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Life Cycle Assessment (LCA) - Overview

Dr. David E. Meyer, Dr. Mary Ann Curran (Retired)

Meyer.David@epa.gov

Office of Research and Development
National Risk Management Research Laboratory, Sustainable Technology Division, Systems Analysis Branch

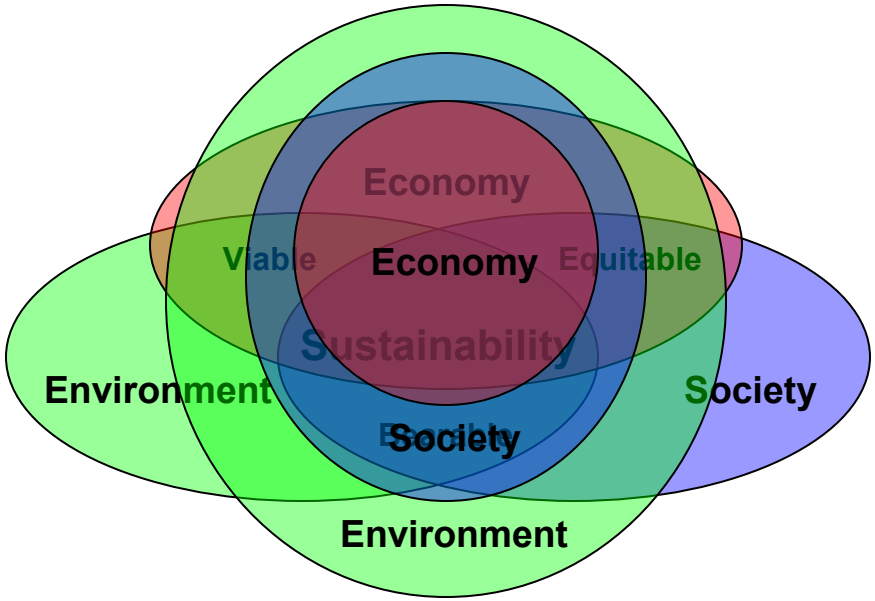
Outline

- **Who Am I (Bio)**
- **Sustainability and Environmental Assessment**
  - *Why consider Life Cycle Assessment (LCA)?*
- **LCA 101**
  - *Defining LCA*
  - *The ISO Approach*
  - *Results example:*
    Which type of display device?
  - *Pros and Cons*
- **LCA and Decision Making**
- **The Take Home Message**
- **Discussion**

Who Am I?

- Hometown: Flatwoods, KY
  - A Tale of “Un”-sustainability
- 2000: B.S. in Chemical Engineering, University of Kentucky
  - From future “process” engineer to “environmental” engineer
- 2005: Ph.D. in Chemical Engineering, University of Kentucky
  - Synthesis and modeling of nanocomposite membranes for groundwater remediation
  - NSF IGERT Fellow (Sensor Design)
- 2006 – 2008: Post-Doc
  - Groundwater remediation (UK)
  - Mercury removal from coal-fired power plants (UK)
- 2008 – 2010: Federal Post-Doc (FTE as of 6/20/2010)
  - Life cycle assessment of nanotechnologies (US EPA)
  - Green membrane systems for environmental applications (US EPA)
  - Reactor modeling of green processes (US EPA)
- 2010 – Present: Chemical Engineer (US EPA)

Pursuing Sustainability



The pursuit of sustainability is a complex endeavor that involves the simultaneous balancing of environmental and socioeconomic impacts with the perceived benefits throughout the life cycle of products and processes to provide for future existence. This can only be accomplished by integrating sustainable thinking early in technology development.

The Life Cycle

The product life cycle of a chemical provides a broader understanding of chemical risk by considering all impacts of the product during material extraction, manufacturing, distribution, use, disposal/recycle.

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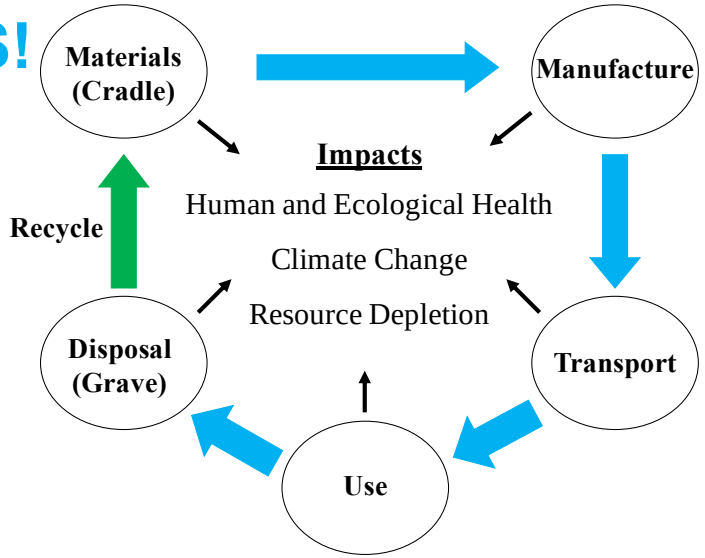
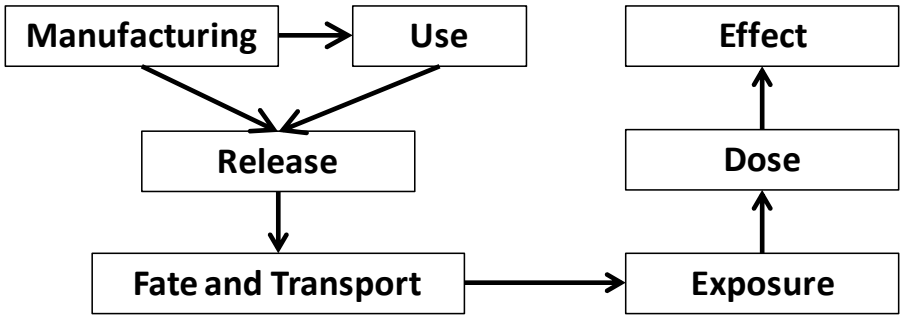


NOT THIS!

