment of Global Trade on Human Health: T-shirts as a case study

Shanna Shaked,* University of Michigan Applied Physics
Julia Steinberger, University of Lausanne
Damien Friot, University of Geneva
Stefan Schwarzer, United Nations Environmental Programme
Cedric Wannaz, University of Michigan
Manuele Margni, Ecole Polytechnique Montreal
Suren Erkman, University of Lausanne
Sebastien Humbert, University of California Berkeley
Olivier Jolliet, University of Michigan

Globalization and the resulting increase in trade result in significant and potentially unequally distributed health impacts between producing and consuming nations. Clothing, in particular, is increasingly exported from developing countries such as India and China to the more developed US and EU. In order to determine the environmental and health impacts of these consumption patterns, we use life cycle impact assessment techniques to design a model that links emissions resulting from production to the subsequent health impacts on both the producing and consuming countries.

Focusing specifically on Chinese and Indian factories, we perform a life cycle analysis to estimate the emissions due to the production of one T-shirt. A GIS-based environmental exposure module then estimates the pollutant transport, deposition and population intake fractions at local and global scales. Finally, the impacts of the pollutants are evaluated through a dose-response and severity module which estimates their impact potential on human health and ecosystems. This combined multicontinental model thus assesses the health impacts due to each country's consumption. Different scenarios of the model are run in order to provide guidance to decision-makers on the optimal methods for decreasing human health impacts and increasing sustainability in global trade.

* corresponding author: shaked@umich.edu

Impact Assessment

An improved method to calculate Land Use effects on endpoint level

An De Schryver,* PRe Consultants
Mark Goedkoop, PRe Consultants
Note: this abstract and the one that follows will be presented as a single presentation

For several years, the impacts of land cover changes on ecosystems are a topic of wide interest in LCA. Unfortunately, until now, no ultimate desirable method has been found and different limited methods are used next to each other. Within the framework of the ReCiPe Project (a cooperation between Radboud University of Nijmegen, Centrum voor Milieukunde Leiden-CML and PRé Consultants), a new method is developed to calculate the damage to ecosystems caused by the effects of occupation and transformation of land.

The goal of this project is to link midpoints (CML) and endpoints characterisation factors (Eco-indicator 99) and to update the underlying methods and data used in the methodologies. For this impact category, we have not yet been able to make a link from midpoints to endpoints. As a result, only the calculation of endpoint characterisation factors will be discussed in this paper. The endpoint indicator for land use describes the loss of species diversity, expressed in Potentially Disappeared Fraction (PDF) of species, due to occupation or transformation. Because the PDF is influenced by the species-area relationship (S=cAz) we took a closer look at the c and z factors to be used in this relation and implemented a different z for each different land use type and area size. Furthermore, special attention is paid at agricultural areas. The fact that the main species richness of an arable field is relatively independent of what grows on the field, but is determined by the edges, made us decide to use the species richness in the boundary of the agricultural area to calculate the PDF of the total field. As a result, three archetypes of land use intensiveness are distinguished: monocultures, intensive and extensive areas. For the calculations, the work of Koellner (2006), the Countryside Survey 2000 (UK), and Crawley and Harral (2001) is used. The resulting method is transparent and novel to its kind because of the inclusion of both midpoint and endpoint characterisation factors and three archetypes of land use intensiveness.

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* corresponding author: Schryver@pre.nl

Impact Assessment

An improved method to calculate climate change effects on midpoint and endpoint level

An De Schryver,* PRe Consultants
Mark Goedkoop, PRe Consultants
Note: this abstract and the previous one will be presented as a single presentation

Since the UNEP-EPA-CML workshop in 1999 in Brighton, a broad consensus has grown among LCA practitioners and methodology experts that it is desirable to "midpoint" approaches and "endpoint" approaches in a common framework, as both have their specific strengths and weaknesses. Within the frame of the ReCiPe Project (A cooperation between the Radboud university of Nijmegen, Centrum voor Milieukunde Leiden and PRé Consultants), an improved method for LCIA is designed in which category indicators can be chosen at the midpoint level or at the endpoint level. This paper describes the way the impact of climate change at midpoint and endpoint-level, on human health and ecosystems, is handled and implemented. The produced method is a follow up of the Eco-indicator 99 method, but totally novel of its kind. In comparison with the Eco-indicator 99 method it has a better framework, using state of the art developments in the field of environmental mechanisms associated to climate change. Furthermore, ecosystem damage endpoints are now included and the calculated human health damage is based on 5 health effects instead of 3 in the Eco-indicator 99 method.

At midpoint-level, the new IPCC equivalency factors are used to combine all different emitted gasses to one single CO2-equivalent score. At endpoint-level a more complex and new model is developed, that somewhat differs from the traditional structure "fate-effect-damage". The usual fate step is not applicable to climate change and the effects are analyzed in a two-way procedure. First, a link between CO2–equivalents and temperature rise is made (temperature factor). Second, the relation between temperature rise and the impact on human health and ecosystems is calculated (damage factor).

The temperature factor describes the change in temperature caused by a certain emission during a certain time period. Almost all studies we found correlate an emission scenario (emissions per year) with a temperature change. For our project we need the link between an emission, expressed as mass load and a (temporary) temperature increase. We found this relation in the PHD dissertation of Meinshausen (2)(4), who analysed the effect of mitigation measures in a wide range of climate models.

The damage factor is different for human health and ecosystem damage. For human damage (DFHH) the marginal change in temperature is linked to marginal changes in DALY [daly/yr.°C]. The health effects considered in this study are malnutrition, diarrhea, cardiovascular diseases, malaria and, inland and coastal flooding. The data needed to calculate the damage factors for human health are derived from McMichael et al. (3). This report describes how health risks increase as a function of temperature increase for the different health effects in different world regions.

Impact Assessment

The damage factor for ecosystem damage (DFES) due to climate change links the marginal changes in temperature to marginal changes in disappeared fraction of species [PDF/°C]. The extinction factors needed are derived from the paper of Thomas et al. (5). This study predicts the extinction of species on a global scale using three different methods . The most specific calculation method, method 3, is chosen. Furthermore, it uses the area species relationship which is also used in land-use, and it is a compilation of several regional studies. It presents extinction risks, for global and local temperature changes, for several taxa and with or without adaptation (in the form of dispersal). Because a global scale effect is analysed, the global temperature changes are used.

