Tools for Assessing Facility and Infrastructure Life Cycle Management

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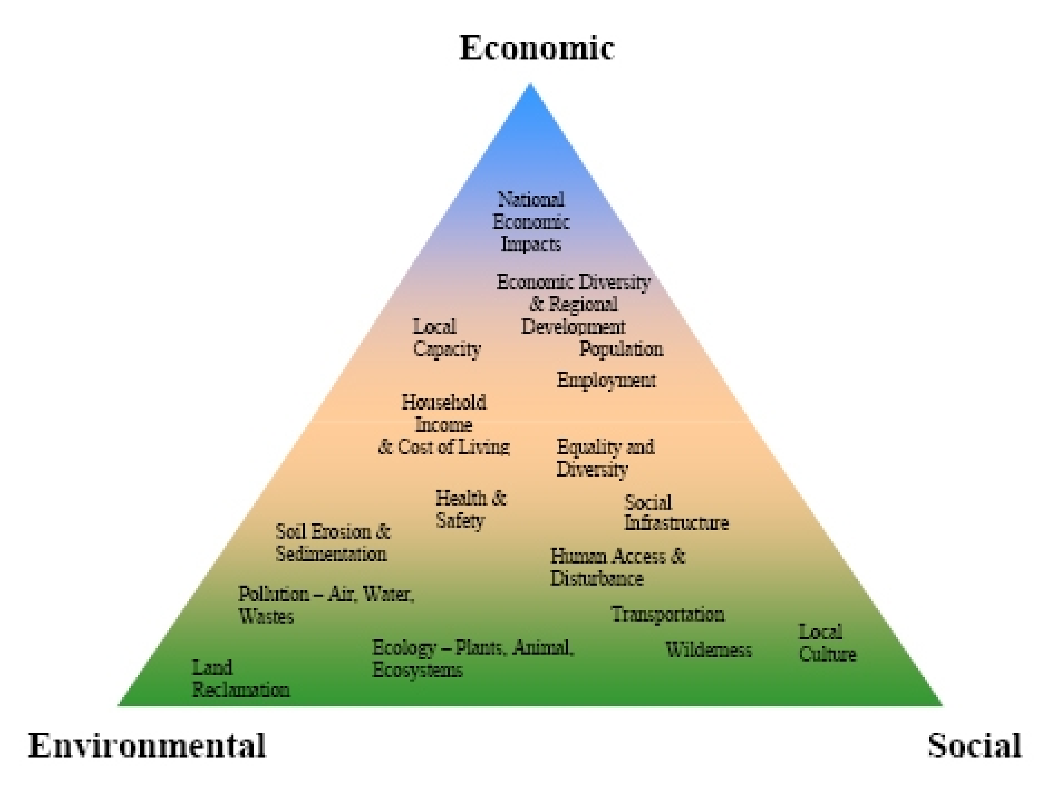
Definition of Sustainable Development

- Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs
  - Our Common Future, The World Commission on Environment and Development, 1987

