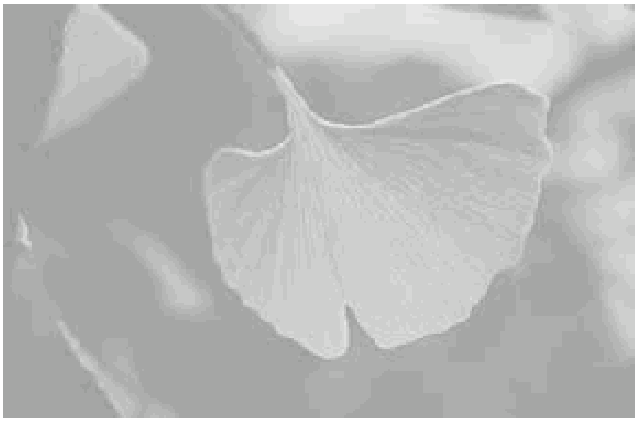


InLCA / LCM 2003 Seattle

Message from the Conference Planning Committee

On behalf or the American Center for Life Cycle Assessment, the City of Seattle, the United Nations Environmental Program and the local planning committee, welcome to the third International Life Cycle Assessment and Life Cycle Management Conference. We hope you will enjoy your stay here in Seattle, a city noted for its concern for the environment and for sustainability. We hope you can take time to enjoy the great natural beauty of this city and region. The time of the conference coincides with the annual migration of orca whale pods to this portion of Puget Sound. If you are lucky, you may be able to whale watch from the waterfront.

Despite difficult economic times, we have a wide diversity of people coming to the conference from all over the world. Every continent but Antarctica is represented here. Bringing together colleagues working in the field of LCA and LCM and their application is sure to help us all see our work in a broader context. Perhaps we can forge relationships that will be lasting, and will help us all to make the world a little bit more sustainable.

This binder is arranged to facilitate you getting the information you need to make best use of the conference. A figure showing the conference at a glance is on the back cover. Inside this binder is

We will have many volunteers at the conference. They are there to help things move more smoothly. Ask them if you have questions, or ask at the registration desk.

Once again, welcome, and best wishes for a successful conference.

The Local Conference Planning Committee

		Doug Huizenga
Emily Burns	Richard Gelb	Ulla Johnson
Joyce Cooper	Eun-Sook Goidel	Johanna Sands
Mary Ann Curran	Roel Hammerschlag	Rita Schenck

Many Thanks to our Sponsors, Donors and Vendors

City of Seattle

Conoco-Philips

Dupont

First Environment

Institute for Environmental Research and Education

Institute for Lifecycle Environmental Assessment

Pacific Northwest Economic Region

Pacific NW Pollution Prevention Resource Center

Pré Consultants

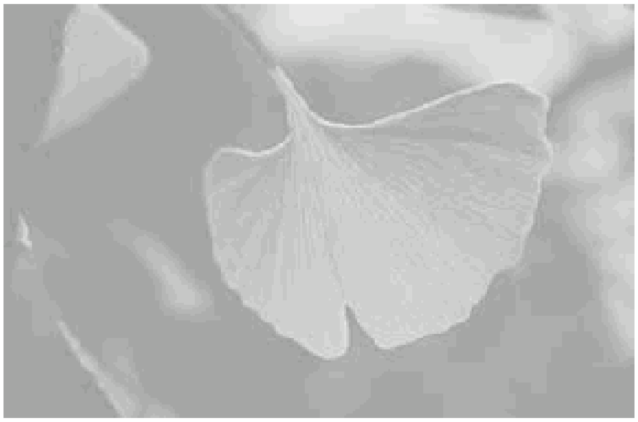
Sylvatica

United Nations Environmental Program

U.S. Environmental Protection Agency

U.S. Department of Energy

And to the many volunteers who shared their time and energy to make the conference a success



Green Conference Notes

The local planning committee has spent some time thinking about how to make this conference more environmentally friendly and sustainable.

You may notice that the Northwest Rooms of the Seattle Center, where we are holding the conference, boast solar cells on the roof. The conference is powered in part by these solar cells.

The other things we have done may be less obvious.

- The binders that hold your conference information are manufactured with recycled materials. They were chosen in part because they are a standard format and can be readily re-used. Take them home when the conference is done, and re-use them there, or leave them here and we will re-use them.

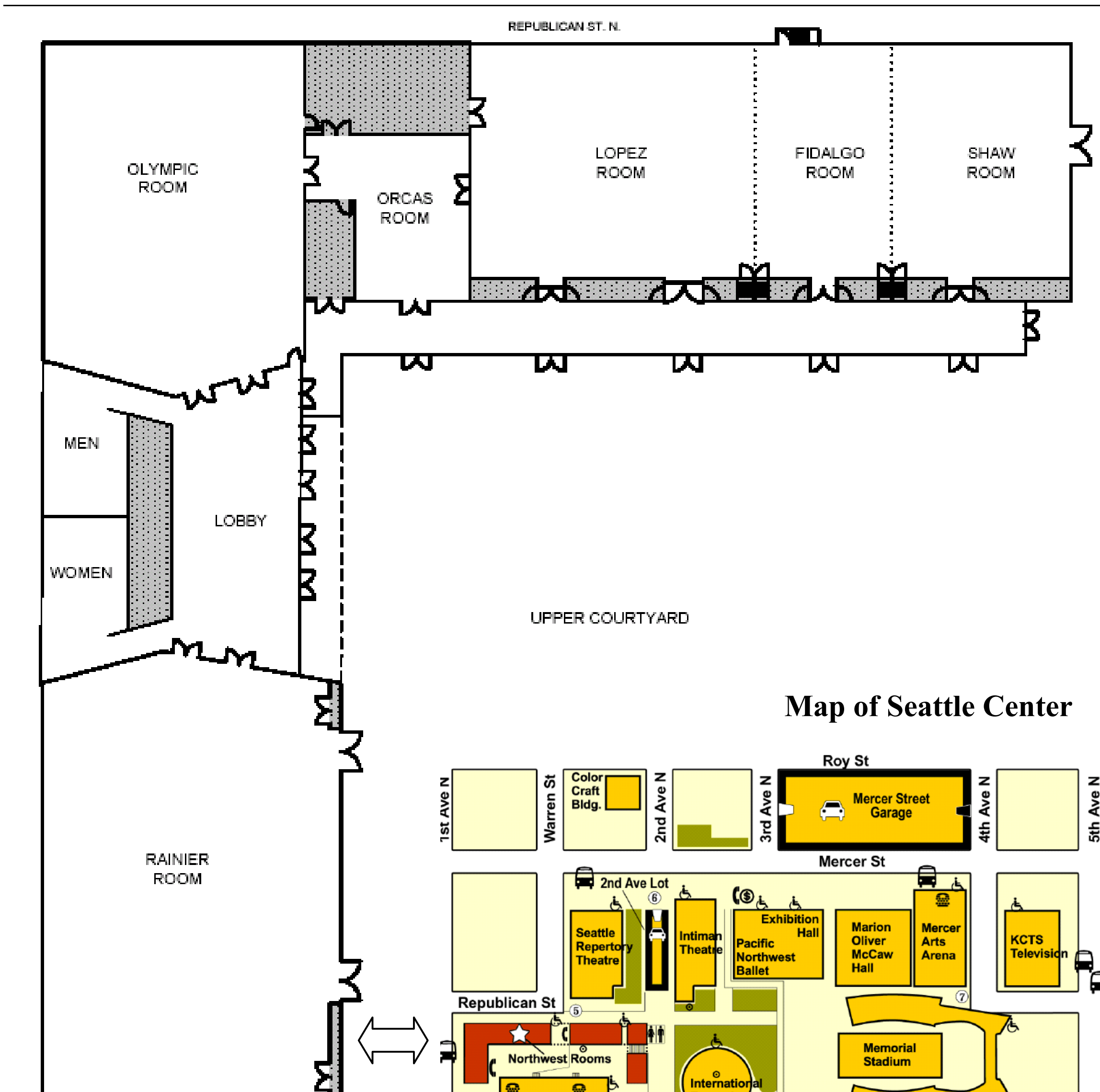
- The bags that hold your binders and other material are made from polypropylene. Although we did not perform an LCA on them, we believe that LCA studies comparing paper bags to plastic bags have made the point that plastic is more eco-friendly. This LCA result is summarized in the cards included in your packet titled “Paper or Plastic” and kindly provided by ILEA.

- The food provided at our breaks are largely produced locally, and we using washable china rather than disposable dishes.

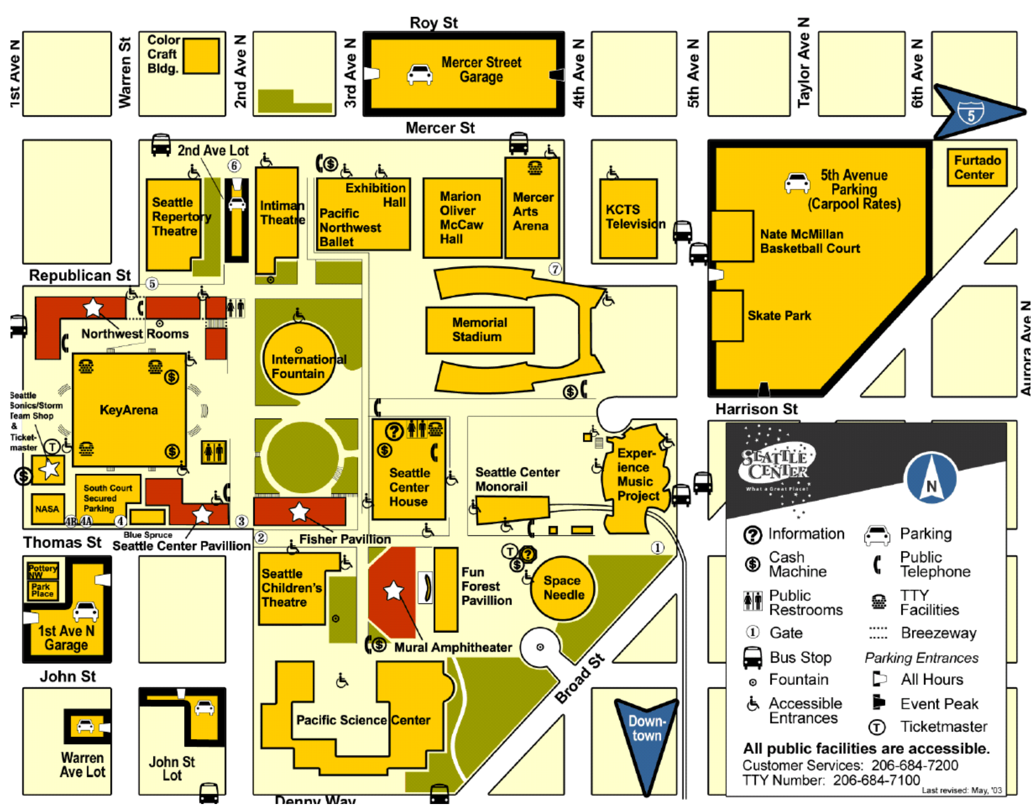
- Your name tags are plain stick-on tags, (one for each day) rather than standard name tags in plastic holders. We did this because although the plastic holders are supposed to be reused, we find (based on the unscientific accumulation of nametag holders in our desk drawers) that only programs that regularly use and reuse name tags actually reuse the holders. Since we are holding InLCA/LCM conferences only once every two years, we doubt our ability to retain and reuse them.

- The conference will not publish printed proceedings. Instead the PowerPoint presentations speakers prepared will be kept on our website for as long as people keep accessing them. This not only reduces the production of print material that is not accessed, but also maximizes the exposure of the authors and provides the cheapest possible way for people from developing countries to learn about what is going on in the LCA and LCM fields. Our conferences in 2000 and 2002 continue to be accessed regularly, and we expect to find the same for the 2003 conference.

Map of Seattle Center Northwest Rooms

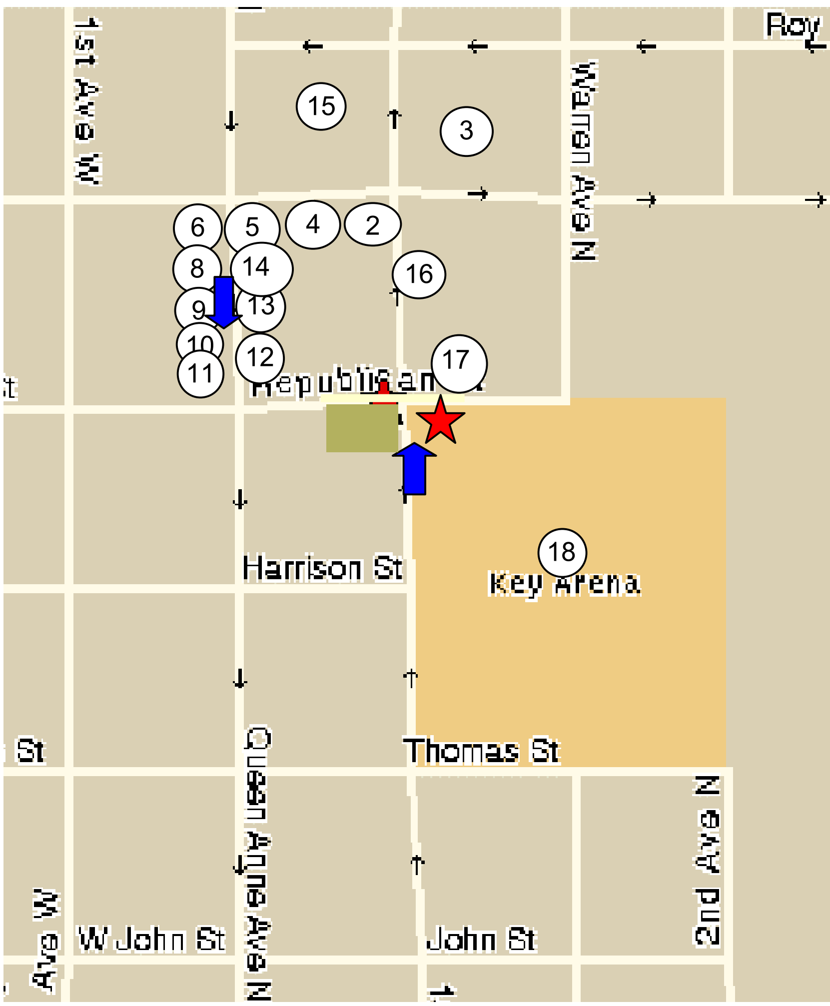


Map of Seattle Center



Restaurants Near Seattle Center

The Seattle Center is located at the foot of the Queen Ann District, a vibrant, multicultural urban neighborhood. There are many restaurants near the conference that are appropriate for a quick lunch, at modest prices. The map below shows where some of them are.



Location of conference

Bus Stop # 1,2,8,13,15,18

1. Chutney's Cuisine of India, Main courses $10-15
2. Racha Noodles & Thai Cuisine Main Course $7-9
3. Larry's Market (Supermarket)
4. T.S. McHugh's Pub. American Food, Lunch Special $6-8
5. Pagliachi Pizza by the slice: Pizza, salad, pasta $3-7
6. Kidd Valley Junction. Hamburgers & Shakes $3-6
7. Choy's Chinese Cuisine $3-8
8. Sorry Charlie's American Cuisine/sandwiches/soup $3-8
9. Sam's Sushi $3-8
10. Phuket Vietnamese $4-8
11. Blue Water Taco Grill Costal Mexican Cuisine $6-7
12. Dick's Drive-in (a Bill Gates favorite) $1 burgers
13. Mecca Café Daily Specials Soup/salad/sandwiches $6-7
14. World Wrapp Fusion cuisine $4-7
15. The Melting Pot Fondue restaurant $7-30
16. Nonna Marie (Tuesday-Friday only). Traditional Italian $5-8
17. QFC Grocery store open 24 hours
18. Seattle Center House Food Court. Variable

Dining Suggestions in Downtown Seattle

Seattle is a food-lover's city. There are many excellent restaurants available to meet every taste and pocketbook. These suggestions are from the Seattle Dining Guide.

American

Hunt Club
900 Madison Street · Seattle
206-343-6156 · Expensive

The Top of the Hilton
1301 Sixth Avenue · Seattle
206-695-6015 · Moderate

Union Square Grill
621 Union Street · Seattle
206-224-4321 · Expensive

13 Coins Restaurant
125 Boren Avenue North · Seattle
206-682-2513 · Moderate

Benjamin's on Lake Union
809 Fairview Place North · Seattle
206-621-8262 · Moderate

Kaspar's by the Bay
19 West Harrison · Seattle
206-298-0123 · Moderate

Last Row Café
2302 24th Avenue East · Seattle
206-328-6710

Mecca Café
526 Queen Anne Avenue · Seattle
206-285-9728 · Inexpensive

Rock Salt Steakhouse
1232 Westlake Avenue · Seattle
206-284-1047 · Moderate

Sazerac
1101 4th Avenue · Seattle
206-624-7755 · Moderate

TGI Friday's
1001 Fairview Avenue · Seattle
206-62--7290 · Inexpensive

The Pike Pub & Brewery
1415 1st Avenue · Seattle
206-622-6044

Big Cliff's Cafe
2200 5th Avenue · Seattle
206-441-9785

Cyclops Restaurant
2423 1st Avenue · Seattle
206-441-1677 · Moderate

Emerald Grill
211 Dexter Avenue North · Seattle
206-728-8123 · Moderate

Family Pancake House
603 SR 906 · Snoqualmie Pass
425-434-6249 · Inexpensive

Portage Bay Cafe
4140 Roosevelt Way NE · Seattle
206-547-8230 · Inexpensive

Asian, Chinese, Japanese

Ohana
2207 1st Avenue · Seattle
206-956-9329 · Inexpensive

Bamboo Garden Vegetarian
364 North Roy Street · Seattle
206-282-6616 · Moderate

I Love Sushi
1001 Fairview Avenue North · Seattle
206-625-9604 · Moderate

Ozaki Café
372 Roy Street · Seattle
206-283-7872 · Inexpensive

Tommy's Sushi
2501 Eastlake Avenue East · Seattle
206-726-9893

Uptown Chinese
200 Queen Anne Avenue North · Seattle
206-285-7710 · Moderate

Casual Dining

Carmelita
7314 Greenwood Avenue · Seattle
206-706-0511 · Inexpensive

Caffe Ladro Bakery
600 Queen Anne Avenue North · Seattle
206-282-7407 · Inexpensive

Crocodile Café
2200 2nd Avenue · Seattle
206-448-2114

Elephant and Castle
1415 5th Avenue · Seattle
206- 6249977

Flynn's Café
3923 Airport Way South · Seattle
206-624-6069 · Inexpensive

Jules Mae Saloon & Eatery 5919 Airport Way South · Seattle*206-763-0570 · Inexpensive*

Kettells
5800 Fourth Avenue South · Seattle
206-767-4777 · Inexpensive

Lake Route Café
9261 57th Avenue South · Seattle
206-723-6580 · Inexpensive

Last Row Café
2302 24th Avenue East · Seattle
206-328-6710

Louisa's Bakery & Café
2379 Eastlake Avenue East · Seattle
206-325-0081 · Inexpensive

Pecos Pit BBQ
2260 First Avenue South · Seattle
206-623-0629 · Inexpensive

Seattle's Best Coffee
1321 Second Avenue · Seattle
206-624-8858

That's Amore
1425 31st Avenue South · Seattle
206-322-3677 · Inexpensive

Willie's Taste of Soul BBQ
6305 Beacon Avenue South · Seattle
206-722-3229 · Inexpensive

International & Fine Dining

Afrikando West African Restaurant
2904 First Avenue · Seattle
206-374-9714 · Inexpensive

Hunt Club
900 Madison Street · Seattle
206-343-6156 · Expensive

India House
4737 Roosevelt Way NE · Seattle
206-632-5072 · Inexpensive

The Painted Table
92 Madison Street · Seattle
206-624-3646 · Moderate

14 Carrot Café
2305 East Lake Avenue East · Seattle
206-324-1442 · Inexpensive

Baker's Beach Café
3601 South McClellan Street · Seattle
206-725-3654 · Moderate

Brasserie Margaux
401 Lenora · Seattle
206-777-1990 · Moderate

Carina Bar & Grill
2501 Fairview Ave East · Seattle
206-324-9396

Cool Hand Luke's
1131 34th Avenue East · Seattle
206-324-2553 · Inexpensive

Dahlia Lounge
1904 Fourth Avenue · Seattle
206-682-4143 · Expensive

Entros World Grill
823 Yale Avenue North · Seattle
206-624-0057 · Moderate

Fullers
1400 6th Avenue · Seattle
206-447-5544 · Expensive

Georgian Room
411 University Street · Seattle
206-621-7889 · Expensive

Kolbeh Persian Cuisine
1956 First Avenue South · Seattle
206-224-9999 · Moderate

Maharaja
500 Elliot Avenue West · Seattle
206-285-9728 · Moderate

Mediterranean Kitchen
4 West Roy Street · Seattle
206-285-6713 · Inexpensive

Rover's
2808 East Madison · Seattle
206-325-7442

Roy Street Bistro
174 Roy Street · Seattle
206-284-9093 · Moderate

T.S. McHugh's
21 Mercer Street · Seattle
206-282-1910 · Moderate

Theoz
1523 Sixth Avenue · Seattle
206-749-9660 · Expensive

World Wraps
528 Queen Anne Avenue · Seattle
206-285-6244 · Inexpensive

Andaluca
405 Olive Way · Seattle
206-623-8700 · Moderate

Italian

Assaggio Ristorante
2010 Fourth Avenue · Seattle
206-441-1399 · Moderate

Beppo Little Italy
701 Ninth Avenue North · Seattle
206-244-2288 · Moderate

Café Capello
429 Eastlake Avenue East · Seattle
206-622-2721 · Inexpensive

Pazzo's on Eastlake
2307 Eastlake Avenue East · Seattle
206-329-6558

Perche No Ristorante
621 1/2 Queen Anne Avenue North · Seattle
206-298-0230 · Moderate

Pizzulto's Italian Café
5032 Wilson Avenue South · Seattle
206-722-6395 · Inexpensive

Serafina
2043 Eastlake Avenue East · Seattle
206-323-0807 · Moderate

That's Amore
1425 31st Avenue South · Seattle
206-322-3677 · Inexpensive

Trattoria Mitchelli
84 Yesler · Seattle
206-623-3883 · Inexpensive

Tulio Ristorante
1100 Fifth Avenue · Seattle
206-624-5500 · Moderate

Latin, Cuban, Spanish

Bandoleone
2241 Eastlake Avenue East · Seattle
206-329-7559 · Moderate

Juan Colorado
8709 14th Avenue South · Seattle
206-764-9379 · Inexpensive

Lucy's Taqueria
5602 First Avenue South · Seattle
206-767-3767 · Inexpensive

Maya's Mexican Restaurant
9432 Rainier Avenue South · Seattle
206-725-5510 · Inexpensive

Taqueria Guaymas
1622 Southwest Roxbury St · Seattle
206-767-4026 · Inexpensive

Steak & Seafood

Ohana
2207 1st Avenue · Seattle
206-956-9329 · Inexpensive

The Top of the Hilton
1301 Sixth Avenue · Seattle
206-695-6015 · Moderate

Union Square Grill
621 Union Street · Seattle
206-224-4321 · Expensive

Anthony's Pier 66
2201 Alaskan Way · Seattle
206-448-6688 · Expensive

Benjamin's on Lake Union
809 Fairview Place North · Seattle
206-621-8262 · Moderate

Kaspar's by the Bay
19 West Harrison · Seattle
206-298-0123 · Moderate

Matt's in the Market
95 Pike Street · Seattle
206-467-7909 · Moderate

Metropolitan Grill
820 Second Avenue · Seattle
206-624-3287 · Expensive

Rock Salt Steakhouse
1232 Westlake Avenue · Seattle
206-284-1047 · Moderate

Space Needle Restaurant
219 4th Avenue North · Seattle
206-443-2100

The Brooklyn Seafood, Steak & Oyster House
1212 2nd Avenue · Seattle
206-224-7000 · Expensive

The Butcher Restaurant
5701 Sixth Avenue South · Seattle
206-763-2215 · Moderate

Big Cliff's Cafe
2200 5th Avenue · Seattle
206-441-9785

Entertainment

Seattle has many entertainment opportunities. Below we have listed some of the event that are scheduled for the week of the 22-26 of September.

