



AF2903 Road Construction and Maintenance

Life Cycle Assessment - LCA

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WE TAKE THE
GREEN ROAD

LCA is a versatile tool to investigate the environmental aspect of a product, a service, a process or an activity by identifying and quantifying related input and output flows utilized by the system and its delivered functional output in a life cycle perspective.

*(The Hitch Hiker's; Guide to LCA
by Baumann and Tillman)*



Introduction

- A tool to investigate the environmental aspect of a product, a service or a process
- Identify and quantify related input and output flows utilized by the system
- Functional output
- Life cycle perspective



Emergence of LCA

- The undertaking of studies that aimed to optimize energy consumption in a context where strong energy consumption represented a restraint for the industrials (costs, possible boycott ...)
- Then was a transition from straight energetic consumption studies to studies that would take into account the energetic raw material consumption, in order to improve the analysis and to get more information about it (inputs)
- And eventually the development studies that take into account not only the inputs (inflows) but also the outputs (outflows)

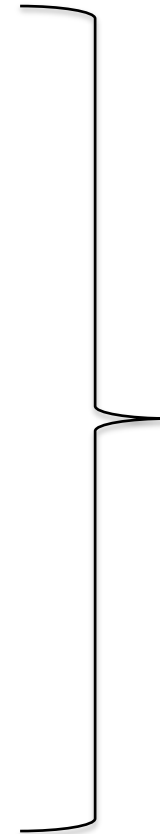
- Coca-Cola (By Harry E. Teastley Jr. 1969)
- Taking into account of the whole environmental impacts, from the raw material extraction to the waste disposal (what is called from the cradle to the grave approach)
- Clear objectives to:
 - choice between glass and plastic for the product bottling,
 - choice between internal or external bottle production,
 - end of life options for the chosen bottle
- The study revealed the plastic bottle as the best choice, contrary to all expectations.



- 1984 : Publication by the EMPA of the Ecological report of packaging material
- 1991 : First works at SETAC
- March 1992 : First European scheme on Eco-labels
- June 1992 : Creation of SPOLD, creation of a data exchange standard between 1995 to 1996
- 1996 : NF X30-300, first standard in France for Life Cycle Assessment
- 1997-2000 : ISO 14040,41,42,43, international series of standard defining the different stages of the LCA methodology
- 1999-2001 : ISO 14020, 25 , 48, 49, series of standard and technical documents concerning communication, environmental declaration directions and working methods...

Explanation

- Structured
- Quantitatively calculates;
 - Material
 - Energy flows
 - Environmental effects of a system.

