Leveraging Variation and Uncertainty in Environmental Footprinting

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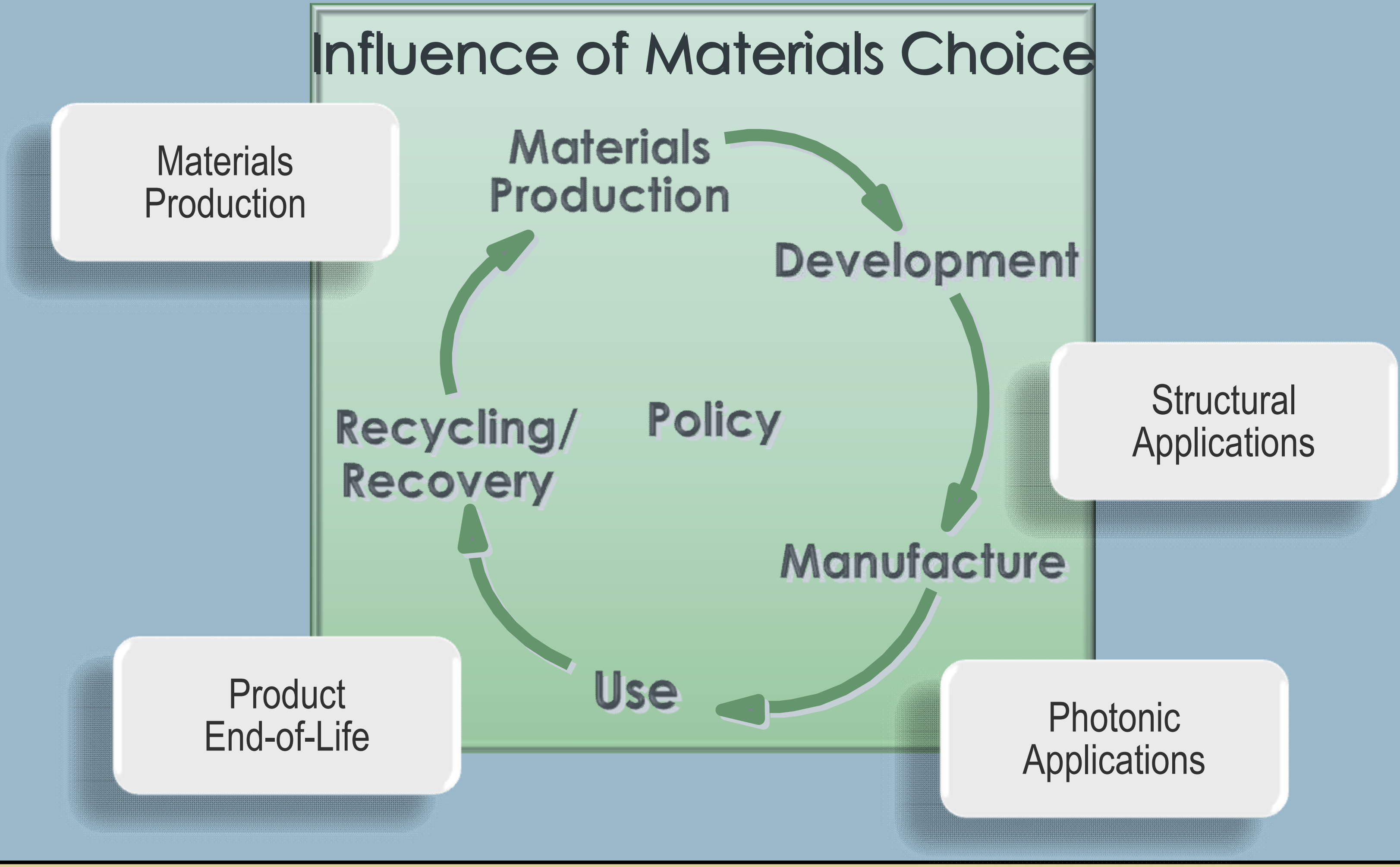
Focus: strategic properties of materials and process technologies

- **Organizational Structure**
  - **MIT School of Engineering**
    - MIT Department of Materials Science & Engineering
    - Engineering Systems Division
  - **Part of several larger MIT Research Centers**
    - Materials Processing Center
    - Center For Technology, Policy & Industrial Development
    - MIT Energy Initiative
- **Joint work with numerous corporate, government, academic, and industrial consortia**
- **2 professors, 3 researchers, 2 postdocs, 15 graduate students**

MSL Scope of Work: Topics & Domains



The Role of Uncertainty: Background

- **Overarching research question:**
  - **How robust is the LCA method for materials selection?**
    - Early in the design cycle
  - **What characteristics of a case / problem weaken the robustness of the method?**
- **Focal issues**
  - **Scope**
  - **Closed-loop Allocation**
  - **Inventory**
    - Uncertainty is a real, significant, and unavoidable aspect of the life-cycle inventory
- **Specific question:**
  What role does inventory uncertainty play in effective life-cycle assessment (footprinting)?