Music

Dimitriou's Jazz Alley, 2033 6th Avenue (206) 441-9729 **Koko Taylor And Her Blues Machine** Sept 25 – 28 $25.50 - 27.50

Monday 22 September **New Music Night** at the Liquid Lounge of the Experience Music Project (EMP), at Seattle Center starting at 9:00 pm.

Wednesday September 24 **Flava: Vitamin D, DJ Scene** at the Liquid Lounge of the Experience Music Project (EMP), at Seattle Center starting at 9:00 pm

Thursday, September 25th **Bandwidth** (heavy metal-influenced music) at the Liquid Lounge of the Experience Music Project (EMP), at Seattle Center starting at 10:00 pm.

Seattle Symphony Orchestra **Beethoven's Pastoral Symphony** 7:30 PM, Thursday, September 25th, 200 University Street(206) 215-4747 (tickets).

Sports

Friday, September 26th, the Seattle Mariners are playing against Oakland at Safeco Field. Tickets maybe obtained through Ticketmaster.

Theater

The 13th Annual Seattle Fringe Theatre Festival plays from September 17 to October 1, 2003 on Capitol Hill (a neighborhood of Seattle, just east of downtown). Approximately 97 plays are being presented in different venues located close to each other. Tickets are available at 206.322.2018, and are quite modestly priced (sometimes as low as $5).

Family Entertainment

In addition to events, there are several other kinds of entertainment available for the family.

The Seattle Aquarium, 206.386.4300 **Pier 59** on the waterfront 1483 Alaskan Way is open 10:00 a.m to 5:00 pm. Admission is Adult 13 and up $11.00
Youth 6-12 $7.00; Child 3-5 $5.00; Child 2 and under Free

The Seattle Art Museum is at 100 University Street, and is open 8:00 a.m to 5:00 pm, or 9:00p.m. on Thursdays. Entrance is $7 for adults, $5 for students, and free for children under 12.

The Seattle Asian Art Museum is located in Volunteer Park, 1400 East Prospect St. It is open 10:00 a.m. to 5:00 p.m, except 9:00 p.m. on Thursdays. Admission is $3.

Woodland Park Zoo is located at 50th and Freemont Avenue North, and is open 9:00 a.m. to 5:00 p.m.. Entrance is $10 for adults, $7.50 for youth and $5:25 for children. Thursday, September 25, Dr. Bill Weber, renowned conservationist and author will speak on IN THE KINGDOM OF GORILLAS:CONSERVATION SUCCESS IN A STATE OF CONFLICT at 7:30 p.m.

The Pacific Science Center is located at the Seattle Center and is open 10:00 a.m to 5:00 p.m. Admission is $9.50 for adults, $7.50 for children (ages 3-13). 206-443-2001

InLCA/ LCM 2003 Conference Session Agenda

FUNDAMENTALS OF LIFE CYCLE ASSESSMENT

Monday 8:30 – 3:00 Lopez Room Moderator: Ulla Johnson

Instructors: Mary Ann Curran and Tapas Das

What you will learn:

- Basic principles of LCA for use in producing, designing or purchasing sustainable processes, products, or services.
- ISO 14000 standards on the three components of LCA: inventory, impact assessment, and interpretation.
- Actual demonstrations of some of the most popular LCA tools: Pré's SimaPro, Sylvatica's software, and Ecobalance's TEAM.
- Generation of unified taxonomy of environmental impacts for analyses of products, processes, and services.
- From an overview of several case studies (LCA on biorenewables vs fossil fuels, mechanical-chemical-bio pulping processes, chlorine versus UV disinfection technologies and other examples), the fundamentals of LCA
- Examples of pollution prevention systems (Green Chemistry and Engineering) that approach sustainability.
- How to conduct or manage someone conducting an LCA

Who should attend: Decision makers and analysts from consulting companies, federal facilities, industry organizations, or academia and anyone in an interest in learning how to better incorporate Life Cycle Assessment and environmental performance indices into their decision-making processes.

OPENING PLENARY

Keynote speakers include Guido Sonneman, from the United Nations Environmental Program, and director of the UN-SETAC Life Cycle Initiative; Barbara Lither, esq. Senior Policy Advisor from the U.S. EPA Region 10 Office, Tony Gale, Architectural Director for the City of Seattle and John Ryan, of the U.S. Business Council on Sustainable Development.

TUESDAY AFTERNOON FIRST SESSION

INVENTORY ANALYSIS I

Tuesday 1:30 Fidalgo Room
Moderator: Gerald Rebitzer

Land-Use Inventories for Sustainable Transportation Scenarios Boyd Hazen Pro and Roel Hammerschlag

ecoinvent: A Comprehensive Web-Based Life Cycle Assessment Database Gerald Rebitzer and Rolf Frischknecht

Attributional and consequential LCI modelling Tomas Ekvall

LCA AND ENERGY ANALYSIS

Tuesday 1:30 Lopez Room
Moderator: Pamela Spath

Comparison of energy turnover of regional and global food. Elmar Schlich and Ulla Fleissner

Reduction of Environmental Impacts by Development of Industrial Symbiosis in Japan - Case Studies for Application of Co-production Technologies in Steel Industries and its Reduction Potential of Greenhouse Gas Emissions Yasunari Matsuno, Ichiro Daigo, Masaru Yamashita, and Yoshihiro Adachi

Life Cycle Metrics for Comparing Alternative Electricity Generating Technologies David Spitzley and Greg Keoleian

SUSTAINABLE PRODUCT PURCHASING COALITION WORKSHOP

Tuesday 1:30 Shaw Room
Moderator: Neil Collie

Real tools for sustainable purchasing and a coalition that can give your more purchasing influence will be highlighted

TUESDAY AFTERNOON, SECOND SESSION

LCA AND PURCHASING

Tuesday 3:30 Shaw Room Moderator: Roel Hammerschlag

Whole Life Considerations in IT Procurement David Matthews and Shirli Axelrod

Integration of life cycle management in purchasing – a promising key to combining efficiency, economic and environmental improvements Jeppe Frydendal

LCA's role in Public Purchasing Policy - the Danish Experience with Product Specific Guidelines Henrik Riisgaard

LCA AND TRANSPORTATION MATERIALS AND TECHNOLOGIES

Tuesday 3:30 Lopez Room Moderator: David Spitzley

Comparable Reference Flows for Lightweight Materials in Transportation Systems Joyce Cooper and Bill Carberry

Are Natural Fiber Composites Environmentally Superior to Glass Fiber Reinforced Composites? Satish V. Joshi, L.T. Drzal and A.K. Mohanty

Life cycle assessment: case study of steel in Brazilian automobiles C.M.L. Ugaya and A.C.S.Walter

Co-Product Function Expansion: A Methodology for Incrementally Considering the Effects of Co-Products in Multi-Product Systems Paul Worhach, Binh Nguyen, Mohammad Nawaz, Rob Abbott and Etop Esen

INVENTORY ANALYSIS II

Tuesday 3:30 Fidalgo Room
Moderator: Gerald Rebitzer

Using Site Specific Life Cycle Assessment to Support a Contaminated Site Management Decision Jean-François Ménard, Julie Godin, Sylvain Hains, Louise Deschênes and Réjean Samson

LCAccess: An On-Line Directory for Global Life Cycle Assessment Information and Data Timothy J. Skone and Mary Ann Curran

Environmental Performance Comparison of Wet and Thermal Routes for Phosphate Fertilizer Production Using LCI - A Brazilian Experience Gil Anderi da Silva and Luiz Alexandre Kulay

Metals LCA: Methodological Problems and Practical Solutions Scott R. Baker

WEDNESDAY MORNING, FIRST SESSION

LCA AND GOVERNMENT POLICY

Wednesday 8:30 Rainier Room
Moderator: Eun-Sook Goidel

Official Danish Center for Life Cycle Assessments and Life Cycle Approach Jeppe Frydendal, Michael Z. Hauschild, Erik Hansen, Heidi K. Stranddorf and Jens B. Legarth

The National Waste Plan for Scotland - LCA and BPEO in Practice Allan Dryer and John Ferguson

Life Cycle Assessment for Brownfield Management Decision-Making Pascal Lesage Louise Deschênes and Réjean Samson

Examining the Effects of Waste Prevention, Material Substitution, Recycled Content, and Recyclability on the Environmental Profiles of Packaging for Mail-Order Non-Breakable Goods: A State Government's Application of Life Cycle Inventory Analysis David Allaway and Bev Sauer

LIFE CYCLE MANAGEMENT

Wednesday 8:30 Lopez Room
Moderators: Andrea Russell and Konrad Saur

Integrating EHS into New Product Development Soontae Jeong, Thomas E. Swarr, and Ellen A. Huang

Life Cycle Management in the Aluminum Industry: Implementation of LCA for Internal Applications Gerald Rebitzer, Kurt Buxmann and Olivier Jolliet

A framework of Computer Aided Engineering and LCA applied for Life Cycle Management Sergio Romero-Hernández and Omar Romero

Life Cycle Management: Generating Value for Rio Tino Borax's Sustainability Program Gerry Pepper, Andrea J.Russell, James J. Qin and Kevin Brady

DECISION-MAKING WORKSHOP

Wednesday 8:30-12:00 Shaw Room

Session Agenda

- **Introduction**
- **Presentations by perspective leaders giving:**
  - the **management** perspective
  - the **product design** perspective
  - the **process development** perspective
  - the **regulatory/ policy development** perspective
- **Break**
- **Breakout Group Discussion (by perspective) used to respond to:**
  - Is LCA a part of what was presented?
  - How would LCA change the perspective?
  - lso, for the group discussions, perspective leaders will be joined by LCA practitioners
- **Presentations by breakout groups**

MUNICIPAL SCOPING WORKSHOP

8:30 –12:00 Fidalgo Room
Moderator: Richard Gelb

Participants will learn about how to use LCA in municipal situations, based on real-life examples at different scales.

WEDNESDAY MORNING, SECOND SESSION

PMWER LEGISLATOR'S ROUNDTABLE

10:30 Rainier Room
Moderator: Rita Schenck

Legislators and policy experts at the municipal, state and federal level have been invited to discuss the opportunities for using LCA as a legislative and policy tool.

LCA AND SUPPLY CHAIN MANAGEMENT

Wednesday 10:30 Lopez Room
Moderator: Ray Smith

Integrating LCIA and LCM: Evaluating environmental performances for supply chain management Alan Brent

Creating Value Through Strategic Supply Chain Partnerships and Life Cycle Management Gil Friend and Eric Olson

WEDNESDAY AFTERNOON, FIRST SESSION

LCA AND COST ANALYSIS

Wednesday 1:30 Fidalgo Room
Moderator: Soontae Jeong

LCA for Optimization of electroplating SME's Robert Ackermann

The Econo-Environmental Return (EER) Gontran F. Bage and Réjean Samson

LCC application in the Polish mining industry Magorzata Góralczyk and Joanna Kulczycka

LCA as input to LCC Bengt Steen

LCA Methods for Buildings

Wednesday 1:30 Lopez Room
Moderator: Mike Levy

Building Investment Decision Support (BIDS) - Cost-Benefit Tool to Promote High Performance Components, Flexible Infrastructures and Systems Integration for Sustainable Commercial Buildings and Productive Organizations Beran Gurtekin, Vivian Loftness, Heakyung Cecilia Yoon, Ying Hua, Min Oh, and Ming Qu

BEES: A Popular Product Selection Tool that Integrates LCA and LCC Barbara C. Lippiatt

A Critical Overview of the Use of LCA in Green Building Design Cory Crocker

LCA Tools in Residential Building - Assessing Their Applicability Richard S. Dooley

LCI Workshop

Wednesday, 1:30-5:00 Rainier Room
Moderator: Mary Ann Curran

Municipal Applications of LCA I

Wednesday 1:30 Shaw Room
Moderator: Jeff Morris

Life Cycle Assessment Of A Bioreactor And An Engineered Landfill For Municipal Solid Waste Treatment Jean-François Ménard, Réjean Samson and Louise Deschênes

A Study on The Eco-efficiencies for Recycling Methods of Plastics Wastes Tak Hur, Song-Tack Lim and Hye-Jin Lee

Energy Conservation and Pollution Prevention Benefits of Residential Curbside Recycling Vs. Landfill Disposal or Waste-to-Energy Incineration Disposal Jeffrey Morris

Wednesday Afternoon, Second Session

Municipal Applications of LCA II

Wednesday 3:30 Shaw Room
Moderator: Jeff Morris

Triple Life Cycle Assessment Richard Gelb and Rita Schenck

Applying Life Cycle tools and Process Engineering to determine the most adequate treatment process conditions. A tool in environmental policy Omar Romero

What's An Engineer to Do? Mary Hansel, and Lydia Holmes

LCA in Design and Manufacturing

Wednesday 3:30 Fidalgo Room
Moderator: Joyce Cooper

Implementation of Life Cycle Assessment (LCA) in development of products Gurbakhash Singh Bhander, Michael Hauschild and Tim McAloone

A Diagnostic Expert System For Green Productivity Assessment Of Manufacturing Processes Ruby Pineda-Henson and Alvin B. Culaba

DANTES - Demonstrate and Assess Tools for Environmental Sustainability Klas Hallberg

Eco-efficiency: Inside BASF and Beyond Charlene A. Wall, Andreas Kicherer and Rolf Wittlinger

LCA CASE STUDIES FOR BUILDINGS

Wednesday 3:30 Lopez Room
Moderator: Bobbie Lippiatt

Comparative Life Cycle Assessment of three insulation materials Anders Schmidt, Anders Ulf Clausen, Dennis Postlethwaithe, Allan Astrup Jensen, and Ole Kamstrup

Incorporating Lifecycle thinking in Green Building Design Rosamund Hyde, Kevin Hydes and Scott Lewis

Life Cycle Assessment of Borate Treated Structural Systems Tarun Bhatia, Andrea J. Russell, Gerry Pepper and Shannon Turnbull

Glass fiber LCA and Environmental and Health Data Sheet Aymon de Reydellet, Michaël Médard and Sylvie Charbonnier

THURSDAY MORNING, FIRST SESSION

INPUT/OUTPUT METHODS

Thursday 8:30 Shaw Room
Moderators: Scott Matthews and Arpad Horvath

Uncertainty in Life Cycle Impact Inventory Estimates from Economic Input Output Models Chris Hendrickson and Francis C. McMichael

The Emergence of Life Cycle SpaceTM and the Life Cycle RatioTM A Proposed Planning Tool for Lowering our Ecological Footprint Pliny Fisk 3rd and David Armistead

Implications of New Economic Classification Systems On Input-Ouput Based LCA Models H. Scott Matthews

A Stochastic LCA framework for embodied greenhouse gas analysis: integrating process and I-O data within a Bayesian graphical model
David Shipworth

ACLCA ADVISORS MEETING

Fidalgo Room- ACLCA Advisors—
open to all

ECO-LABELS AND EXTERNAL REPORTING

Thursday 8:30 Lopez Room
Moderator Liila Woods

(Because there are 5 papers in this session, the session will run into the break.)

The Use Of Life Cycle Analysis in Environmental Labelling Standards Petar Johnson

A Natural Selection System to Drive Life Cycle-Based Eco-Efficiency and Sustainable Development Gregory A. Norris

LCA External Reporting and its Application in the Socially Responsible Investment (SRI) Community Esther Garcia

The contribution of Life Cycle Assessment to global sustainability reporting of organizations Matthias Fischer, Julia Pflieger, Thilo Kupfer and Peter Eyerer

Ecolabel and transparency Sophie Lavallée and Sylvain Plouffe

THURSDAY MORNING, SECOND SESSION

INPUT-OUTPUT CASE STUDIES

Thursday 10:30 Shaw Room
Moderators: Scott Matthews and Arpad Horvath

Evaluation of the Environmental Impact of Wired Telecommunication Networks in Japan Kazue Ichino Takahashi; Jiro Nakamura, Toshiyuki Maeda, Takeshi Origuchi, Tatsuya Kunioka, Hiro Havada, Shigeyuki Miyamoto and Jun Fujimoto

Comparison of "CO2 Efficiency" between Company and Industry Kiyotaka Tahara, Masayuki Sagisaka, Kazuo Yamaguchi, and Atsushi Inaba

Analyzing Life-cycle Environmental Impacts of Local Development Initiatives Using Regional Economic and Environmental Input-Output Models Satish Joshi

A Comparison of U.S. and Canadian Industry Environmental Performance Using Economic Input-Output Life Cycle Assessment Models Andrew Bjorn and Heather L. MacLean.

LCA DATABASES

Thursday 10:30 Fidalgo Room
Moderator: Mary Ann Curran

How to Use the US LCI Database Gregory A. Norris, Jamie K. Meil, Wayne B. Trusty and Scot Horst

The U.S. LCI Database – Moving Toward Full LCI Data by Material and Product Bill Franklin and Bev Saur

German Network on Life Cycle Inventory Data - Setup of a Data Collection C. Bauer, J Buchgeister and L Schebek.

The LCA Data Library -A result of National LCA Project in Japan Nobuhiko Narita, Yoshifumi Nakahara, Mamoru Morimoto, Ryohsuke Aoki and Shigeru Suda

IMPACT ASSESSMENT

Thursday 10:30 Lopez Room
Moderator: Guido Sonnemann

LCA of Aboveground Bioremediation of Diesel-impacted Soil Laurence Toffoletto, Réjean Samson and Louise Deschênes

Externality Analysis of the Flue Gas Desulphurization System at Mae Moh Lignite-Fired Power Plant in Thailand from LCA-NETS Point of View Sate Sampattagul, Seizo Kato, Prof. Tanongkiat Kiatsiriroat and Anugerah Vidiyanto

Taxonomy of Impact Categories and the Taxonomy Structure: Results from the UNEP/SETAC/EPA Hamburg Workshop Thomas Gloria and Jane C. Bare

THURSDAY AFTERNOON, FIRST SESSION

INTERPRETATION AND EDUCATION

Thursday 1:30 Lopez Room
Moderators: Annie Landfield and Margaret Mann

Uncertainty Analysis for the Life Cycle Study of Municipal Solid Waste Gasification Using Probabilistic Simulation Anthony Halog, Masayuki Sagisaka and Atsushi Inaba

Considering Uncertainties in the Functional Unit: Development of a More Flexible Strategy to Achieve the Goal of an LCA Study Gontran F. Bage, Laurence Toffoletto, Louise Deschênes and Réjean Samson

Teaching LCA to Interdisciplinary Graduate Students Joyce Cooper

Teaching Life Cycle Concepts to School Children Rita Schenck, Roel Hammerschlag and Hank Patton

HYBRID INPUT-OUTPUT STUDIES

Thursday 1:30 Shaw Room
Moderators: Scott Matthews and Arpad Horvath

(Because there are 5 papers in this session, the session will run into the break.)

Global Warming Effect Assessment in the Electricity Sector Using Hybrid Life-cycle Inventory Assessment Arpad Horvath and Sergio Pacca

Estimation of Life Cycle Energy Use Implications of Wired and Wireless Communications Networks Using Hybrid LCA Models H. Scott Matthews

Electricity Generation Mix by US Industrial Sectors: Disaggregating Electricity Generation and Modeling Interstate Transfers Joe Marriott and H. Scott Matthews

A Comparison between Conventional LCA and Hybrid EIO-LCA: a Portuguese Food Packaging Case Study Paulo Ferrão, Paulo Ribeiro and Jorge Nhambiu

Transport of Coal by Rail vs. Transmission for Electricity Generation: An Application of Hybrid LCA Comparative Analysis Joule Bergerson, Lester Lave, Chris Hendrickson, Scott Mathews and Alex Farrell

NOVEL LCA METHODS

Thursday 1:30 Fidalgo Room
Moderator: Bruce Vigon

Sustainability Indicators related to Energy and Material Flow Koji Amano, Misato Ebihara, Katsutoshi Tobe, and Masahiko Harada

Evaluation of two simplified life cycle assessment methods Elisabeth Hochschorner and Göran Finnveden

Using the Balanced Scorecard as a Framework for Life Cycle Management Burton Hamner

CLOSING PLENARY

Our Closing Plenary will be keynoted by Alan Hecht, Sustainability advisor the U.S. President, member of the Council on Environmental Quality, and former international advisor at the U.S. EPA.

Awards will also be presented for the conference's best presentations.

THE USE OF LIFE CYCLE ANALYSIS IN ENVIRONMENTAL LABELLING STANDARDS

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Ecolabelling has been referenced for a long time as being both a driver for further LCA development and as a benefactor of the results and methodological approaches. The use of voluntary or mandatory environmental standards and environmental labels are an emerging and growing trend in overseas markets and some Australian industries. The Australian Ecolabel Program label develops environmental performance standards under the guidance of an international standard for Third Party Environmental Labelling Programs – ISO 14 024. The standard development process illustrates the use of life cycle analysis methodology in order to ensure that the voluntary environmental labelling standards have overall scientific rigour and are comprehensive in their environmental impact assessment and product performance benchmarking. The key function of the voluntary environmental labelling standards is to define benchmarks of acceptable product environmental performance on the basis of priority impact categories. Other priorities include verification on fitness for purpose, compliance to environmental regulations and compliance to social criteria based on consumer expectations.

