Tools for Assessing Facility and Infrastructure Life Cycle Management

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Definition of Sustainable Development

- Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs
Pillars of Sustainability
Life Cycle Assessment (LCA)

How can we answer questions about relative sustainability of products or processes?
- Conventional versus green roofs
- Plastic versus glass product packaging
- Ethanol versus fossil fuels
Process-based LCA – What is it?

- An **objective** process to evaluate the environmental burdens associated with a:
  - Product
  - Process
  - Activity

By identifying and quantifying energy and materials used and wastes released to the environment,
And to evaluate and implement opportunities to effect environmental improvements
(SETAC Code of Practice 1991)
LCA – What can it do?

- Develop a systematic evaluation of the environmental consequences associated with a given product.
- Analyze the environmental trade-offs associated with one or more specific products/processes to help gain stakeholder (state, community, etc.) acceptance for a planned action.
- Quantify environmental releases to air, water, and land in relation to each life cycle stage and/or major contributing process.
- Assess the human and ecological effects of material consumption and environmental releases to the local community, region, and world.
- Compare the health and ecological impacts between two or more rival products/processes or identify the impacts of a specific product or process.
Product Life-Cycle

Raw materials acquisition

Material manufacture

Product manufacture

Use

Disposal

Transport

Energy

Raw materials

Waste

Product remanufacture

Materials recycle

Product reuse
Product Life Cycle

• Stages of a product/process
  • Raw materials acquisition – includes harvesting materials from earth and transportation to processing site

• Manufacturing
  • Materials manufacture
  • Product fabrication
  • Filling/Packaging Distribution
Product Life Cycle

- Use/Reuse/Maintenance
  - Energy demands/environmental wastes from product storage and consumption
  - Any maintenance or service required
- Recycle/Waste Management
  - Energy demands/environmental wastes associated with disposition of the product or material
LCA Framework

- Goal definition and scoping
- Inventory analysis
- Impact assessment
- Interpretation
Goal definition and scoping

- Define the goals of the project
- Determine what type of information is needed to inform decision-makers
- Determine the required specificity
- Determine how results should be displayed
- Define the scope of the study
- Determine the ground rules for performing the work
Defining the Goals

- Potential applications:
  - Support broad environmental assessments
  - Establish baseline information for a process
  - Rank the relative contribution of individual steps or processes
  - Identify data gaps
  - Support public policy
  - Support product certification
  - Provide information to decision-makers
  - Guide product/process development
Determine required specificity

- Range of specificity
  - Completely generic
  - Completely process-specific
  - Hybrid
- Is product or process specific to one company or manufacturer?
- Is product (process)-specific data available?
**Functional Unit Definition**

- Typically based on equivalent use or function (volume or weight)

<table>
<thead>
<tr>
<th>Functional Unit</th>
<th>number of functional units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>12 oz aluminum can</strong></td>
<td>1</td>
</tr>
<tr>
<td>holds 12 oz of soda</td>
<td>1</td>
</tr>
<tr>
<td>one container</td>
<td>1</td>
</tr>
</tbody>
</table>
Life Cycle Inventory (LCI)

- Process to quantify energy and raw materials requirements, emissions and other releases for the lifetime of the product/process
- Inventory – list containing all quantities of pollutants released to environment and amount of energy and material consumed.
Steps in LCI

- Develop a flow diagram of process being evaluated
  - more detailed = greater accuracy, more time
- Develop a data collection plan
- Collect data
- Evaluate and report results
Types of data and sources

- Measured
- Modeled
- Non-site specific (surrogate data)
- Vendor data

Sources: equipment readings; equipment operating logs; industry reports; laboratory tests; government documents; journals/books; previous LCIs; equipment specs; engineering judgement; surveys
Environmental Burdens

- GHG emissions
- Pollutant loadings to environment (air or water)
- Water consumption
- Solid waste production
- Hazardous Waste production
- Land use
- Resource consumption
Life Cycle Impact Assessment (LCIA)