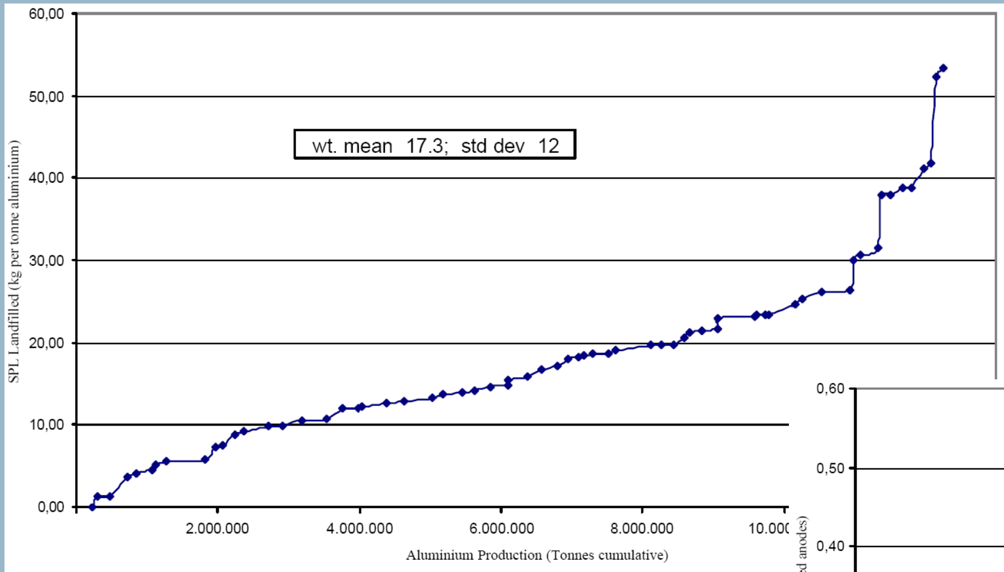
The Opportunity to Leverage Uncertainty Information

- Effectively characterizing inventory uncertainty should
  - Improve efficiency of analysis
  - Identify targets for improvement
- Efficiency
  - Often, most of the impact for a product is tied to a few decisions
  - Without any understanding of uncertainty, it is challenging to know how few
- Targets
  - Depending on source of uncertainty, it may be possible to know whether supply-chain or design change is effective

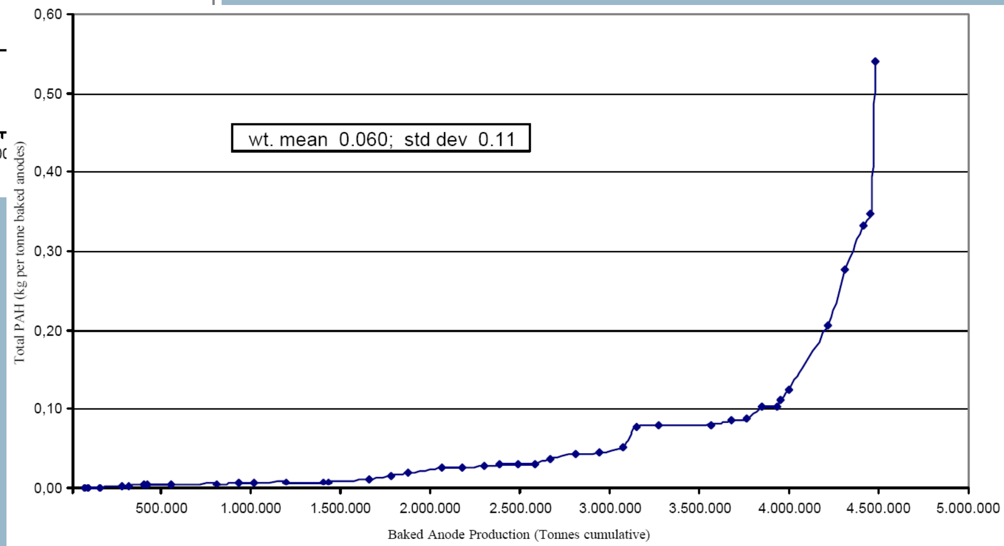
Issue 1:
Significant Variation Exists in the Environmental Performance of Real-world Processes

Significant Variation Exists in the Real-world:
Examples from a Global Survey of Al Production