The LCA framework has shown to be an important scientific tool in criteria determination and benchmarking for the environmental performance requirements of the standards. In particular the ISO 14 040 series methodology has allowed for some of the problems of needing exact quantification of all environmental impact categories to be easily overcome through prioritisation. Normalisation and characterisation contribute to analysis of environmental impact relevance and the formation of suitable criteria for standards. Ecolabelling will continue to challenge the LCA methodology and take it to its limits as labelling tries to standardise environmental load benchmarks in a real market environment with different technologies, opportunities for environmental innovation and by giving due consideration to the sensitivities of unique ecological regions. LCA methodologies that are qualification based rather than quantification orientated show particular value when LCA data is inadequate. The streamlined LCA methodology also promises to deliver quality a methodology of particular use for ecolabelling programs. LCA methodology with however be only one element of a broader issues that need to be considered by such programs including regulatory requirements, fitness for purpose requirements and social expectations.

Keywords: ecolabel, environmental labelling standards, design for environment, environmental load assessment, life cycle product design, standard development for sustainable development, ISO 14 024, ISO 14 020, ISO 14 021, ISO 14 040.

A Natural Selection System to Drive Life Cycle-Based Eco-Efficiency and Sustainable Development

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Recent research on the effectiveness of eco-labeling raises concerns that despite past successes in specific product groups (notably paper and laundry detergent), companies see decreasing promise for market benefits in other product areas. At the same time, international consumer surveys indicate high and increasing support for companies with a strong reputation on the broader issues of corporate responsibility and sustainable development. The World Summit on Sustainable Development in Johannesburg re-affirmed the imperative for linking the "two sides" of the sustainable consumption agenda: reducing pollution and wasteful consumption in rich countries while promoting life-sustaining consumption and sustainable development in developing nations. And user need input expressed to the UN Environment Program's Life Cycle Initiative continues to stress the need for building the capacity for – and relevance of – LCA in developing countries.

This presentation will describe a newly-launched system for making – and then exercising accountability for -- voluntary arrangements that generate private and societal benefits (what economists call "positive externalities"). The "New Earth" Initiative enables such arrangements to be created voluntarily and spontaneously by and among individuals, communities, for-profit companies, governments, and non-governmental organizations (NGOs). The system provides a label to the products of companies that make five commitments, which include contributions to a fund for sustainable development, and engagement of stakeholders to characterize, continually improve, and transparently report the environmental, economic, and social impacts of the company.

The presentation will describe the operation and target benefits of the system, and the expected impacts on the development and usage of LCA, ecolabeling, and corporate sustainability reporting.

LCA External Reporting and its Application in the Socially Responsible Investment (SRI) Community

Esther Garcia, LL.B, LL.M, M.Sc.,
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The proposed paper aims at establishing the link between Life Cycle Analysis (LCA) External Reporting and the impact it has on the Socially Responsible Investment (SRI) community. The paper will try to answer the question: Can indicators be developed to benchmark corporate progress on LCA?

Background:

In the past decade the SRI movement has seen great expansion and recognition. As the investment community increasingly develops ethical and SRI funds and competition increases, SRI analysts need to develop new methodologies to benchmark companies' environmental and social policies, management systems and performance in order to make informed investment decisions. SRI analysts may look at a different range of issues depending on the industry sector. For example, in the case of a vehicle manufacture company, the SRI analyst will not only consider in-house operations and management, e.g. environmental management system, but also will look at the progress of such company in developing environmentally sound products by using tools such as LCA.
Fund managers may use different approaches in selecting companies for their ethical / SRI portfolios. They may use in-house teams of SRI analysts or use external resources provided by sustainability rating agencies such as the Ethical Investment Research Services (EIRIS) Ltd.

At EIRIS, companies have been traditionally benchmarked against each other in the following areas: policies, management systems, reporting, and performance. However, whereas there is currently some standardisation in reporting mainstream emissions, e.g. CO_2 (tonnes), there is lack of harmonisation in reporting advances in Life Cycle Analysis. LCA information contained in Sustainability reports is very much ad hoc and based on case studies, making companies difficult to benchmark.

EIRIS has developed a methodology to overcome this situation.

The presentation will cover the following topics:

- The link between LCA and the SRI community
- An introduction to EIRIS mainstream methodology
- The current status of LCA reporting across sectors, e.g. automotive, electronics
- The development of reporting indicators for LCA. What is the role of EIRIS and the GRI?

The Contribution of Life Cycle Assessment to Global Sustainability Reporting of Organizations

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The three dimensions of sustainability are economy, socio-economy and ecology. In enterprises as well as public authorities the interaction of these aspects is of more and more interest. Economic decisions are often made with a close look on environmental and social aspects and in the fields of public relation and corporate identity all three dimensions are important.

In the area of environment the first step is already done: management systems with an explicit focus on environmental viewpoint, as specified for example in ISO 14001, are established. Thereby the organizations become aware of their local environmental effects. The consideration of the whole life cycle broadens the view to cover also Extended Product Responsibility (EPR). So environmental reports, which describe the situation of companies and their products in the global context, are a byproduct of the consequent internal environment protection of an organization. Parallel to the efforts of the companies to protect the environment, also the economic progress and the social improvement can be considered and an integrated global sustainability report can be published by the organization.

In enterprises the economic aspects are very well known, but often it is a problem to consider environmental and social aspects. Environmental aspects can be covered for example by Life Cycle Assessment (LCA). LCA is a proved scientific method to get quantitative results to environmental questions. With a manageable initial effort for a database using existing databases as a good starting point and a modular and parameterized model, regularly updates for yearly reports are practicable, quick and easy. With a case study of an SME it can be shown, that LCA provides very useful results in reference to environmental management systems and sustainability reports.

It will be shown, that results of impact assessments as central parts of an LCA are a good basis to create significant indicators for sustainability reports. They show environmental performance on a scientific basis and with the claim to include all relevant environmental problems. An other point is to show how results of LCA can contribute to an environmental management system (support decisions, define environmental goals, verify environmental improvements quantitatively, include indirect aspects, …) and to show that LCA today is a tool highly efficient and relatively easy to use that combines scientific based results and manageability.

Ecolabel and Transparency

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The goal of the different national and supranational ecolabelling programmes is to encourage consumers to favor products which are the least damaging to the environment. It is clear that the involvement of product and service users is essential to the establishment of a more sustainable social system. For this reason, ecolabelling must necessarily limit any risks of confusion[1]. To this end, labels must show all the impacts of a product's life cycle and use an objective, reliable, verifiable, and comprehensible evaluation method[2].

In general, the organizations in charge of ecolabelling programmes claim that the multicriteria approach is used to define the exact labelling criteria appropriate for the product categories in question. These organizations generally maintain that their approach is based on the completion of exhaustive and complete life cycle analyses which take into account all of the impacts caused by a product throughout its life cycle. And yet, the real situation is often far less clearcut, and these simplified approaches, which tend to reconcile economic realism and methodological coherence[3][4], constitute the usual procedure for criteria definition.

Thus, the procedures involved in criteria development often rely on a «semi qualitative»[3] approach to the life cycle which uses both qualitative and quantitative data in order to identify the product's significant stages on the environment[5].

Presently, the ecolabel is «non-verifiable expert property» for the consumer. The ecolabel's lack of objectivity in its criteria and its lack of transparency, resulting from simplified and non standardized methods whose accuracy cannot be measured, can only damage this sustainable development tool's credibility. In effect, the primary hindrance to ecolabel development lies precisely within this difficulty of finding a compromise between economic feasibility and the scientific and methodological rigor that are indispensable to the label's credibility and veracity[6].

Is it possible to seek to reduce LCA costs and length without, at the same time, compromising LCA precision and transparency?

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Global Warming Effect Assessment in the Electricity Sector Using Hybrid Life-cycle Inventory Assessment

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The global warming effect (GWE) calculation utilizes global warming potential (GWP) factors applied to results from life-cycle inventories. This presentation demonstrates the application of GWE to a comparison of renewable and non-renewable electricity generation options: wind, hydro, solar, coal, and natural gas power plants. The inventory includes the direct and supply chain emissions from construction, burning of fuels, flooded biomass decay in the hydroelectric plant's reservoir, loss of net ecosystem production (NEP), and maintenance of the power plants. Land use by these facilities is also assessed. The inventory assessment uses a combination of process-based (SETAC-EPA-ISO) and economic input-output analysis-based LCA. Such a hybrid LCA method allows for an integration that enhances the advantages and reduces the disadvantages normally observed in an LCA. All power plants reflect U.S. conditions, and have been scaled and co-located so that a comparison becomes appropriate. The results indicate that a wind farm and a hydroelectric plant in an arid zone (such as the Glen Canyon Dam on the Colorado River) have lower GWE than the other electricity technologies. The type of ecosystem displaced by the reservoir and the period of analysis is fundamental to the assessment of the alternatives. Sensitivity analysis includes the periodic upgrades that power plants are put through, as well as ecosystem variations for technologies where NEP is important: hydropower plants (reservoirs) and solar farms. After 20 years of operation, the upgrade of the Glen Canyon hydropower plant (in 1984) increased the power capacity by 39%, and resulted in a mere 1% of the CO_2 emissions in comparison with the initial construction effects. No additional emissions from the reservoir occurred, making a periodic upgrade an important action for a hydropower plant.

Estimation of Life Cycle Energy Use Implications of Wired and Wireless Communications Networks Using Hybrid LCA Models

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There has been rapid growth in the popularity of mobile phone use in the US. According to the Cellular Telecommunications and Internet Association (CTIA) semi-annual Wireless Industry Survey, the US has seen a steady increase in the number of subscribers, wireless minutes of use, cumulative capital investments, total number of cell sites and total service revenue. Further, a 2002 report from the Yankee Group stated that 3% of US households have completely replaced landlines with wireless phones. As the size of the cellular network grows, it is important to analyze the energy impacts and implications of its growth, compared with the 'traditional' Public Switching Telephone Network.

This paper investigates the energy consumption of the telecommunications network in the United States. The scope of the study covers the 'voice' network, including both the Public Switching Telephone Network (PSTN) and the Mobile cellular network. Using results from a previous study, the estimated total electricity consumption of the telecommunications network in the US was found to be about 25 TWh/year, about 0.6% of the US total electricity consumption. This paper also analyzes the breakdown of the energy consumption between the PSTN and the Mobile network, and found the Mobile network to be more energy efficient in terms of energy used per subscriber connection.

One important consideration when making such comparisons is the allocation of core communications network services to wired and wireless networks. This is because wireless networks are only wireless at the endpoints. They still depend heavily on a wired core network to provide service. These results on the energy consumption of voice communications networks are compared to previous work done by the authors on energy implications of data networks.

An additional component to this analysis is an estimate of the energy required to manufacture the wired and wireless telecommunications equipment (e.g. network cards, etc.). This estimation is done using EIO-LCA, an economic input-output based LCA model available freely on the Internet. Economic input output models have been used as an alternative approach to process based life cycle assessment models. A United States input-output model for this purpose is maintained by Carnegie Mellon's Green Design Institute and is available at the website http://www.eiolca.net. The model traces the supply chain requirements, energy use, and environmental impacts of purchases from any of up to 480 economic sectors. The current model uses the 1997 benchmark of the US economy, as released by the US Department of Commerce Bureau of Economic Analysis.

Overall, this paper will show the relative energy use of wired versus wireless networks considering manufacturing and use-phase energy effects.

Electricity Generation Mix by US Industrial Sectors:

Disaggregating Electricity Generation and Modeling Interstate Transfers

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The environmental life-cycle impacts of a product, process or industry sector tend to be dominated by energy-related impacts, specifically electricity generation. The impacts from the electricity generation sector occur in the form of air pollution, fuel use, and global warming. It is important to have good measures of these impacts in order to quantify the possible implications for health, environment, economy, etc.

However, most current analyses which include electricity generation use aggregate measures for electricity generation mix and a great deal of detail is lost at the plant or state level. For example, in EIO-LCA (www.eiolca.net), all sectors consuming electricity are assumed to use the United States' average electricity mix which is largely fossil-fuel based – over 50% coal. However, certain sectors – based either on their geographical location or other factors – buy electricity with very different generation parameters than those of fossil fuel-based electricity. A good example of this would be aircraft manufacturing in the Pacific Northwest, which may purchase and use more than 80% hydroelectric power, which, in turn, would have a significant impact on the generation mix of the entire industry sector.

Existing data which places percentages of industry sectors in each state using Department of Commerce facility location, employment and shipment data is combined with electricity generation mix data from the Department of Energy to produce a sector-by-sector accounting of the *usage* mix as opposed to a single set of national values for generation mix. Also a part of this approach is the inclusion of an estimate of interstate electricity trading; in many cases the inclusion of import and export data has significant effects on the electricity consumed within the state. California, for example, uses over 30% imported electricity, much of which is coal generated.

The estimate of interstate trading is a physical one, based on the principle that electricity will flow along the least resistive (shortest) path from source to sink. An economic model using transactional, plant-level data would be less accurate from a usage standpoint: electrons generated in Canada will not make a point of traveling to California, simply because that is where they were purchased from. The method used is a linear optimization which minimizes a total "travel" cost by calculating two matrices – the first of which is a distance matrix that uses both "hop count" or, alternately, mileage, and second which is the amount of electricity exported from each state with a surplus to each state with a deficit.

These updated sector usage/generation mixes can then be used to derive a much more accurate picture of the effects of the electricity sector in life cycle analyses and an estimate of the total electricity needed across the supply chain to produce a particular product or service can be estimated – but with full sector-level generation mix detail. Of course, the more diverse the supply chain, the more the electricity mix of that product trends towards the US average, but there are some specific cases where significantly different effects are found. There are many relevant public policy concerns with such data, such as determining which sectors would be most sensitive to energy taxes, carbon taxes, etc. When the model is combined with historical facility location and state generation mix data trends can be analyzed, particularly effects of deregulation or shift in generation types. This paper reports on the progress and research results of this project and shows how they can be used to better inform decisions in the policy arena.

A Comparison between Conventional LCA and Hybrid EIO-LCA: a Portuguese Food Packaging Case Study

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Packaging is a fundamental element of almost every food product and at the same time an important source of environmental burdens and waste. Acknowledging this fact, the European Union has created a legal framework to extend the producer responsibility over packaging residues, which constitutes an opportunity to promote Industrial Ecology policies and infrastructures.

In this context, a traditional Life Cycle Assessment (LCA) of the most important Portuguese food products was conducted, commissioned by the green dot society for packaging in Portugal, *Sociedade Ponto Verde*, whose primary objective was to contribute to environmental awareness and thus to minimizing environmental impacts of food packages over its entire life-cycle. The packaging assessed were constituted by steel, wood, plastic, paper/board and glass and originated from the dairy products, alimentary fats, fruits and vegetables, confectionery and frozen products sectors. For each primary package the overall packaging system associated was analyzed, in a cradle-to-grave perspective, and the main results are provided in this paper.

In addition, this paper makes use of an integrated Hybrid Environmental Input-Output Life Cycle Assessment (hybrid EIO-LCA), which was programmed in a custom software tool. The Hybrid EIO-LCA analysis comprises economical data on sector purchase requirements, and this is transformed in physical quantities making use of a database where economical and physical inputs and outputs are provided for about 7000 products by the national statistics office, thus providing a relevant input to support the hybrid EIO-LCA methodology.

The compiled process-specific data used in the LCA, was reworked as an input to the hybrid EIO-LCA method. The benefits and limitations of both methodologies are discussed as a function of the results obtained for greenhouse gases emissions for selected food packages.

Keywords: Life Cycle Assessment, Hybrid EIO-LCA, packages, food products, input-output tables.

Transport of Coal by Rail vs. Transmission for Electricity Generation: An Application of Hybrid LCA Comparative Analysis

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The USA mines almost one-billion tons[7] of coal each year to produce 52%[8] of its electricity supply. A major question for the industry is whether to build generating plants near the mine or near electricity customers. I have built a model to evaluate this question. To demonstrate the use of this model, I examine the most important example, the shipment of coal from the Powder River Basin (PRB) in Wyoming to Texas. Currently, 50 million tons[9] of PRB coal is shipped annually to generation plants in Texas by unit trains. I investigate whether a new 1,000 megawatt plant (producing electricity to meet demand growth) burning 3.3 million tons of PRB coal annually should be built near the mine mouth or near the Texas customers in terms of the cost and environmental implications. I assume that new transmission lines are required but that the existing railroad bed has sufficient capacity to accommodate the increased traffic. I find that the annualized cost of building this new transmission system is roughly equal to the cost of maintaining and operating the existing rail system (between $92 and $117 million/yr). This is primarily due to the high capital costs involved in constructing the transmission system. I also find that the additional power that would be required in order to compensate for the losses of electricity from the transmission lines would add to the cost of the transmission system and the environmental emissions significantly. In addition, there is an equity issue involved in this decision, should the residents of Wyoming bear power plant emissions and a power line to provide power for residents of Texas? There are some key assumptions which, if changed could impact this analysis. Examples of these include carbon sequestration, reduction of transmission losses and new rail construction. These tradeoffs are examined within this paper.

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[7] Energy Information Administration. Department of Energy. USA. Coal Production by State, 1991, 1996-2000. http://www.eia.doe.gov/cneaf/coal/cia/html/t1p01p1.html.

[8] Energy Information Administration. Department of Energy. USA. Percent of Electricity Generated at U.S. Electric Plants by Energy Source and State, 2000 and 1999. http://www.eia.doe.gov/cneaf/electricity/epav1/generation.html#tab7.

[9] Energy Information Administration. Department of Energy. USA. Table 59. Domestic Distribution of U.S. Coal by Coal-Producing Region and State, and Destination Census Division and State, 1996-2000. http://www.eia.doe.gov/cneaf/coal/cia/html/t59p01p12.html.

LCA of Aboveground Bioremediation of Diesel-impacted Soil

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Primary and secondary impacts associated with bioremediation of diesel-contaminated sites were assessed using a life cycle assessment (LCA). The case study was the remediation of 8000 m^3 of subsurface soil impacted with an average of 6145 mg of diesel fuel/kg soil during a two year period. Two scenarios were compared; the construction of a single-use treatment facility in the vicinity of the site or the use of a permanent treatment centre that can accept 25000 m^3 soil/year. Moreover, since bioremediation is never 100% efficient, different efficiency scenarios, including the transportation of partially treated soil to landfill were analyzed. The primary impact of residual soil contamination was determined by developing a specific characterization factor (ecotoxicity and human toxicity categories in the EDIP method) based on the toxic components of diesel.

One major observation was the fact that the soil itself is responsible for an important fraction of the system's total impact, suggesting that it is beneficial to reach the highest level of remediation. The reutilization of the treatment facility is also an important issue in the overall environmental performance of the system. In the case of a single-use treatment center, the analysis showed that site preparation and closure were the two major contributing stages to the overall impact, mainly due to the bulk waste impact category. This significant contribution is explained by the asphalt production, paving and landfilling. Results indicated that off-site transport and the biotreatment process did not contribute notably to the level of environmental impact. The use of a permanent treatment centre is preferred since it allows a significant decrease of the remediation impacts. However, for isolated sites (away from a permanent treatment centre for a distance greater than 200 km), it should be more beneficial to treat the soil on site.

LCA was found to be an efficient tool to manage contaminated soil in a sustainable way. However, because of the major contribution of soil residual contamination, additional spatial and temporal data should be collected and integrated in the substance characterization factors.

Externality Analysis of the Flue Gas Desulphurization System at Mae Moh Lignite-Fired Power Plant in Thailand from LCA-*NETS* Point of View

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The mine mouth coal-fired power generation plant in Mae Moh region is the biggest thermal power generation plant in Thailand, which has used coal-lignite as fuel. It has held the second share of utility power generation about 22.7% of all utility-produced electricity referred from the Electricity Generating Authority of Thailand (EGAT). In year 2000, the gross electricity production by type of fuels used are approximately from natural gas, lignite, fuel oil, hydro, diesel oil and others about 52.5%, 22.7%, 16.8%, 7.8%, 0.2% and 0.0026%, respectively. Due to the lignite fuel in Mae Moh region contains high amount of sulphur about 3% therefore, in some year, the number of health complaints have increased during the cool season when high concentrations of SO_2 has been emitted. EGAT responded this problem by gradually installing the flue gas desulphurization systems (FGD) in power generation unit 4-13 since 1992 and have completed in January 2000. Sulphur dioxide has been controlled by FGD and produced satisfactory results. On the other hand, Life cycle thinking point of view, it is important to study and understand about the environmental impacts of the power generation plant after installation of FGD in whole life cycle (from cradle to grave). Moreover, when EGAT installed and operate the FGD, it has also required high investment budget, operation cost, maintenance cost and other cost. Therefore, the externality analysis of SO_2 ought to be investigated for whole life span of the FGD. This paper discussed about Life Cycle Assessment (LCA) and externality study, in which focus on Mae Moh lignite-fired power generation plant with the generated capacity of 2,625 MW and generated electricity 15,547.56 GWh (2000). The aim of the study is first to apply LCA with Numerical Environmental Total Standards (*NETS*), which used for evaluating the environmental burdens by identifying and quantifying energy and materials used and waste released to environment, and to identify and determine the opportunities for environmental improvement methods. The impacts due to the global and regional environmental issues are numerically evaluated in *NETS*, which is based on the balance of L & R (Loader and Receiver) theory. The second is to estimate the externality cost by using cost and benefit ratio on the basis of LCA-*NETS* method. As the result according to the Life cycle thinking point of view, the environmental load and the externality cost are discussed and the green lignite-fired power generation technology and the environmental cost are recommended for further ecological and economical improvement.

Keyword: Life Cycle Assessment, Life Cycle Costing, Numerical Eco-load Total Standardization, Flue Gas Desulphurization, Lignite-fired Power Generation Plant

Taxonomy of Impact Categories and the Taxonomy Structure: Results from the UNEP/SETAC/EPA Hamburg Workshop

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The selection of impact categories is considered dependent upon the application, goal, and scope of the study and is ultimately the responsibility of the study practitioner and commissioner. While it is anticipated that the responsibility will continue to rest with the study practitioner and commissioner, it would be useful to have a broader structure to ensure that at a minimum, a comprehensive list of impact categories have been considered prior to the selection process. Gloria and Bare presented a first draft for a Taxonomy Structure, developed in a compatible way to the Taxonomy Structure of the Life Cycle Initiative at the SETAC Europe Meeting in May of 2003.

The workshop presented the following questions:

Is the Taxonomy Structure in general a good proposal?
Is the Structure of the given main blocks consistent?

1. Is there a need and/or better way to differentiate the Life Support Functions?

2. Looking at the Taxonomy Structure, how well do the subdivisions enable a flexible but consistent framing of LCIA for decision making? For example, is there general agreement on the divisions presented under how to categorize human health? What are the suggested improvements?