Life Stages

or

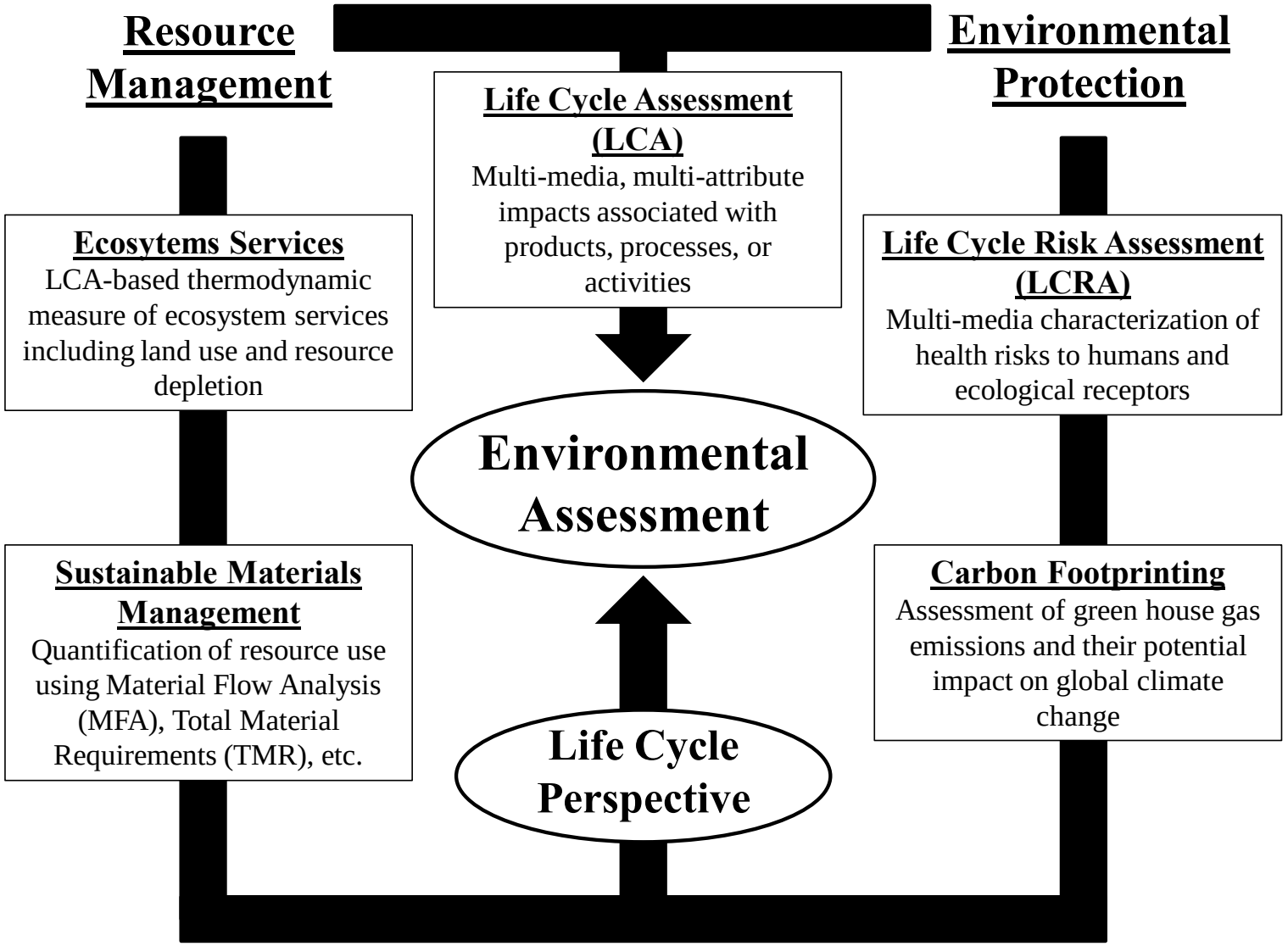


Chemical Health Risk

Assessing Environmental Impact

- There are many questions regarding the impact of products during their manufacture, use, disposal and/or potential recycle.
  - Are there material resources to support global-scale production of products?
    - *Shortage of Rare Earth Metals?*
  - How stable are chemical components across the life cycle of a product?
    - *Nanomaterials?*
  - If chemicals are released during a product life cycle, will they affect ecosystems?
- Multiple tools addressing environmental concerns:
  - **Life Cycle Assessment (LCA)**
  - **Risk Assessment (RA/LCRA)**
  - Thermodynamic Analysis (Emergy/Exergy Flow)
  - Comprehensive Environmental Assessment (CEA)
  - Misc. (Green Factors, Carbon Footprinting, etc.)

Putting the Tools Together…

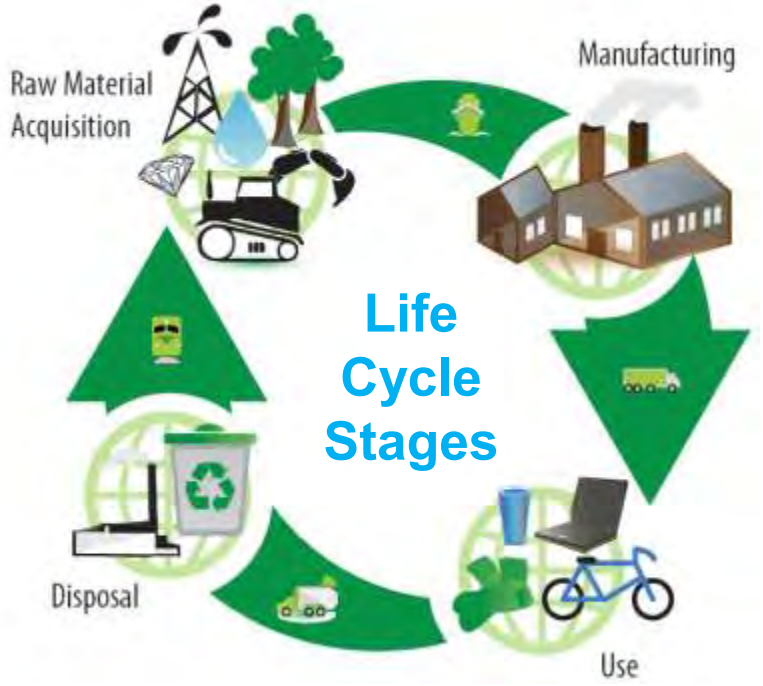


Life Cycle Assessment

An **industrial** environmental management approach to look **holistically and comprehensively** at products, processes, and activities.

Life Cycle Assessment is…

- The identification and quantification of natural resource usage and releases to the environment across all stages of the life cycle;
- The assessment of the potential environmental impacts of these material uses and releases;
- The identification of opportunities to reduce environmental burdens and achieve system-wide improvements.