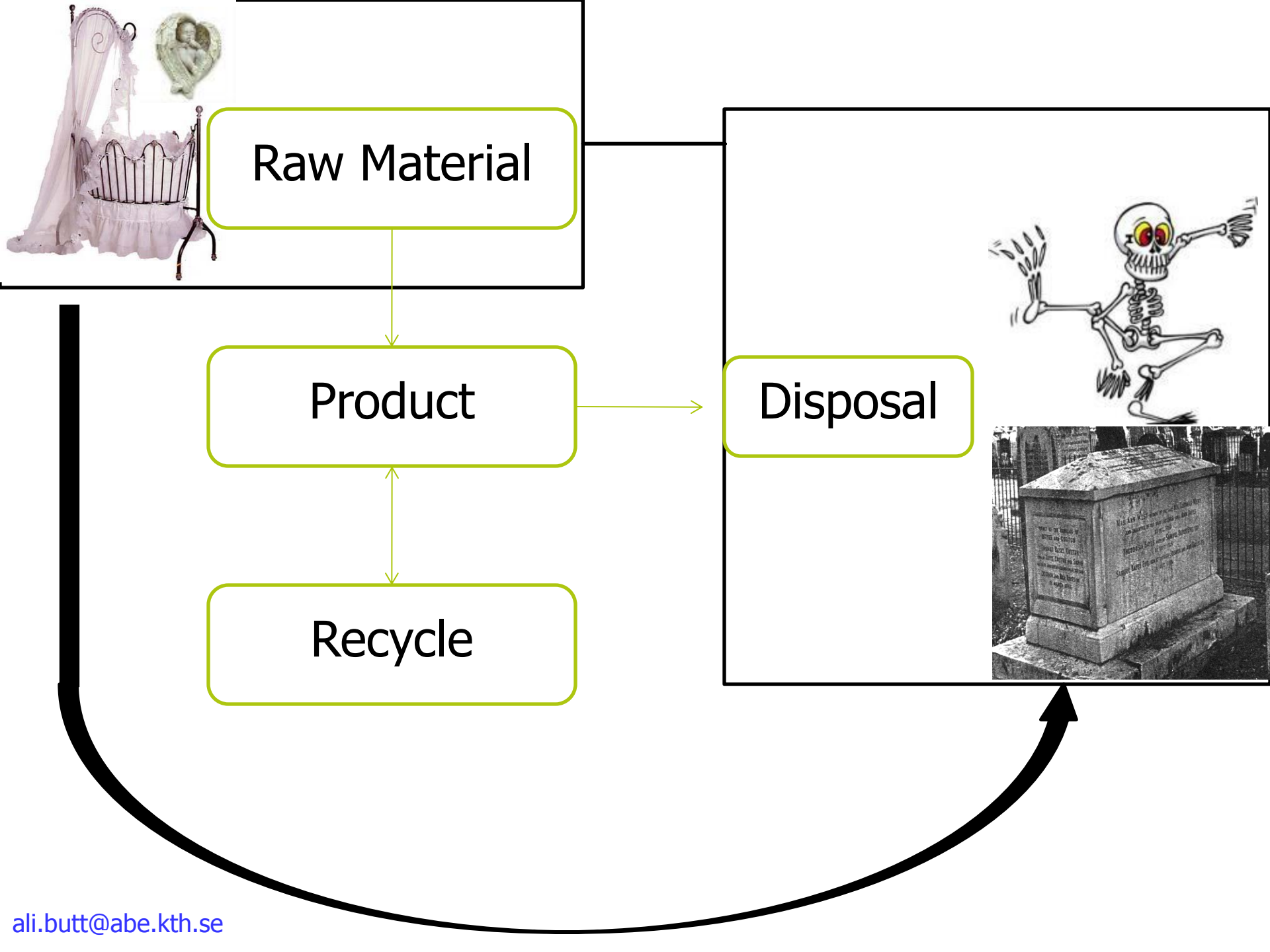


CRADLE
TO
GRAVE



Life Cycle Perspective

- “CRADLE” describes Raw Material Extraction
- “GRAVE” describes Disposal (burial in ground etc..)
- “GATE” in some cases describes factory gate (before it is transported to the consumer)