3. Looking at the proposed Taxonomy Structure, are their inconsistencies, missing elements, redundant elements, or elements which are presented at too finely differentiated or too coarsely differentiated levels?

4. What are the recommended guidelines for the use of the Taxonomy Structure for specific LCA studies? For example, on which basis and criteria should we select or exclude categories in the Taxonomy Structure for given applications?

This presentation will summarize the findings of the workshop, report the status of current initiatives and next steps.

Uncertainty Analysis for the Life Cycle Study of Municipal Solid Waste Gasification Using Probabilistic Simulation

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Various types of uncertainty and variability are often mentioned as crucial factors complicating the clear interpretation of Life Cycle Assessment (LCA) outcomes. One study reported that more than half of performed LCA studies made no reference with uncertainty. Variability is understood as stemming from inherent variations in the real world while uncertainty comes from inaccurate measurements, lack of data, model assumptions that used to convert the real world into LCA outcomes. Due to these limiting factors, uncertainty analysis is gradually gaining importance in performing LCA' studies, but still its use is not a common practice among LCA practitioners. An LCA study that takes into account variability and uncertainty has been conducted for a municipal solid waste gasification plant around Ibaraki area, Japan. The methodology used involves the determination of suitable probability distributions, Monte Carlo Simulation and/or Latin Hypercube Sampling, importance analysis and finally interpretation of final LCA outputs. Monte Carlo and Latin Hypercube methods are the common probabilistic simulation used to address data inaccuracy and variability in objects and sources. The main difference between the two is that the latter involves the segmentation of uncertainty distribution into a number of non-overlapping intervals of equal probability. To reduce the number of parameters considered, only the essential ones of life cycle inventories for solid waste gasification are considered in this study. The variations of the chosen parameters in the inventory of waste gasification process chain have been characterized in the form of probability distributions. In the final step, life cycle analyses of other configurations of waste gasification technology are experimented and its inventories are compared. In this way, it is possible to take into account regional variation as well as technological variability. Using appropriate probability distributions of the essential parameters, the results of the inventory analysis is transformed from a mere single concrete value into probability distributions of mean value of the output parameters, thus, producing a more robust and convincing LCA outcomes.

Considering Uncertainties in the Functional Unit: Development of a More Flexible Strategy to Achieve the Goal of an LCA Study

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CIRAIG

LCA studies are often based on a well-accepted assumption that the parameters comprising the functional unit, such as quantity and time, are known. This assumption can be true, but in some cases the values of these parameters have a certain degree of uncertainty such as when mean, most probable or target values are used. This uncertainty can significantly reduce the quality of an LCA, particularly in compared LCA studies. In this type of LCA, uncertainties associated with the functional unit can drastically modify the final results and should not be ignored. These uncertainties can be found in site remediation. The level of contamination is often an average of sample concentrations spread over the entire site. In addition, many remediation technologies are not fully effective.

The METEnvOrs (*Model for the Evaluation of a Technically and Environmentally Optimal Remediation Strategy*) model, based on a technico-economic multi-period decision model (METEORS), has been developed to manage these two additional types of uncertainty associated with some parameters of the functional unit. This model explores different ranges of possible values for the uncertain parameters of the functional unit. This environmental decision model has been used to select the optimal remediation strategy for a diesel-contaminated site for which two remediation technologies were being considered: the biopile (fully effective) and the *in situ* bioventing (not fully effective). Compared to the deterministic case (the technology having the lowest environmental impact considering a traditional LCA), the optimal remediation strategy has a main advantage. It allows the decision-maker to review the chosen technology according to the reduction in contamination, meaning that during the remediation process a part of the real functional unit parameters are revealed to him. This flexibility insures that a minimum of environmental impact is produced during the site remediation considering all the possible occurrences resulting from the uncertainties in the functional unit. As another advantage, the strategy presents all possible scenarios that could occur during the remediation strategy application and caused by the uncertain parameters of the functional unit. For a decision-maker, knowing all the possible scenarios is a way to manage the uncertainties surrounding the functional unit and to stay with the most favourable position regarding the remediation goals.

The optimal remediation strategy obtained is compared to the deterministic case. If the impact of the deterministic case lies between the worst and the best scenarios comprising the strategy, it is nevertheless higher than the expected impact of the optimal remediation strategy. For this case study, 75 % of the 28 scenarios (for a total probability of occurrence of more than 70 %) have a lower environmental impact than the deterministic case. Considering the uncertainties associated with the functional unit, this not only shows clearly that worst cases than traditionally expected are possible, but also that more valuable cases ignored by the deterministic approach can occur.

Teaching LCA to Interdisciplinary Graduate Students

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LCA has been taught to seniors and graduate students at the University of Washington as part of a Design for Environment course for six years. This year, LCA was offered as a stand-alone course to graduate students from engineering, forestry, business administration, and public policy. The course objectives were to analyze and apply the computational structure of environmental LCA and to understand the relationship between the product life cycle, environmental impact, resource conservation, and pollution prevention.

Course resources included a textbook to provide the computational structure of LCA, the ISO14040 standards, articles on each assessment phase and on streamlining methods, several LCA case studies, LCI and LCIA software (both publicly available and free), and a web-board to facilitate data exchange. Specifically, the students used a software tool called *Chain Management by Life Cycle Assessment* (CMLCA) developed at Leiden University to support inventory analysis as described in the course textbook. The students also used the *Tool for the Reduction and Assessment of Chemical Impacts* (TRACI) developed at the USEPA to support impact assessment. The web-board was a TWiki site which is an easy-to-use open communication environment that allows people on the Web or on an intranet to exchange and update text, documents or other files. Students used the LCA course web-board to exchange inventory data that they identified from publicly available sources or that they developed themselves.

For the course project, each student analyzed a product or process related to their thesis or dissertation, a personal interest, or from a list suggested by the instructor. Given the time constraints of a 10-week course, students prepared written and oral reports of their LCA that included at a minimum a goal and scope definition, a list and impact classification of material and energy use and waste for the life cycle, and an inventory and impact characterization of material and energy use and waste for at least two life cycle stages, most often representing manufacturing, use, and end-of-life.

Teaching Life Cycle Concepts to School Children

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If life cycle thinking is to be integrated into how our society views issues of sustainability and protecting the environment, new generations must be taught to use life cycle thinking at an early age. They must become familiar with the concepts of systems analysis, input output analysis and the holistic evaluation of environmental impacts.

The life cycle framework provides an excellent way to organize the teaching of math and science as well as the social sciences. Teachers can choose a particular product as the basis of the entire curriculum for a term or a year. That product is then evaluated from cradle to grave, allowing children to understand the implications of the decision to use a particular product. Along the way, concepts such as sampling and statistics, chemistry and materials science and physics are incorporated in the curriculum.

Concepts such as historical and societal choices can also be incorporated, allowing children to see the ripple effects of decisions, and to understand the law of unintended consequences. In fact, Life Cycle thinking should provide an anodyne to that law.

We have developed a program to teach teachers of middle school children (roughly ages 10 to 14) life cycle concepts. The program is offered over a two-day period, with a curriculum based in part on the book *LCA for Mere Mortals* (Schenck, 2000). Specific product LCA's are reviewed, and the participants leave the workshop armed with materials to teach children using life cycle tools.

Land-Use Inventories for Sustainable Transportation Scenarios

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A future, truly sustainable system for providing energy to the United States transportation fleet requires that energy be generated from truly renewable sources such as sunlight, wind or biomass. Furthermore, the renewable energy must be converted to, and stored as, a fuel that is useful to vehicles, and especially to small vehicles. Of the various scenarios postulated for meeting these two requirements, three primary paths stand out as the most likely candidates for implementation:

1. Renewable electric generation --> hydrogen production --> fuel cell-electric vehicles
2. Renewable electric generation --> battery-electric vehicles
3. Biomass production --> liquefaction --> combustion-electric hybrid vehicles

Currently the transportation sector consumes roughly one-third of the nation's total primary energy consumption. Hence, even with substantial improvements in vehicle efficiency, any foreseeable transportation scenario based on renewable energy will entail very large land use impacts. *Land-Use Inventories for Sustainable Transportation Scenarios* will estimate minimum and maximum expected land areas affected by the three sustainable transportation scenarios. The minimum and maximum for each scenario will be determined by technology forecasts for system efficiencies, and in addition the minima and maxima for all scenarios will further be influenced by available forecasts of future energy demand of the U.S. transportation system.

The paper will conclude with a discussion of life-cycle impact assessment methodologies available for comparing the three scenarios' land use impacts to each other.

ecoinvent: A Comprehensive Web-Based Life Cycle Assessment Database

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In late 2000 the life cycle inventory (LCI) database project ecoinvent 2000 has been launched. Several Swiss Federal Offices and research institutes of the ETH domain (Swiss Federal Institute of Technology) agreed on a joint effort to compile, harmonise, and update life cycle inventory (LCI) data for their use in life cycle assessments (LCA). For this purpose a central database (ecoinvent database) is being developed building on past experiences with a large network-based LCI database created at ETH Zürich in the 1990s. The database comprises LCI data from the sectors of energy generation, transport, building materials, chemicals, paper and pulp, waste treatment, and agriculture. Furthermore, several new and/or widespread impact assessment methods such as the Dutch Eco-indicator 99, the CML characterisation scheme 2001, or the Swiss ecological scarcity 1997, as well as EPFL's IMPACT 2002 will be implemented. Quality guidelines have been established in order to ensure a coherent data acquisition and reporting across the various institutes involved. Aspects that require a harmonised procedure involve the reporting of pollutants (e.g., heavy metals), the modelling of electricity generation, the system boundary definitions, allocation, the reporting and quantification of data uncertainty, the treatment of transport service requirements, the naming of processes and elementary flows, etc.

The content of the database will be publicly available via the Internet from fall 2003 at www.ecoinvent.ch. Processes as well as impact assessment methods are documented with the help of meta-information and flow data (in the form of single (raw) process data as well as building blocks with elementary flows). The data format has been structured according to the ISO 14048 data documentation format. The web interface allows for an easy and detailed search for processes, elementary flows, and impact assessment methods. Meta information and flow data can easily be downloaded and imported into commercial or other LCA software. In order to facilitate data exchange between project partner institutes and the database and its clients XML technology is employed.

The presentation will elaborate on the content, capabilities, and specific features of the database and its interfaces as well as its contribution to a more widespread and flexible application of LCA, presently and in the future.

Attributional and Consequential LCI modelling

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The life cycle model developed in a life cycle inventory analysis (LCI) should be an appropriate description of the relevant parts of the technological system. What parts are relevant depends on the aim of the study. An attributional LCI aims at describing the environmentally relevant physical flows to and from a life cycle and its subsystems. Such a description is useful to assess the environmental performance of the systems investigated. Consequential LCI, on the other hand, aims at describing how the environmentally relevant physical flows to and from the technological system will change in response to possible changes in the life cycle. It generates information on the consequences of decisions.

The distinction between attributional and consequential LCI was originally made to resolve the methodological debates on allocation and on marginal versus average data. To describe the environmental burdens of a life cycle and its subsystems, an attributional LCI model includes all stages of the life cycle from cradle to grave. To avoid irrelevant information, it does not include technological activities outside of the life cycle investigated. This means that system expansion is not an applicable way to avoid allocation. Since other methods for avoiding allocation are rarely feasible, allocation is typically not avoided in an attributional LCI. Instead, a method for partitioning must be chosen.

The environmental burdens from the life cycle are divided by the functional output from the life cycle to obtain the environmental burdens per functional unit. Similarly, the environmental burdens of any subsystem are described by the use of average data, i.e., the total environmental burdens of the subsystem divided by the functional output from that subsystem.

The consequential LCI model, on the other hand, should ideally include the activities where the environmental burdens are affected the most by a change within the life cycle of the product investigated. A consequential LCI excludes unaffected parts of the life cycle, but it includes activities within and outside the life cycle to the extent that they are affected. In many cases this implies the use of marginal data. It also means that allocation is typically avoided through system expansion. However, the aim to describe effects of decisions on environmentally relevant physical flows has implications for the system boundary far beyond allocation problems. The consequential LCI model includes the alternative use of constrained production factors. It also includes the marginal supply and demand on markets that are affected by decisions in the life cycle investigated. As a result consequential LCI model does not resemble the traditional LCI model, where the main material flows are described from raw material extraction to waste management. Instead, the starting point of a consequential LCI is the decision at hand or the decision-maker to be informed by the study. The consequential model is a model of causal relationships originating at this starting point. Economic causal relationships are at least as important as physical flows in this context.

Describing the consequences of decisions also means facing the general challenge of futures studies. The future is inherently uncertain, and the actual future consequences of decisions are very uncertain. Dealing with this uncertainty requires that methods of futures studies are applied in the consequential LCI.

Using Site Specific Life Cycle Assessment to Support a Contaminated Site Management Decision

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An LCA was used as a tool for managing the remediation of contaminated sites. The study was performed at an Aluminium production plant where four remediation management options were assessed for the remediation of existing aluminium processing waste landfill site. Three of the studied options were active remediation methods (requiring excavation and treatment of the waste) while one consisted in a passive *in situ* remediation method (leaving the source in place). The (eco)toxic impacts resulting from the presence of the pollutants in the soil (primary impacts) and impacts generated by remediation activities (secondary impacts) were compared.

To improve the reliability of the primary impacts assessment, site-specific data from hydrogeological, geochemical, and microbiological characterization were used. A fate and transport model was also used to simulate the evolution of groundwater contaminant. The resulting concentrations were introduced in the comparative LCA. For the Life Cycle Impact Assessment (LCIA), the EDIP methodology was used.

The results revealed a too large dominance of the (eco)toxic impacts associated with the presence of *in situ* pollutants. This was explained by the fact that the EDIP method was not well adapted for the evaluation of primary impacts. Consequently, the level of the assessment of ecotoxicity was improved. For this purpose, a new ecotoxicity characterization model was developed, which 1) differentiated freshwater and seawater, 2) considered the sediments ecotoxicity category, and 3) excluded the acute ecotoxicity category. The introduction of the primary impact assessment and the integration of an appropriate characterization model in the LCA study has then allowed to identify the optimal scenario according to local (eco)toxicity and to global environmental load.

LCAccess: An On-Line Directory for Global Life Cycle Assessment Information and Data

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Evaluating environmental impacts holistically from raw material acquisition, through manufacture, use and disposal using a life cycle perspective is gradually being viewed by environmental managers and decision-makers as an important element in achieving environmental sustainability. However, the lack of readily-available, quality data can hamper the incorporation of life cycle considerations into the environmental decision-making process. A major barrier to using life cycle assessment tools is the difficulty in obtaining viable data for completing the analysis, called the life cycle inventory (LCI). *LCAccess* is a U.S. Environmental Protection Agency sponsored website intended to help overcome this barrier and promote the use of life cycle assessments in business decision-making by facilitating access to data sources that are useful in developing an LCI.

LCAccess serves as a central source for life cycle assessment information. The main goal of the website is to promote the use of life cycle thinking in decision-making by facilitating access to resources and data sources useful in developing a life cycle inventory. It accomplishes this goal by providing information on EPA=s role in life cycle assessment, the benefits of life cycle assessment, what is life cycle assessment, a brief overview of how to conduct a life cycle assessment, how to find data sources (through the LCI Global Directory), available resources (i.e., documents, software tools, other related links), on-going efforts in the field (e.g., EPA, other US efforts, international efforts), and upcoming events (i.e. conferences and workshops). While *LCAccess* does not itself contain data, it is a searchable global directory to potential data sources. From the results of a key word search on an industry sector, data profiles on individual data sources are generated to give the user an idea of what each data source contains. To find the *LCAccess* web-site go to: http://www.epa.gov/ORD/NRMRL/lcaccess.

LCAccess is currently soliciting organizations that have completed life cycle assessment studies to provide their data sources for reference in *LCAccess*. Inquiries should be directed to the development manager, Mr. Tim Skone (703/318-4604) and/or the EPA Sponsor, Ms. Mary Ann Curran (513/569-7782).

Environmental Performance Comparison of Wet and Thermal Routes for Phosphate Fertilizer Production Using LCI – A Brazilian Experience

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Phosphorous plays a fundamental role in any crop's growth. Therefore this element's main use is for fertilizer production. The most frequently used raw material for phosphate fertilizer manufacture is phosphate rock which main mineral is fluorapatite - $Ca_{10}(PO_4)_6F_2$. In this form phosphorous is not available for ready abosorption by vegetals requiring further industrial processing to make it accessible for them. The processes used for this transformation can be divided into two major groups: the thermal route and the wet sulfuric route. In the thermal route, fluorapatite's crystalline structure is modified by a thermal action, producing soluble phosphate compounds known as Fused Magnesium Phosphate (FMP).

FMP has an alcaline characteristic very adequate for acid soils (which is the case in most of the Brazilian agriculturable areas). Their slow nutrient release is also favorable for many crops grown in this country. Nevertheless the thermal route presents a major disadvantage being very energy intensive.

In the wet sulfuric route, the phosphate rock is digested by sulfuric acid yielding as main products Single Superphosphate (SSP) or phosphoric acid, an intermediate used for the manufacture of Triple Superphosphate (TSP) and Ammonium Phosphates.

Environmentally speaking, the sulfuric route's main disadvantages are the consumption of elemental sulfur - a non-renewable natural resource used for the sulfuric acid production - and in the phosphoric acid production, the generation of phosphogypsum - a solid residue - whose disposal may cause, as environmental impacts, underground waters contamination and intensive land use.

In this context, this work intends to compare the environmental performance of the wet sulfuric route and the thermal route.

LCA was the methodology selected for this comparison as it is the most powerful tool for environmental comparison of products that fulfill the same function.

To perform this comparison, the environmental impact profiles were established using a "cradle to gate" LCA approach for TSP and FMP chosen as reference products respectively for wet and thermal routes.

Metals LCA: Methodological Problems and Practical Solutions

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The copper industry is engaged in cradle to cradle life cycle assessments for specific copper product applications in specific geographic regions. This includes cradle-to-gate life cycle inventories that have already been prepared in the US and Europe and a comparative LCA that has been prepared for residential copper tube and plastic pipe in the US. Along the way, several obstacles were encountered that required changes in strategy and design of the LCA. Several of these changes were specific methodological improvements to reduce the ambiguities in source databases and uncertainties in LCA analyses.

These improvements will be described, with broader recommendations for improvements to LCA methodology in general for downstream product applications involving metals. Linking LCA-based outcomes (quantification of energy input/output balances and their impacts on pollution indices) and risk-based outcomes (estimation of health and ecological risks) in DfE decision-making regarding materials selection will be discussed. Other nonferrous metal industry sectors have produced LCIs (nickel) and LCAs (lead battery). This presentation will describe the experiences of the nonferrous metals industry in developing LCIs and LCAs, and the present interim outcome of the copper LCA — still a work in progress. Future plans for further development of copper-based LCA and recycling activities will also be described in the context of product stewardship goals of the copper industry and their coordination with global activities in LCA guideline development (the UNEP-SETAC initiative) and recycling database developments.

Evaluation of the Environmental Impact Of Wired Telecommunication Networks in Japan

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Life cycle assessment (LCA) can be applied not only to products but also to services such as information and communication technology (ICT) services. The ICT infrastructure is huge and many services share the same networks. This makes the LCA of ICT difficult, because a complete analysis of all facilities and equipment is impossible and the portion of the environmental burden imposed by each service is unclear. Process LCA is considered to be efficient at evaluating individual products, but rather inefficient at assessing huge systems that include unknown processes. Input-output (I-O) LCA is considered efficient for evaluating general services, because direct and indirect effects can be evaluated at a national level. For these reasons we used both process LCA and I-O LCA to evaluate ICT services. We employed process LCA according to our telecommunication network model, which includes end-user terminals, access facilities, transmission facilities, end office and repeater-station facilities in Japan. We also evaluated I-O LCA using the Japanese input-output table for 1995. We found that throughout the entire lifecycle, the CO_2 emissions emanating from wired telecommunication networks during the use stage accounted for 50-80% of the total. The emissions from customers' equipment were particularly heavy. The total environmental burdens imposed by 10,000 subscribers were about 700t-CO_2 and 1,700t-CO_2 as determined by process and I-O LCA, respectively. The tendency was almost the same. The differences between these results can be explained by the evaluation limits of the two methods.

Comparison of "CO2 Efficiency" between Company and Industry

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Recently, many people pay attention to improving "Environmental efficiency" for sustainability. However, the definition of "Environmental efficiency" is still unclear. It might need the different definitions for each level (material, company, industry and country levels).

First, we defined some types of the CO2 efficiencies for industries. They were calculated using the dada such as producer's price, gross value-added and cost of each industry published in the I-O tables and the data obtained by the I-O table analysis such as direct and indirect CO2 emissions (339/32 classification $(I-A)^{-1}$ 1995: Domestic). The first one was the "Total CO2 efficiency" of the industry, which was defined as the ratio of the CO2 emissions including indirect emissions as well as direct emissions in the industry to its producer's price. The second one was the "Direct CO2 efficiency" of the industry, which was defined as the ratio of the direct CO2 emissions excluding indirect emissions in the industry to its gross value added. And, the last one was the "Indirect CO2 efficiency" of the industry, which was defined as the ratio of the indirect CO2 emissions in the industry to its cost.

Second, we defined the "Direct CO2 efficiency" of the company by the same way of the "Direct CO2 efficiency" of the industry, which was calculated as the ratio of the direct CO2 emissions of the company cited by their environmental report to their gross income of the company, and then we compared it with the Direct CO2 efficiency of the industry to which the companies belong. It was found that the "Direct CO2 efficiency" of company tended to be similar to the "Direct CO2 efficiency" of each industry. Finally, it was suggested that this tendency might be useful to evaluate environmental activity of the company. In this paper, a new method to evaluate the environmental activity of the company will be proposed.

Analyzing Life-cycle Environmental Impacts of Local Development Initiatives Using Regional Economic and Environmental Input-Output Models

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Communities and planners need quantitative estimates of both economic and environmental impacts of development projects to make informed decisions about the tradeoffs and synergies between development and environmental protection. Regional input output models have been extensively used to analyze local economic impacts of development initiatives. Regional input-output models augmented with social accounting matrices (SAM) enable estimation of direct, indirect and induced impacts of development projects on local income, output, employment, and tax revenues. However, few practical tools exist for estimating the life cycle (i.e direct and indirect) increases in local resource use, pollutant emissions, waste generation, and local environmental degradation from these initiatives.

The potential usefulness of integrated economic and environmental input-output models has been recognized for decades, but few empirical models have been built due to lack of data. Integrated economic and environmental modeling requires linking changes in the level of economic activity in different economic sectors such as manufacturing, agriculture, and tourism with changes in environmental pressures such as pollutant emissions, waste discharges and resource use.