ISO Standards for LCA

ISO provides a standardized methodology for conducting multi-media, cradle-to-grave environmental assessments:

ISO 14040 “Life Cycle Assessment – Principles and Framework” 2006

ISO 14044 “Life Cycle Assessment – Requirements and Guidelines” 2006

ISO 14040 and 14044

Goal & Scope Definition:

- Determine the scope and system boundaries

Life Cycle Inventory:

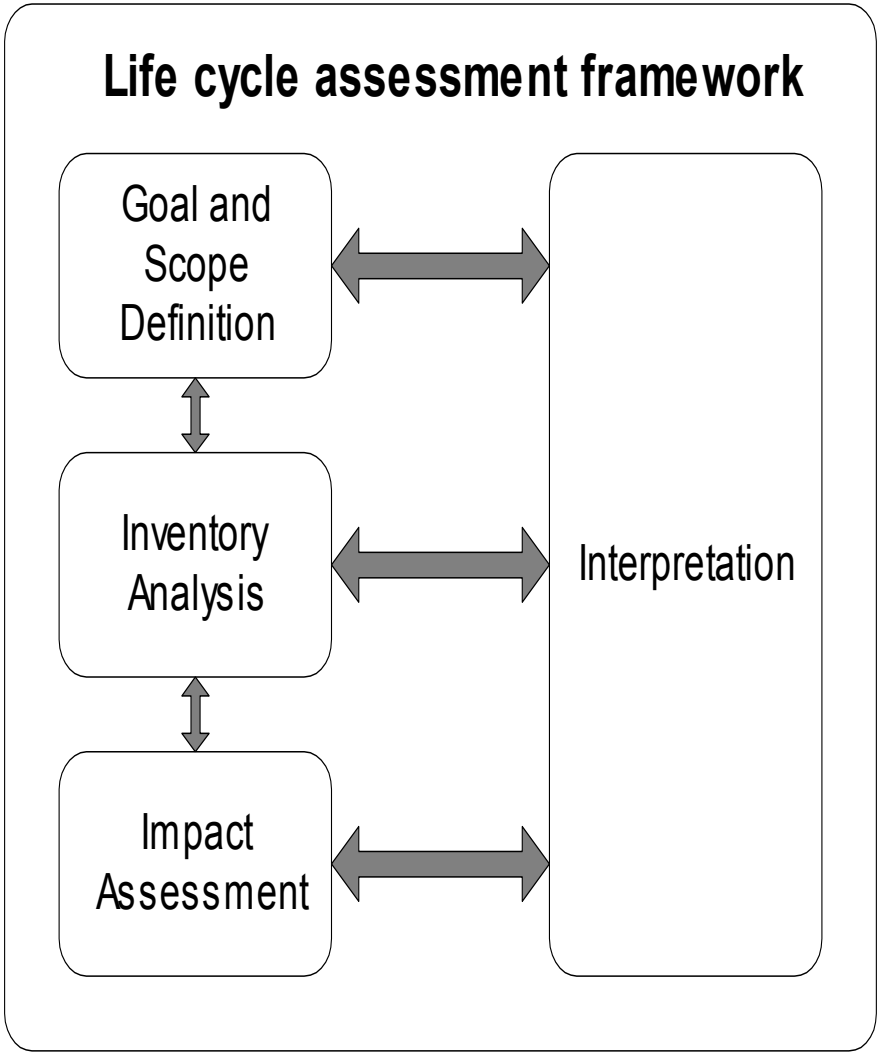
- Data collection, modeling & analysis

Impact Assessment:

- Analysis of inputs/outputs using category indicators
- Group, normalize, weight results

Interpretation:

- Draw conclusions
- Checks for completeness, contribution, sensitivity analysis, consistency w/goal and scope, analysis, etc.



Unintended Consequences

How environmentally friendly are plant-based products on a life-cycle basis?