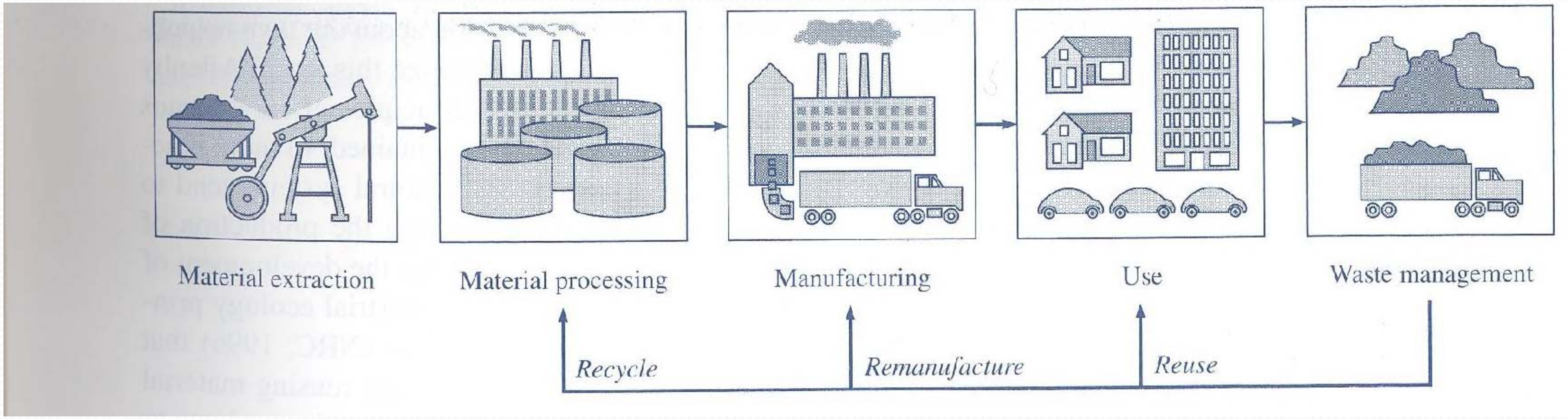
Pillars of Sustainability



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,

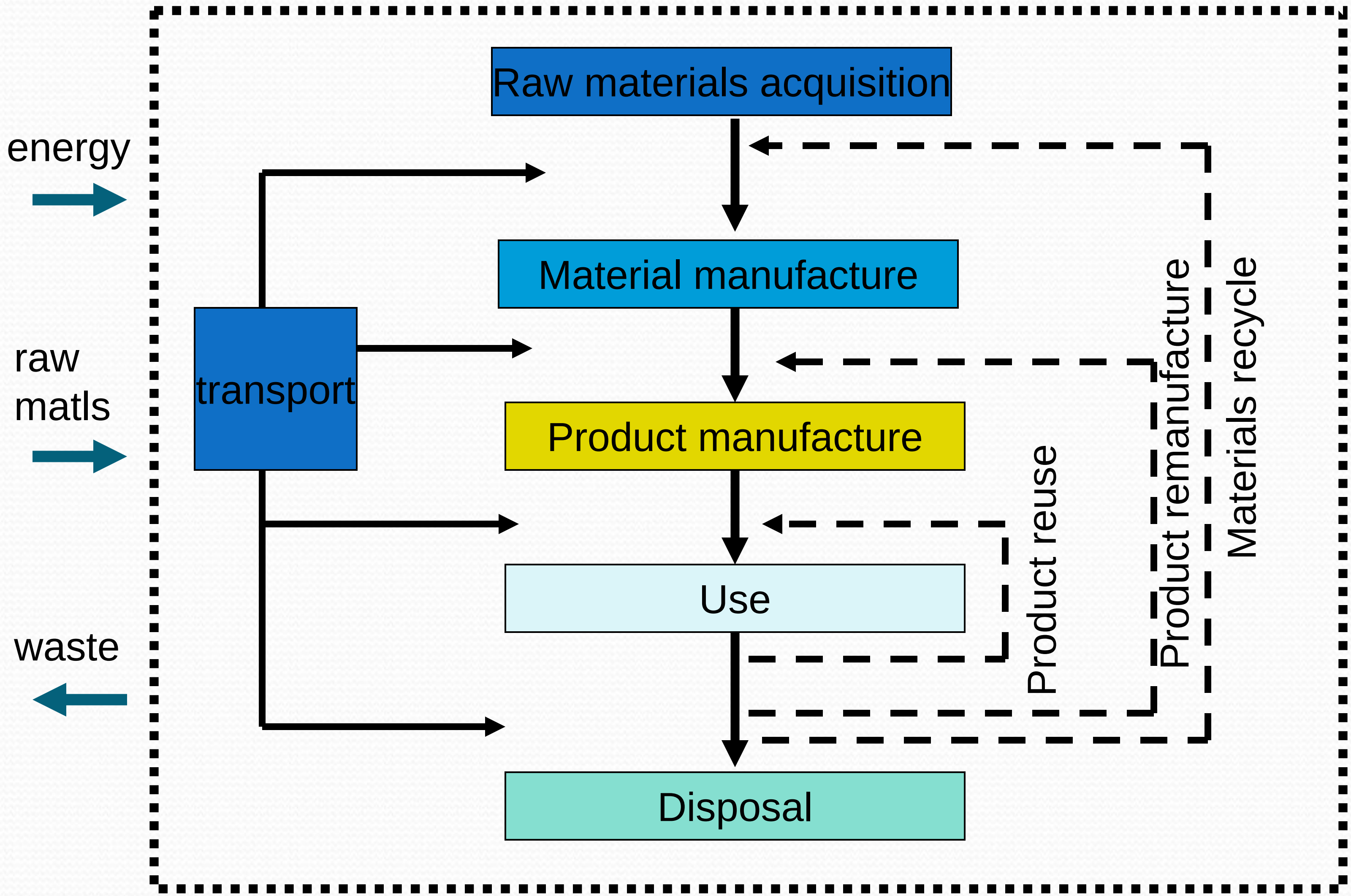
And to evaluate and implement opportunities to effect environmental improvements