In this research, we build a conventional 498 sector regional input-output model for the Muskegon River Watershed in Michigan. We then augment it with a comprehensive environmental impact coefficient matrix covering, conventional air pollutant emissions, green house gas emissions, toxic chemical releases, hazardous waste generation, water effluent discharges, municipal solid waste generation, energy use, non-renewable mineral use, fertilizer use etc. We draw on a number of data sources such as the USEPA's Toxic Release Inventory, RCRA hazardous waste database, Aerometric Information Retrieval System (AIRS), NPDES permits database, DOE's energy consumption surveys, and input-output workfiles developed by the Bureau of Economic Analysis (BEA) and estimate sector level environmental burden and resource use coefficients. We estimate environmental burdens from both production and consumption activities. We generate summary indices using appropriate aggregation factors such as global warming potential, acidification potential, ozone depletion potential, eutrophication potential, and toxicity.

The regional input-output model and the environmental burden matrix are designed as a user friendly software. As a result, it provides a practical tool that can quantify both economic and environmental impacts of any developmental initiative within the watershed. The tool can also be easily adapted for use in other regions/watersheds. Obviously, the tool shares the well-recognized strengths and weaknesses of input-output analysis.

The paper also analyzes a proposed dam removal project aimed at restoring a local trout stream as a case study illustrating the application of the methodology and the tool.

A Comparison of U.S. and Canadian Industry Environmental Performance Using Economic Input-Output Life Cycle Assessment Models

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The U.S. and Canadian economies are intrinsically linked. While the Canadian economy is approximately one-tenth of the size of that of the U.S., the two countries are each others' largest trading partner. Production methods and environmental concerns in the two countries are similar, and many businesses are actively engaged in cross-border trade. However, there are many differences in the countries, including environmental regulatory systems. Comparing the environmental performance of industrial sectors in the two countries is of significant interest from economic, technical and public policy perspectives. However, comparisons are difficult due to many factors and have been limited in practice. Important in any comparison is a 'life-cycle' approach, where the economy-wide implications of production by the industrial sectors are included. Additionally of key importance is the analysts' understanding of the limitations of the comparison. We discuss this issue in detail in this work.

Economic input-output life-cycle assessment (EIO-LCA) models for the U.S. have been developed by the Green Design Initiative at Carnegie Mellon University. We have developed a similar model for Canada. These models allow the inclusion of the economy-wide economic and environmental impacts resulting from demand for products/services from sectors of the economy. An important consideration in life-cycle assessment is the inclusion of the set of indirect effects that do not lie along the main industrial supply chain. EIO-LCA models allow these indirect effects to be considered, which can enhance our understanding of the 'true' benefits and disadvantages of product production and associated environmental programs and policies. Our model estimates the increases in National Pollutant Release Inventory (NPRI) contaminant releases, greenhouse gas emissions, energy and non-renewable resource extraction and use that can be expected from increases in demands for goods or services in Canada.

In this work, we present an EIO-LCA model for the Canadian economy and determine the sectors of the economy which have the largest impacts on the environment with respect to energy and non-renewable resource use, greenhouse gas and pollutant emissions. In addition, we compare a number of key sectors in the Canadian economy with corresponding sectors in the U.S. economy with respect to the above environmental metrics. Finally, we investigate the sources of differences in the results (i.e., differences in the structure of the economies, the environmental performance of the sectors, differing regulations, technologies, etc.). Future research using the Canadian and U.S. models will attempt to address the economic and environmental linkages between the two countries.

Uncertainty in Life Cycle Impact Inventory Estimates from Economic Input Output Models

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Economic input output models have been used as an alternative approach to process based life cycle assessment models. A United States input-output model for this purpose is maintained by Carnegie Mellon's Green Design Institute and is available at the website http://www.eiolca.net. The model traces the supply chain requirements, energy use, and environmental impacts of purchases from any of up to 480 economic sectors. The current model uses the 1997 benchmark of the US economy, as released by the US Department of Commerce Bureau of Economic Analysis.

Any model that relies on underlying data to estimate effects will be subject to uncertainty. For LCA, few studies have considered or estimated the uncertainty that exists. In this paper, the major sources of uncertainty in input-output models, specifically the eiolca.net web model are identified and quantified. Various types of uncertainty exist, including underlying data uncertainty that results from the firm-level survey of economic and environmental data used to create the model. In addition, the effects of correlations among impacts for comparison of alternative designs is evaluated.

The resulting uncertainty is discussed and shown via several cases of using the model for analytical purposes.

The Emergence of Life Cycle Space™ and the Life Cycle Ratio™ A Proposed Planning Tool for Lowering our Ecological Footprint

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DEFINITION OF LIFE CYCLE SPACE

Buckminister Fuller once stated that "A geodesic is the most economical relationship between any two events." Life Cycle Space™ is dependent on three determining elements. First, on how the processing phases (nodes) of the life cycle are configured in a manner that these nodes are multi-tasked and therefore shorten the distances (linkages) between them. Second, the careful matching of nodal (processes) to the ambient elements of the environment. Finally, the degree of balance (the ratio of source area to re-source area) within a given spatial context (boundary scale). The latter relies heavily on our understanding of a goal of developing a spatial performance (source to re-source) to life cycle activities. We refer to this spatial performance as the Life Cycle Ratio™. At this time there are over 12.5 million businesses in the U.S. with the only recordable linkage between them being the Input/Output model of the U.S. economy. Presently the use of the I/O tables merely expands (via regional businesses analysis) the one directional nature of an already one directional extractive economy. The recording of business practice according to its life cycle phase, linkage potential as well as the spatial positioning in a GIS format would enable the procedure of the use Life Cycle Space™ and the Life Cycle Ratio™ in planning with the potential balancing of our economy. The employment expansion implications of looking at both sides of the life cycle within a regional context could have considerable impact on the economy and on our overall environmental impact. This paper presentation will explore the implications of this thinking partially using our national I/O-GIS modeling procedures referred to as BaseLineGreen™ and GreenBalance™ and partially the growing disciplines of Industrial Ecology, ZERI, and other land integrated life cycle balanced systems as examples of a reduction in our life cycle space.

EVOLUTION TOWARDS LIFE CYCLE SPACE

Life cycle thinking has progressed steadily from Life Cycle Cost accounting (L.C.C.) to Life Cycle Analysis and Life Cycle Assessment (L.C.A.) to Life Cycle Balancing (L.C.B.) and finally with this paper the introduction of Life Cycle Space™ (L.C.S.) and the establishment of the Life Cycle Ratio™ (L.C.R.) Each development is dependant on the one previous with the emergence of the Life Cycle Ratio™ becoming a direct result of establishing the spatial footprint protocols of Life Cycle Space™. This paper will introduce the present topic by using this evolutionary sequence.

Implications of New Economic Classification Systems On Input-Output Based LCA Models

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Economic input output models have been used as an alternative approach to process based life cycle assessment models. Input-output models depend on input-output tables created by governmental economic agencies to track purchases between the economic sectors of a country. This form of economic modeling was originally created by Leontief in the 1930s.

The classification of sectors is necessarily arbitrary; any disaggregation from the national level down to the sectoral level is possible. In the United States, the classification system used for many years has been based on Standard Industry Classification (SIC). In the past decade, the US, Mexico, and Canada agreed upon a new North American Industry Classification System (NAICS) that was intended to streamline economic analyses across these three key trading partners. Internationally, a new NAICS-like classification system is proposed.

Input-output models also rely on supplemental industry-level estimates of resource use, environmental emissions, and energy use to estimate effects of production across the supply chain for a particular good or service. In the US, the primary data sources are the Environmental Protection Agency (EPA) and the Department of Energy (DOE). However these agencies continue to release data in SIC basis. To continue to use the latest economic input-output data, intermediate reclassifications are needed to accommodate this discrepancy. This additional reclassification can lead to misleading and more uncertain results.

A United States input-output model for this purpose is maintained by Carnegie Mellon's Green Design Institute, EIO-LCA, and is available at http://www.eiolca.net. The model traces the supply chain requirements, energy use, and environmental impacts of purchases from any of up to 480 economic sectors. The current model uses the 1997 benchmark (NAICS-based) of the US economy, as released by the US Department of Commerce Bureau of Economic Analysis.

We show the implications of maintaining multiple classification systems via several case studies of input-output based LCA using EIO-LCA. A goal in this talk is to increase awareness of the uncertainties related to LCA as well as motivating changes in the data collection and reporting practices at government agencies.

A Stochastic LCA framework for embodied greenhouse gas analysis: integrating process and I-O data within a Bayesian graphical model

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A stochastic, hybrid, CO_{2eq} LCA model is presented. Current hybrid I-O models present single figure mean values for embodied CO_{2eq} emissions for the analysed materials. Such mean values fail to convey any information regarding the form of the distribution of individual values around that mean. Understanding the variability of embodied CO_{2eq} in materials is important for assessing the extent to which emissions reductions can be achieved through economic mechanisms which drive preferential selection of low embodied CO_{2eq} materials through the supply chain – such as carbon taxes and emissions trading.

The model is developed using Bayesian methods. Construction of Bayesian statistical models requires integrating prior information with new data to form posterior probability distributions. In this context, prior distributions are generated from the stochastic I-O model and, after integration of process analysis data, a posterior distribution is generated. The form of the posterior distribution is determined through the process of Bayesian integration, with the posterior distribution deriving its primary form from the prior distribution, or the available data, according to their relative strengths. The rationale for employing the Bayesian approach in this context is to permit the integration of the more product-specific process analysis embodied CO_{2eq} data, into the more system boundary complete stochastic I-O model. Bayesian methods also support the progressive integration of new data into the model. This allows the model to 'learn' and for uncertainties to be reduced over time.

Constructing the Stochastic I-O model: The stochastic I-O LCA model is created from a disaggregated expansion of the UK National Environmental Accounts (UKNEA), data from the National Atmospheric Emissions Inventory (NAEI) and data from the Annual Business Inquiry (ABI). The stochastic input-output model is effectively a stochastic map of CO_{2eq} flows between sectors of the economy broken down to the Standard Industrial Classification (SIC) 3-digit level. The National Environmental Accounts differ from National Economic Accounts (standard I-O tables) in that sectors are defined by environmental similarity rather than economic similarity. This gives stricter adherence to input-output homogeneity assumption than is possible using the traditional economic sector based input-output tables. Disaggregation is done using Generalized Maximum Entropy (GME) reconstructions of transaction values between SIC 3-digit level sectors. This is performed using a beta release of the SAS 9.0 programming environment and follows Golan, A.; Judge, G.; et al. (1996). Within each of the 91 sectors of the UKNEA defined at the SIC 2-digit level there are some number of SIC 3-digit sub-sectors. The reconstructed transaction values at the 3-digit level then form a Dirichlet prior distribution for that 2-digit sector.

Stochastic process analysis data: Available process analysis data is then aggregated at the 2-digit level and multinomially distributed. This is then integrated with the Dirichlet prior using Bayesian methods implemented in the WinBUGS software.

The final model: The final model then takes the form of a stochastic graph (here 'graph' is used in the mathematical sense). This graph contains 91 nodes corresponding to the 91 SIC-2 digit sectors of the UKNEA. These nodes are linked by directed edges showing the flow between sectors. Within each node there is a posterior distribution generated by integrating the prior I-O distribution with available process analysis data. A data set of sampled values from each of these 91 posterior distributions is then exported from WinBUBS into the SAS Interactive Matrix Language (IML). In a Monte Carlo process, a single value is then drawn from each of these 91 data sets and the Leontif inverse of the stochastic I-O matrix is approximated using the Euler series method. This is repeated until the histogram of the final embodied CO_{2eq} distribution for the selected material is sufficiently dense.

LCA for Optimization of Electroplating SME's

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Processes and plants may be improved in terms of economic, technical and/or ecological factors. Usually, technical optimisation is worked out for single processes of a complex process chain, but possibly worsening the performance of the overall system. As a result, both financial and natural resources can be wasted. In order to avoid misjudgements, there is need for an integrated approach to be applied from the beginning of the optimisation process requiring an individual analysis and a tailored proposal for each plant.

The complex instrument Ecological Plant Optimisation (EPO) helps to assess ecological and economic impacts from the start-up to investment and realisation processes. As it is based on the principles of Life Cycle Assessment (LCA) and Cost Accounting it delivers important indicators concerning both ecology and economy. In that way the Ecological Plant Optimisation constitutes a helpful instrument to prepare strategic and integral decisions on a management level. This instrument is used for the decision making process in the galvanising industry in Germany. The main target was to find a optimised solution for the process chain for different electroplating process chains under market conditions. The decision making process with EPO started from the idea of optimisation up to realisation of new production line. The decision making process was a joint activity of the manufacturer, technical, economical and ecological consultants, plant engineering enterprises and recycling enterprises.

Currently in 18 case studies of different small or medium size enterprises have been accomplished. Overall more than 900 detailed models of electroplating processes and more than 250 life cycle models for the special life cycle segment of surfacing technology have been calculated. The methodology and the database is partially published by the German society for surface technology "Zentralverband Oberflächentechnik" (ZVO; www.dgo-online.de).

The Econo-Environmental Return (EER)

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Due to an increase in environmental consideration from many stakeholders, it is difficult for business managers to ignore the environmental consequences of the goods produced or services provided by their companies. Nevertheless, economic performance is still at the base of the economic system. How, in such a context, can one provide managers and decision-makers with useful data without overloading them with incomparable values? How to combine environmental impact, provided by a life cycle assessment study, with economic costs or benefits resulting from a life cycle cost study or through the use of accounting tools? How to choose among several goods or actions the one representing the best compromise between environmental impact and economic aspects?

Even if tools or concepts have already been published on this subject, these questions have not been fully answered. The reasons for this lie in the fact that the tools are too specific regarding a product or an impact category and that concepts based on assumptions may not always represent reality. Considering the selling price as a good indicator of the production cost is one of these assumptions. In a non-free market (when a single producer is able to influence the entire market), the selling price is affected by competition among producers and as such the information provided to the decision-maker may be wrong. In this circumstance, there is a need for a tool sufficiently flexible to be adapted to the available data of a study, but strong enough to clearly point out the best compromise between environmental impact and economic aspects.

The concept of the Econo-Environmental Return (EER) has been developed based on the idea of the ratio between benefits and costs (the present worth annuity) in the economic notion of the Return On the Investment (ROI). In contrast with the ROI, the assumption made in the EER is that economic aspects and environmental impact all occur at the same time. This return is to the ROI what the product of two ratios (benefits/cost and positive/negative environmental impact) is to the present worth annuity.

Knowing the EER of a product or a service may be useful. However, in contrast with the ROI, which has the interest rate as a comparison basis, there is no reference value for a single EER. This tool's real strength is its capacity for comparing similar goods. Knowing a product's negative environmental impact and total costs can be somewhat easy; on the other hand the two other values required in the EER can be more difficult to assess. In such cases, taking advantage of the EER concept is still possible by considering one of the products to compare as the reference and using the relative EER. This consists in attributing to the unknown environmental impact of each product the value of the known environmental impact of the reference (as for the economic aspect). Relative EER of the reference product therefore becomes null. All others having a positive relative EER value are better compromises between economic and environmental aspects than the reference product.

This notion of relative EER is applied in two different case studies. In the first one, the relative EER is used to select between two different types of carpet. In the second one, two different site remediation technologies are compared on both economic and environmental aspects.

LCC Application in the Polish Mining Industry

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Sustainability is developing into a target idea for increasing number of industries and governments and as a consequence the importance has shifted from production process to entire life cycle.

LCA is a tool that can help producers make better decisions pertaining to environmental protection. LCC includes all financially measurable items, such as energy recovery, reduced fines for pollution, lower operation and maintenance costs, etc. There are also some non-measurable benefits, for instance: improved company image and increased competitiveness, both on domestic and international markets.

The aim of LCC analysis is to create a cost effective model solution in respect to the predicted environmental impact of the particular project, for both those currently in operation and those in plans. Any comparison study of the influence of the environmental cost on projects should be based on long term cost-benefit analysis of environmental investment. Using the NPV method it is possible to compare these conditions, and this method can be treated as a tool that can help producers to make better decisions pertaining to environmental protection. The Life Cycle Net Present Value (LCNPV) is proposed to evaluate and select the best solution for new investment plans in existing mining projects, or for evaluation of the economic and ecological feasibility of new projects. Depending on the accuracy of the model, the LCC calculation can consist of the sum of costs for functional units or a sum of costs for every process. LCC can be used in any investment decision especially where initial high costs are balanced by future operation savings.

The LCNPV, method proposed in the paper, is a valuable tool in evaluating investment decisions and alternatives, both for functional units and processes. In LCNPV analysis, the most important factors are: proper definition of functional units, system boundaries, input and output analysis, and calculation of the range of costs (internal, including direct and indirect, and external). Mining producers can reasonably expect that implementation of LCA and LCC will lead not only to minimisation of environmental impact of their activities, but also to more effective environmental, cost and waste management. This means savings through reducing the amount of waste emissions, and reducing fees and fines in consequence. Thank to tools described in the paper decision making process will become more efficient, demonstrating the connection between the activity and devastation of the environment. A benefit that cannot be omitted is the improvement of the image of producers in the world market.

LCA as Input to LCC

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From a methodological aspect, LCC is well developed with respect to conventional costs. However, when it comes to costs related to environmental issues, neither the items, nor their estimation is well developed.

In the EU project DANTES, (Eco-Efficiency evaluation of new and existing products), an attempt is made to use LCA information to identify and estimate environmentally related costs and benefits in an LCC. Case studies will be performed at ABB and Akzo Nobel. The methodology presented here is being developed at Chalmers.

Some of the items of an LCC have to do with increased/decreased sales, others with goodwill. Both are difficult to estimate, but LCA or LCA-like investigations may be used for benchmarking and trend analysis.

Future costs to the product system may also be estimated, e.g. with a distance-to-target type of weighting, like in the DESC model.

LCA may be used to estimate risks, especially together with those LCA impact assessment methods that model damage. Such an item in the LCC can be dealt with as an insurance fee or in case the risk is too high, as a way to include necessary preventive actions.

In today's cost accounting it is often difficult to find environmental related costs. An LCA helps in identifying many of these costs.

LCA data may be difficult to make public and LCC data are even worse. Therefore a procedural methodology for the use of LCA as input to LCC is developed as a first step.

Comparison of Energy Turnover of Regional and Global Food

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Usually people assume regional production and consumption of food needs in all cases less energy than global processes. To verify or falsify this by empirical data and to improve the used method of Life Cycle Assessment a scientific evaluation of specific energy turnover of food production and distribution is carried out, comparing regional with European-continental and with global food processes. This study points at the question if the operation efficiency and the logistics are more important than the transport distances as such, regarding all the specific energy efforts of the whole process chain.
Performing this investigation two examples of food – fruit juices and lamb meat - comparing regional and global food chains were researched, allocating all energy efforts to the functional units, from the very beginning of primary production including all transports and distribution steps up to the point of sale in Germany. Countries of origin of the fruit juices were Brazil, England, Poland, Italy and Germany. The data were compared with information from different regional German producers, who harvest their crop, squeeze their juice and sell it locally. Lamb meat from New Zealand, which is shipped round the world to Germany, was compared with data of local German farmers, who produce lamb meat very close to their point of sale.

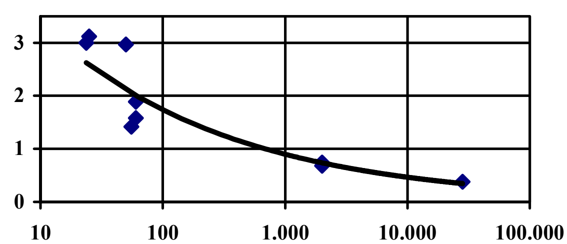

Fig. 1: Specific energy of juices [kWh/l] dependent on the yearly fruit throughput [t/a]

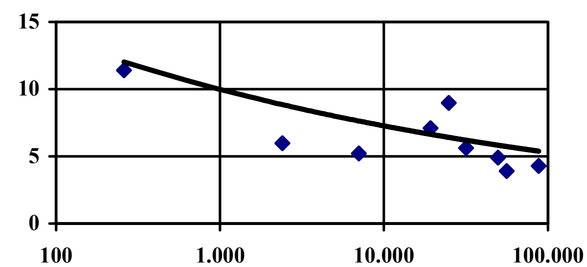

Fig. 2: Specific energy [kWh/kg] of lamb meat dependent on the yearly lamb throughput [t/a]

All empirical data demonstrate a strong logarithmic degression of the specific energy turnover in kWh per l juice (fig. 1) or kWh per kg lamb meat (fig. 2), dependent on the business size. Small farmers need basically more energy to producing and distributing their products than bigger business does. The influence of the business size is much more important than the transport distance.
Both examples demonstrate the influence of good manufacturing and marketing logistics on the ecological quality. Small farmers are usually not able to produce and market effectively, compared with larger units, despite of the global transports. This principle seems to be comparable with economic functions as well. High quality juices, which are concentrated in Brazil and diluted in Germany, need less total energy input than regional German juices. The production and distribution of German lamb is less efficient than the New Zealand process, since of the climatic differences and the very bad logistics of the local German marketing. Regarding these scientific results, which are methodical and empirical evaluated, it is evident, that not the transport distance of food as such is decisive on terms of energy. The sophisticated logistics of producing and marketing are much more important. Further investigations are running upon frozen vegetables and upon wines, comparing regional and global process chains.

Reduction of Environmental Impacts by Development of Industrial Symbiosis in Japan
Case Studies for Application of Co-production Technologies in Steel Industries and its Reduction Potential of Greenhouse Gas Emissions

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Japanese industries are required to reduce greenhouse gas emissions for the achievement of COP 3 goal. Although many energy conservation technologies have been widely adopted, the adoption of such technologies seems to be a limited stage. Recently, some researchers have proposed a new energy conservation technology concept of “Co-production”. This technology involves the incorporation of a new industrial process into an existing industry. It maximizes the use of energy in an industry, while producing substances required in other industries by using cheap industrial by-products as raw materials. Thus, Co-production enables energy generated by one industry to be supplied to another industry through conversion into a substance that stores the chemical energy. Therefore, use of co-production technologies will achieve industrial symbioses and improve overall energy efficiency and reduce environmental impacts for the industrial complex. Research is under way in Japan on the development of leading and pioneering technologies for use in co-production systems.

In this study, we examined the introduction of co-production systems at steel industries; a low-temperature gasification plant and a CO2 recovery and utilization system for effective utilization of waste heat and resources in steel works. Constructed was a model whereby exhaust heat was recovered and the industries simultaneously produced the main steel product and other by-products (methanol, steam, electric power, dry ice etc.) for supply to other industries and transport sectors. Reduction potential of greenhouse gases were calculated for each steel works in Japan, based on a life-cycle assessment (LCA), considering production capacity, waste heat distribution, location and avoided impacts in conventional systems.