To handle the model uncertainties arising in the step from temperature rise to impact effect, the cultural perspectives , as used in Eco-indicator 99, are applied in our calculations (1)(6).

Impact category	Assumptions	Individualist	Hierarchist	Egalitarian
Human health	Time horizon	20 year	100 year	500 year
Human health	Emission scenario	S550-unmitigated	S550-unmitigated	S550-unmitigated
Human health	Adaptation	full	mean	No
Ecosystems	Dispersal	Yes	Yes	No
Ecosystems	Taxa	All	All	Red list species

As a result, characterization factors on both midpoint and endpoint level are produced. The endpoint characterization factors for climate change health damage and ecosystem damage, for three different cultural perspectives, are presented in the table underneath

Impact on	Unit	Individualist	Hierarchist	Egalitarian
Human health	Daly/kgCO 2	1,19E-09	1,40E-09	3,51E-09
Ecosystems	PDF.m 2 .yr/ kgCO 2	0,512	0,512	1205

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* corresponding author: goekoop@pre.nl

Using the US Life Cycle Inventory Database

Special Session Coordinator: Michael Deru, National Renewable Energy laboratory
Mike Levy, Plastics Division of the American Chemistry Council
Annie Landfield Greig, Four Elements, LLC

The US LCI Database is a free source of LCI data applicable to US industry. Michael Deru will present an overview of the LCI database. Mike Levy will provide a data supplier's perspective. Annie Landfield Greig will present a data user's perspective on how to use the data and the strengths and weaknesses of the database.

Agriculture

Session Chair: Amy Landis

Ecologically Based Life Cycle Assessment
Yi Zhang, Anil Baral, Bhavik R. Bakshi, Gary Jakubcin, Joseph Fiksel

The relationship between environmental impacts and economic performance in crop and vegetable production: Reconsidering assessments using representative farm data
Kiyotada Hayashi, Miyuki Kurosawa

Calories in Context: Life Cycle Considerations for Improving the Sustainability of Industrial Food Production
Nathan Pelletier, Peter Tyedmers

Agriculture

Ecologically Based Life Cycle Assessment

Yi Zhang, Dept. of Chemical and Biomol. Eng., Ohio State University
Anil Baral, Dept. of Chemical and Biomol. Eng., Ohio State University
Bhavik R. Bakshi,* Dept. of Chemical and Biomol. Eng., Ohio State University
Gary Jakubcin, Owens Corning Science & Technology, LLC.
Joseph Fiksel, Dept. of Integrated Systems Engineering, Ohio State University

Traditional LCA mainly focuses on emissions and their impact throughout the life cycle. Consumption of some nonrenewable resources and land use are also sometimes included, albeit in a variety of units. Impact assessment methods combine these results. Other commonly used life cycle approaches include energy analysis, which only accounts for nonrenewable energy use and has been popular for the analysis of energy processes and transportation fuels. Despite many advances, most existing methods ignore the crucial role that ecosystem goods and services: the very resources that are vital for sustainability. Consequently, resources such as fertile soil, pollination, water, and carbon sequestration are often ignored. This can result in misleading conclusions and incorrect decisions.

This presentation will describe an original approach to LCA that accounts for the contribution of ecosystem goods and services to industrial activity (natural capital). This "Ecologically-Based LCA" or EcoLCA accounts for inputs from nature such as water use from different sources, soil erosion, land use, pollination services, fish, wind, sunlight and bio-geo-chemical cycles. Other resources such as minerals and fossil fuels are also included. Such information is available in diverse units of mass, quantity or energy, which are difficult to combine and highly multivariate. Methods are proposed for characterizing and categorizing this information in a few categories such as ecosystem goods, ecosystem services, renewable, nonrenewable etc. These mid-point categories may be further combined to yield end-point indicators. Various physical methods such as mass, energy, cumulative exergy and emergy are explored for the proposed categorization. If emissions and impact data from a conventional LCA is available, it can also be combined with the proposed approach. Combination with an input-output model (1) will also be described.

This approach has been applied to a variety of products, some of which will be included in this talk. These include paper and plastic products, and an analysis of fiberglass insulation. Implications of this work for the evaluation of emerging technologies or at early stages of decision making will also be discussed.

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*corresponding author: bakshi.2@osu.edu

Agriculture

The relationship between environmental impacts and economic performance in crop and vegetable production: Reconsidering assessments using representative farm data

Kiyotada Hayashi,* National Agriculture and Food Research Organization
Miyuki Kurosawa, National Agriculture and Food Research Organization

Agricultural and environmental policies to establish sustainable production systems have been established in Japan. One of the main characteristics in these policies is that the attention is paid to improvements in fertilizer and pesticide application practices. Since the policy objectives correspond to the areas of protection in life cycle impact assessment (LCA) terminology, LCA will play an important role in evaluating and establishing sustainable production systems. However, the environmental and economic impacts of the practices have not fully been analyzed in Japan. One reason may be the lack of well-organized databases such as the Farm Accountancy Data Network in Europe.

This study analyzes the relationship between the environmental impacts of agricultural practices such as fertilizer and pesticide application and income indicators including crop yields and gross income. The data used in this study are farm accountancy data, which are gathered to clarify the environmental and income impacts of management practices for reducing fertilizer and pesticide application. Although the data are not exhaustive, this study analyzes the relationship on the case basis; the production of rice and that of lettuce are analyzed as examples.

The results can be summarized as follows: (1) In rice production, there is a positive relationship between environmental impacts of, e.g., pesticide application and crop yields. This means that in order to increase crop yields, environmental degradation is unavoidable; there is a trade-off between environmental and agronomic performances. In contrast, there is a negative relationship between environmental impacts and gross income. This implies that strong sustainable improvements in eco-efficiency can be realized. (2) In lettuce production, the detailed differences among farmers and their fields are analyzed. Although the results are relatively complicated, there is a tendency that sustainable production practices do not necessarily give higher income performance. These results indicate that rethinking the appropriateness of using representative farm data in agricultural production systems would be necessary.