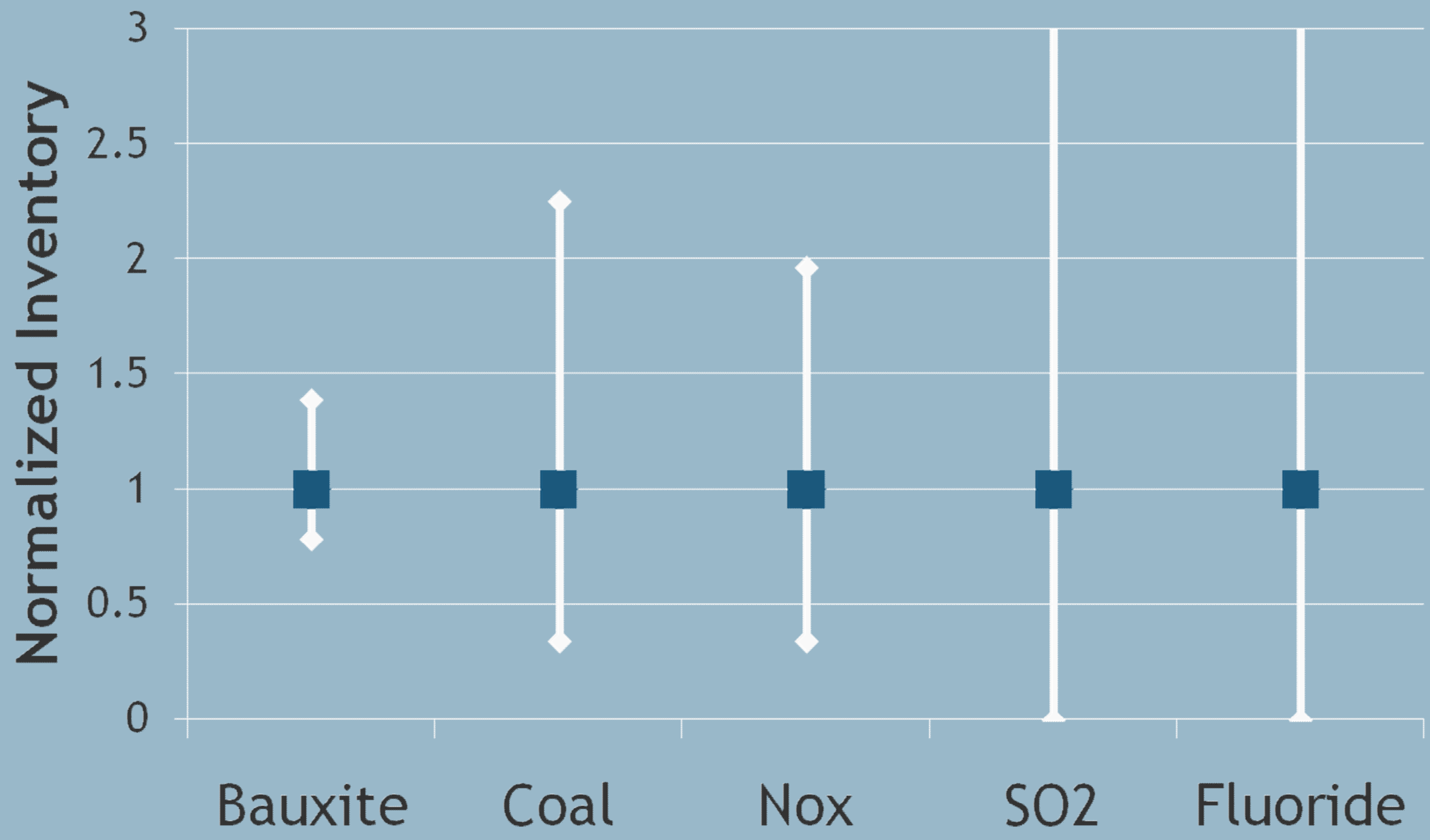
Solid Waste



PAH Emissions

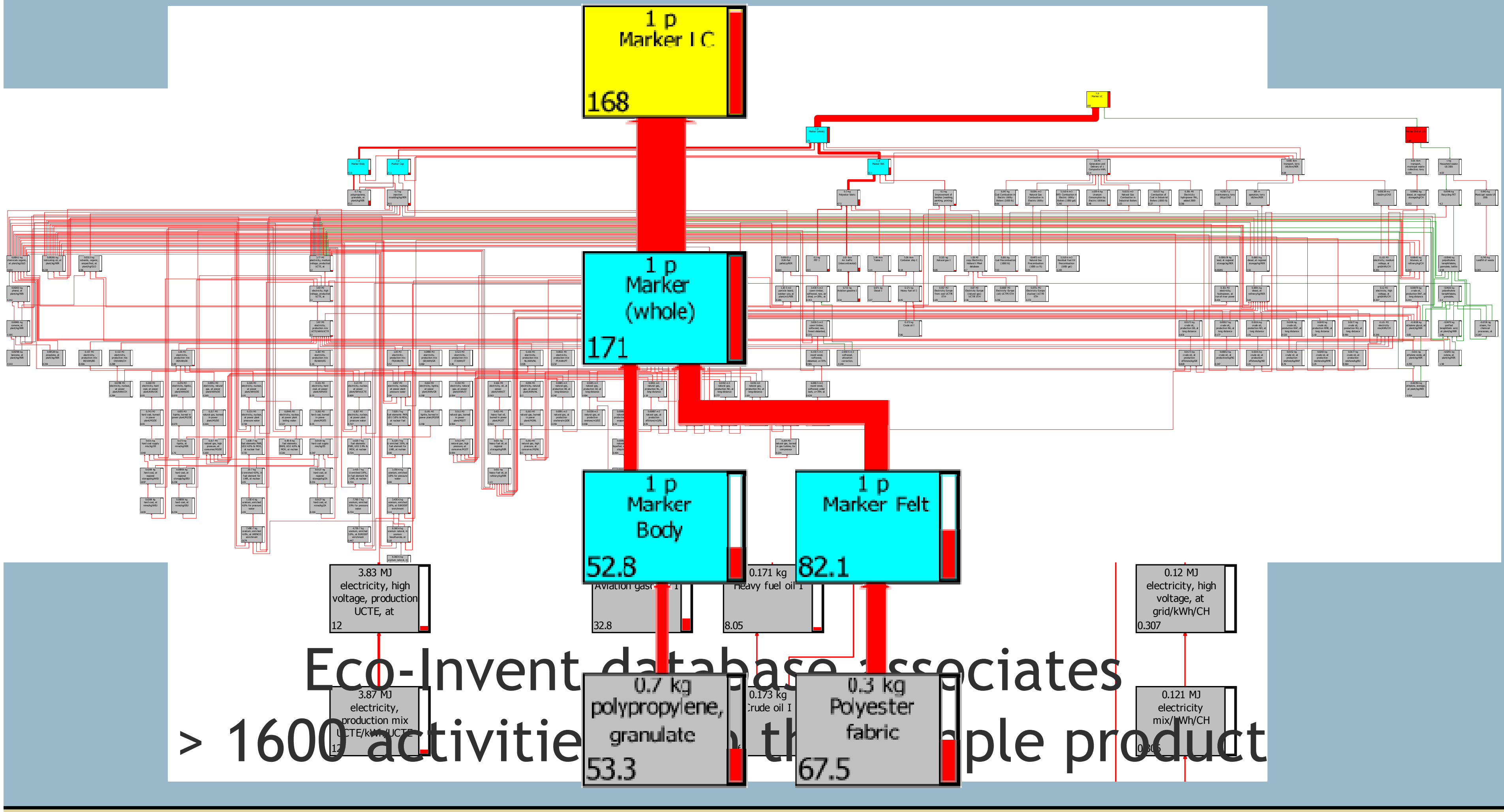


Significant Variation Exists in the Real-world:
Examples from a Global Survey of Al Production