(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



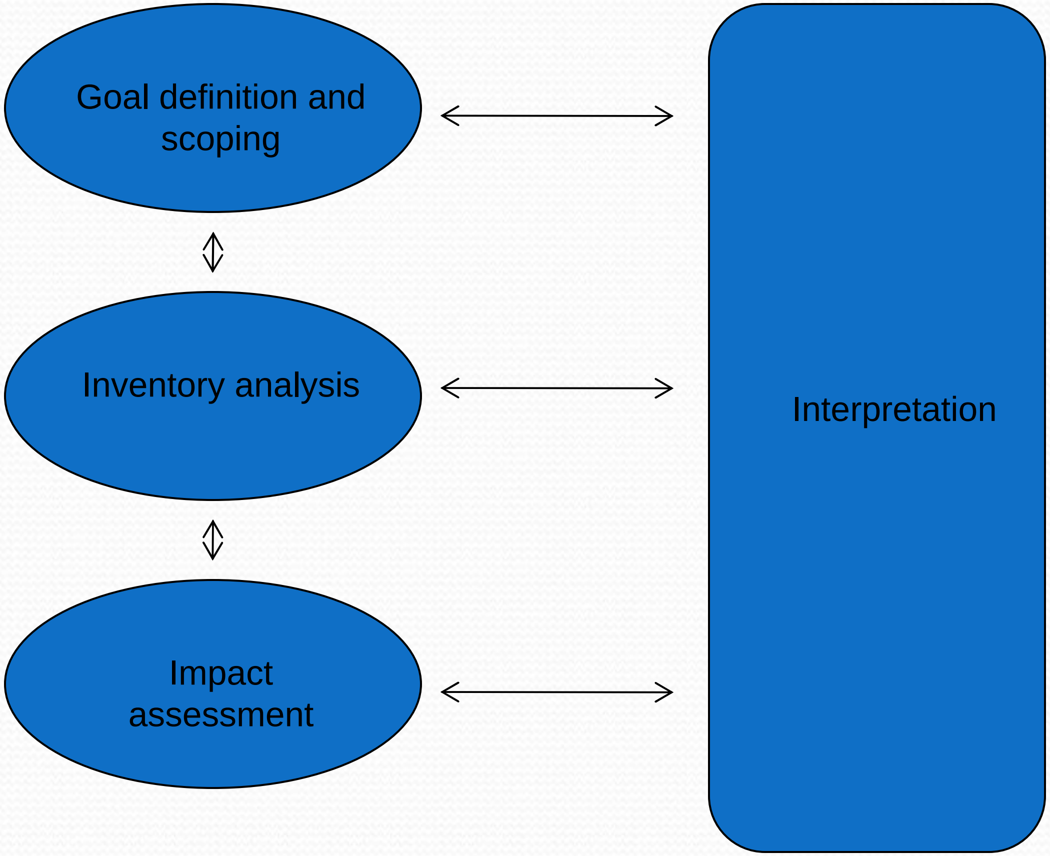
Product Life Cycle

- 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

- 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)

Functional Unit	number of functional units		
	12 oz aluminum can	16 oz. glass bottle	2-L PET bottle
holds 12 oz of soda	1	1.25	5.33
one container	1	1	1

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 CO_2?