It was estimated that he CO2 emissions per unit product were significantly smaller than those from conventional technologies. The total reduction of CO2 emissions made possible by the co-production technologies was about 6 million-tons.

Life Cycle Metrics for Comparing Alternative Electricity Generating Technologies

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The use of energy and the production of electricity are known to contribute significantly to global sustainability challenges such as non-renewable resource depletion, greenhouse gas production, and acidification. Renewable energy sources are being promoted to address these issues. LCA offers a useful framework for evaluating the full costs and benefits of alternative renewable technologies. Key life cycle metrics supporting differentiation of electricity generating technologies include: energy ratio (net energy ratio and external energy ratio); net emissions of greenhouse gases; net acidification potential of emissions; total life cycle cost (private and social); and total land area requirements. These metrics, derived from life cycle inventory results, help clarify the societal tradeoffs associated with competing energy technology options.

In this paper we consider several "cradle to grid" LCI studies of renewable and nonrenewable electricity generating technologies relative to the proposed life cycle metrics. Technologies considered include: coal fired boilers; natural gas boilers and turbines; willow biomass gasification, direct fire, and co-firing with coal; and building integrated photovoltaics. The results of this investigation support enhanced understanding of the potential role of renewable technologies in a sustainable energy portfolio.

Official Danish Center for Life Cycle Assessments and Life Cycle Approach

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Denmark is the first country in Europe with an official center for Life Cycle Assessments and the life cycle approach. The Danish EPA supports the start up of this important initiative, the aim of which is to:
1. promote the use of Life Cycle Assessment and other environmental tools in companies,
2. support companies and other in using environmental assessment of products and services,
3. ensure that the effort in the LCA area is based on a solid and scientific basis, and
4. maintain the well-established co-operation between all important actors in the LCA field in Denmark.

Three partners within the LCA area in Denmark manage the center - IPU, COWI and dk-TEKNIK ENERGY & ENVIRONMENT. Together they cover the main areas of LCA, combining experience and knowledge of scientists from universities, authorized research and technological institutes and private consulting companies.

The scope of the center will in many aspects be international. LCA Center Denmark will fulfill its goals by undertaking different activities directed at companies and organizations. Communication about LCA and the life cycle approach is one of the most important activities within the center. This includes for example training courses, newsletters, homepage, and an answering service for LCA-related questions. Other issues within communication are distribution of a software tool and LCA data. Furthermore, the partners of the center will play a natural role in Danish and international LCA method development.

The presentation will introduce the center and the many activities and initiatives the center will support, and how it promotes the use of LCA in companies.

The National Waste Plan for Scotland – LCA and BPEO in Practice

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The National Waste Strategy: Scotland, published in 1999, laid out the framework for the development of Area Waste Plans and the National Waste Plan for Scotland. The plan is designed to produce a step change in waste management practices in Scotland which currently rely very heavily on landfill, with over 90% of waste disposed of in this way, and to set out how Scotland will move from a waste management culture to a resource management culture. Central to the development of the plans is the use of a best practical environmental option (BPEO) decision making process which puts, for the first time in Scotland, life cycle assessment (LCA) in a pivotal position in assessing the environmental impacts of the waste management options considered. The BPEO was designed to take into account a complex range of factors and provide a structure to enable an open and transparent decision to be made. Apart from environmental impacts it also takes into account social issues, economics, practicality and the fit with other policies. The decision criteria were adopted from the basic premise that sustainable waste management could only be achieved with the full participation of all stakeholders – waste producers (including the general public and commerce), the waste industry, regulators, planners and interest groups. Using the life cycle assessment for waste management software WISARD, up six options for each of the 11 waste strategy areas were modelled. The outputs from the model were then used to inform the final BPEO decision. A final model of the National Waste Plan compared to the current situation for Scotland, which was developed by integrating the 11 Area Waste Plans, was also produced. The LCA outputs demonstrated considerable environmental benefits from all options assessed when compared to the current situation. Two case studies will be presented, the Lothian and Borders options assessment and the National Plan which will demonstrate the significant benefits that will be achieved if the Plans are successfully implemented. The paper looks at the successes, problems, challenges and failures of the approach, and discusses how the lessons learnt will be addressed for the future as well as SEPA's future plans for developing the use of LCA for both policy and regulatory development.

Life Cycle Assessment for Brownfield Management Decision-Making

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Decision-oriented environmental evaluation of urban contaminated sites (brownfields) has mostly been limited to identifying and quantifying hazard and risk, and interventions have been focused on compliance and/or risk management. This approach was proven necessary to ensure human and ecological health on the local scale (primary impacts). However, impacts associated with the actual implementation of brownfield management strategies (secondary impacts), such as resource consumption and pollutant emissions, are rarely considered in decision-making, even though methods and data for their evaluation are available. Also, impacts related to changes in land occupation and urban planning (tertiary impacts), such as reduction of urban sprawl pressure, are usually presumed without verification. Since trade-offs between these three types of impacts characterize the selection of brownfield management options, a need for integrating them has been identified. A quantitative LCA was used for this purpose. This evaluation focuses on reliability and validity aspects of integrating disparate environmental impacts by LCA methods, and this for different applications.

A case study is used, for which distinct LCA models were developed for three environmental decision-making contexts: (1) formulation of implementation strategies in 'dig & haul' remediation projects; (2) choice between brownfield management options for a specific site; and (3) public policy development concerning environmentally sustainable brownfield management. Application dependence of modelling choices, data quality goals, system boundaries, and their impact on overall confidence in results, are considered. The three aforementioned scenarios are evaluated using different types of inventory and environmental data but processed using the same evaluation framework. For primary impacts, high quality site-specific data originating from the physico-chemical characterization is used to consider contaminant flows in the inventory and then develop low-uncertainty site-specific characterization factors for spatially differentiated LCIA methods. Secondary impacts are evaluated using usual LCA data sources for all remediation activities as well as for long-term landfilled contaminant fate. LCI data for tertiary impacts rely on scenario development using urban development data and transport models. The product system, stakeholder involvement procedure, LCA methodology and confidence assessment approach are presented.

Examining the Effects of Waste Prevention, Material Substitution, Recycled Content, and Recyclability on the Environmental Profiles of Packaging for Mail-Order Non-Breakable Goods: A State Government's Application of Life Cycle Inventory Analysis

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Solid waste policy in Oregon is based on a hierarchy of preferred options: prevent, reuse, recycle, compost, recover energy, and landfill. Historically, most waste reduction efforts sponsored by the public sector have focused on recycling and composting, and have overlooked prevention and reuse. The Oregon Department of Environmental Quality (DEQ) has recently begun to address this imbalance by introducing a number of new initiatives intended to reduce waste at the source. One of these initiatives addresses packaging materials, which comprise approximately 20% of all materials disposed of in garbage in Oregon. In 2002, the Oregon DEQ began a project to work with businesses on voluntary, non-regulatory strategies to reduce packaging waste.

Several of the businesses participating in DEQ's packaging project are catalog/Internet retailers and ship millions of packages to customers each year. Options for packaging non-breakable goods include:

- Corrugated box with or without void fill. Void fill options include expanded polystyrene or bio-based (vegetable starch) loosefill, polyethylene "air pillows", sheets of kraft paper or newsprint, and shredded waste paper.
- Padded and unpadded polyethylene shipping bag.
- Padded and unpadded kraft paper shipping bag.
- Padded and unpadded multi-material shipping bags (paper/plastic combinations).

To better understand the relative environmental burdens of these options, DEQ has commissioned Franklin Associates Ltd. to conduct a cradle-to-grave life cycle inventory analysis of these packaging materials. The purpose of the study is not to set policy but rather to inform packaging users of the relative environmental profiles of different packaging options. Awareness of life-cycle environmental burdens among the general population of packaging users appears to be simplistic and focused on down-stream impacts, e.g. "recyclable packaging is good; non-recyclable packaging is bad." The study analyzes recyclability, recycled content and waste prevention through material substitution for various packaging options, as well as the relative significance of transportation energy in the product life cycle. The study is co-funded by Metro, the regional solid waste authority of the Portland area, and the U.S. EPA is providing support for the critical review.

This presentation will address the policy basis for DEQ's interest in waste prevention and life cycle analysis, the methodology, challenges, and key findings of the study, and how DEQ and partnering businesses may use the study results.

Whole Life Considerations in IT Procurement

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The City of Seattle has long been considered a leader in environmentally sustainable purchasing practices. In recent years, the City has made efforts to extend that culture of whole life responsibility to the purchase of its Information Technology (IT) equipment.
To illustrate that commitment we present case studies of three recent purchasing decisions and examples of our ongoing relationship with the City's main computer workstation vendor.

In the first procurement example, the committee responsible for standardizing on a laptop platform used a list of environmental questions as a part of the vendor evaluations. They asked questions about toxic materials used in manufacturing and contained in the products themselves. They also asked about end of life recycling options and packaging. A list of the questions used is available. Vendors were informed that the environmental considerations would be given equal weight with the features and cost of their products. This provided vendors and the City with a new paradigm in IT purchasing. It gave the City and its vendors an opportunity to consider the whole life of their products and how they affected the planet and those who live on it.

Another IT procurement project is just coming to a close. It is an attempt to standardize on a single vendor for our handheld computer (PDA or personal digital assistants) needs. Again, the City submitted a similar list of environmental consideration questions to the different vendors and emphasized that they would be given equal weight with the other considerations used to select a standard. We learned once again that this is sometimes difficult information for sales representatives to gather. However, with persistence we were able to get a good sampling of relatively complete answers.

The third procurement exercise was a study in which we compared CRT (Cathode Ray Tube) monitors to LCD (Liquid Crystal Display) monitors. We ran tests to compare the relative HVAC (Heating Ventilating Air Conditioning) and electricity use impacts. Then we looked at the overall costs and the environmental impacts. Due to our mild climate and relatively low cost of electricity, the HVAC and electrical use impacts didn't make enough of a difference to justify the increased cost. However, the environmental impacts of CRTs vs. LCDs lead to the decision go to LCDs as the new standard.

Finally, in our relationship with Gateway, Inc. (the vendor we standardized on for all of our desktops and laptops), we have made great strides in raising their level of environmental stewardship. Because they value our business and the good PR that environmental responsibility brings them, they have worked with us extensively to make their products more easily recyclable and to address other environmental issues.

The City of Seattle is proud of the important progress we have made in this regard and hope to share our lessons learned with as many private and public sector procurement professionals as possible.

Integration of life cycle management in purchasing – a promising key to combining efficiency, economic and environmental improvements

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Suppliers have a direct impact on the performance of most aspects in a company: A good supplier performance with respect to timely delivery in the agreed quality at a low price is a key element in all business concepts. With an increased environmental awareness of public and private consumers, environmental aspects of the whole value chain must be included in order to ensure the market position or build up a brand with a good environmental reputation.

Many companies, however, find it difficult to integrate environmental, social and ethical aspects in purchasing. The experiences at Berendsen – one of the leading European textile service companies – were investigated in an industrial research project performed in cooperation between Berendsen, dk-TEKNIK ENERGY & ENVIRONMENT, Technical University of Denmark and Roskilde University. Traditionally, Berendsen evaluated their suppliers by a questionnaire sent to all suppliers of importance. The initial research phase showed that collection and handling of the information from suppliers caused some practical problems and, accordingly, also frustration:

- Very time consuming paper work
- Large costs for sending out questionnaires and administration
- Difficulties in integration of environmental, social and ethical aspects with typical business values at Berendsen
- Ambiguous results
- Suppliers did not receive feedback – hence they are not motivated

The conclusion within Berendsen was that there was a need to make a holistic evaluation of suppliers to ensure that all aspects were evaluated. A second conclusion was that there was a need for a tool that can handle questionnaires with individual weighting of questions and categories.

Berendsen decided to include the following aspects in the holistic approach and thus defined a set of questions and criteria for different supplier types e.g. textile suppliers, chemical suppliers and suppliers of transportation services.

- Financial situation
- Management and business ethics
- Logistics
- Products, product quality and environment
- Service and support
- Price

As there were no tools on the market that could fulfil the needs, a concept for such a tool was developed within the frames of the industrial research project. Recently dk-TEKNIK ENERGY & ENVIRONMENT invested in the project and realised the concept as an Internet based tool called supplier-e-valuation.
The presentation will include experiences and examples from Berendsen and present how Berendsen have started implementing the new tool.

LCA's role in Public Purchasing Policy
– the Danish Experience with Product Specific Guidelines

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Green public purchasing has since 1991 been an official strategy of the Danish environmental authorities. It is now one of the cornerstones of the Danish product-oriented environmental policy as well as a key element in the European Union equivalent, the so-called Integrated Product Policy (IPP). Governance

Early experiences in the '90ies made clear that procurement personal needed guidance to be able to request greener products. The guidance had to be:

- looking the products in a life cycle perspective
- product specific
- easily understood
- updated, which calls for a flexible tool
- efficiently distributed
- covering both environment as well as working environment to avoid problem shifting

These specifications were taken into consideration when building a new information tools for public purchasers: the product specific guidelines. From 1996 to 2001, the Danish EPA had more than 50 product categories analysed and made guidelines with communication tools based on qualitative LCA and stakeholder involvement. These guidelines were distributed to thousands of purchasers.

This paper analyses the making of guidelines, the concept of LCA used, and evaluates the results of the guidelines.

Keywords: green public purchasing, matrix LCA, life cycle thinking, public policy, IPP, organizational innovation, life cycle management.

Integrating LCIA and LCM: Evaluating environmental performances for supply chain management

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Manufacturing industries in the global marketplace are increasingly pressurised to incorporate economic, environmental and social performances in their policies, culture and decision-making processes. These performances objectives manifest in three operational focal points that are fundamental to the manufacturing industry: projects that drive internal operational changes, assets that are required in the manufacturing process, and products that determine the economic value of manufacturing operations. A holistic Life Cycle Management (LCM) approach would subsequently require an effective integration of these three life cycles within the manufacturing organisation. Sustainable product LCM, or product stewardship, implies the incorporation of the principles of supply chain management. The manufacturer of a product assumes responsibility for the economic, environmental and societal consequences of supplied components, materials and energy inputs. Automotive Original Equipment Manufacturers (OEMs) in South Africa have initiated the process to assess the environmental performances of their first-tier suppliers. However, the lack of process information to determine the precise environmental impacts of suppliers is a common problem in South Africa (as in other developing countries). OEMs have subsequently commenced to systematically obtain process information limited to: water usage, energy usage, and waste produced per manufactured item. These three process parameters do not, however, directly show the overall burden of a supplier on the environmental resources of South Africa. An Environmental Performance Resource Impact Indicator (EPRII), which is based on the LCIA framework of the UNEP/SETAC Life Cycle Initiative, has subsequently been introduced for environmental supply chain management purposes. The EPRII methodology calculates impact indicator values of the process parameters on four natural resource groups that have been separately addressed by the national government and the manufacturing sector: water, air, land and mined abiotic resources. The EPRII enables a company to evaluate and compare the environmental performances of suppliers, and to identify improvement possibilities.

Creating Value Through Strategic Supply Chain Partnerships and Life Cycle Management

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A well-conceived strategic partnership approach provides a powerful platform for achieving meaningful business impact, in part by engaging key decision-makers "outside" EHS/Sustainability (e.g., Sales & Marketing, Product Development, etc.) in important environmental initiatives. It can also address many of these obstacles and create significant value for suppliers/customers

There is growing interest in the opportunity to significantly increase the business impact of environmental and social initiatives by focusing on key customer/supplier relationships to improve the life-cycle impacts of company activity, products and services. This is being driven, in part, by powerful market trends that increase the attractiveness of a proactive approach to supply chain issues and opportunities.

While most companies report that they still employ an ad hoc, reactive approach to supply chain partnerships, a few leaders are showing the way forward with more strategic approaches. A number of critical skill gaps and organizational barriers need to be overcome in order for more companies to take full advantage of strategic supply chain opportunities.

This presentation will
- give an overview of major corporate perspectives on key supply-chain trends and untapped opportunities
- identify some key implications
- propose a potential approach to capturing the opportunity

Comparable Reference Flows for Lightweight Materials in Transportation Systems

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ISO 14040 defines the *functional unit* as a measure of the performance of the functional outputs of a product system. The purpose of the functional unit is to provide a reference to which the inventory data are related to ensure alternatives are compared on a common basis. For each product system or alternative being assessed, the amount of product necessary per functional unit is known as the *reference flow*. Definition of the reference flow must include the type and quantity of materials and energy linked to the functional unit and the number of times materials must be replaced during the analysis lifetime.

Because reference material and energy flows dictate up and downstream process alternatives, definition of the functional unit and reference flows are critical steps in LCA. In fact, in an ideal case, alternatives investigated in a study should provide the same service during their lifetime. In reality, definition of the functional unit and reference flows can be difficult due to issues related to lifetime (subject to customer habits and non-systematic variations), performance (subject to customer habits, the introduction of alternatives, and multifunctionality), and system dependencies (changes in the system design that result from changes in component design).

In this presentation, requirements for defining functional units and reference flows for comparative analyses in LCA are suggested and demonstrated. Requirements are grounded in a differentiation between the system and sub-system functions, functional units, and reference flows. Also, the requirements highlight the need to include data quality and uncertainty information and analysis of multifunctionalities needed in the interpretation phase of LCA.

A case study is presented that illustrates the use of the requirements in aircraft lightweight material selection. The subsystem of interest is a plate within the structure of an aircraft. Four materials are evaluated: a wrought aluminum alloy (the baseline), a cast aluminum alloy, an epoxy laminate carbon prepreg composite, and a titanium/silicon carbide composite. In addition to the lightweight materials used in the plates, use of the requirements led to the identification of interface materials (finishes and fastening materials) and wing and propulsion system enhancements that needed to be included in the reference flows to ensure comparability of alternatives. These additions were found to influence aircraft fuel use, the identity of up and downstream processes considered in the LCA, and related impacts.

Are Natural Fiber Composites Environmentally Superior to Glass Fiber Reinforced Composites?

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Natural fibers are emerging as low cost, lightweight and apparently environmentally superior alternatives to glass fibers in composites. We review select comparative life cycle analysis studies of natural fiber and glass fiber composites, and identify key drivers of their relative environmental performance. Natural fiber composites are likely to be environmentally superior to glass fiber composites in most cases for the following reasons: (1) natural fiber production has lower environmental impacts compared to glass fiber production; (2) natural fiber composites have higher fiber content for equivalent performance, reducing more polluting base polymer content; (3) the light- weight natural fiber composites improve fuel efficiency and reduce emissions in the use phase of the component, especially in auto applications; and (4) end of life incineration of natural fibers results in recovered energy and carbon credits.

Life Cycle Assessment: Case Study of Steel in Brazilian Automobiles

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The objective of this study is to identify the main pollutant emissions due to the utilization of steel in Brazilian automobiles. Therefore it was performed Life Cycle Assessment (LCA). LCA takes into account all the life cycle of a product, that is, from its extraction till its disposition.

In order to perform this evaluation, the life cycle of the automobile was limited into three phases: materials manufacturing, automobile usage and discard. It was considered an automobile of 1.300 kg. Steel was chosen due to its high proportion in an automobile in weight terms. Besides, Brazilian automobile industry consumed 1.999 thousands of tons in 2001, which accounted for 12,7% of the steel national production. Steel represents 878 kg of an automobile, considering that it is 67,5% of the automobiles weight. Nevertheless, the functional unit was 263 kg, which represents 30% of the steel, due to the possibility of exchanging it for another material.

Collected data of resources (iron ore, clay, scrap and water) and energy consumption (mineral coal, vegetable coal, electricity, gasoline, alcohol) , air pollutants (NH_3, CO_2, CO, NO_x, HC, SO_x, MnO, SiO_2, P_2O_5, HCN, HCl, Pb and particulate matter) and solid residues production were from year 2000. Whenever possible, lack of data was fulfilled with estimations and the data was stored in worksheets. Sensibility analysis was performed for each life cycle stage.

Main results showed that the automobile utilization and the materials manufacturing were responsible for most of the energy and resources consumption. The solid residues production occurs mainly in the discard, due to the low recycling level in the country. Sensibility analysis showed that the most important phase of the life cycle was the automobile usage, except for CO, SO_x, particulate matter and solid residues production.

Co-Product Function Expansion: A Methodology for Incrementally Considering the Effects of Co-Products in Multi-Product Systems

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An important component of Life Cycle Assessment (LCA) is the methodology by which energy and emissions in multi-product production systems, such as petroleum refining, are attributed to the production of the different products.

One approach is to allocate energy and emissions from the production and upstream stages among all products, co-products and by-products on the basis of mass, energy content, or economic value. In an LCA using such a method for a product such as gasoline, only a share of emissions from the crude oil extraction and petroleum refining stages is allocated to gasoline, and only the downstream effects attributable directly to gasoline are included. Co-products are placed entirely outside the system boundary. This is known as an *allocation* approach.

Another approach is to fully expand the system boundary, including all primary products, co-products, and by-products within the overall product system. All system downstream functions are included, and multiple functional units are defined. To compare alternative production systems and products, each system must be made equivalent by adding functions, from outside of the direct product system, if necessary. This is known as a *system boundary expansion* (SBE.)

This paper proposes an alternative methodology called Co-Product Function Expansion (CFE). CFE is an incremental approach in which selected co-products and a selected set of co-product functions are placed within the product system boundary, and the energy and emissions for upstream stages and co-product production are accounted for in the LCA. The downstream functions of the co-products are compared with alternative products serving the same functions, and the net energy and emissions, as either debits or credits, are assigned to the primary system products.

The objective of the CFE methodology is to allow the effects of individual co-products to be assessed without having to apply a full SBE. The methodology is particularly relevant for co-products that have a potentially significant impact on energy and emissions in production or downstream stages, and would not otherwise be accounted for by an allocation approach.

The scope of a CFE is defined with respect to market information and to a specific set of co-product functions. In some cases, only certain co-products are included, with the remainder allocated outside the system boundary, This occurs when market data indicate that no technically or economically feasible product alternatives exist for certain co-product functions.

Comparative Life Cycle Assessment of Three Insulation Materials

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Insulation of buildings in order to save heating energy is an important technology for promoting sustainable development. This paper summarises the results of a comparative LCA study of stone wool (HT Rockwool), flax and paper wool (shredded paper cellulose) applied for insulation of attics.

The three materials are very different with respect to their life cycles. Stone wool is a traditional industrial product based mainly on abundant inorganic raw materials; flax is an agricultural product being reinvented for new industrial purposes, and paper wool is based on recycled raw material, i.e. old newsprint. The study shows how to address the methodological problems associated with the different origin of the materials. System expansion is used where possible, e.g. by examining the combined paper cycles of newspapers, old newsprint and shredded paper cellulose. In the case of flax insulation, the agricultural system is expanded to include oil seeds and shives (for cattle fodder). Furthermore, a comparison is made between the environmental interventions when using system expansion and conventional economic allocation. Stone wool is examined by using information from one production site and comparing the results to earlier LCA's.