Evaluation of human health and environmental impacts of environmental resources and releases identified in the LCI

for example: What is the impact of 5000 tons of methane emissions vs. 9000 tons of CO₂?
# Exhibit 4-I. Commonly Used Life Cycle Impact Categories

<table>
<thead>
<tr>
<th>Impact Category</th>
<th>Scale</th>
<th>Examples of LCIA Data (i.e. classification)</th>
<th>Common Possible Characterization Factor</th>
<th>Description of Characterization Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Warming</td>
<td>Global</td>
<td>Carbon Dioxide (CO₂) Nitrogen Dioxide (NO₂) Methane (CH₄) Chlorofluorocarbons (CFCs) Hydrochlorofluorocarbons (HCFCs) Methyl Bromide (CH₃Br)</td>
<td>Global Warming Potential</td>
<td>Converts LCIA data to carbon dioxide (CO₂) equivalents. Note: global warming potentials can be 50, 100, or 500 year potentials.</td>
</tr>
<tr>
<td>Stratospheric Ozone Depletion</td>
<td>Global</td>
<td>Chlorofluorocarbons (CFCs) Hydrochlorofluorocarbons (HCFCs) Halons Methyl Bromide (CH₃Br)</td>
<td>Ozone Depleting Potential</td>
<td>Converts LCIA data to trichlorofluoromethane (CFC-11) equivalents.</td>
</tr>
<tr>
<td>Acidification</td>
<td>Regional Local</td>
<td>Sulfur Oxides (SOx) Nitrogen Oxides (NOx) Hydrochloric Acid (HCl) Hydrofluoric Acid (HF) Ammonia (NH₃)</td>
<td>Acidification Potential</td>
<td>Converts LCIA data to hydrogen (H⁺) ion equivalents.</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>Local</td>
<td>Phosphate (PO₄) Nitrogen Oxide (NO) Nitrogen Dioxide (NO₂) Nitrates Ammonia (NH₃)</td>
<td>Eutrophication Potential</td>
<td>Converts LCIA data to phosphate (PO₄) equivalents.</td>
</tr>
<tr>
<td>Photochemical Smog</td>
<td>Local</td>
<td>Non-methane hydrocarbon (NMHC)</td>
<td>Photochemical Oxidant Creation Potential</td>
<td>Converts LCIA data to ethane (C₂H₆) equivalents.</td>
</tr>
<tr>
<td>Terrestrial Toxicity</td>
<td>Local</td>
<td>Toxic chemicals with a reported lethal concentration to rodents</td>
<td>LC₅₀</td>
<td>Converts LC₅₀ data to equivalents; uses multimedia modeling, exposure pathways.</td>
</tr>
<tr>
<td>Aquatic Toxicity</td>
<td>Local</td>
<td>Toxic chemicals with a reported lethal concentration to fish</td>
<td>LC₅₀</td>
<td>Converts LC₅₀ data to equivalents; uses multimedia modeling, exposure pathways.</td>
</tr>
<tr>
<td>Human Health</td>
<td>Global Regional Local</td>
<td>Total releases to air, water, and soil.</td>
<td>LC₅₀</td>
<td>Converts LC₅₀ data to equivalents; uses multimedia modeling, exposure pathways.</td>
</tr>
<tr>
<td>Resource Depletion</td>
<td>Global Regional Local</td>
<td>Quantity of minerals used Quantity of fossil fuels used</td>
<td>Resource Depletion Potential</td>
<td>Converts LCIA data to a ratio of quantity of resource used versus quantity of resource left in reserve.</td>
</tr>
<tr>
<td>Land Use</td>
<td>Global Regional Local</td>
<td>Quantity disposed of in a landfill or other land modifications</td>
<td>Land Availability</td>
<td>Converts mass of solid waste into volume using an estimated density.</td>
</tr>
<tr>
<td>Water Use</td>
<td>Regional Local</td>
<td>Water used or consumed</td>
<td>Water Shortage Potential</td>
<td>Converts LCIA data to a ratio of quantity of water used versus quantity of resource left in reserve.</td>
</tr>
</tbody>
</table>
## Potential Inconsistencies in LCA