Raw Material

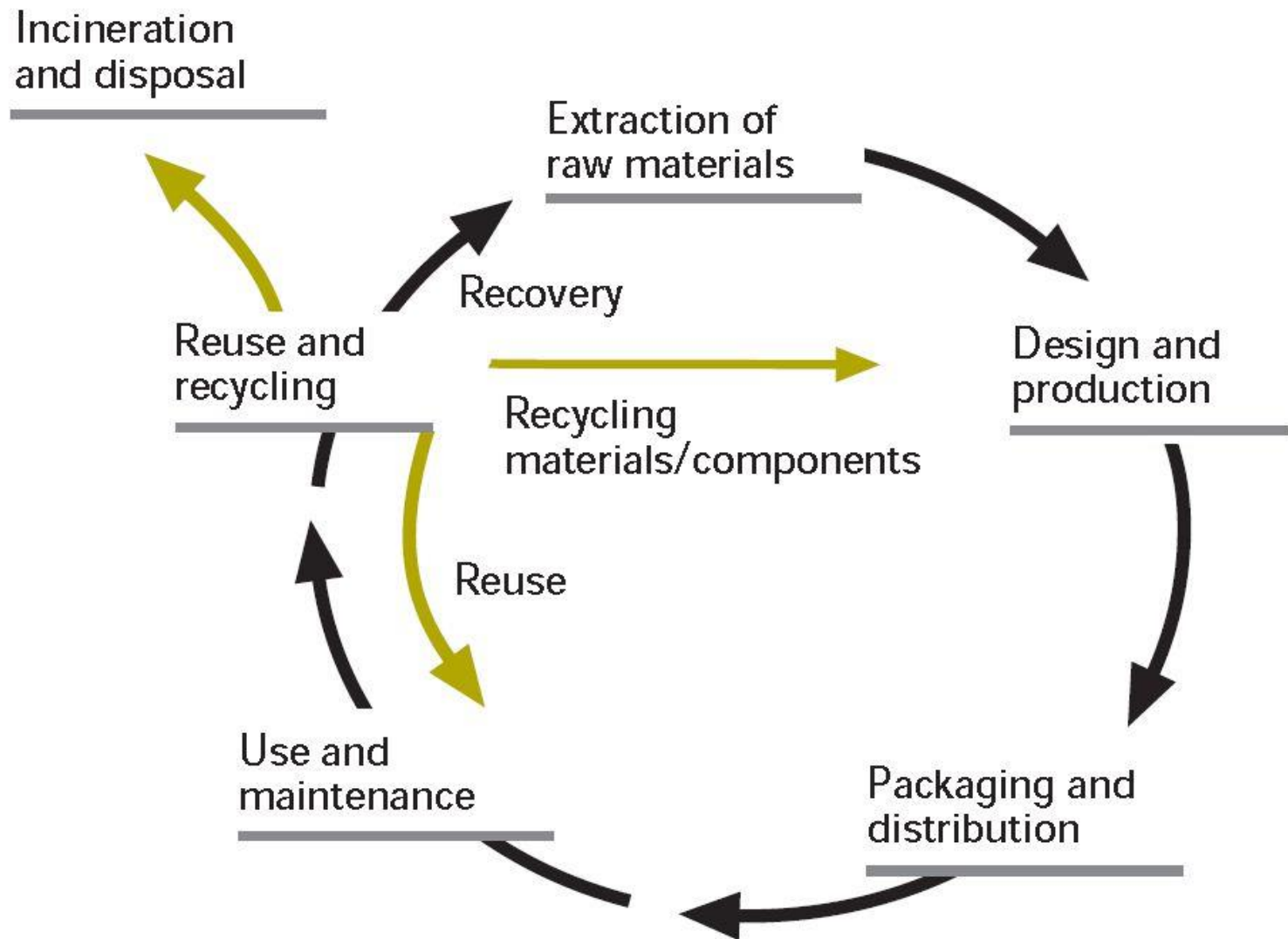
Product

Recycle

Disposal



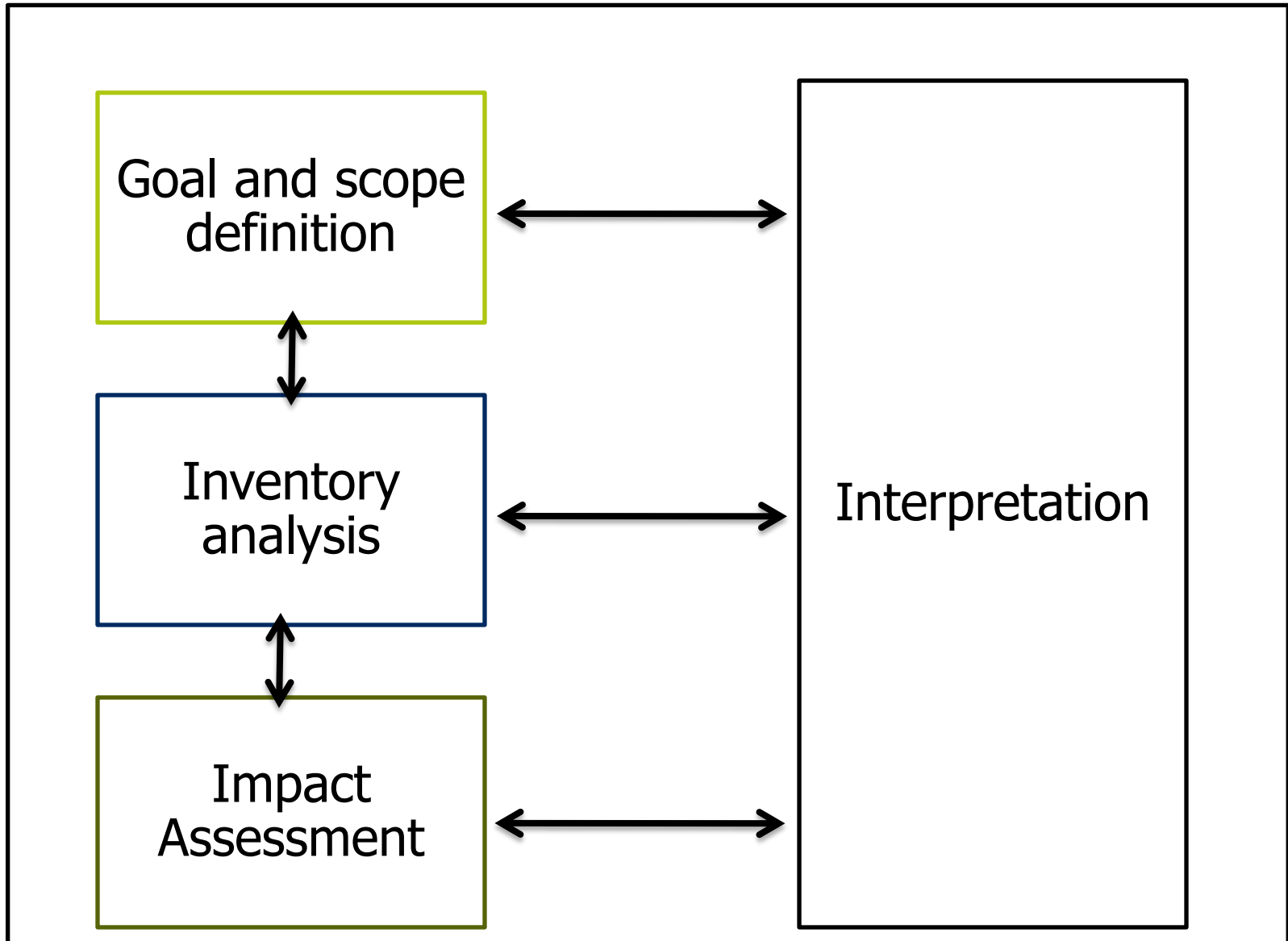
The life cycle of a product – and closing the resource cycle