Full Life Cycle Assessment: Avoiding Burden Shifting

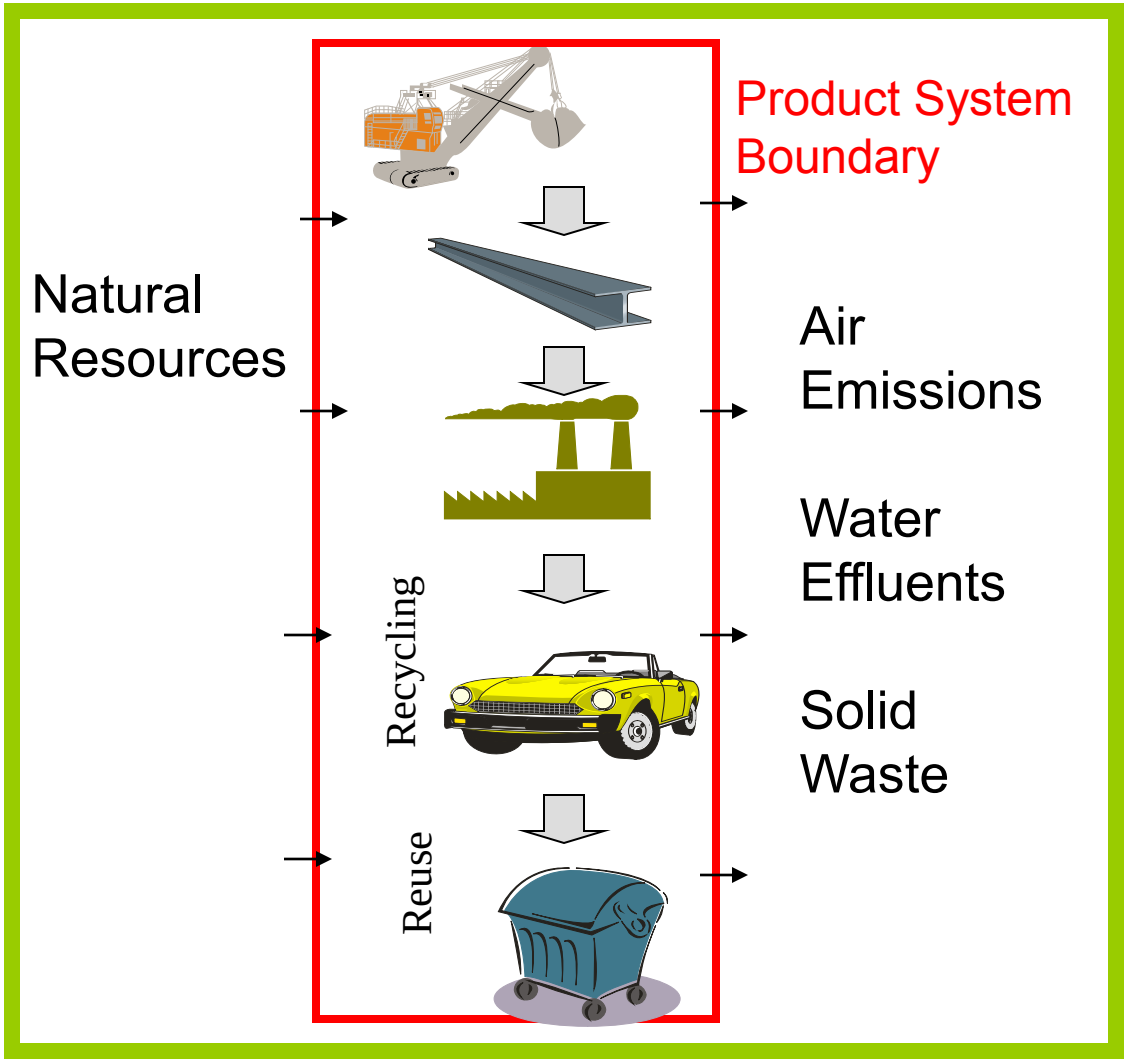
Raw Material Acquisition

Material Processing

Production

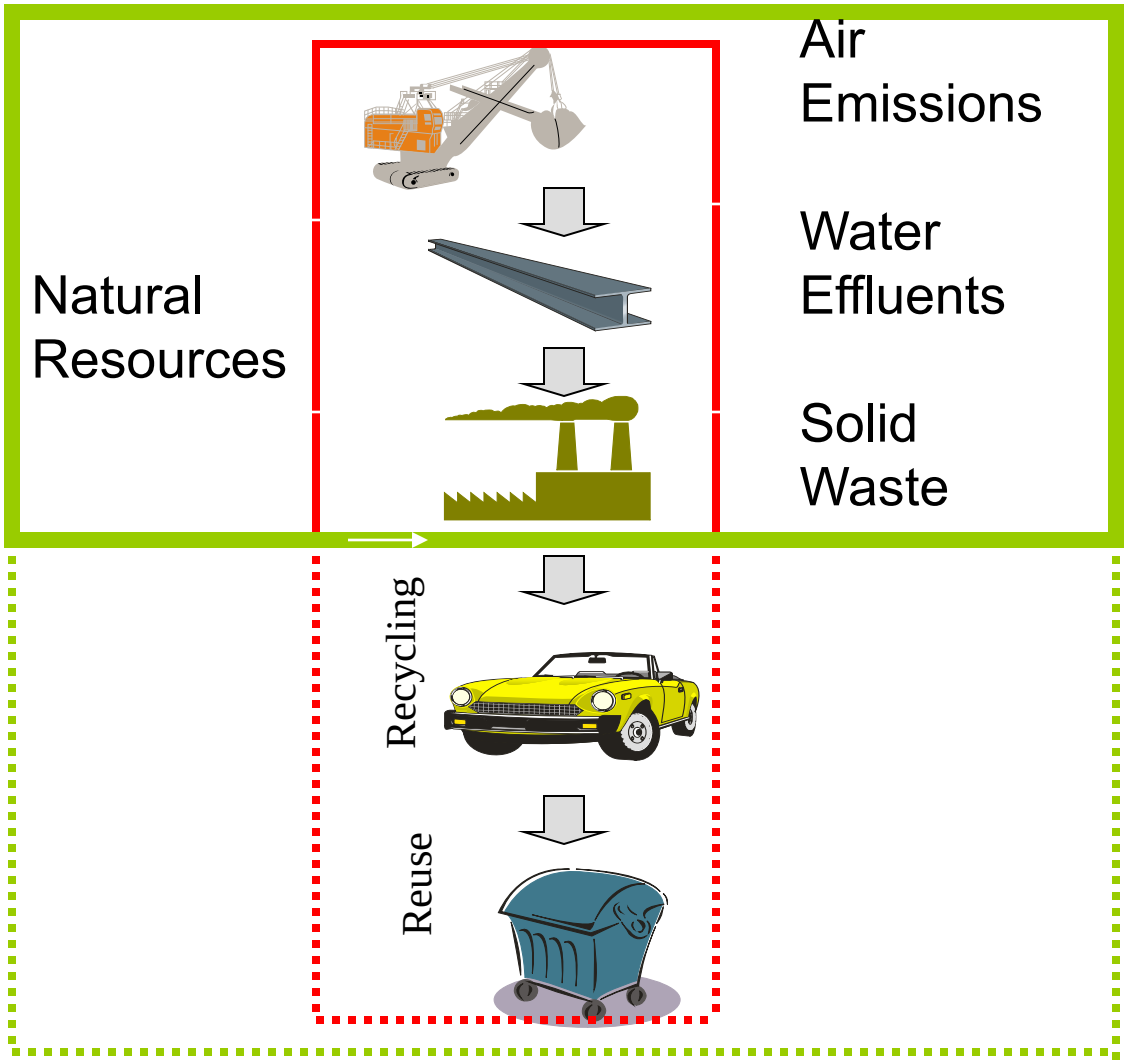
Use and Maintenance

End-of-Life Management

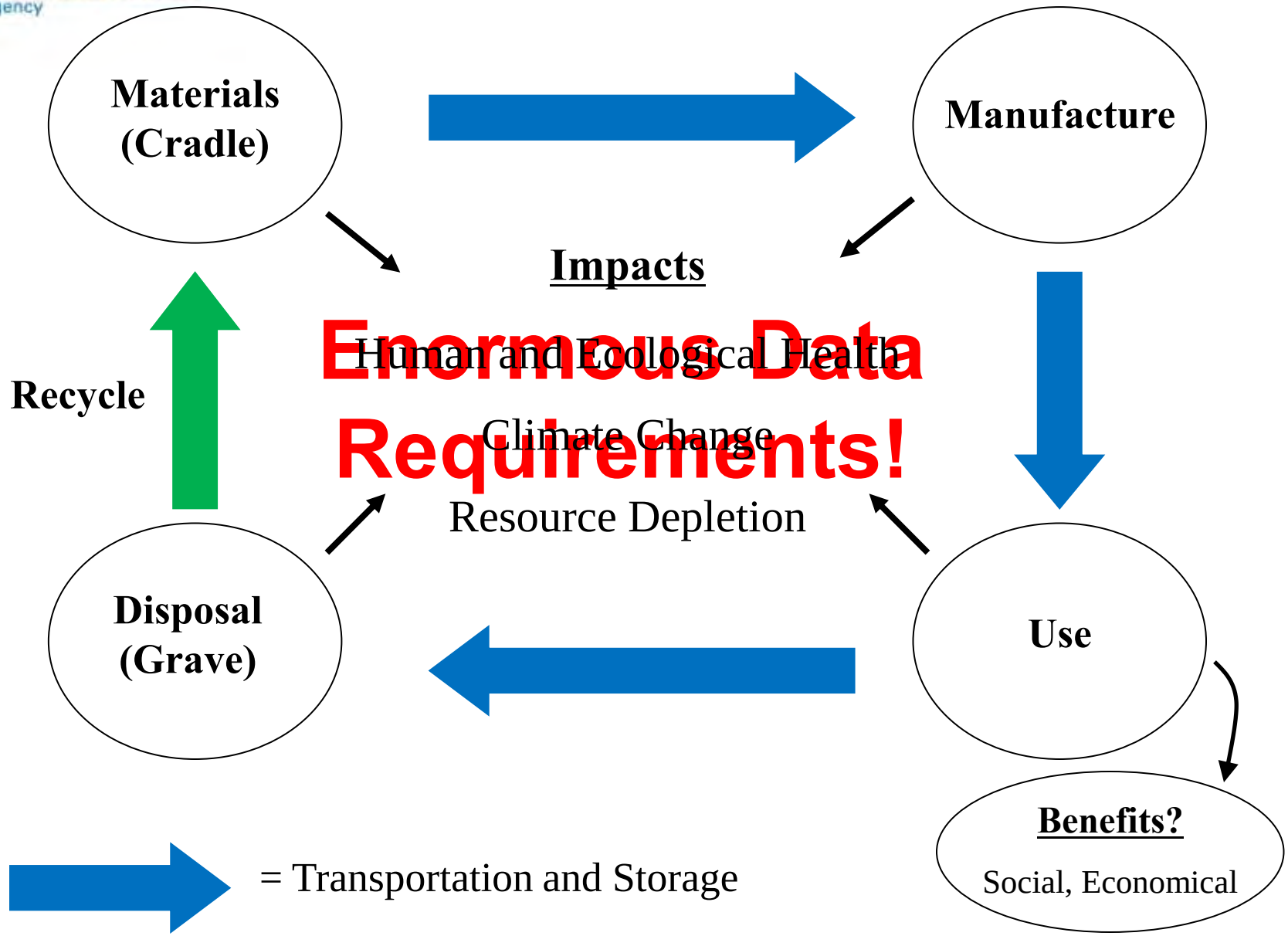


Cradle-to-Gate Studies*

Cradle to Gate:
Exclude downstream activities past product manufacture – but conclusions must relate to what was studied and not be overstated.
*Such studies are helpful in improving the product supply chain but may miss important impacts that occur during use and at end of life.



Life Cycle Assessment



Goal & Scope Definition

The results of an LCA can be used for many purposes, for example:

- Product Comparison ("Comparative Assertion" is required by ISO to undergo peer review).
- Develop a Baseline of environmental and human health consequences associated with a given product, process or activity.
- Identify Opportunities for System Improvement.
- Policy Development (Private and Public Policy).
- Provide the Basis for Eco-Labeling.
- Etc.

A clearly defined goal:

- Determines the scope of the study
- Sets the boundaries and scale
- Identifies the product or process function
- Sets the Functional Unit (important for comparing equivalent systems).
- Defines the level of data detail & quality

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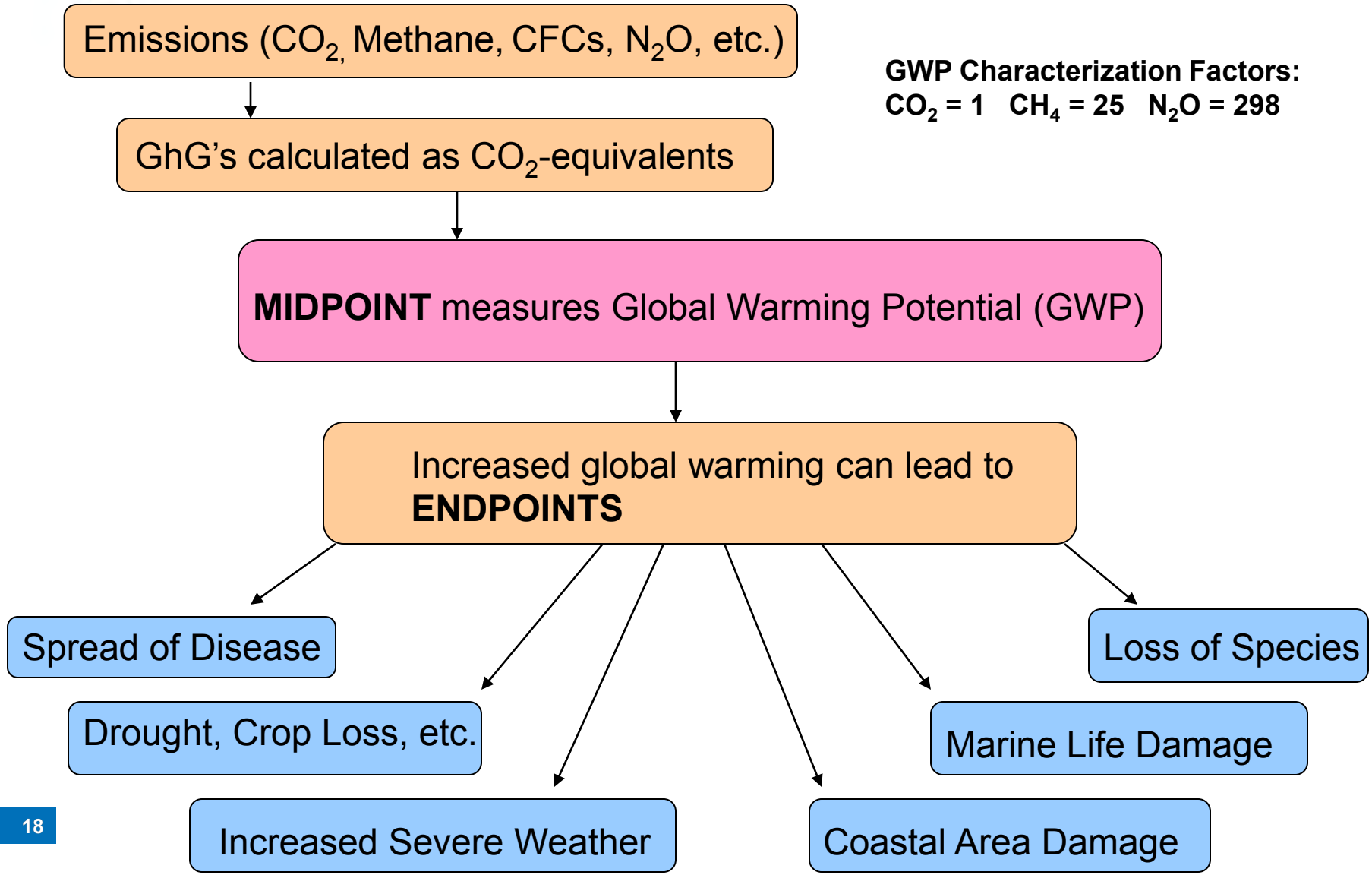
Life Cycle Inventory (LCI)
Modeling Input/Output Data