Issue 2:
Conventional Life-cycle Assessment Requires Significant Resources

Resource Requirement of LCA: An Example from a 3 Component Marker



Eco-Invent database associates > 1600 activities to the example product

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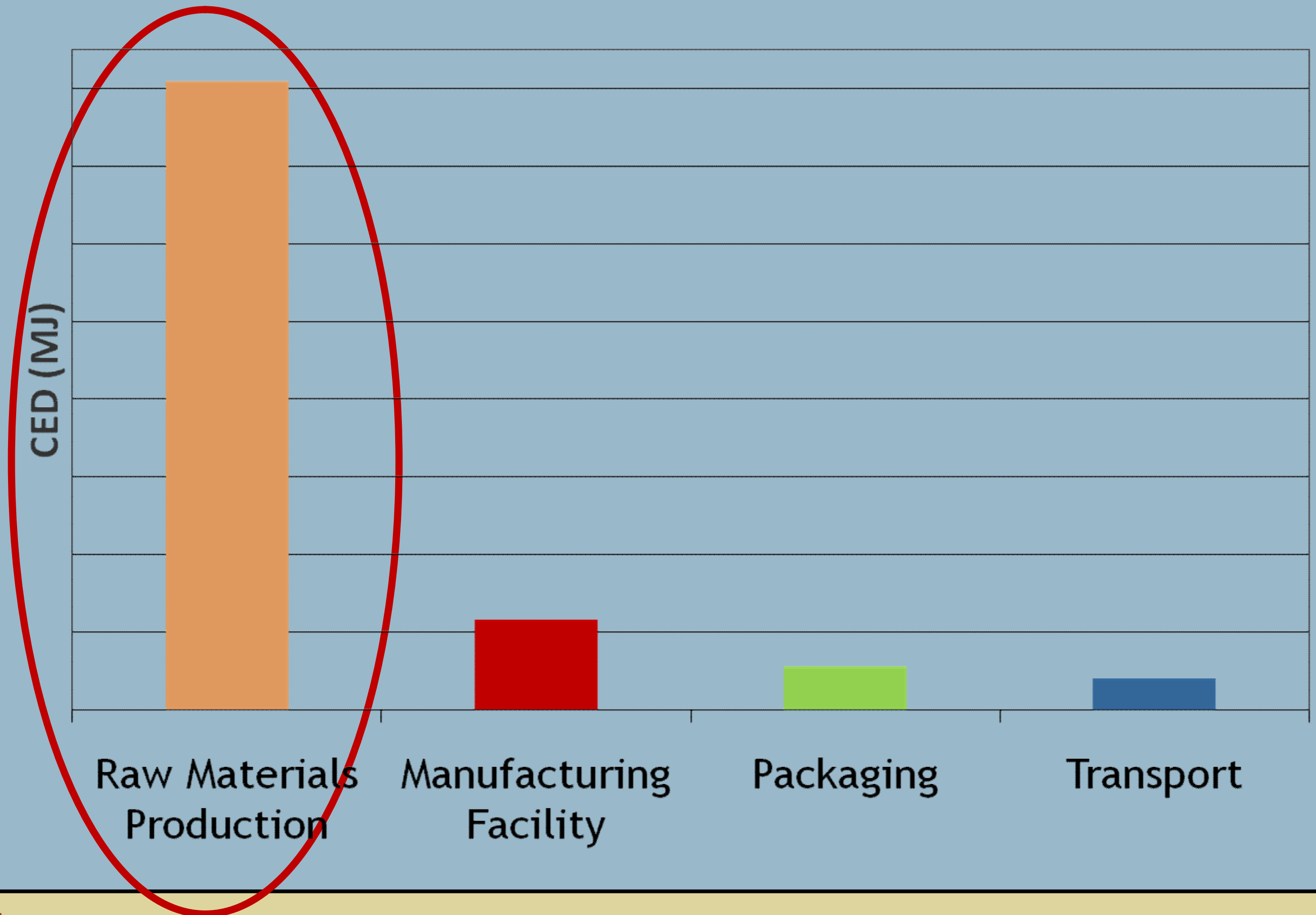
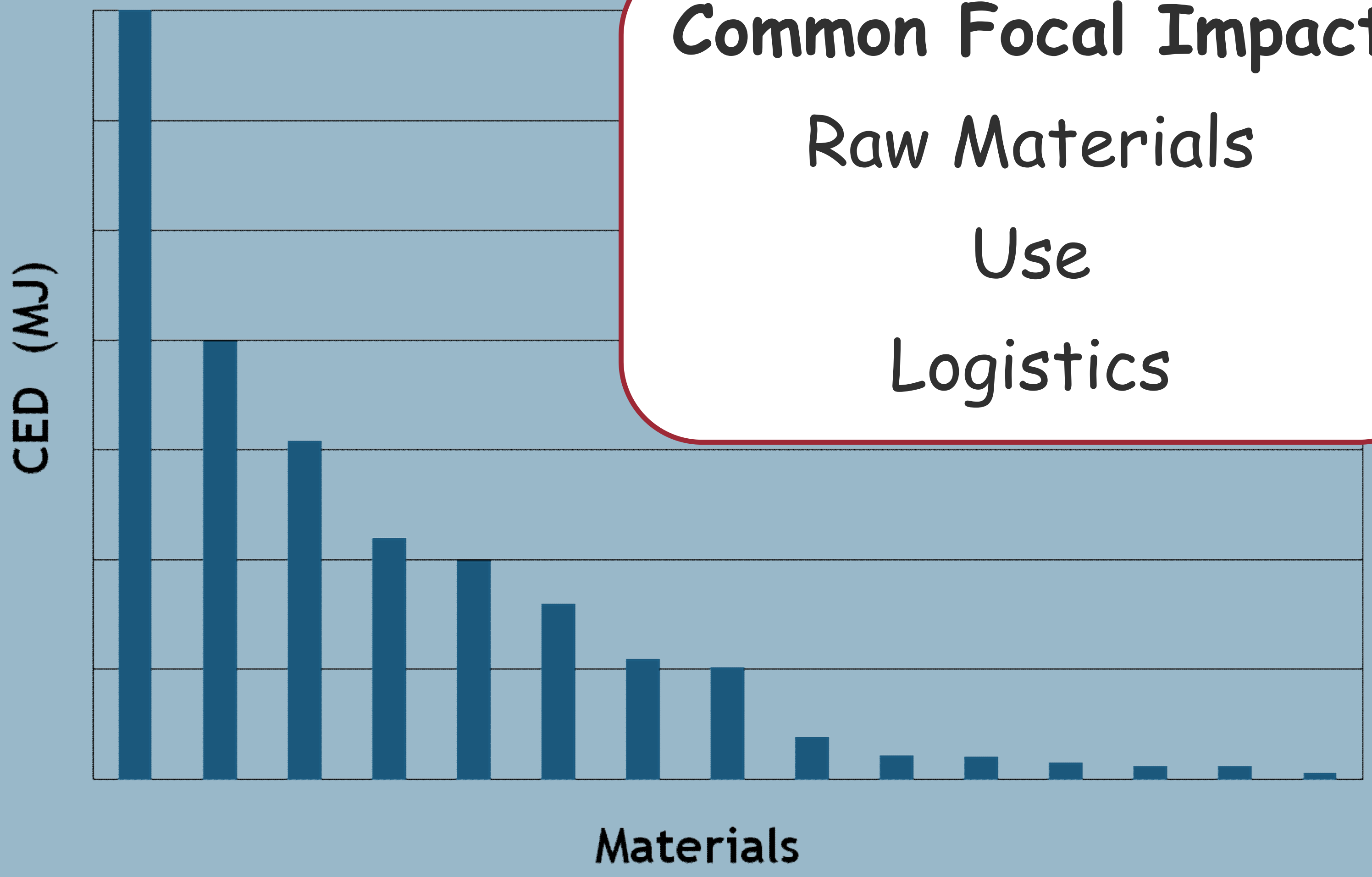
Issue 3:
Inventory Often Dominated by a Few Activities