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* corresponding author: hayashi@affrc.go.jp

Agriculture

Calories in Context: Life Cycle Considerations for Improving the Sustainability of Industrial Food Production

Nathan Pelletier,* Dalhousie University
Peter Tyedmers, Dalhousie University

In recent decades, the cumulative contribution of industrial activities to the disruption of global biogeochemical cycles has become increasingly apparent. Although considerable uncertainly exists regarding the actual levels of perturbation that natural systems can accommodate, it is widely recognized that the scale of human activities is ultimately constrained by biophysical limits, and that sustainable development must include efforts to vastly improve the biophysical efficiency of industrial society.

Life Cycle Assessment provides a powerful, and increasingly popular, means of quantifying the contributions of discrete industrial activities to a broad range of biophysical concerns including resource depletion and greenhouse gas, ozone depleting and acidifying emissions. Such an approach provides a rigorous foundation for improving environmental performance within industrial supply chains and, more generally, for making comparisons between competing production technologies.

While fulfilling a fundamental human requirement, food production is also among the most important contributors to every major environmental problem, from local to global scales. Indeed, how to meet the nutritional requirements of a growing human population without further compromising the stability of the very biogeochemical cycles that provide the implicate order for biological productivity is among the most pressing challenges of the 21st century. This presentation will discuss key insights gained from life cycle analyses of three distinct food production systems (Canadian field crops, the US broiler sector, and feed production for salmon aquaculture) in the context of strategies for maximizing resource returns on investment while minimizing environmental harms.

* corresponding author: nathanpelletier@dal.ca

LCA Methods

Session Chair: Liila Woods

Economic Input-Output Life Cycle Assessment at Regional Level
H. Scott Matthews, Y. Anny Huang

The Role of Displaced Production in Life Cycle Assessments
Roland Geyer, Vered Doctori Blass

From Product to Material Analysis - Challenges, Chances and Limits of LCA
Julia Pflieger

Time-Dynamic Parameterised LCI-Modelling - A Further Dimension in LCA
Matthias Fischer, Julia Pflieger

LCA Methods

Economic Input-Output Life Cycle Assessment at Regional Level

H. Scott Matthews,* Carnegie Mellon University
Y. Anny Huang, Carnegie Mellon University

Planning and investment decisions at the regional and local levels have great impacts on people's everyday life. Most environmental issues are experienced locally and are most effectively managed at regional or local levels. Various life cycle assessment (LCA) tools developed in the past decade have helped decision makers in industry and government alike to consider the life cycle impacts of project, products, and services. However, impacts throughout the supply chain may occur in different regions or states, but the standard process-based LCA as well as input-output LCA based on national economic model have not been able to effectively estimate the locations of impacts occurred elsewhere throughout the product's supply chain. In recent research, the authors created a tool for visualizing the spatial distribution of life cycle impacts in the national Economic Input-Output Life Cycle Assessment (EIO-LCA) model by applying regional multipliers to the national model. The regional or state multipliers are created for all production processes using publicly available data. The results of visualization inform EIO-LCA users about the regions or states that bear the most environmental burdens, including conventional air pollutants, greenhouse gas emissions, toxic releases, and energy consumption, due to certain economic activities.

In addition, the authors have developed environmental impact factors (i.e. environmental vectors in EIO-LCA background calculation) for conventional air pollutants that are specific to the industrial efficiency in the states of interest. The environmental impact factors are created using the National Emission Inventory, public data available from the U.S. Environmental Protection Agency. They can be used in customized regional EIO-LCA model to help inform decisions on regional or local scale. They can also be used to compare the production efficiency of industry among states for benchmarking environmental performance purposes.

Using these tools, decision makers can assess economic and environmental impacts of their projects, justify changes in operation and budgeting, estimate local or regional pollutant releases due to certain economic activities, and visualize spatial distribution of life cycle impacts throughout the supply chain of products and services.

* corresponding author: hsm@cmu.edu

LCA Methods

The Role of Displaced Production in Life Cycle Assessments

Roland Geyer,* Bren School of Environmental Science and Management, UCSB
Vered Doctori Blass, Bren School of Environmental Science and Management, UCSB

Recycling of materials and reuse of products or their components is a critical part of life cycle management and product stewardship. Many life cycle management initiatives are driven by the idea of turning production and product wastes into secondary resources that avoid primary production processes. Life cycle assessments consistently show that the environmental benefits of displacing other production processes, like primary material production, are usually substantially larger than the benefits of avoiding landfill or incineration. In fact, the emerging standard for modeling product systems with reuse or recycling, the avoided burden approach, is based on the premise of displaced production. However, life cycle assessments of product systems with reuse and recycling all share one fundamental problem: How do we know that reuse and recycling activities displace other production processes, and how do we determine which processes are displaced and to what extent? This is not a trivial matter since any proof of displacement has to be based on counterfactual reasoning. An example of counterfactual logic is: ‘Virgin paper production would have been x tons higher if y tons of paper had not been recycled.’ This presentation gives an account of the existing practices in life cycle assessment with respect to displacement and reviews efforts to substantiate these practices with empirical evidence. It is surprising and troublesome how little empirical work exists to date, given the importance of reuse and recycling in life cycle assessments. The second part of the talk presents an empirical analysis framework of displacement and its application to several case studies.

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* corresponding author: geyer@bren.ucsb.edu

LCA Methods

From Product to Material Analysis - Challenges, Chances and Limits of LCA

Julia Pflieger,* Department: Life Cycle Engineering, LBP, University of Stuttgart

The life cycle characteristics of a material varies as a function of its reuse or recycling in future application within consumer products, not only the first use in a product. Providing Life Cycle Inventory (LCI) data on reused and recycled materials relies upon ISO-conforming use of the supplied data within Life Cycle Assessment (LCA) studies of products, taking into account all relevant life cycle aspects.

LCI data providers from industry sectors with high material recycling potential are concerned that one of the main life cycle benefits of their materials, the recycling potential, is not appropriately accounted for by non-LCA experts.

One of the drivers for this concern are the national and international database activities activities which are characterised by an increasing use and application of the provided data by non-LCA experts. In addition, the data is usually offered for download without registration or specification of the intended application, and this gives no possibility for discussion or user guidance in view of the intended use of the data. To ensure the appropriate consideration of end-of-life issues for products containing materials with high recycling potential, it may be appropriate to incorporate the recycling credit within the cradle-to-gate inventory data.