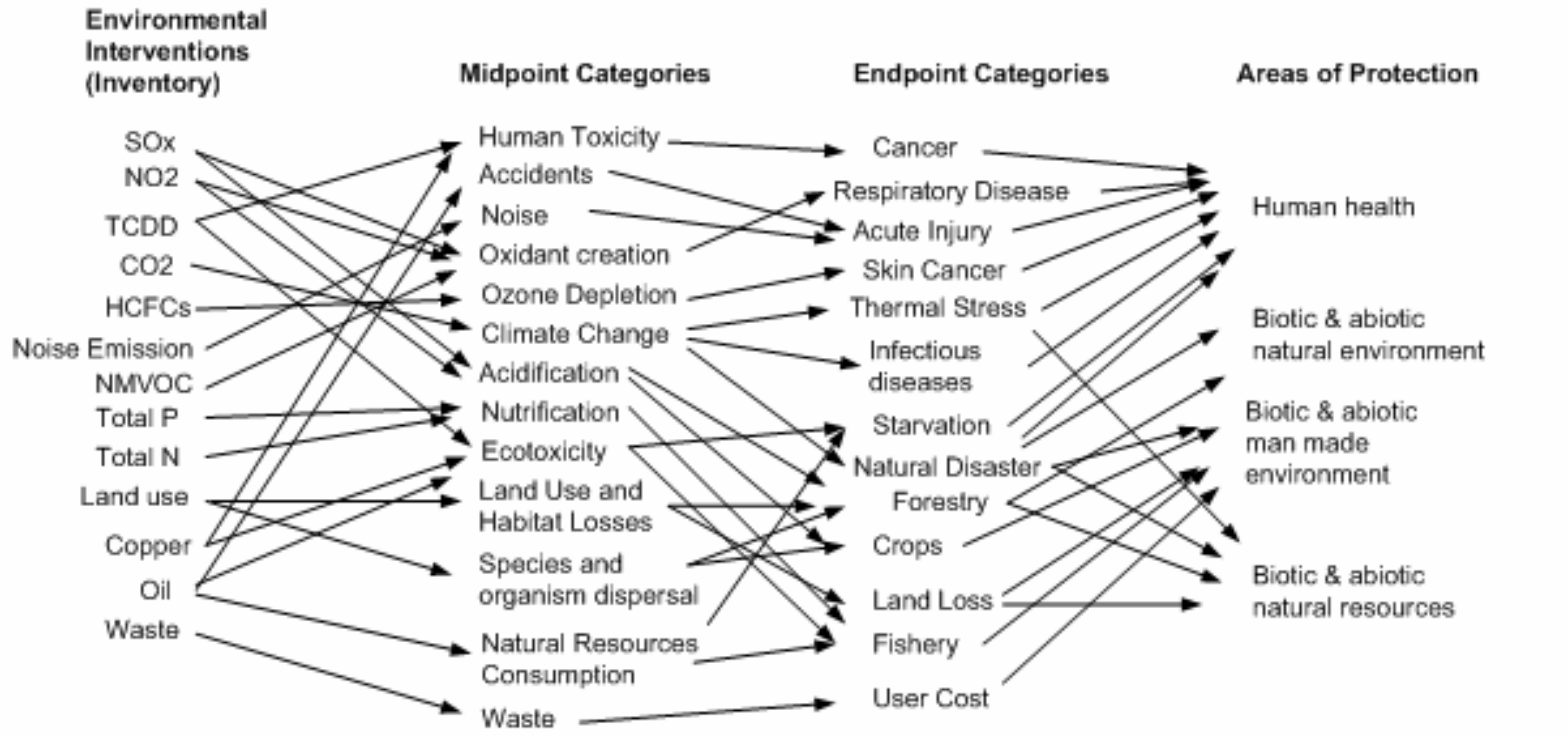
- The goal is to account for all material and natural resource inputs and outputs to the environment for each process within the system.
- At times, a manufacture may have process-specific data but need the upstream and downstream data.
- Data are usually presented as highly aggregated averages to represent an industrial average.
- Application of assumptions, rules of exclusion, etc., must be transparent.

Life Cycle Impact Modeling: Midpoints and Endpoints



GWP Characterization Factors:
CO_2 = 1 CH_4 = 25 N_2O = 298

Life Cycle Impact Categories



From Jolliet et al. (2004) The LCIA Midpoint-damage Framework of the UNEP/SETAC Life Cycle Initiative, *IJLCA* **9** (5) 394-404.

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Calculating an Environmental Score