Effects Often Isolated for a Given Product:
Recent Study of a Consumer Product



Even within Raw Materials, Impact is Focused

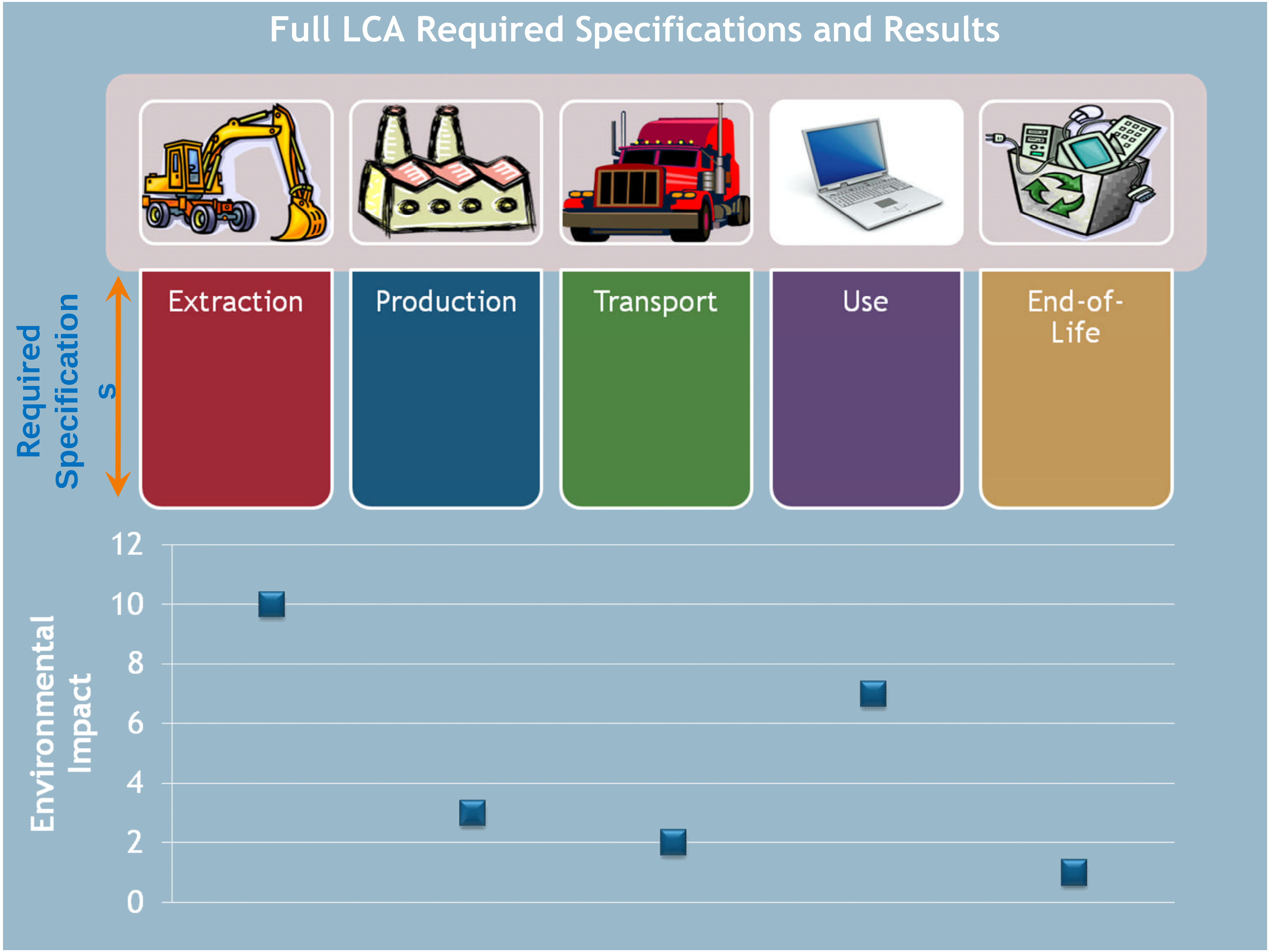


Common Focal Impact