It follows that an intelligent and context sensitive approach to data provision is required. The reason is that a variety of parameters, describing the recycling effects within LCA studies, are only defined in the context of the product-specific life cycle characteristic, e.g. the application-specific recovery rate of materials.

This presentation will discuss the challenges and consequences of this approach and will give an overview of the main key aspects of influence in this context:

a) the methodological approach to consider recycling effects within LCA, e.g. system boundary expansion by crediting

b) the life cycle aspects of influence on recycling, e.g. the specific recovery rate which is specified by the collection efficiency, the recycling process efficiency, the degree of separation, etc.

In addition, the discussion will be opened about an appropriate methodological approach to incorporate those aspects in a scientifically adequate and practical way.

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* corresponding author: julia.pflieger@lbp.uni-stuttgart.de

LCA Methods

Time-Dynamic Parameterised LCI-Modelling - A Further Dimension in LCA

Matthias Fischer, Department Life Cycle Engineering, University of Stuttgart
Julia Pflieger,* Department Life Cycle Engineering, University of Stuttgart

Time relations in LCA (Life Cycle Assessment) are occurring in different context like weighting of past, current and future emissions / resource consumption and related impacts, chemical fate and long-term impacts, prognoses for future LCA and dynamic LCI (Life Cycle Inventory) modelling. In the following the focus will be set to the time-dynamic LCI modelling as basis for various analyses of time relations in LCA.

Presently, LCA is used on a static basis related to boundary conditions of a certain time and based on evaluations done for a certain time period. Within existing LCA-tools time aspects in LCI modelling are not comprehensively implemented.

In present LCA time aspects are taken into account only for few and very specific issues such as long term emissions from landfill. In this case the prognosticated overall emissions occurring during the landfill operation and the subsequent degradation phase are often aggregated and calculated as being released right now. Therewith the long term time dependent emissions are taken into account but the specific technical future boundary conditions (e.g. changed technical options for landfill waste water treatment and landfill gas collection and handling) are neglected. Especially in LCA considering long time periods, assessment of products with long life cycle time or future prognoses, changes in the results are expectable. If only present boundary conditions are considered, this leads to significant differences in results in comparison to using the boundary conditions of the in each case corresponding time period. With the consequent integration of time aspects in the modelling process the results will be more precise and more significant – and thus will lead to a strengthening of LCA method and the conclusions drawn from LCA results.

Integration of temporal aspects in LCA is of special interest e.g. in the following cases:

- Mapping of past and future developments and the related environmental effects (e.g. power grid mix).
- Consideration of past and future boundary conditions of known future life cycle phases (e.g. calculation of End-of-Life options in 50 years with boundary conditions in 50 years and comparison with present boundary conditions to answer the question “which end-of-life treatment option is most suitable in future?”).
- Evaluation of long-term life cycles with the respectively actual boundary conditions and upstream processes (e.g. buildings).

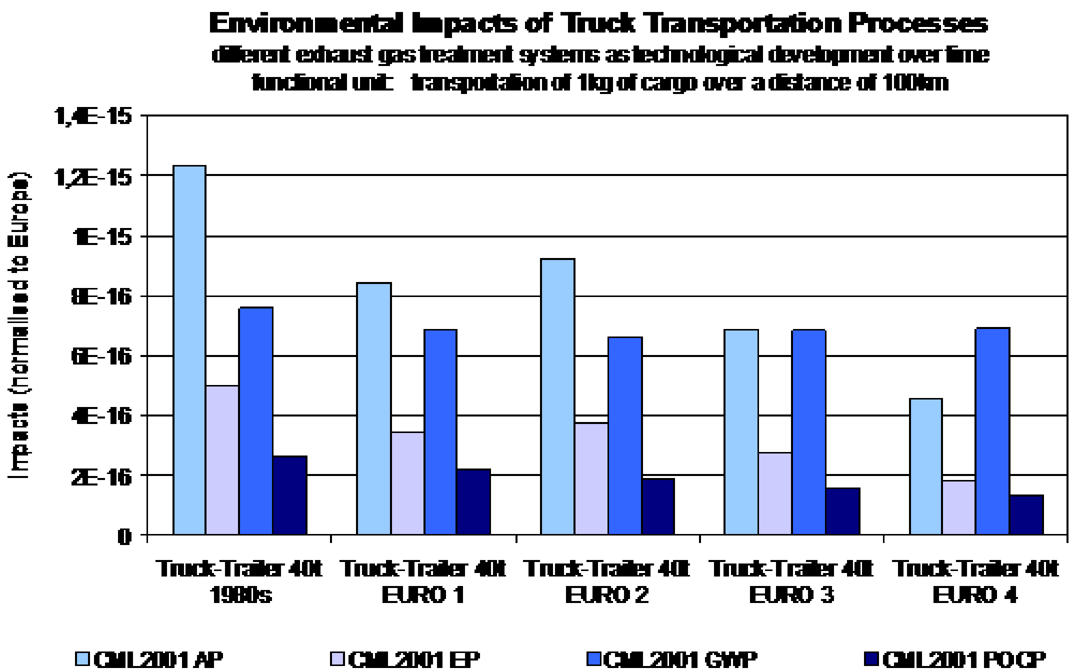
The next question is in which cases are time aspects of relevance and therefore of interest to be included in LCI modelling? In general this can be answered as follows:

- in case of dynamic development on site (foreground system),
- in case of dynamic development in LCA relevant upstream processes (background system),
- in case of long life cycle (e.g. long use phase),
- in case of LCA relevant end-of-life phase,
- in case of countries with dynamic (technical/economic/social) development.

Also other cases could occur and not all mentioned cases lead stringently to a big influence of time aspects to the overall results. So the specific boundary conditions and technical parameters of processes as well as relevant life cycle phases and processes with a high rate of change are analysed. For a detailed analysis relevant time-sensitive parameters have to be identified. These are parameters with a high environmental relevance and/or important technological changes or variations within short time periods.

Technological development as fundamental part of our societal development is dynamic development over time. One example of technological development is the increasing exhaust gas treatment in transportation, which directly influences the environmental impacts of transportation (see the figure below). Over the last twenty years the exhaust gas treatment technology was adapted to the respectively valid regulations – in Europe beginning in the 1980s (ECE R 49.00/ECE R 49.01) over EURO 1 (1993), EURO 2 (1996), EURO 3 (2000) actually to EURO 4 (2006).