ISO Standards

- Principles and framework (ISO 14040)
- Goal and Scope definition and inventory analysis (ISO 14041)
- Life cycle impact assessment (ISO 14042)
- Life cycle impact interpretation (ISO 14043)





Some other tools

- MFA (Material Flow Analysis)
- SFA (Substance Flow Analysis)
- IOA (Input-Output Analysis)
- CBA (Cost-Benefit Analysis)
- ***EIA (Environmental Impact Assessment)***
- ***SEA (Strategic Environmental Assessment)***
- ***LCA (Life Cycle Assessment)***
- ***LCC (Life Cycle Cost)***
- ***En (Energy Analysis)***

Example of Different Tools

- EIA - Environmental Impact Assessment
 - A process tool rather than an analytical tool (different tools can be incorporated in the process)
 - Site-specific
- SEA - Strategic Environmental Assessment
 - A process tool rather than an analytical tool (different tools can be incorporated in the process)
 - A more recent tool
 - Earlier in the decision process than EIA
 - Used for plans, programs and policies



Example of Different Tools

- LCC - Life Cycle Costing
 - Assessing the costs of a product over its life cycle
 - May include environmental costs
- En - Energy Analysis
 - Focus on energy flows
 - Evaluation method, can be used on different objects
 - Different measures of energy.



LCA - Life Cycle Assessment

- Focus on products, services, functions, from ”*cradle to grave*”
- Largely site-independent
- Can be used in both retrospective and prospective studies using different data and methods



Procedure to Perform LCA

- LCA is a technique for assessing system aspects and potential impacts associated with the product by:
 - Compiling an inventory of relevant inputs and outputs of the Road system;
 - Evaluating the potential environmental impacts associated within those inputs and outputs;
 - Interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.



Primary Stages

- Goal and Scope Definition
 - Establish the system to evaluate
 - define the boundaries of the study.
- Life Cycle Inventory [LCI] assessment
 - Accounting stage (Inputs to and outputs from the system assessed)
 - Generalised material and energy balances through the life of the road.
- Impact Assessment
 - Effects from LCI translated to impacts on humans and the environment.

- Function is a service provided by the system; performance characteristics of the product
- Goal revised; function of the system defined; identify and define the output of the system (why we need to study LCA for).
- Example of Akzo Nobel (Arvidsson 1995);

Two detergents were studied in which the quantity was kept the same 100 Kg and were equivalent concerning function i.e. *cleaning efficiency*.



System Boundary Definition

- The system boundary defines which unit processes and which parts of the life cycle should be included in the study (Cradle to Grave OR Cradle to Gate etc..)
- Defines the boundaries of a study
- One of the most important step

1. Goal and Scope Definition

Define;