Life Cycle Impact Categories

Exhibit 4-1. Commonly Used Life Cycle Impact Categories

Impact Category	Scale	Examples of LCI Data (i.e. classification)	Common Possible Characterization Factor	Description of Characterization Factor
Global Warming	Global	Carbon Dioxide (CO_2) Nitrogen Dioxide (NO_2) Methane (CH_4) Chlorofluorocarbons (CFCs) Hydrochlorofluorocarbons (HCFCs) Methyl Bromide (CH_3Br)	Global Warming Potential	Converts LCI data to carbon dioxide (CO_2) equivalents Note: global warming potentials can be 50, 100, or 500 year potentials.
Stratospheric Ozone Depletion	Global	Chlorofluorocarbons (CFCs) Hydrochlorofluorocarbons (HCFCs) Halons Methyl Bromide (CH_3Br)	Ozone Depleting Potential	Converts LCI data to trichlorofluoromethane (CFC-11) equivalents.
Acidification	Regional Local	Sulfur Oxides (SOx) Nitrogen Oxides (NOx) Hydrochloric Acid (HCL) Hydroflouric Acid (HF) Ammonia (NH_4)	Acidification Potential	Converts LCI data to hydrogen (H+) ion equivalents.
Eutrophication	Local	Phosphate (PO_4) Nitrogen Oxide (NO) Nitrogen Dioxide (NO_2) Nitrates Ammonia (NH_4)	Eutrophication Potential	Converts LCI data to phosphate (PO_4) equivalents.
Photochemical Smog	Local	Non-methane hydrocarbon (NMHC)	Photochemical Oxident Creation Potential	Converts LCI data to ethane (C_2H_6) equivalents.
Terrestrial Toxicity	Local	Toxic chemicals with a reported lethal concentration to rodents	LC_{50}	Converts LC_{50} data to equivalents; uses multi-media modeling, exposure pathways.
Aquatic Toxicity	Local	Toxic chemicals with a reported lethal concentration to fish	LC_{50}	Converts LC_{50} data to equivalents; uses multi-media modeling, exposure pathways.
Human Health	Global Regional Local	Total releases to air, water, and soil.	LC_{50}	Converts LC_{50} data to equivalents; uses multi-media modeling, exposure pathways.
Resource Depletion	Global Regional Local	Quantity of minerals used Quantity of fossil fuels used	Resource Depletion Potential	Converts LCI data to a ratio of quantity of resource used versus quantity of resource left in reserve.
Land Use	Global Regional Local	Quantity disposed of in a landfill or other land modifications	Land Availability	Converts mass of solid waste into volume using an estimated density.
Water Use	Regional Local	Water used or consumed	Water Shortage Potential	Converts LCI data to a ratio of quantity of water used versus quantity of resource left in reserve.

Potential Inconsistencies in LCA

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

Category	Example of Inconsistency
Data Source	Alternative A is based on literature and Alternative B is based on measured data.
Data Accuracy	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.
Data Age	Alternative A uses 1980's era raw materials manufacturing data. Alternative B used a one year-old study.
Technological Representation	Alternative A is bench-scale laboratory model. Alternative B is a full-scale production plant operation.
Temporal Representation	Data for Alternative A describe a recently developed technology. Alternate B describes a technology mix, including recently built and old plants.
Geographical Representation	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.
System Boundaries, Assumptions, & Models	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.

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

	Process-Based LCA	EIO-LCA
Advantages	results are detailed, process specific	results are economy-wide, comprehensive assessments
	allows for specific product comparisons	allows for systems-level comparisons
	identifies areas for process improvements, weak point analysis	uses publically-available data, reproducible results
	provides for future product development assessments	provides for future product development assessments
		provides information on every commodity in the economy
Disadvantages	setting system boundary is subjective	product assessments contain aggregate data
	tend to be time intensive and costly	process assessments difficult
	difficult to apply to new process design	availability of data for complete environmental effects
	uses proprietary data	difficult to apply to an open economy (with substantial non-comparable imports)
	cannot be replicated if confidential data are used	uncertainty in data
	uncertainty in data	

Questions?