This temporal differentiation is also used to evaluate transportation processes in product LCA to analyse and compare environmental impacts of production, use phase and end-of-life options in long life cycles.



Basis for the advanced time dynamic LCI-modelling are parameterised models which are calculated for several time frames. The results of current work in the sector of energy (mainly power generation and environmental impacts of the grid mix) will be shown in the presentation.

Further use of the results is the broad integration in complex product models. The for each temporal boundary conditions the corresponding background processes can be chosen and therewith more significant results for life cycles and parts of life cycles can be calculated. Therewith conclusions about the environmental soundness of expenditures e.g. to recycle materials can be compared to the expenditures in the production phase.

* corresponding author: julia.pflieger@lbp.uni-stuttgart.de

Choosing Life Cycle Impact Indicators

Special Session Coordinator: Wayne Trusty, Athena Institute

Panelists:
Tom Gloria, Life-Cycle Services
Anne Landfield Greig, Four Elements, LLC
Gary J. Jakubcin, Owens Corning Science & Technology, LLC

There is currently considerable discussion and intensive work underway throughout the LCA community on the question of selecting relevant and appropriate life cycle impact assessment measures to meet specific study goals, especially in existing and emerging tools. The UNEP-SETAC Life Cycle Initiative is being especially proactive in this regard, working towards developing criteria to determine relevant impacts one would consider when conducting a LCA study. As might be expected in an evolving methodology, there is also considerable controversy and misunderstanding about the specific requirements in the ISO 14040 ff series of standards, as well as in the emerging standards such as ISO FDIS 21930. This session will attempt to shed light on the issues through an interactive forum, not only among panelists but also with the audience. Each of four panelists will represent a distinct perspective: that of the impact measure expert, the data provider, the tool developer, and manufacturers who perform and/or commission LCAs and are affected by comparative measures. The moderator will set the stage by outlining the current requirements under ISO and then invite each of the panelists to briefly outline their position on the use and future development of impact measures. The balance of the time will be devoted to a facilitated exchange involving the audience as much as possible. This is an opportunity for those involved with LCA or concerned about its implications to voice their opinion and hear what other have to say.

Fisheries

Session Chair: Nathan Pelletier

Socioeconomic Indicators as a Complement to LCA – The Case of Salmon Production
Sarah A. Kruse, Anna Flysjö, Astrid J. Scholz, Nadja Kasperczyk

All salmon are not created equal: the life cycle environmental impacts of salmon fisheries and culture in the NE Pacific
Peter Tyedmers, Nicole Arsenault, Nathan Ayer, Anna Flysjo, Sarah Kruse, Nathan Pelletier, Astrid Scholz, Ulf Sonesson

Fresh, Frozen or Smoked? - The Impacts of Seafood Processing Choices
Ulf Gunnar Sonesson, Anna Flysjo, Astrid J. Scholz, Peter Horst Tyedmers

A Life Cycle Assessment of the Nova Scotia Lobster Industry: Evaluating Impacts and Striving for Efficiency
Catherine J Boyd, Peter H Tyedmers

Fisheries

Socioeconomic Indicators as a Complement to LCA – The Case of Salmon Production

Sarah A. Kruse,* Ecotrust
Anna Flysjö, SIK
Astrid J. Scholz, Ecotrust
Nadja Kasperczyk, The Institute for Rural Development Research (IfLS)

There is a growing global recognition that sustainable industry practices are needed to maintain environmental and social well-being. Life cycle assessment (LCA) is one of the most established methods for conducting such environmental analyses; however, even though attempts have been made to integrate social aspects into the LCA framework, no set of metrics exists to describe the causal links between a product and a socioeconomic impact, nor is there a shared understanding as to how such metrics should be developed.

This presentation will discuss methods for and development of a suite of socioeconomic indicators that complement the LCA methodology and provide policy makers, industry and consumers with a more comprehensive approach for assessing the cradle-to grave sustainability of a product or process. A combined top-down and bottom-up approach is used to determine relevant socioeconomic indicators. Generally recognized societal values, product/process specific issues and the financial constraints associated with collection of data necessary for measurement of the indicators are all factors considered. Indicators are then categorized based on fundamental methodological differences.

We also will present results from an application of these socioeconomic indicators to salmon production systems (i.e. capture and culture) in the Northeast Pacific Ocean. The primary focus of the selected indicators is the capture and culture phases, but the entire chain, from fishery/farm to consumer, is also included in the assessment. Additionally, we will discuss next steps for continued development and integration of socioeconomic indications within the LCA framework.

The inclusion of socioeconomic impact categories in an LCA of salmon, or other, production system can be useful in informing producers as to the current economic and social performance of their operations. Integrating socioeconomic aspects in the same way as biophysical impacts, to guarantee that a product has been produced in a ”fair” way along the chain, not only will complement the existing LCA framework, but also improve the approach to sustainable production.

* corresponding author: skruse@ecotrust.org

All salmon are not created equal: the life cycle environmental impacts of salmon fisheries and culture in the NE Pacific

Peter Tyedmers,* School for Resource and Environmental Studies, Dalhousie University
Nicole Arsenault, School for Resource and Environmental Studies, Dalhousie University
Nathan Ayer, School for Resource and Environmental Studies, Dalhousie University
Anna Flysjo, SIK, the Swedish Institute for Food and Biotechnology
Sarah Kruse, Ecotrust
Nathan Pelletier, School for Resource and Environmental Studies, Dalhousie University
Astrid Scholz, Ecotrust
Ulf Sonesson, SIK, the Swedish Institute for Food and Biotechnology

Salmon are one of the most widely consumed seafood products globally. Although most current environmental concern regarding salmon production activities focus on largely proximate biological impacts – stock declines, by-catch, habitat damage, disease and potential genetic impacts, this focus overlooks the diverse environmental impacts that flow from the interlinked series of industrial activities that characterize most modern salmon fishing and farming systems. This presentation describes the results of an international life cycle assessment project to evaluate the impacts associated with major salmon fishing and farming activities of the NE Pacific. This includes those associated with Alaskan troll, purse seine and gillnet fisheries along with both conventional net-pen and experimental land-based culture systems based in British Columbia. Key findings include: impacts vary by an order of magnitude between fishing gears; although impacts associated with feed provision dominate within farming systems, the adoption of land-based culture technologies to address local ecological effects can markedly exacerbate global impacts; and differences in the location of primary production results in substantial impacts as a result of both the mix of primary energy availability and waste utilization. Opportunities for improving the environmental performance of both capture and culture systems will also be discussed.