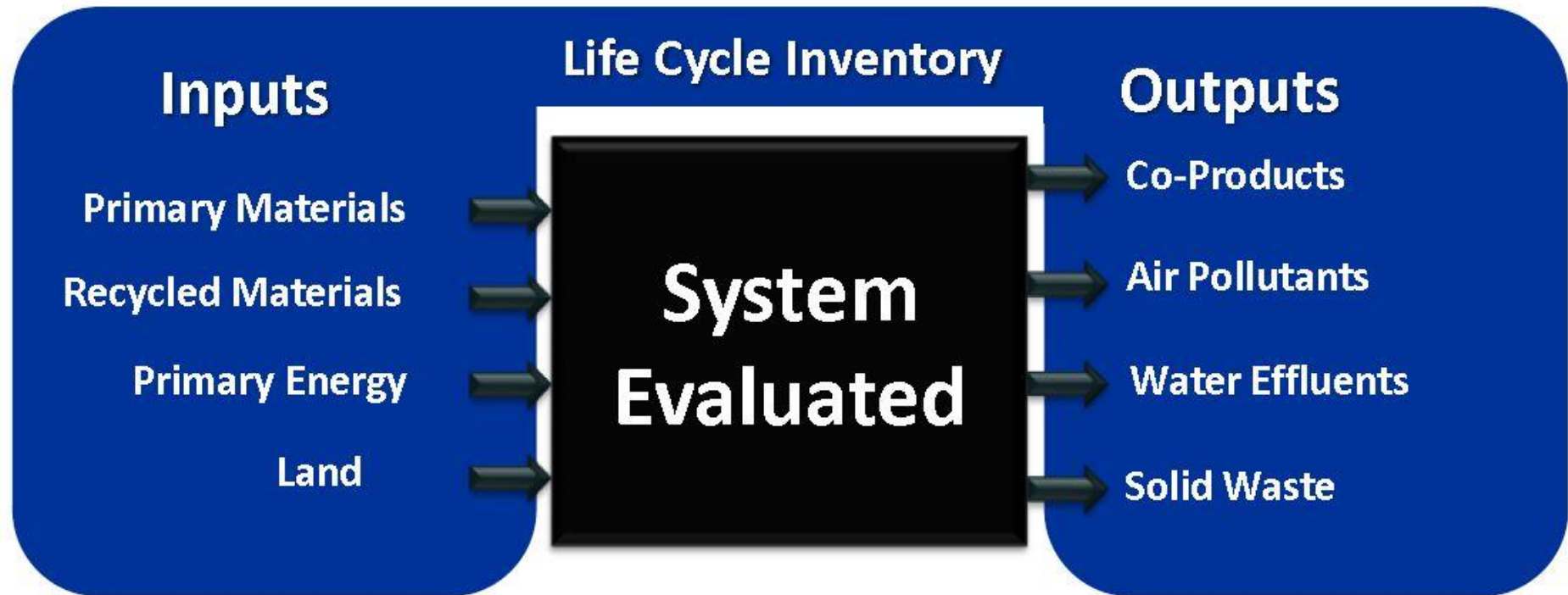
- Includes intended application of the study, the reason/purpose for carrying it out and to whom the results are intended to be communicated (ISO 14040 1997).
- The context of the study should be defined. (to whom and how results are to be communicated)
- System boundaries (which processes to include); limitations, assumptions, methodology for environmental impact assessment, data collection/requirements.



2. Inventory Analysis

- Build a systems model according to the goal and scope defined.
- Quantify and define inputs and outputs, search for databases and previous study of LCA's.
- An accounting stage
- It's an iterative process.

Framework (Kandell and Santero)