Σ Impact Indicator **x** Normalization **x** Valuation

the measure of a potential impact, usually given in units of equivalents

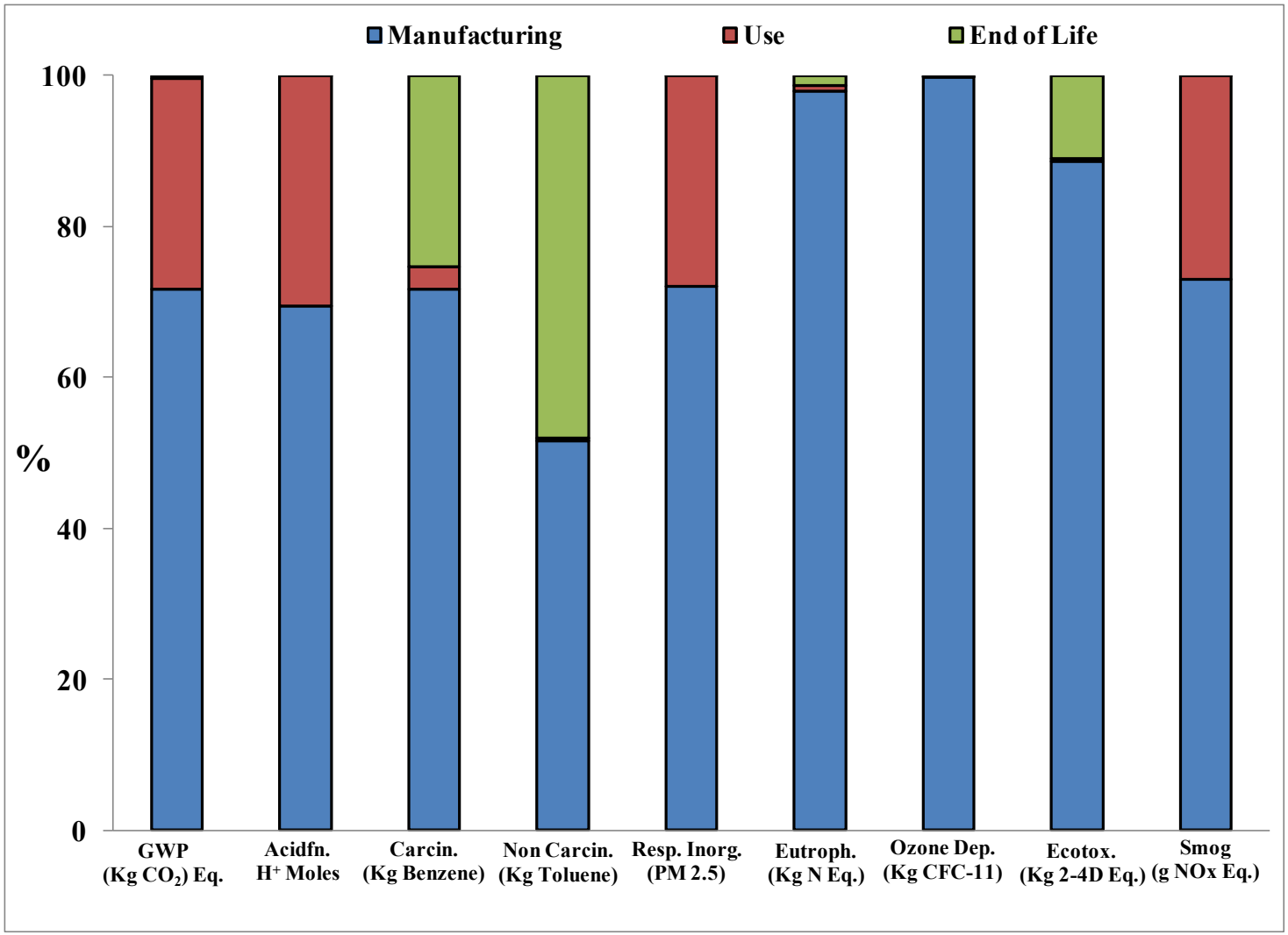
the magnitude of an indicator result relative to a reference

numerical factors based on the decision maker's value choices

= Score

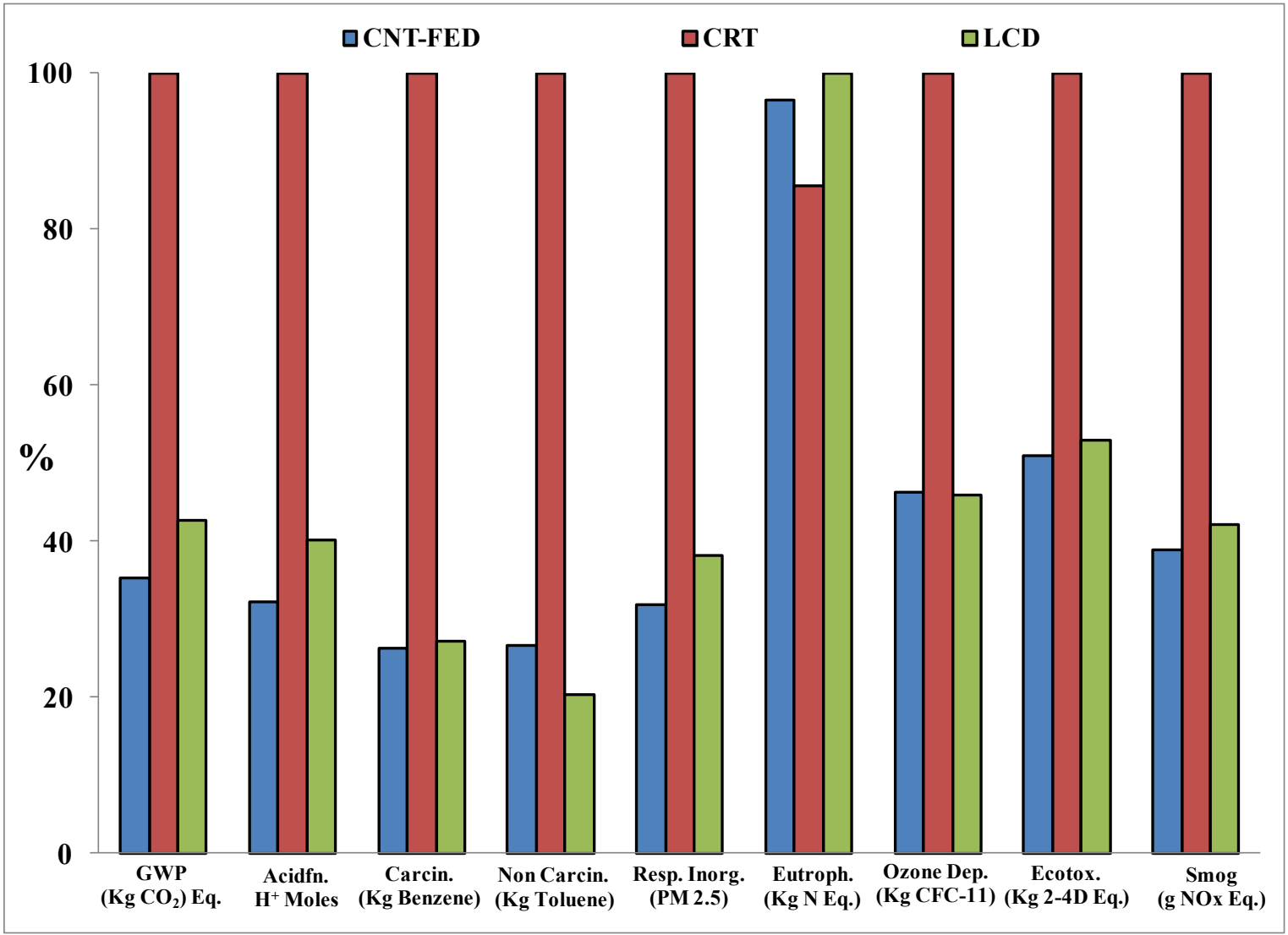
Sample LCIA Results: Stage Analysis

Screening Level Cradle-to-Grave LCIA Results for a CNT-FED



Sample LCIA Results: Comparative Analysis

Comparison of Three Electronic Displays Based on Manufactured Life



LCIA versus RA

Life Cycle Impact Assessment (LCIA) characterizes emissions over a product's life cycle; it reports emissions at an aggregated level and for a chosen functional unit basis.