The study addresses a selection of global and regional environmental impacts for which the database and the impact assessment methods are believed to be satisfactory, e.g. global warming, acidification, nutrient enrichment and photochemical ozone formation, complemented with inventory information regarding consumption of different energy sources.

Of the three products investigated, paper wool has in general the lowest global and regional environmental impacts and flax insulation the highest, with stone wool falling in between. A somewhat surprising exception from this is that the total primary energy consumption is lower for stone wool than for flax and paper wool. The findings are considered as robust given the available database, but especially for flax insulation there may be large variations in the impacts, due to differences in yield as well as product design. The presentation will give a thorough overview of the critical elements in the comparison.

The study also addresses occupational health, using an approach similar to that used for risk assessment. Here, the modern less biopersistent stone wool products are seen as the safest alternatives, because of a low potential for exposure, sufficient animal testing and the absence of carcinogenic properties.

However, the differences between the investigated products are of minor environmental significance when keeping in mind that insulation of buildings saves up to 100 times the environmental impacts associated with the production of insulation materials. The main conclusion is that the quality and fitness for use of an insulation product throughout its useful life span is the most important aspect in the life cycle of insulation materials.

Incorporating Lifecycle Thinking in Green Building Design

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Green buildings, also known as sustainable buildings, include design features which may increase capital costs but reduce operating costs and environmental costs in the long term. Building project clients, who in most cases are strongly focused on limiting first costs, tend to need education about the use of lifecycle thinking for financial and environmental costs. Providing this education, often under the pressure of design meetings for specific projects, becomes a responsibility of engineers and cost consultants.

Based on experience with buildings designed and constructed in North America, the proposed presentation will describe methods which have proven successfully persuasive for integrating lifecycle thinking in actual building designs. Examples of green design processes involving lifecycle thinking include building energy modeling at an early project stage, choice of air delivery system, design of high-performance building façades, and decisions whether to rebuild or replace building components in major renovations.

The presenters, representing an engineering firm and a cost consultant, have seen repeatedly how the implementation of low-energy building designs depends not only on doing the design well, but also on communicating to decision-makers the long-term vision revealed by lifecycle thinking. The connection with sustainability will be explored and key factors in green building lifecycle thinking will be explained. The future possibilities and directions for better green building design decisions, using lifecycle thinking informed by increased performance data, will be projected.

Life Cycle Assessment of Borate Treated Structural Systems

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Rio Tinto Borax has undertaken an initiative to integrate Sustainable Development into its business practices. At the outset of this effort, an internal team at the company established several objectives to help guide the project. These include employee safety, contribution to community needs, optimization of borate deposits, and sustainable development assessment of borate products and their applications.

With regard to products and applications, Borax has completed cradle-to-gate Life Cycle Assessment of its products consistent with ISO 14040 series LCA standards[1]. Further, among the first LCA of borate applications, Borax has completed cradle-to-gate Life Cycle Assessments of Tim-bor® pressure treated lumber and zinc borate treated oriented strand board (OSB) structural sheathing consistent with ISO 14040 series LCA standards.[10] An important goal for the LCA work on borate treated lumber and OSB is to place the resulting data into authoritative databases such as BEES and ATHENA™ so that architects, engineers, and builders can better characterize the sustainability of using borate treated structural materials in their building projects. A third party critical review was not carried out for this study, given the goal definition and the requirements of ISO 14040. However, Athena Sustainable Materials Institute was engaged throughout the study to review goal and scope definition and data as it was collected and modeled. Additionally, both Five Winds International (Borax's LCA contractor) and Borax employees internally reviewed the data.

The study includes the extraction of materials from earth (mining), processing and treatment (production) and packaging. It also includes the manufacture and transportation of raw and processing materials to Borax's sites, and onsite co-generated and purchased electricity. The extraction, refinement and delivery of purchased primary fuels are also included within the boundaries of the study. Additionally, it includes forestry/wood production and the manufacturing processes and raw materials to produce OSB and treated lumber. It also includes the transportation of both Borax products and borate treated lumber and OSB. Infrastructure, such as capital equipment, and overhead are excluded. This is common practice in LCA studies as they have shown minimal overall impact in the context of a product system life cycle. Overall, the study supports the business development efforts currently underway for Borate Treated Structural Systems that are currently available in the marketplace. This paper will provide the methodology utilized, resulting data sets as well as some analysis.

10 ISO 14040 (1997). Environmental management – Life cycle assessment - principals and framework. International Organization for Standardization, Geneva.

ISO 14041 (1998). Environmental management – Life cycle assessment – Goal and scope definition and inventory analysis. International Organization for Standardization, Geneva.

ISO 14042 (1998). Environmental management – Life cycle assessment – Life cycle impact assessment. International Organization for Standardization, Geneva.

Glass fiber LCA and Environmental and health data sheet

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For about 10 years Saint-Gobain Isover is making life cycle analysis of its glass fibre and rock wool insulation products. Nowadays, these are completed by environmental and health datasheet to fulfil more and more customers' requests.

Saint-Gobain Isover is updating and improving its LCA in collaboration with Ecobilan SA (member of PriceWaterhouseCooper) and their software TEAM. This, to be able to fill in accurately environmental and health datasheets as defined by the French standard AFNOR XP01-010 and the French association of building materials producers – AIMCC.

These datasheets contain information on :

- the caracterization of the products,
- the inventory data and other data such as consumption of natural resources,
- emission to the environment
- production of waste
- the contribution of the products to environmental impacts and to health and quality of life within the building and
- other contributions with respect to eco management concerns.

These datasheets are more and more widely used and therefore requested by architects and other building's stakeholders in order to be able to chose among several materials those which have the lowest impact on environment and health taking into account the whole life cycle "from cradle to grave".

The methodology used to do these LCA and the use and content of these environmental and health datasheets will be explained as well as the means necessary to generate them.

How to Use the US LCI Database

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A project is underway in the US which is developing a publicly available life cycle inventory database to track the pollution and resource consumption consequences of commonly used materials, products, and processes within the US and North America. The project receives funding from various US government agencies and the private sector. The project has developed a web-based system for making the resulting peer-reviewed LCI data and accompanying documentation transparent and available to the widest possible user base.

This presentation is intended to inform LCA practitioners how to make use of the data, how to contribute to the database. The presentation will begin with a brief status update on the project. It will then describe the outcome of a process that lead to selection and implementation of an internationally compatible data documentation and formatting system. This documentation format allows exchange of data from the US LCI database with other international LCI databases such as the EcoInvent 2000 project in Switzerland; it also allows download of files that are ready for import into a wide set of popular LCA software tools. Finally, a streamlined format was created specifically for the North American LCA market, to enable LCA practitioners a simple, straightforward way to make data available for publication and dissemination via the US LCI database website.

The U.S. LCI Database – Moving Toward Full LCI Data by Material and Product

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The U.S. LCI database project fills a critical need to make LCI data available for use by the public. The critical aspects of this database presented in another paper at this conference are:

A common protocol for all data inputs

Unit process data presented in a transparent way and fully documented as to source, age, primary or secondary sources, etc.

A format based on EcoSpold that makes the data consistent with international LCA/LCI databases

In the first years of this project the objective is to populate the LCI database with as much unit process data as can be submitted based on funding. The initial data priority of the Athena International team is a fuels and energy database plus basic materials manufacture - steel, wood, plastics, aluminum, etc.

At this stage the U.S. LCI database while publicly available will be usable principally for LCI/LCA practitioners or others knowledgeable enough to build complete process trees without specific guidance within the database users manual.

The purpose of this paper is to present an overview of how the U.S. LCI database can become more accessible and usable to non LCI/LCA practitioners by developing full process trees within the database itself.

The paper will present a vision of the ultimate goals that might be reached to make the U.S. LCI database usable to almost anyone namely cradle to grave process trees for all activities including products, their use, and end of life disposition.

Currently there is privately funded work underway that will result in both unit process data and process trees for about seventeen plastic resins e.g., HDPE, PET, LDPE, etc. What this privately funded work will do is to create an input to the U.S. LCI database that meets the requirement for unit process data, but that also creates the complete cradle to resin process tree for each resin in a detailed and "rolled up" format.

Finally, the paper will discuss the goal of adding product use and end of life considerations. Ultimately this should be the goal so that companies, organizations, practitioners, and others can build alternative scenarios for product design and sustainability considerations.

German Network on Life Cycle Inventory Data – Setup of a Data Collection

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Reliability of LCA results crucially depends on the availability and quality of LCI data. In order to provide high-quality LCI data for background systems in LCA but also for a larger variety of possible application fields harmonization strategies for already existing data sets and data bases are required.

In view of the high significance of life cycle inventory data as a basis of major fields of action within a sustainability strategy, the German Helmholtz Association under the leadership of the Forschungszentrum Karlsruhe (FZK) has taken up this issue in its research program. In 2002, the FZK conducted a preliminary study on "Quality Assurance and User-oriented Supply of a Life Cycle Inventory Data" funded by the Federal Ministry of Education and Research (BMBF). Within the framework of this study, a long-term conception for improving the scientific fundamentals and practical use of life cycle inventory data was developed together with external experts. The focus is on establishing a permanent German **"Network on Life Cycle Inventory Data"**. This network shall integrate expertise on life cycle assessment in Germany, it shall harmonize methodology and data, and it shall use the comprehensive expert panel as an efficient basis of further scientific development and practical use of LCA. At the same time, this network shall serve as a platform for cooperation on an international level.

Current developments address methodological definitions for the initial LCI data base. This prototype will serve as starting point to collect and integrate available data. As a novel element user needs are differentiated in parallel according to the broad application fields of LCI-data from product declaration to process design. The results will be used to define tailored interfaces for the data base.

The presentation will focus on progress in this initiative.

The LCA Data Library -A result of National LCA Project in Japan

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The LCA National Project in Japan funded by the Ministry of Economy, Trade and Industry (METI) since 1998 has been completed at the end of March 2003, in which (1) LCA methodologies, especially the LCIA method and the practical LCI method for recycling, (2) LCA database for Japan and (3) a network system to show the results of (1)&(2) have been developed.

The project has been conducted by the Steering Committee, under which three committees conducted the specific researches: the Inventory Study Committee, the Impact Assessment Study Committee and the Database Study Committee.

In the Inventory Study Committee, the LCI data for approximately 200 products were collected based on the sub-system, i.e. from Gate to Gate, by 22 industrial associations joined to the project officially, and by around 30 industrial associations contributed to the project unofficially. The inventory data such as resource exploitation and oversea transportation were prepared by the survey of the literatures. These LCI data were deployed into the system together with the LCIA characterization and weighting factors, which was developed to be operated easily at the website by users.

This system will be called as the LCA data library in Japan. We are now discussing the operation rules of the system. It will be opened soon to the public with some restrictions for users.

Implementation of Life Cycle Assessment (LCA) in Development of Products

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Today's industry is being forced to consider the environmental performance of its products concurrently with traditional requirements such as quality, price or functional performance. The Life Cycle Assessment (LCA) technique has been identified as a powerful tool to calculate environmental impacts derived from products and system, and calculate resource consumptions. However, the complexity of LCA poses restrictions to its use in current product and system development given the need for a reduction in product development cycle time which is needed to meet the increasing competitive pressures and the rapid changes in markets for many products.

The overall aim of the paper is to provide an understanding of the environmental issues involved in the early stages of product development and the capacity of life cycle assessment techniques to address these issues. The paper aims to outline the problems for the designer in evaluating the environmental benignity of the product from the outset and to provide the designer with a framework for decision support based on the performance evaluation at different stages of the design process. The overall aim of this paper is to produce an in-depth understanding of the barriers to implementation of LCA by developers of products, and of the opportunities for introducing environmental criteria in the design process through meeting the information requirements of the designer on the different life cycle stages, producing an in-depth understanding of the attitudes of practitioners among product developers to the subject area, and an understanding of possible future directions for product development.

An Environmentally Conscious Design method is introduced and trade-offs are presented between design degrees of freedom and environmental solutions. It also discusses a number of possibilities which can be introduced in the design stage compared to the other life cycle stages of the product system.

The paper collects experiences and ideas around the state-of-the-art in eco-design, from literature and personal experience and further provides eco-design life cycle assessment strategies.

The paper reviews the current environmental evaluation practices with respect to product life cycles. As a number of deficiencies in LCA are identified, strategies are presented to provide a solution to many of the deficiencies. The result of the paper is a definition of the requirements for performance measurement techniques and a performance measurement environment necessary to support life cycle evaluation throughout the evaluation of early stages of a product system.

A Diagnostic Expert System For Green Productivity Assessment of Manufacturing Processes

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Green Productivity (GP) is a new paradigm in sustainable manufacturing where resource conservation and waste minimization constitute the strategy in simultaneously enhancing environmental performance and productivity. This productivity approach to the sustainability of industries requires the adoption of clean technology techniques and the development of appropriate indicators and instruments to measure eco-efficiency.

The methodology for GP assessment integrates the use of life cycle assessment (LCA) as the technical framework and the analytic hierarchy process (AHP) as the multicriteria decision analysis (MCDA) support. LCA provides a systematic and holistic perspective to GP analysis that spans inventory, impact and improvement assessment. AHP addresses the need for a valuation tool in impact and improvement assessment. An input-output analysis approach using appropriate material and energy balances provides the basis of GP performance measurement.

Expert system technology is explored in developing a diagnostic prototype that emulates how human experts diagnose green productivity of manufacturing processes. Using CLIPS (C Language Integrated Production System), rule-based knowledge processing is made on the parameters derived from the application of the LCA-based model to generate the diagnostic interpretation and advice on the priority weights obtained from the AHP procedure and the resulting GP performance ratios and indices. Initial application of the diagnostic model on a semiconductor assembly/packaging case study demonstrated the suitability of a diagnostic expert system in implementing GP assessment in an 'intelligent' fashion so that it is easily accessible as a decision support for industries.

DANTES
Demonstrate and Assess Tools for Environmental Sustainability

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In order to make sound environmental decisions, it is important to consider many different environmental aspects, such as increased demand on inherent properties of chemicals in the EU "Strategy for the future chemicals policy" and goals on the reduction of CO_2 emissions in the Kyoto protocol. The problem is that today there is no existing tool that covers e.g. both of these issues. There is also the problematic aspect of economic costs and yields in relation to enhanced environmental performance.

Akzo Nobel Surface Chemistry will therefore together with their partners ABB, Stora Enso and Chalmers University of Technology run the EU LIFE project DANTES with the intention to integrate existing tools into a new method that step-by-step covers environmental aspects. The purpose is to test, evaluate and demonstrate the method for several different kinds of products.

The project will assess and demonstrate tools such as Life Cycle Assessment (LCA), Risk Assessment and Life Cycle Cost (LCC). LCA and LCC are tools to assess the environmental impact and the costs arising from a product throughout its entire life cycle. Risk Assessment is an evaluation of the risk posed to human health and/or the environment by the presence or use of chemical substances. By demonstrating the applicability of existing tools on different kinds of products systematically, the DANTES project will deliver a completely new state of the art method for estimating the environmental load from products. The tool integration will not result in one combined tool but will provide a method describing under what circumstances and in what order different tools should be applied to evaluate the eco-efficiency of a product. Tools, potential tool integration, case study results, evaluations and other findings will be disseminated through a public website and through several informative activities during the project period so that authorities and companies of all sizes will be able to use them and accelerate their work towards sustainability.

In the long term perspective, DANTES will lead to more sustainable products through a more holistic approach where economical and local as well as global environmental aspects are considered.

The project will run for 3 years and started in September 2002. For questions or inquiries about DANTES, please go to www.dantes.info or contact Klas Hallberg, project manager.

Keywords: Sustainability, Environmental Risk Assessment, ERA, Life Cycle Assessment, LCA, Life Cycle Cost, LCC

Eco-efficiency: Inside BASF and Beyond

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BASF uses Eco-efficiency to evaluate the environmental and economic aspects of products and processes. It is a versatile tool that starts with a "Base Case" and then expands the analysis to include "Scenarios", which determine the effect of varying the input data. The Eco-efficiency Manager allows the end-user to assess the environmental and economic impact of variables specific to their application, such as differing production methods using the same raw material, or differing cost structures. Three case studies will be presented:
-an Eco-efficiency Manager for textile dye works in Morocco
-an Eco-Logistix Manager for transportation logistics decision-making
-an Eco-efficiency on refrigerators with potential application in the consumer sector.

Textile Dye Works Case Study

The Eco-efficiency Manager for textile dye works in Morocco was developed by BASF for the United Nations Environmental Protection and United Nations Industrial Development Organization (UNEP/UNIDO) National Cleaner Production Center (NCPC) in Morocco. The goal was to provide a tool to support sustainable development in emerging markets for use by developing industries. An Eco-efficiency analysis was carried out for various dyeing processes and products. These results were then combined with a cost-analysis tool which included raw material and equipment prices. The final results were assembled in an Eco-efficiency Manager, so that the combined environmental and economic impacts of various processing and capital investment decisions can be shown. The NCPC and BASF Morocco were trained in the use of this tool, to be able to provide its use as a consulting service for dye-houses. Upon completion of the pilot project in Morocco, UNIDO anticipates initiating similar programs in all 23 of its NCPCs.

Logistics Case Study

The Ecologistix Manager is a tool to determine the best mode of transportation for bulk shipment of materials. The environmental and cost impacts of truck vs. rail transport are evaluated for Europe. This tool can be used by both customers and internally when making decisions with regards to material movement.

Refrigerator Case Study

An Eco-efficiency analysis was done to determine whether replacing an old refrigerator with a new energy-efficient model is preferable. The study showed that purchasing a new refrigerator can be cost-effective and reduce the environmental burden. These results could potentially be used by a consumer in order to make a buying decision which supports sustainable development.
BASF is committed to sustainability. We have developed both an analysis method for products and processes, and a user-friendly interface to make this method more accessible to customers and other external parties. We offer our customers workshops, courses and joint projects in support of this. Thereby Eco-efficiency is not only a company-internal sustainability tool, but can be put to use industry-wide and beyond.

Building Investment Decision Support (BIDS) Cost-Benefit Tool to Promote High Performance Components, Flexible Infrastructures and Systems Integration for Sustainable Commercial Buildings and Productive Organizations

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The investment in higher performance building solutions and technologies is limited by first cost decision-making. The development of a life cycle tool comparing the cost-benefits of building technologies is central to the commercialisation of higher performance building solutions. Examples of the environmentally-driven life cycle justifications include energy efficiency, waste management, indoor environmental quality, and renewability.

A new building investment decision support tool – BIDS™ - has been developed by the NSF/IUCRC Center for Building Performance at Carnegie Mellon University, with the support of the Advanced Building Systems Integration Consortium. The cost-benefit decision support tool presents the results of field case studies, laboratory studies, simulation, and other research, clearly demonstrating the relationship of quality building investments for – privacy and interaction, ergonomics, lighting control, thermal control, network flexibility, and access to the natural environment – to ten cost benefit factors (see below). The four-year status of this multi-media decision support tool will be presented with illustrations from the 100 case studies that demonstrate the substantial environmental cost-benefits of a range of advanced and innovative building systems.

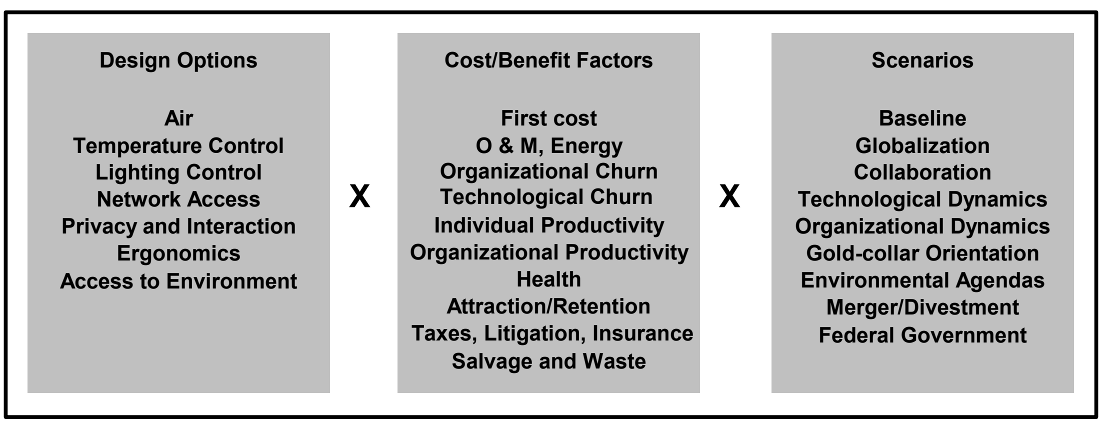

Figure 1 The three dimensions of the Intelligent Workplace BIDS™/ EVA® Matrix

Keywords: high performance building technologies, life cycle, environmental cost-benefit analysis, decision support.

BEES: A Popular Product Selection Tool that Integrates LCA and LCC

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The BEES (**B**uilding for **E**nvironmental and **E**conomic **S**ustainability) software brings to your fingertips a popular technique for selecting cost-effective, environmentally-preferable building products. The tool integrates life-cycle assessment and life-cycle costing in a multi-attribute framework that scores products based on the decisionmaker's values. Version 3.0 of the Windows-based decision support software, aimed at designers, builders, and product manufacturers, includes life-cycle data for nearly 200 building products. The free tool has attracted over 9000 users in more than 80 countries.

BEES is supported in part by the U.S. EPA Environmentally Preferable Purchasing Program, which encourages Executive agencies to reduce the environmental burdens associated with the $200 billion in products and services they buy each year, including building products. In addition, BEES is being required by the U.S. Department of Agriculture as part of a new "USDA Certified Biobased Product" labelling program.

Qualitative Spatial Reasoning and LCA in Green Building Design

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Life cycle assessment (LCA), and life cycle thinking in general, has greatly enriched the tools available for green building design. Nonetheless, it remains just part of the comprehensive decision-making process required for sustainability, where project design teams are challenged by the complexity of considering multiple factors simultaneously. To make the process more manageable one can either ignore complicating relationships or develop a better way to manage these complexities. This presentation explores the latter possibility by proposing a novel method to support the application of informed common sense to building design while incorporating many considerations currently absent from the process. As life cycle costing (LCC) methods evolved to include the related environmental impacts through life cycle impact assessment (LCIA), so can we now begin to incorporate another missing dimension—the human impacts of certain materials, products and strategies.