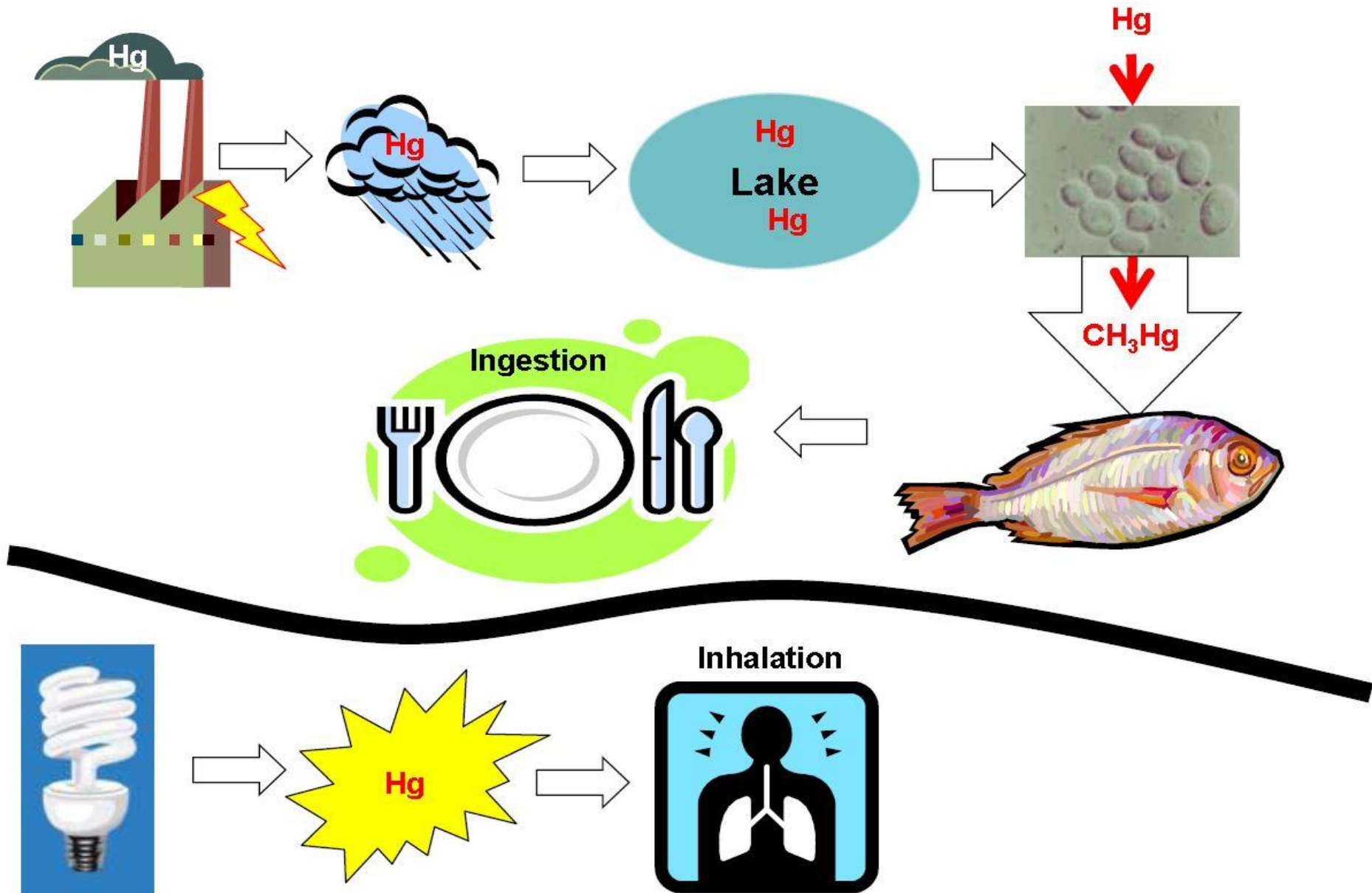


3. Life Cycle Impact Assessment

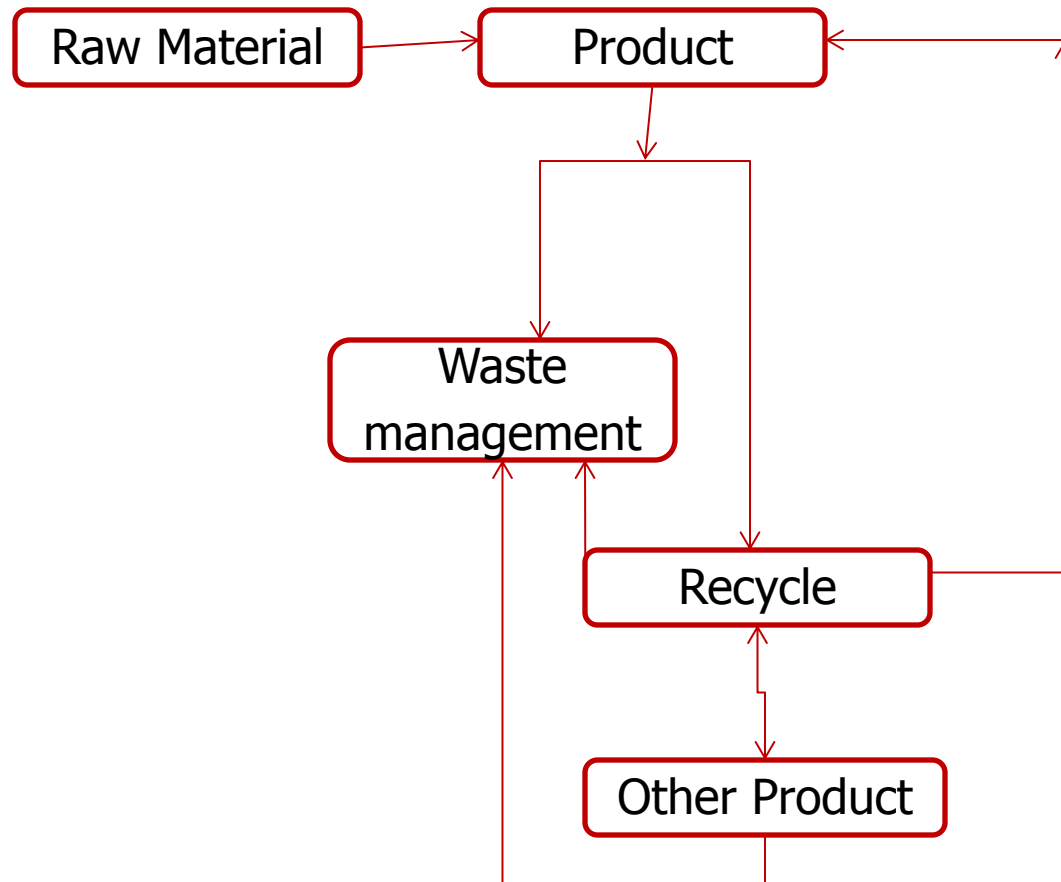
- Impacts of environmental loads quantified in inventory analysis.
- Translating the inventory results into environmental relevant information (it is an iterative process so that based on sensitivity analyses further inventory might be needed)
- It should be discussed in detail.
- Sensitivity analysis and uncertainties identified.