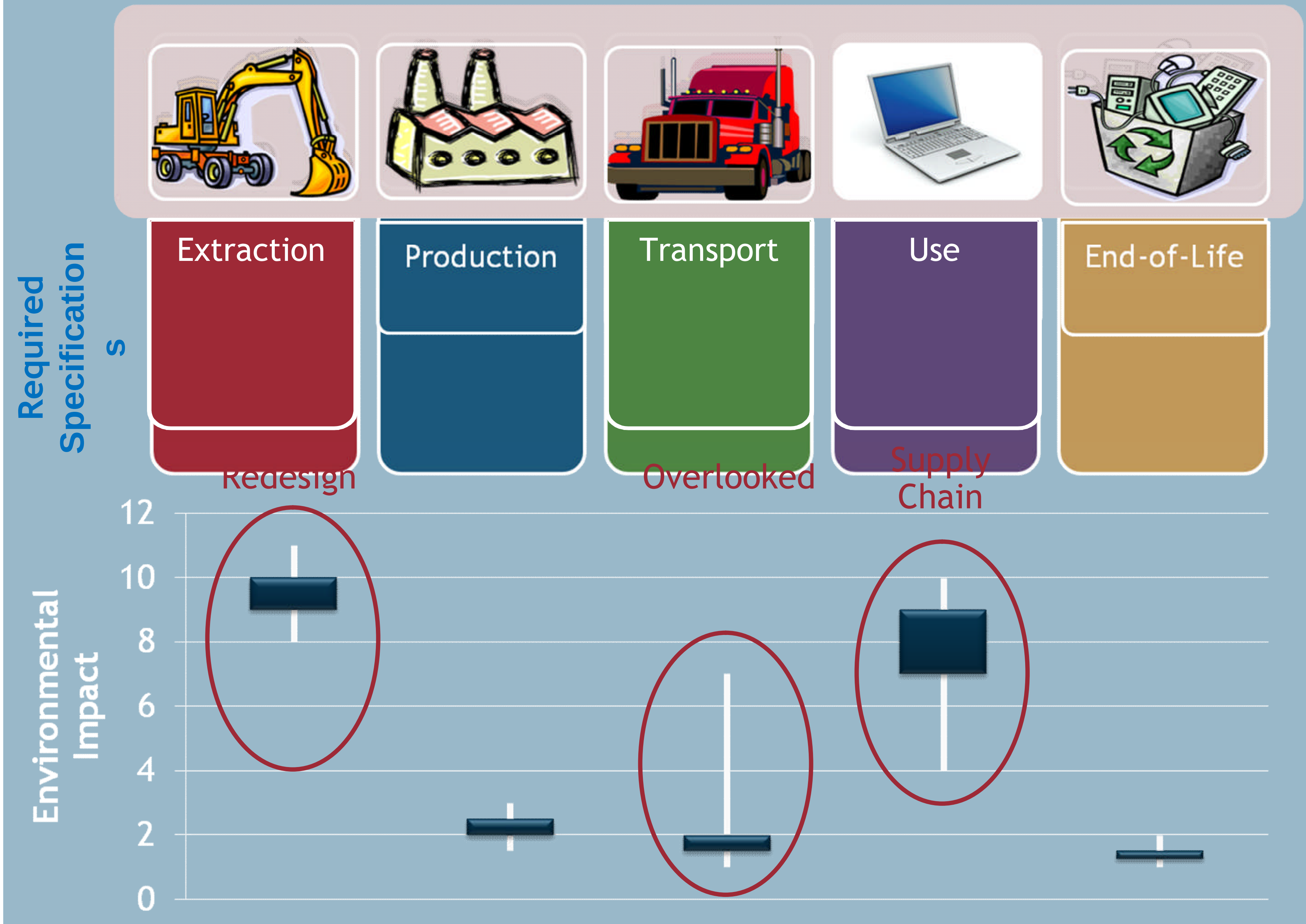
Raw Materials

Use

Logistics


Full LCA Required Specifications and Results
Extraction
Production
Transport
Use
End-of-Life
Required Specifications
Environmental Impact
12
10
8
6
4
2
0