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* corresponding author: Peter.Tyedmers@dal.ca

Fisheries

Fresh, Frozen or Smoked? - The Impacts of Seafood Processing Choices

Ulf Gunnar Sonesson,* SIK - The Swedish Institute for Food and Biotechnology
Anna Flysjo, SIK - The Swedish Institute for Food and Biotechnology
Astrid J. Scholz, Ecotrust, Portland OR, USA
Peter Horst Tyedmers, School for Resources and Environemntal Studies, Dalhousie University, Halifax Canada

Environmental impact of food products occurs throughout the products life cycle, but for the absolute majority of products the impact are largest in the primary production, e.g. agriculture and fishery. In certain cases the later stages in the chain can contribute significantly, depending on level of processing and packaging but most critical transports. The product form often decides how the product is processed, packed and transported.

In the present study, an LCA comparing different product forms of wild caught Alaskan salmon was performed. The three products where fresh fillets, frozen fillets and smoked side. The functional unit (FU) was one single serving (225 g, 8 oz) of salmon at the consumers table in San Francisco. The place of processing was Cordova Alaska; an important Salmon harbour. Data for fishery and processing was inventoried through surveys and direct contacts with fishermen and processors. The differences between products were; the fresh fillet was flown to Seattle and then trucked, the frozen and smoked salmon was shipped to Seattle and trucked. More differences where in packaging, need of frozen/chilled supply chains and in processing. Five environmental impact categories were included in the study, but a selection is done here.

The results showed large differences in energy use and emissions of potential global warming potential. The lowest impact was from the smoked salmon, 11 MJ/FU, and 620 g CO_2-eq/FU. The frozen fillet used 16 MJ/FU and emitted 1000 g CO_2-eq/FU. Finally, the fresh product used 24 MJ/FU and emitted 1610 CO_2-eq/FU. The most important difference was that of transport mode, which explained more or less the whole difference to the smoked product. The smoked product did not require any home cooking which more than compensated fro the higher energy use in industrial processing. The frozen fillet had as low transport impacts as the smoked, but used more energy for the frozen supply chain; storage in wholesale and retail. General for all three products was that home transports are a large energy user, and packaging is different but does not contribute much to the life cycle impacts.

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* corresponding author: usn@sik.se

Fisheries

A Life Cycle Assessment of the Nova Scotia Lobster Industry: Evaluating Impacts and Striving for Efficiency

Catherine J Boyd,* Dalhousie University, School of Resource and Environmental Studies
Peter H Tyedmers, Dalhousie University, School for Resource and Environmental Studies

Increasingly, Life Cycle Assessment has been applied to food production systems. Typically the bulk of the environmental 'hot spots' associated with food delivery system are accrued upstream, as is the case with agriculture and livestock rearing or during the capture phase of fisheries. Depending on the types of processing and means of transport engaged after the farm gate or the wharf, downstream impacts, although sometimes significant, are often dwarfed by the impacts associated with primary production. The Nova Scotia, Canada live lobster industry is an exception, however. The post harvest storage and transport of live lobsters contribute proportionally high levels of environmental impacts.

Although the target species and the geographic location of the lobster fisheries in both the US and Canada are quite similar, the management structures are unique in both countries, and also vary among provinces and states. In addition, unlike its US counterpart, the Canadian lobster industry includes a significant amount of infrastructure dedicated to long-term storage of live animals. This research looks at the lobster industry in the south western part of Nova Scotia (lobster fishing area 34) which provides 40% of Canada's total landings. Also included in the analysis is a modest storage and transport scenario for lobsters delivered to Los Angeles, California.

Although the fishing phase of the industry (including boat and gear construction and maintenance, fuel and bait use) contributes greatly to most impact categories, the storage and transport phases can contribute as much or more to certain impacts. Fuel consumption on the fishing vessels drives many of the fishing-related impacts while the impacts related to storage are driven by the high coal consumption in the Nova Scotia electricity mix and the long periods of time that live lobsters can be stored before being shipped to market. The need to transport live animals quickly demands the use of air transport, which drives many of the impacts associated with this phase of the production chain. Efforts to reduce the overall environmental impact of the industry should be focused in these areas.

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* corresponding author: cboyd@dal.ca

LCA Studies

Session Chair: Julia Pflieger

Sorting, collecting, treating model study of discharged plastics from office builings in Tokyo Environmental evaluation of scenarios in this model using LCA
Junichi Nakahashi

Life Cycle Analysis of Disposable and Reusable Healthcare Garments
Celia Steward Ponder, Michael Overcash

Life cycle comparison of two carpet tile products
Yong Li, Michael Overcash, Matthew Realff, Kellie Ballew, Jeff Wright, Jeff Segars

Life cycle assessment for sewage sludge treatment in Japan
Jinglan Hong, Masahiro Otaki

Coupled Cost and Environmental Life Cycle Modelling of Composite Car-Bodies for a Korean Tilting Train
Olivier Jolliet, Isabelle Blanc, Pascale Schwab, Marcel Gomez, Bastien Ecabert, Martyn Wakeman, Jan-Anders Manson, Daniel Emery

Sorting, collecting, treating model study of discharged plastics from office builings in Tokyo
Environmental evaluation of scenarios in this model using LCA

Junichi Nakahashi,* Plastic Waste Management Institute, Japan

Discharged plastic from office buildings in Tokyo 510,000 t/y is industrial non-combustible waste and currently 77% of it is properly disposed to landfill site. Tokyo has changed its policy from "plastic is non-combustible waste and is permitted to dispose to landfill site" to "plastic is not good to dispose to landfill site and should be treated other than disposal to landfill site" in 2006.