- Output related categories
 - global warming potential
 - e.g. convert LCI outputs of GHG emissions using global warming potential to CO₂e
 - human toxicity
 - e.g. convert toxic pollution recorded in the LCI into its potential or estimated toxicity to humans
 - ecotoxicity
 - photo-oxidant formation
 - acidification
 - nutrification

Impact Assessment (Example)



Open-Loop Recycling



STEP 1

Classification

Resources

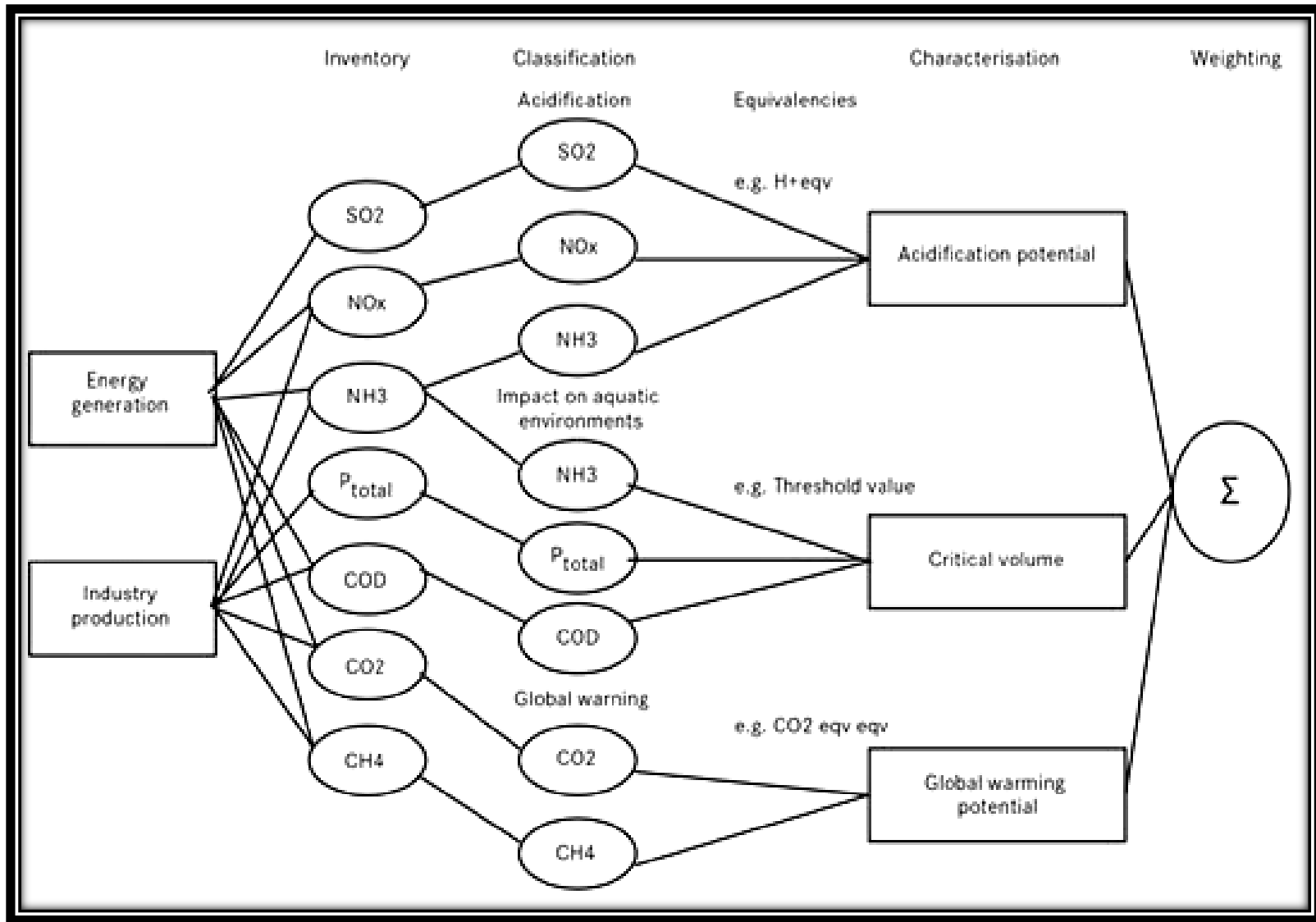
Type of Environmental impact (CO₂, NO, CH₄)

STEP 2

Characterisation

Emissions

Comparative study (Change units in terms of CO₂ emissions)



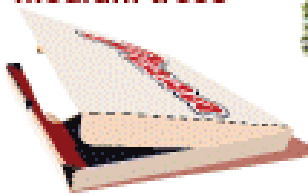
NOTE: Classification and characterisation are compulsory in LCA whereas weighting is optional (ISO 14042 2000).