### Exhibit 5-2. Examples of Checklist Categories and Potential Inconsistencies

<table>
<thead>
<tr>
<th>Category</th>
<th>Example of Inconsistency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Source</td>
<td>Alternative A is based on literature and Alternative B is based on measured data.</td>
</tr>
<tr>
<td>Data Accuracy</td>
<td>For Alternative A, a detailed process flow diagram is used to develop the LCI data. For Alternative B, limited process information was available and the LCI data developed was for a process that was not described or analyzed in detail.</td>
</tr>
<tr>
<td>Data Age</td>
<td>Alternative A uses 1980’s era raw materials manufacturing data. Alternative B used a one year-old study.</td>
</tr>
<tr>
<td>Technological Representation</td>
<td>Alternative A is bench-scale laboratory model. Alternative B is a full-scale production plant operation.</td>
</tr>
<tr>
<td>Temporal Representation</td>
<td>Data for Alternative A describe a recently developed technology. Alternate B describes a technology mix, including recently built and old plants.</td>
</tr>
<tr>
<td>Geographical Representation</td>
<td>Data for Alternative A were data from technology employed under European environmental standards. Alternative B uses the data from technology employed under U.S. environmental standards.</td>
</tr>
<tr>
<td>System Boundaries, Assumptions,</td>
<td>Alternative A uses a Global Warming Potential model based on 500 year potential. Alternative B uses a Global Warming Potential model based on 100 year potential.</td>
</tr>
<tr>
<td>&amp; Models</td>
<td></td>
</tr>
</tbody>
</table>
Limitations of LCA

- Assumptions made when choosing system boundaries and data sources
- Use of regional or global data
- Poor quality data
- Unavailable data
- Similar data across unit operations must be available to do meaningful comparisons
- Decisions about which inventory parameters are most important may be site-specific
  - NOx may be more important in some areas of US than others
  - Emissions location: local/global
LCA software

- GaBi
- SimaPro
- EIO-LCA (Economic Input Output – LCA)
EIO-LCA

Economic Input-Output Approach
based on economic Input-Output models- represent monetary transactions between industry sectors in a mathematical form (matrices)

US economy can be divided into production sectors
~500 – defined by Dept. of Commerce
SIC codes, NAICS – North American Industry Classification System
average size - $27 billion
Limitations

- Industry sectors are aggregated – sector reports industry average emissions
- Non US models - ~100 sectors, more aggregated
- EIO-LCA equivalent to LC inventory
  - No impact categories or evaluation of health effects
- Only include some environmental effects
  - No data on: habitat destruction, non-hazardous solid waste, non-toxic water pollutants
## Comparison of LCA methods

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Process-Based LCA</th>
<th>EIO-LCA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>results are detailed, process specific</td>
<td>results are economy-wide, comprehensive assessments</td>
</tr>
<tr>
<td></td>
<td>allows for specific product comparisons</td>
<td>allows for systems-level comparisons</td>
</tr>
<tr>
<td></td>
<td>identifies areas for process improvements, weak point analysis</td>
<td>uses publically-available data, reproducible results</td>
</tr>
<tr>
<td></td>
<td>provides for future product development assessments</td>
<td>provides for future product development assessments</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>Process-Based LCA</th>
<th>EIO-LCA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>setting system boundary is subjective</td>
<td>product assessments contain aggregate data</td>
</tr>
<tr>
<td></td>
<td>tend to be time intensive and costly</td>
<td>process assessments difficult</td>
</tr>
<tr>
<td></td>
<td>difficult to apply to new process design</td>
<td>availability of data for complete environmental effects</td>
</tr>
<tr>
<td></td>
<td>uses proprietary data</td>
<td>difficult to apply to an open economy (with substantial non-comparable imports)</td>
</tr>
<tr>
<td></td>
<td>cannot be replicated if confidential data are used</td>
<td>uncertainty in data</td>
</tr>
</tbody>
</table>
|               | uncertainty in data | }
Questions?