In the scope of this policy the project "sorting, collecting, treating model study of discharged plastics from office buildings in Tokyo" was entrusted to Plastic Waste Management Institute (PWMI) by Ministry of Economy, Trade and Industry (METI) and was carried out in 2006-2007. And we made environmental evaluation of scenarios adopted in this project using LCA. We used "basket method" to compensate the value difference of outputs of scenarios in LCA analysis. We evaluated resource consumption, energy consumption, global warming potential (GWP), air acidification potential (AP) and solid waste as environmental impacts. And then we made normalization and weighting on these environmental impacts and calculated the "integrated environmental impact index".

The scenario sorted and collected "clean plastic" which has no metals and no impurities like as garbage is melt-blended with paper and molded into solid fuel pellets called RPF (Refuse Paper and Plastic Fuel) and the "rest plastic" is disposed to landfill site, the scenario sorted and collected "clean polypropylene and polyethylene" which has no metals and no impurities like as garbage and no paper is mechanically recycled into articles and the "rest plastic" is disposed to landfill site and the scenario the "rest plastic" is not disposed to landfill site and utilized by energy recovery are evaluated.

The result showed that the "integrated environmental impact indexes" of the settled model scenarios were smaller by 3-73% compared with the current treating scenario of discharged plastic.

* corresponding author: nakahashi@pwmi.or.jp

LCA Studies

Life Cycle Analysis of Disposable and Reusable Healthcare Garments

Celia Steward Ponder,* North Carolina State University
Michael Overcash, Raleigh, North Carolina

Garments are used in hospitals as patient gowns, surgical gowns, isolation gowns, and drapes and are worn to protect patients and healthcare workers from infection due to contact with fluids containing microbes that cause infection. These garments must be water repellent, but also comfortable for the wearer. Reusable, cloth woven gowns were originally used, but as concerns for infection grew and disposable fabrics became available, the market shifted from reusable to disposable garments. Disposable garments are used once, discarded, and usually incinerated, causing society to view these as more sanitary than reusable gowns, even though infection rates are similar. Disposable garments, however, are usually made of polyester that is derived from nonrenewable fossil fuels, and disposal generates waste. The reusable garment is used multiple times and is made with cotton that is a biodegradable and renewable resource. The laundering process will use additional energy and will generate wastewater. With the addition of a biocidal coating to the reusable garment, infection rates may be lowered, and the environmental impact of the garment may be reduced. Life cycle assessments should be used during the product design phase to optimize production to make a product with fewer impacts to the environment including energy use, air, water, and land emissions. The intent of this body of work is to compare processes using a life cycle assessment and recommend viable alternatives to reduce energy consumption, emissions, and resource usage.

The process design-based method is used to generate inventories for each unit process in the cradle-to-gate production of the hospital gowns and for laundering the reusable gowns. The cradle-to-gate inventories show that production of the reusable gown used more than four times the energy compared to production of the disposable gown. In the production chain of the reusable gown, production of the fabric was the largest consumer of energy, followed by yarn and then cotton growing. Also, more raw materials are used, and more emissions are generated. However, this life cycle analysis compares 75 disposable gowns to 1 reusable gown used 75 times. When the use phase is factored in, energy usage for the reusable gown is decreased.

* corresponding author: csponder@ncsu.edu

LCA Studies

Life cycle comparison of two carpet tile products

Yong Li,* Department of Chemical & Biomolecular Engineering, NCSU
Michael Overcash, Department of Chemical & Biomolecular Engineering, NCSU
Matthew Realff, Department of Chemical Engineering, GIT
Kellie Ballew, Shaw Inc.
Jeff Wright, Shaw Inc.
Jeff Segars, Shaw Inc.

Growing concerns about national energy security, global climate change, and sustainability of natural resources have made the development of sustainable technology and products a priority worldwide. Our society has realized that environment-related problems should be viewed in a more global and systematic scale. Traditional industries, such as the carpet industry, are under pressure to develop more sustainable technologies and products. Life cycle assessment can be a powerful tool when a comparison has to be made among several products concerning environmental performance. Two carpet tile products: PVC-backed PERMABAC tile and polyolefin-backed ECOWORX tile from Shaw Inc. , are studied and compared using a life cycle approach. The cradle-to-grave environmental impact assessments are conducted using TRACI (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts) (1). Based on the structure and composition of carpet tile product, carpet tile supply chain is grouped into four categories: face fibers, primary backing, polymeric backing system, and fillers. We find that the supply chains of carpet products play very important roles in the life cycle environmental performance of carpet products. Nylon fibers, as the economically significant component in carpet products, are also environmentally significant in the life cycles of carpet products. Carpet tile fillers, although the heaviest component in carpet tile, play the least significant role in the life cycle environmental performance of carpet tile product. PERMABAC tile consumes less natural resource energy in the tile manufacturing process than ECOWORX tile, but the life cycle natural resource energy consumption of PERMABAC tile is more than that of ECOWORX tile. As a result, the global warming impact of PERMABAC tile is more than that of ECOWORX tile.

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* corresponding author: yli13@ncsu.edu

LCA Studies

Life cycle assessment for sewage sludge treatment in Japan

Jinglan Hong,* University of Michigan
Masahiro Otaki, Ochanomizu University

The environmental impact of sewage sludge treatment has been studied widely using life cycle assessment (LCA) method. However, several important research needs have to be addressed to provide a more reliable assessment:

- All scenarios with and without digestion need to be compared.
- Environmental impacts of construction and equipment have to be better described.
- The economic analysis should cover all life cycle stages including post-treatment.
- The environmental and economic performances of the melting technology need to be characterized and compared to other technologies.

To address these needs, a LCA of sewage sludge treatment was carried out to estimate the environmental and economic impact of the six different processes mostly used in Japan: dewatering, compost, drying, incineration, incinerated ash melting and dewatered sludge melting, each of them with and without digestion. This research quantifies in detail the environmental and cost impacts of equipment, construction, energy, operation and transport of these above alternatives. The post-treatments of landfilling, agricultural use and construction material use were also studied. Results show that

- Sewage sludge digestion, leads to the lowest costs and environmental impacts.
- Environmental impacts of construction and equipment are low.
- The incinerated ash melting scenario has the highest impact in the global warming (GW), acidification (AP) and human toxicity (HT).