Simplified Quantitative LCA with Uncertainty Required Specifications and Results

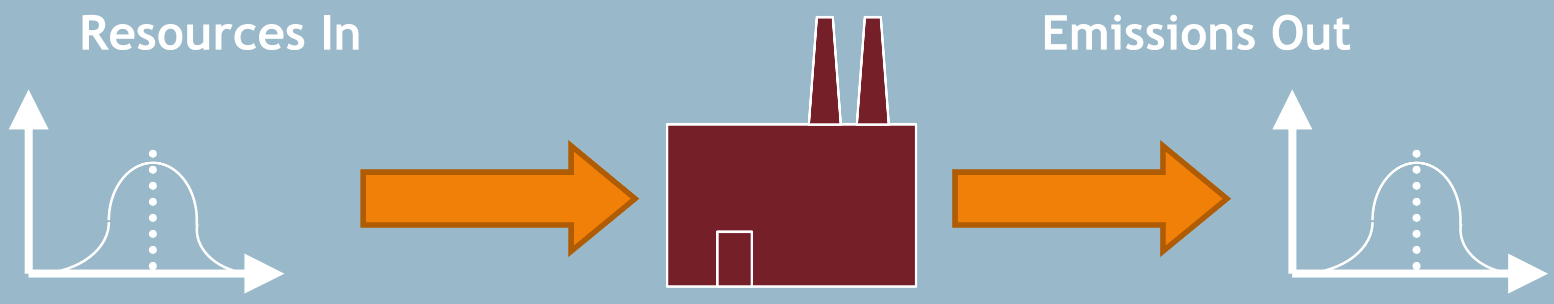


Implementing a Simplified Quantitative Analysis

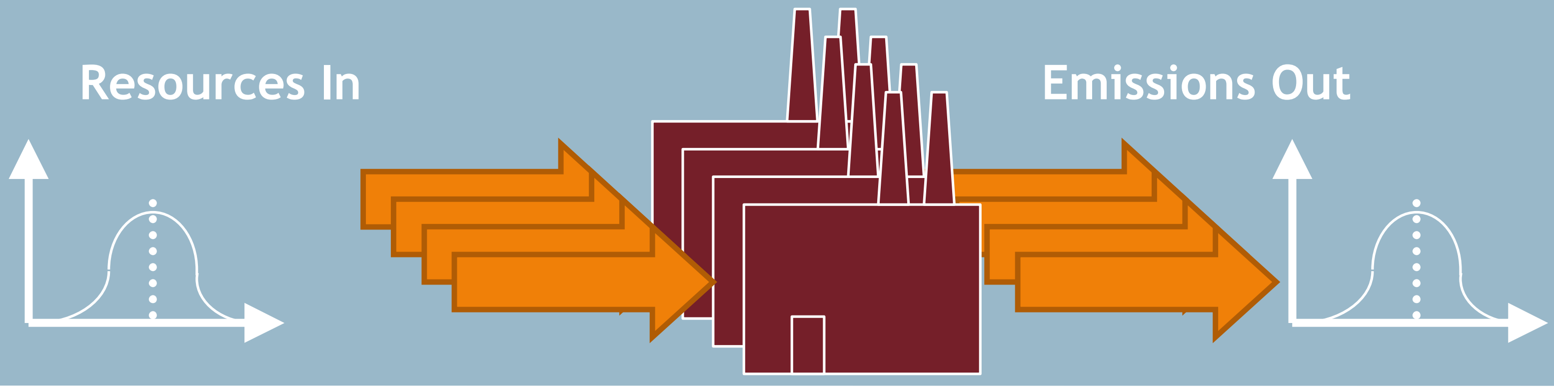
- Effectively characterizing inventory uncertainty should
  - Improve efficiency of analysis
  - Identify targets for improvement
    - Differentiate targets
- Data collection
  - Begin to estimate supply-chain inventory uncertainty through selected data collection
- Case study
  - Examine analytical value
    - Resource savings
    - Fidelity with complete analysis

Terminology

Estimation Error = *irreducible* spread on measured flows from a *single* activit



Variation = *reducible* spread on measured flows from multiple activities



Uncertainty = convolved estimation error and variation

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