To be successful however, we must embrace an approach suited to the simultaneous consideration of the economic, environmental and human impacts equally without reducing all three to a linear scale of mere financial costs. What is necessary is a shift in our way of thinking as revolutionary as the concept of sustainability itself. By using ‘qualitative spatial reasoning’ we can easily add the human dimension, reduce the abstractions from source data, and make the process understandable to all project stakeholders.

By expanding the standard two-dimensional grid, representing the economic factors on one axis and the ecologic factors on the other, to include a third axis addressing human factors we build a three-dimensional framework where qualitative spatial reasoning can occur. While the economic scale tracks the relative efficiencies or costs for each functional unit (material, product or strategy), the ecologic scale traces the relative impacts to the natural environment, and the human scale records the benefits or burdens to human participants of the built environment related to health, comfort and psychological well-being.

Most innovative is that within this model the environmental and human factors are no longer collapsed into economic quantities, abstracted numbers, or convenient LEED* credits but are addressed *directly* as prioritized values related to their context through a group weighting exercise. By doing so, the apparent conflict between costs on the one hand and either the environment or humans on the other is resolved into a way that ranks each quality independently along its particular axis *and* relates them collectively within the framework. Therefore, the methodology encourages a form of ethical, value-based decision-making particular to the project stakeholders, project location and its region that resists *de*-valuation into monetary terms. It is also consistent with the long-term demands of sustainability, with its holistic focus on the complex interrelationships within the greater environment.

An ideal combination, qualitative spatial reasoning can harness the wealth of life cycle inventory (LCI) data through dynamic, continuously updated links filtered by region, climate (biome), and typology. Likewise, LCA can take advantage of a more balanced analysis method that considers the goals of each perspective (economic, ecologic and human) and acknowledges the expert judgments, ad-hoc assumptions and subjective interpretations inherent to the process. After all, qualitative reasoning is just common sense used in absence of precise quantitative information. As we recognize the computational limits to our knowledge and consider aspects poorly translated into economic terms (like productivity or psychological health) we must embrace value-based reasoning.

Traditionally the weighting of factors is the least developed stage in LCA, the most difficult for users, and the most suspect contributor to the final appraisal. Using this methodology however, the value assessment process is easy to understand and employ. In green building design for example, an essential step is a group exercise where all stakeholders meet first to establish the project’s economic, ecologic and human goals and parameters and then, to consider design alternatives to achieve those goals. This weighting exercise shares the decision-making process, builds teamwork and consensus. When combined with qualitative spatial reasoning it should produce a better building design—one that is more respectful of the integration of economic, ecologic and human needs. If the success of sustainability relies on doing what is right and not just what is within budget or only what can be quantified, why do we continue to use abstract numbers or costs as the denominator for our reasoning methods?

*** The LEED™ Green Building Rating System is a national program to rate buildings by a prescriptive checklist of credits.**

LCA Tools in Residential Building – Assessing Their Applicability

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On April 20, 2001, a group of international experts met in Baltimore for a full-day workshop to discuss life cycle assessment (LCA) issues and the current state of LCA tools. In particular, the discussion focused on the ways in which LCA tools affect and concern the home building industry. The tools thus far have been used primarily by architects, designers, product manufacturers, builders and engineers in the commercial building industry; the workshop was an opportunity to examine their usefulness for the residential building sector.

The workshop included a mix of participants of varied backgrounds. The goal was to have in the same room, not only LCA tool developers and LCA experts, but also professionals who are well versed in the environmental indicators (impact categories) that LCA tools attempt to profile via their algorithms. The general conclusions from the workshop indicated that the current tools are in constant flux and the science is evolving. More work remains to be done in order to make LCA useful and applicable to the home building industry.

Integrating EHS into New Product Development

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United Technologies Corporation (UTC) provides a broad range of high-technology products and services to the aerospace and building systems industries. UTC is a publicly listed corporation with 2002 revenues of $28.2 billion and over 152,000 employees operating in 180 countries. The company has five core commitments that underpin its business strategy: performance, pioneering innovation, personal development, social responsibility, and shareowner value. This operating philosophy combined with highly decentralized decision- making has presented unique challenges in deploying a corporate policy on design for safety and environment (DFES). The policy challenges operating divisions to proactively move beyond the current regulatory and market requirements, but at the same time meet demanding performance goals and earnings projections.

Effective integration of DFES practices into routine new product development processes is a critical enabler. The DFES policy was initially deployed in a top- down flow from the corporate environment, health, and safety (EHS) department. That focus has gradually been shifted to the engineering functions within each operating division. DFES champions were established at each division to help overcome implementation barriers. There is a need for dedicated resources to develop tools and methods required by line functions in order to successfully complete integrated tasks. Cross- divisional teams share best practices and jointly develop necessary support resources. One team developed a common definition and calculation method for a hazardous material index (HMI) to characterize UTC product offerings. Team members wanted a common UTC metric to facilitate cross- divisional product development projects and to present a common requirement to UTC suppliers. Developing common methods in a highly decentralized company is just one of the organizational challenges.

Moving DFES from an EHS focus to an engineering focus has presented other organizational problems. Engineering and EHS define and use metrics in fundamentally different ways. Engineers use metrics primarily to guide design choices and trade studies. Fuzzy multi- criteria problems are common. EHS tends to view metrics as a reporting mechanism to assure compliance with requirements. This diversity of views has been a significant barrier to effectively inserting LCA, or even life cycle thinking, into product development practices. A simplified pair- wise comparison tool has been used with some success to explicitly show the priority between “green” and traditional product design attributes. A remaining challenge is to assess the feasibility of rolling up and reporting UTC- wide goals for environmentally- responsible products.

Effective integration of DFES means less visibility as a separate initiative. The ultimate objective is to embed DFES into DFx procedures as simply one more life cycle customer requirement. Corporate efforts are focused on reducing the anxiety of engineers unsure of what they are expected to do and traditional EHS managers unsure that engineering will comply. The soft issues of communication and training are key drivers often neglected in favor of technically sophisticated tools.

Life Cycle Management in the Aluminum Industry: Implementation of LCA for Internal Applications

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Life Cycle Management (LCM) aims at expanding the scope of the environmental management system of a company to address the up- and downstream impacts associated with the activities of its suppliers and customers. In addition, LCM takes a perspective that focuses on products and the corresponding processes rather than only on facilities and production sites. Therefore, the Life Cycle Assessment (LCA) methodology plays a central role in implementing LCM.

At Alcan, the worldwide second largest producer of aluminum materials and products, LCA as the core element of LCM is being used for a variety of applications. These include strategy planning, marketing, and applications to improve the environmental performance on an internal and supply chain level (including end-of-life activities). The former two are primarily joint activities of the aluminum industry on a European or global level. The latter, however, are firm and product specific and aim at analyzing, assessing, and improving the processes and products of Alcan. To identify hot-spots and to minimize the life cycle impacts caused by its products, Alcan is conducting LCAs for all of its product groups.

In order to achieve the aforementioned objectives of LCM and to ensure efficient decision support, the LCAs are performed in a simplified mode. Simplifications predominantly concern up- and downstream processes outside of Alcan's direct control as well as impact assessment procedures, the re-use of internal life cycle inventory analysis modules, and the aggregation and presentation of the results for top-management and other internal decision-makers.

The presentation will give insights into the internal application patterns of LCA and its role in LCM at Alcan and will discuss specific methodological challenges and proposed solutions for using LCA in the environmental management of a multinational corporation. The implementation will be demonstrated with selected results from recent LCA activities regarding aluminum products for the building and transport sectors.

A framework of Computer Aided Engineering and LCA applied for Life Cycle Management

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The present paper is concerned with an integrative approach related to (i) the use of modern CAD and CAE tools, for early effective product design, and (ii) an environmental management framework that evaluates the environmental performance of the product along its whole life cycle (raw materials selection, materials transformation, production processes, transportation, use, re-use, recycle, retirement/decommissioning). The main result is a conceptual and research-based framework for multidisciplinary life cycle management.

The presented research provides a high-end technical solution to determine the best product alternative in terms of market expectations, product-process specifications, economic and environmental impact in the long term, that is, along the whole life of a product. The integration of this framework is oriented towards rapid generation of prototypes and evaluation of innovative products.

In order to achieve this objective, we have developed two inter-connected sub-frameworks:
(i) a sub-framework for total computer aided engineering (TCAE), which allows for designing an optimised product alternative, taking into account the need to come up with a fast, reliable design and prototype, and (ii) a sub-framework that could be used to consistently evaluate and compare the economic and environmental performance of every product alternative.

This framework was successfully applied into a experimental high speed rotor prototype . The main results showed that an optimised design can be achieved in the early stages of the design process, by combining computer aided tools for design, analysis and predictions in a feed-back process loop which allowed the development of a product in a faster, cost effective and environmentally friendly manner. Furthermore, the framework developed in this paper can be effectively applied into almost any product design project.

Life Cycle Management: Generating Value for Rio Tino Borax's Sustainability Program

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Rio Tinto Borax has undertaken an initiative to integrate Sustainable Development into its core operations. Borax has established several objectives to help guide the implementation of its sustainable development program. Objective five is "to expand how our products contribute to sustainable development." In order to achieve this objective, the company identified Life Cycle Assessments (LCA) of its products as a tool to quantify and better understand the environmental performance of its products throughout the product lifecycle.

To date, the company has completed LCA's for several of its products, including Optibor®, Neobor®, Dehybor®, Borax, Boric Oxide, Zinc Borate, Tim-bor® and Granubor®. The results of these studies are being used by Borax for several efforts under their sustainability program. The software models are being used to aid in identifying and tracking significant aspects under the ISO 14001 Environmental Management Systems. The models can also be used to assess various process improvement or technology change scenarios from both a life cycle and site perspective. For example, LCA is being used to evaluate various process modification alternatives in terms of environmental impacts, such as energy consumption, and significant aspects identified under the ISO 14001 program. The study results are being used at a corporate level to help produce business benefits such as increasing access to various markets, for example by working with Borax customers on life cycle initiatives, utilizing the life cycle inventories. Further studies on downstream applications are currently underway, such as borate treated wood and Oriented Strand Board containing zinc borate. This paper will summarize these initiatives to explore the value of utilizing a life cycle management approach as part of a broader sustainability program.

Life cycle assessment of a bioreactor and an engineered landfill for municipal solid waste treatment

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Potential environmental impacts associated with the treatment of municipal solid waste (MSW) in two types of landfills, the engineered landfill and the bioreactor landfill, were assessed using a life cycle assessment (LCA). The hypothetical case study was the treatment of 600 000 tonnes of MSW generated over a period of two years. Since the landfill gas produced from the bioreactor landfill can be energetically valorized to either electricity or heat, this additional energy production function must be added to the systems considered through system boundaries expansion. The potential impacts were evaluated using the EDIP method, stopping after the characterization step. The CO_2 produced from the MSW placed in the landfill was considered to be biomass CO_2 and was not counted in the greenhouse gases inventory. A fraction of the potential landfill gas was assumed not to be produced since the conditions in the landfill are not ideal; the carbon contained in this un-emitted fraction remaining in the landfilled MSW, the CO_2 that would have been produced from this carbon, was assumed to be removed from the atmosphere and the carbon cycle and represents an environmental credit. A first observation from the inventory phase of the LCA is that the bioreactor landfill uses fewer natural resources and generates fewer wastes throughout its life cycle. This is mainly due to the fact that MSW is assumed to take up 25% less space in this type of landfill thus the material needs, proportional to the size of the landfill cell, and associated generated wastes are also reduced. The evaluated impacts are essentially associated with the added energy production unit processes (natural gas electrical power station and boiler) and the landfill gas, either the treatment of the collected fraction or the direct release to the atmosphere of the uncollected one.. Since, in the case of the engineered landfill, 1) no energy is recovered from the landfill gas and 2) the landfill gas is produced much slower so more of it is released untreated (the methane and chlorinated compounds it contains are not destroyed, i.e. transformed to biomass CO_2) after the end of the post-closure monitoring period, the evaluated impacts are on average 85% higher than for the bioreactor landfill.

A Study on The Eco-efficiencies for Recycling Methods of Plastics Wastes

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Decision-making with respect to recycling methods of plastics wastes includes a variety of factors such as environmental, economic and other elements. However, it is very difficult to consider these various factors within a single integrated index because they all possess different basic measurement units for the decision-making process. Only when all of these factors are integrated under the same index will it become possible for decision makers to select the most environmentally friendly and economically efficient alternative.

In this study, it is attempted to measure eco-efficiencies of different recycling methods such as material recycling (MR), chemical recycling (CR) and thermal recycling (TR) by using the VER(Value /Eco-costs Ratio) model. The VER model is modified from the existing EVR model which is based on the marginal prevention costs and it enables to combine the environmental and far-reaching economic aspects of the system into the integrated fashion. Cost-Benefit Analysis (CBA) is utilized to measure the value in the model and the eco-cost is calculated from the LCA results by applying the 'virtual pollution costs'. In this way, the LCA results of recycling methods can be expressed in terms of costs and, thus, the VER becomes dimensionless.

The LCA results of three different recycling methods showed that MR was the most environmentally sound recycling method and in the current situation of Korea. And, the eco-efficiencies of the recycling methods were obtained by calculating the VERs from the eco costs and CBA. The eco-efficiencies of MR, CR and TR were 2.48, 1.26 and 0.11, respectively indicating that in Korea MR is currently the most effective method and TR is not effective neither environmentally nor economically.

Key words: LCA, eco-efficiency, value/eco-cost ratio, cost-benefit analysis, material recycling, chemical recycling, thermal recycling

Energy Conservation and Pollution Prevention Benefits of Residential Curbside Recycling Vs. Landfill Disposal or Waste-to-Energy Incineration Disposal

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This study compared life cycle energy consumption, as well as releases to air, water and land of greenhouse gases, acidifying compounds, eutrophying compounds, and substances that are toxic to humans, for materials collected through residential curbside recycling programs versus disposal of those materials via landfill or via waste-to-energy (WTE) incineration with landfill disposal of combustion ash. Waste management systems in Washington state were examined, with separate analyses completed for systems in urban west, urban east, rural west and rural east regions of the state. The LCA boundaries were defined to include virgin resource extraction, resource refining and product manufacturing for 100% recycled- versus 100% virgin-content products, plus management of solid wastes at the end of product life, including the processing of recycled materials to specifications required for manufacturing of recycled-content products. Northwest energy grid offsets were included for energy and emissions reductions credited to energy generated from waste-to-energy disposal of recyclable materials. Landfill disposal practices for Washington state waste typically involved landfill gas collection and flaring, so no energy or emissions offsets were included for landfill.

Results show that curbside recycling conserves energy and reduces emissions versus either landfill or WTE disposal. This is due to reductions in energy usage and emissions for recycled-content production compared with manufacture of products from virgin materials. These upstream reductions outweigh the additional energy usage and emissions associated with curbside recycling trucks, cleaning and packaging of collected recyclables for sale on recycling markets, and shipping of packaged recyclables to end-use markets for use in manufacture of recycled-content products. In general, upstream energy and emissions reductions associated with recycled-content production are an order of magnitude larger than the increased energy usage and pollutant releases associated with curbside recycling collection trucks, material processing facilities and shipments of processed materials to end users.

Triple Life Cycle Assessment

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As sustainable development becomes more important in the face of growing environmental, economic and social challenges, so too, will the need for tools, methods and resources for assessing the sustainability of various policies, investment decisions and development strategies. Public and private organizations are increasingly recognizing the three major domains of sustainable development as economic/fiscal, environmental and social. These domains are also referred to as:

- the three E's -- ecology, economy and equity
- the three P's -- people, planet, profits, or
- the triple bottom line

Sustainable activities and solutions are often considered those which concurrently address the values and perspectives of these three domains.

Though the Global Reporting Initiative and other model for triple bottom reporting are gaining ground, these are primarily reporting, rather than assessment tools. A universal, transparent, verifiable method for assessing the degree that various courses of action are optimizing performance across the economic/fiscal, environmental, and social domains remains elusive to date.

Life Cycle Cost Assessment (LCCA) now serves as a broadly applicable and reliable tool for understanding cradle to grave production costs in manufacturing and/or the total cost of ownership for asset developers. Though usually requiring a more intensive data collection effort, Life Cycle Impact Assessment methods are providing useful environmental accounting information for a range of audiences who want to understand how various products, services or development actions vary in their total environmental impacts.

Though these mature assessment frameworks exist for the fiscal and environmental domains, those interested in a sustainable development perspective still lack a shared approach for assessing impacts and benefits to society across temporal and spatial scales. Sustainable development requires interdisciplinary teams with interoperable methods for assessment across fiscal, environmental and social dimensions. We have yet to see LCCA and LCIA brought together with a viable transparent social assessment framework. To address this growing need, the authors assert that Life Cycle Cost Assessment should be brought together with Life Cycle Impact Assessment and a new field of Life Cycle Social Benefit Assessment.

These three life cycle tools, wielded concurrently, will provide the most comprehensive assessment framework for helping steer (especially public) development toward sustainable approaches. The authors propose a flexible and auditable method for carrying out life cycle social benefit assessment and discuss the opportunities, benefits and challenges related to carrying out this triple lifecycle assessment method on a simple trail hardening project in a local park in Seattle.

Applying Life Cycle tools and Process Engineering to determine the most adequate treatment process conditions. A tool in environmental policy.

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The traditional approach used to assess waste treatment technologies is contrasted with a life cycle analysis (LCA) approach. The optimal design of a granular activated carbon adsorption process is used as a model system to demonstrate the advantages of LCA approaches over traditional approaches. The use of LCA revealed that the environmental burdens associated with the wastewater treatment may outweigh the environmental benefit. Economic and environmental considerations regarding the optimum process design are introduced as a basis for decision towards the selection and operating conditions of wastewater treatment technologies.

The analysis of a wastewater treatment technology, under a expanded boundaries system, quantifies the overall environmental impact that may result from the treatment of a wastewater stream. In order to explore differences between a traditional assessment and a life cycle assessment approach, the author has studied a widely used end-of-the-pipe treatment technology: activated carbon adsorption. This process is considered as one of the most effective methods of controlling emissions of volatile organic compounds, VOCs, a class of pollutant that is often presented in industrial wastewater streams.

Further sections of the paper describe design considerations applied in the cost optimised carbon adsorption model, the use of LCA techniques to perform an inventory of all emissions associated to the process system and, its environmental impacts.

Finally, the paper highlights the string advantages that environmental policy makers may have once adopted LCA approaches as opposed to traditional ones. This approach can be incorporated into other existing treatment processes or for process designers.

What's An Engineer to Do?

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How can engineers include life cycle ecological impacts in decision-making criteria for planning and design alternatives… within limited budget and time constraints?

Carollo Engineers, working with the non-profit Redefining Progress, has used the Ecological Footprint to measure the relative ecological impacts of decisions affecting the design of two municipal water recycling facilities. The Ecological Footprint measures the amount of bioproductive space required to produce all materials and energy consumed, and to sequester or absorb all wastes produced, for a given activity or to support a given population.

This presentation will describe our process for calculating the footprints and report on our findings, as well as on the strengths and challenges of using this tool to aid decision-making at the facility level.

Sustainability Indicators related to Energy and Material Flow

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This study analyzed energy and material flows in different regions and industrial sectors to evaluate regional and industrial sustainability. Several life cycle approaches that are used to quantify environmental efficiency related to energy and material flows were investigated as applications of life cycle tools in emerging markets, including the service industry and the public sector. The regions included all 47 Japanese prefectures and the data for each prefecture considered 16 industrial categories based on the national physical distribution census and national input-output tables for 1995.

When using life cycle carbon dioxide emissions as a typical environmental loading item, sustainability indicators related to energy and material flows can be extracted using the following equation,

$$CO_2 = \frac{CO_2}{energy} \times \frac{energy}{flow} \times \frac{flow}{GDP} \times GDP$$

where CO_2 is the carbon dioxide emission (direct or life-cycle); *energy* is the energy consumption or primary energy supply; *flow* is the total material input or total material flow; and *GDP* is the gross domestic product or amount of industrial product.

This is a way to identify energy and material flows in a regional economic system. The energy flow consists of the primary energy supply and the recycled energy recovery, since the material flow consists of primary and recycled resources. A reduction in CO_2 with economic growth (increasing GDP) needs remarkable reductions in "$CO_2/energy$", "*energy/flow*", and "*flow/GDP*" as an advanced sustainability indicator. These ratios were compared in each region and industrial category.

The ratio of the primary energy supply to the total material input for service industries ranged from 0.1 to 0.5 [TOE/10^3ton] for the 47 prefectures. Ultimately, several relationships between "energy/flow" and regional or industrial characteristics were obtained, such as regional population, distance from major markets, and so on.

Evaluation of Two Simplified Life Cycle Assessment Methods

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A simplified LCA is as a simplified variety of detailed LCA conducted according to guidelines not in full compliance with the ISO 1404X standards and representative of studies typically requiring from 1 to 20 person-days of work. It can be qualitative, quantitative or semi-quantitative. Two methods for simplified LCA have been evaluated: the SLCA-method (presented by Graedel and Allenby) and the MECO-method (presented by Pommer et al). The methods were chosen since they are well documented and fundamentally different.

The methods were used in a case study on electric cars and the results were compared with the results from a traditional quantitative LCA. The evaluation also included the field of application, the level of arbitrariness, the flexibility and easiness of the method, the use of weighing method and also the possibilities to include qualitative information, toxicity, land use and production of consumables.

The usefulness of simplified LCA-methods, generally and in relation to their suitability in a purchasing process, is discussed. Choosing a simplified LCA-method involves a balance between the simplification of the method and the type of results the user is looking for. There is no method that is preferable over all others under all conditions. In a comparison of two simplified LCA-methods, two of the most important criteria are the field of application and whether the method can deliver the required information.

The evaluation shows that the MECO method has some positive qualities compared to the SLCA-method and that a simplified and semi-quantitative LCA (such as the MECO-method) can provide information that is complementary to a traditional quantitative LCA. The concluding suggestion is a procedure where a simplified LCA is used both as a pre-study to a traditional quantitative LCA and as a parallel assessment, which is used together with the traditional LCA in the interpretation.

Using the Balanced Scorecard as a Framework for Life Cycle Management

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Life Cycle Management (LCM) is a significant challenge because it requires both integrated teamwork within organizations, and linking LCM to the core strategies and mission of the organization. LCM also needs to be managed using indicators of business performance that show management how LCM is improving business value. The Balanced ScoreCard (BSC) is a popular model for managing business metrics, in support of mission and strategy, that can be used to implement and support LCM. The BSC focuses on metrics for managing four major aspects of business performance: Financial, operational, customer satisfaction, and organization learning and development. All these perspectives are highly relevant to LCM. This paper discusses the linkages between LCM and BSC concepts, demonstrates how the BSC can be used to strategically support LCM and offers example LCM performance indicators for each BSC perspective. It also discusses the challenges and opportunities for promoting the BSC as a framework for sustainable business management.