The dewatering and compost scenario generate the highest impact on land depletion potential (LDP) and cost, respectively. The dewatering scenario generates the lowest GW and AP impacts, whereas compost and drying lead to lower human toxicity. In addition, the lowest impact in LDP and cost was compost and drying scenario, respectively. The flocculants use in dewatering had the highest contribution to GWP, AP and cost. Hence, it is important to increase the efficiency of the thickening unit and flocculants use. Heavy metals released from the atmospheric effluent of incineration generated the highest human toxicity impact, the effect of dioxin emissions being significantly lower. This study proved that drying scenario is an optimal environmental and economic affordably method. Nevertheless, the dewatered sludge melting scenario may be relevant regarding the scarcity of land resource in Japan.

* corresponding author: hongjing@umich.edu

Coupled Cost and Environmental Life Cycle Modelling of Composite Car-Bodies for a Korean Tilting Train

Olivier Jolliet,* University of Michigan, School of Public Health
Isabelle Blanc, Ecole Polytechnique Fédérale de Lausanne-ISTE
Pascale Schwab, Université de Lausanne
Marcel Gomez, EPFL-ISTE and J.G. Proyectos, El Masnou, Spain
Bastien Ecabert, Ecole Polytechnique Fédérale de Lausanne-LTC
Martyn Wakeman, Ecole Polytechnique Fédérale de Lausanne-LTC
Jan-Anders Manson, Ecole Polytechnique Fédérale de Lausanne-LTC
Daniel Emery, Ecole Polytechnique Fédérale de Lausanne-ITEP

A coupled technical cost modelling (TCM) study and environmental life cycle analysis was performed of composite car bodies for the Korean Tilting Train eXpress (TTX) project. This included the cost of both carriage manufacture and the use phase power cost, coupled with the life cycle impacts of all stages from raw material production, through carriage manufacture and use, to end of life scenarios. The functional unit for both cost and environmental LCA was: one car body with a life time of 25 years and used over 7'500'000 km. Metallic carriages for a production capacity of 90 carriages per year for 5 years were compared with 4 material candidates: 1. Full composite car-body (7.6t), 2. Hybrid composite - aluminium car-body (8.5 t), 3. 100% Aluminium (9.0t) and 4: 100% Stainless steel (11.5t). For each process, material and energy consumptions, required labour and other auxiliary inputs are determined depending on train body characteristics. These auxiliary inputs are then combined to a cost database in order to deliver the Total Cost. The model predicts the manufacturing cost and cost segmentation as a function of volume. In parallel, these auxiliary inputs are combined with the ecoinvent Life Cycle Inventory database to yield the total life cycle emissions and extractions as a basis for the calculation of Life cycle impacts. The environmental impact has been assessed using the IMPACT 2002+ method.

Results are analysed plotting cost versus energy consumption - as one major indicator of the environmental impacts - for the stages of: a) raw material production, b) manufacturing stage, and c) use phase. The coupled results show that the raw material and manufacturing phase costs are approximately half of the total life cycle costs, whilst the environmental impact is relatively insignificant (3-8%). The use phase of the car body is the most important in terms of environmental impact, for all scenarios. In terms of cost, it represents approximately half of the whole life cycle. With steel rail carriages being of greater weight, the use phase cost is correspondingly higher to give both the greatest environmental impact and the highest life cycle cost. Compared to the steel scenario, the hybrid composite variant has a lower life cycle cost and a lower environmental impact. Though the full composite rail carriage may have the highest manufacturing cost, it is nevertheless the optimum solution when considering total life cycle cost and secondly environmental impact considerations: it indeed leads to both lower total life cycle costs and lower environmental impact than all of the alternatives.

* corresponding author: ojolliet@umich.ed

LCA Professional Certification

Session Coordinator: Rita Schenck

The demand for Life Cycle Assessments is rising in the USA, due in part to the decision of Wal-Mart and others to include LCA in their sustainability programs. Certification of LCA professionals could provide assurance to study commissioners that those performing their studies have the knowledge and skills needed to provide a high quality product. This session discusses the results of our surveys and the process towards developing a certification.

Posters

Life cycle inventory of methyl methacrylate

Yong Li,* Department of Chemical & Biomolecular Engineering, NCSU
Evan Griffing, Department of Chemical & Biomolecular Engineering, NCSU
Celia Ponder, Department of Chemical & Biomolecular Engineering, NCSU
Michael Overcash, Department of Chemical & Biomolecular Engineering, NCSU

Among many methacrylic monomers, methyl methacrylate (MMA) is the most important. World consumption of methyl methacrylate was about 2.5 million metric tons in 2005 (1). It was predicted that world consumption of methacrylate would grow at a rate if 5.1% each year from 2006 to 2010 (1). Application of MMA is mainly in construction/remodeling activity, automotive applications and original equipment manufacture. In 1933, first commercial production of MMA monomer started in Germany using original acetone cyanohydrin route (2). In 1934 a patent was issued for the conversion of acetone cyanohydrin to methacrylamide sulfate using concentrated sulfuric acid (3). The methacrylamide sulfate could then be hydrolyzed to methacrylic acid and esterified to form MMA. The methacrylamide sulfate route has dominated the commercial production of MMA since then. In this study, design-based approach methodology (4), (5) is used to obtain life cycle inventory data of MMA manufacturing process. The functional unit is defined as per metric ton MMA production. The methacrylamide sulfate route is designed based on chemical engineering design techniques. Energy requirement of the process is obtained based on chemical engineering unit operation principles and models. Mass balance and energy balance are conducted for each process unit and the overall process. Air, water, and solid emissions from the process are classified and listed in the life cycle inventory result.

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* corresponding author: yli13@ncsu.edu

Posters

Gold Mining at Yanacocha, Peru

Wesley Ingwersen,* University of Florida

The purpose of the LCI is to quantify the environmental contribution to gold production at the largest surface gold mine in the world. Yanacocha produced approximately 3 million ounces of gold in 2006 - 40% of the gold exported from Peru. (1) The cradle-to-gate process of heap-leach gold mining is diagrammed from the mine infrastructure creation to export of semi-refined gold bars (doré). Production is divided into seven primary unit processes: infrastructure creation, extraction, heaping and leaching, refining, waste processing, export, and reclamation. Capital costs for major mining and processing equipment are included. System identification was confirmed through site visits and data is derived from primary sources and indirect calculation.

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* corresponding author: wwi@ufl.edu

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