Risk Assessment (RA) characterizes the nature and magnitude of health risks to humans and the environment from potential chemical contaminants and other stressors at the site-specific level.

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An Effective Life Cycle Assessment

- Examines system-wide effects (cradle-to-grave)
- Analyzes multi-media (air, water, waste, etc.)
- Analyzes multi-attributes (all impacts)
- Helps identify *trade-offs* among alternatives
- Identifies opportunities for *improvement*
- Supports environmental decision making
- Provides the cornerstone of Sustainability

Conducting an LCA:

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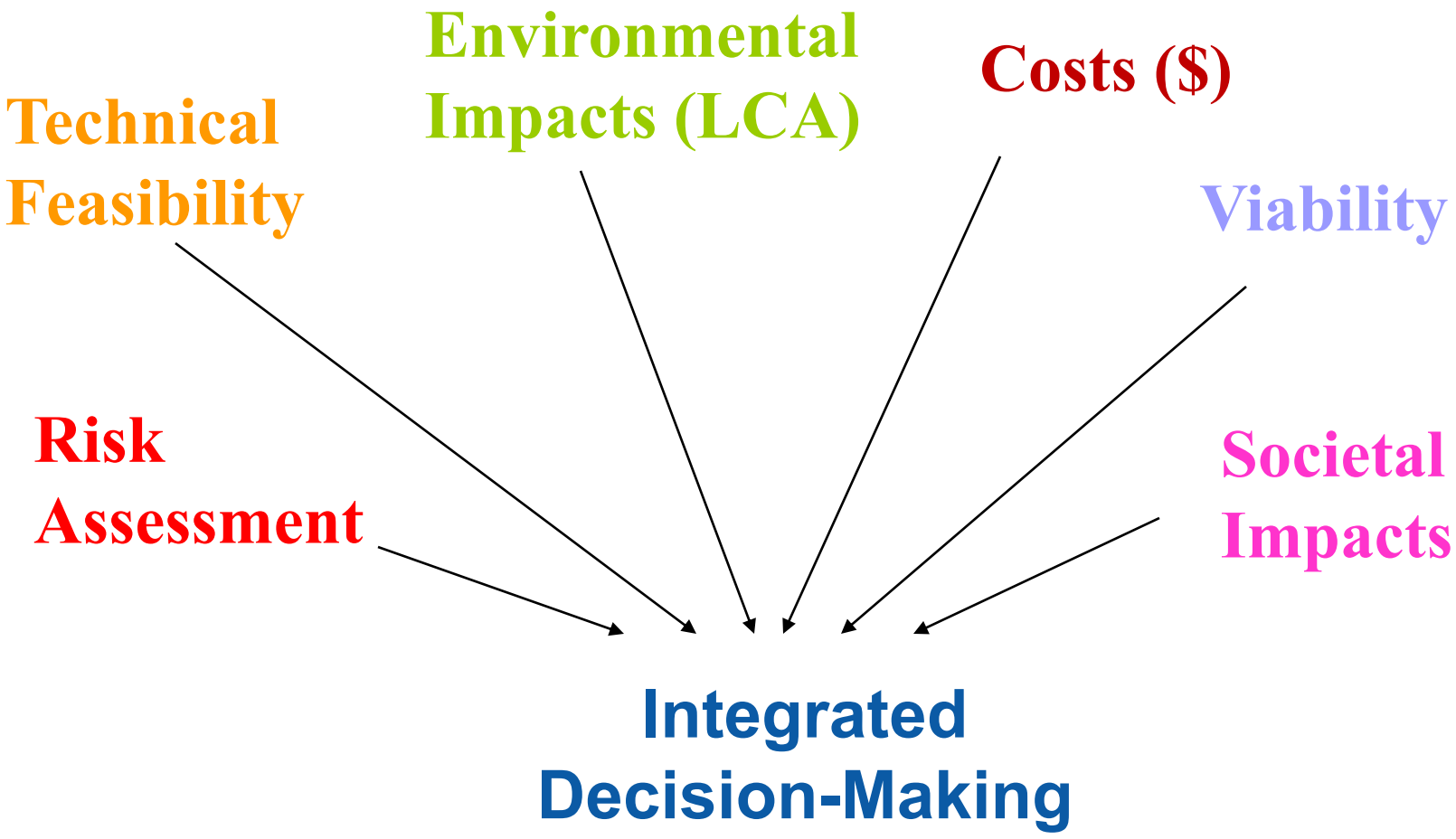
Weaknesses

- LCA can be very resource and time intensive especially in gathering the inventory data.
- Life cycle impact assessment models vary.
- Additional impact data are needed, especially for new frontiers, such as nanotechnology.
- All assumptions or decisions made throughout the study must be reported. If not, the final results may be taken out of context or misinterpreted.

Strengths

- LCA is a holistic, comprehensive analysis of a product, process, or activity.
- It can provide structure to the investigation to determine the potential environmental impacts of an industrial system.
- It highlights potential environmental tradeoffs.
- At times, it provides information that challenges conventional wisdom
- It captures the knowledge base.
- It fosters better communication and discourse among decision makers.

LCA is One Part of the Decision Making Process



In a Nutshell: The Take Home Message

- LCA is a standardized method of evaluating the environmental impacts across a product life cycle.
- A holistic view of the full product life cycle is necessary to avoid burden shifting and unintended consequences.
- LCIA results will only be as good as the collected LCI data and underlying impact models.
- LCA is only a piece of the puzzle when making informed decisions for sustainability.

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Feel Free to Discuss!

"A single conversation across the table with a wise person is worth a month's study of books"

- Chinese Proverb