- Pull tabs were an environmental disaster (1963 by the Pittsburgh Brewing Company)
- New stay tabs (Virginia in 1975)



Example SSSB

Your carton packaging has saved **1 463** pc medium trees



Your plastic packaging has become **27 281** pc plastic crates



Your clear glass packaging has become **250 324** pc new glass packaging



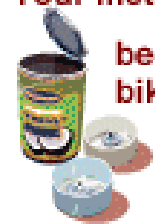
Your papers has become **744 513** pc toilet rolls



Your coloured glass packaging has given insulation for **343** houses



Your metal packaging has become **1 196** pc bikes



Thank you for your contribution to a better environment!



Goal and Scope



LCI



Impact Assessment



Problems

- Time consuming
- False picture
- Doesn't include social and economical aspects
- Uncertainties
- Verification of results

WHY LCA?????

- LCA should be studied as absolute result rather as a study of the system
- LCA increases system knowledge and awareness
- LCA is a decision support tool

• WHY DO WE NEED IT

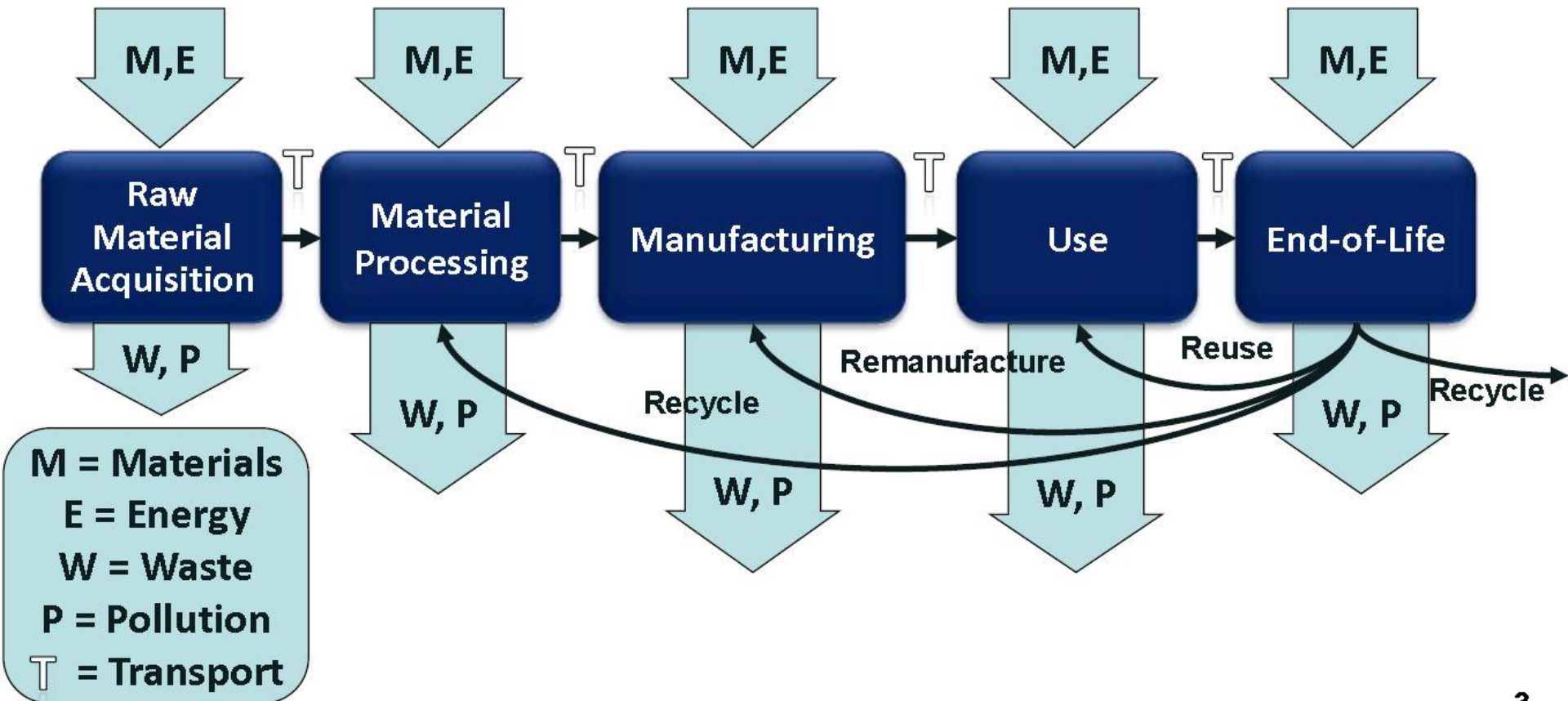


Questions to be answered for LCA;

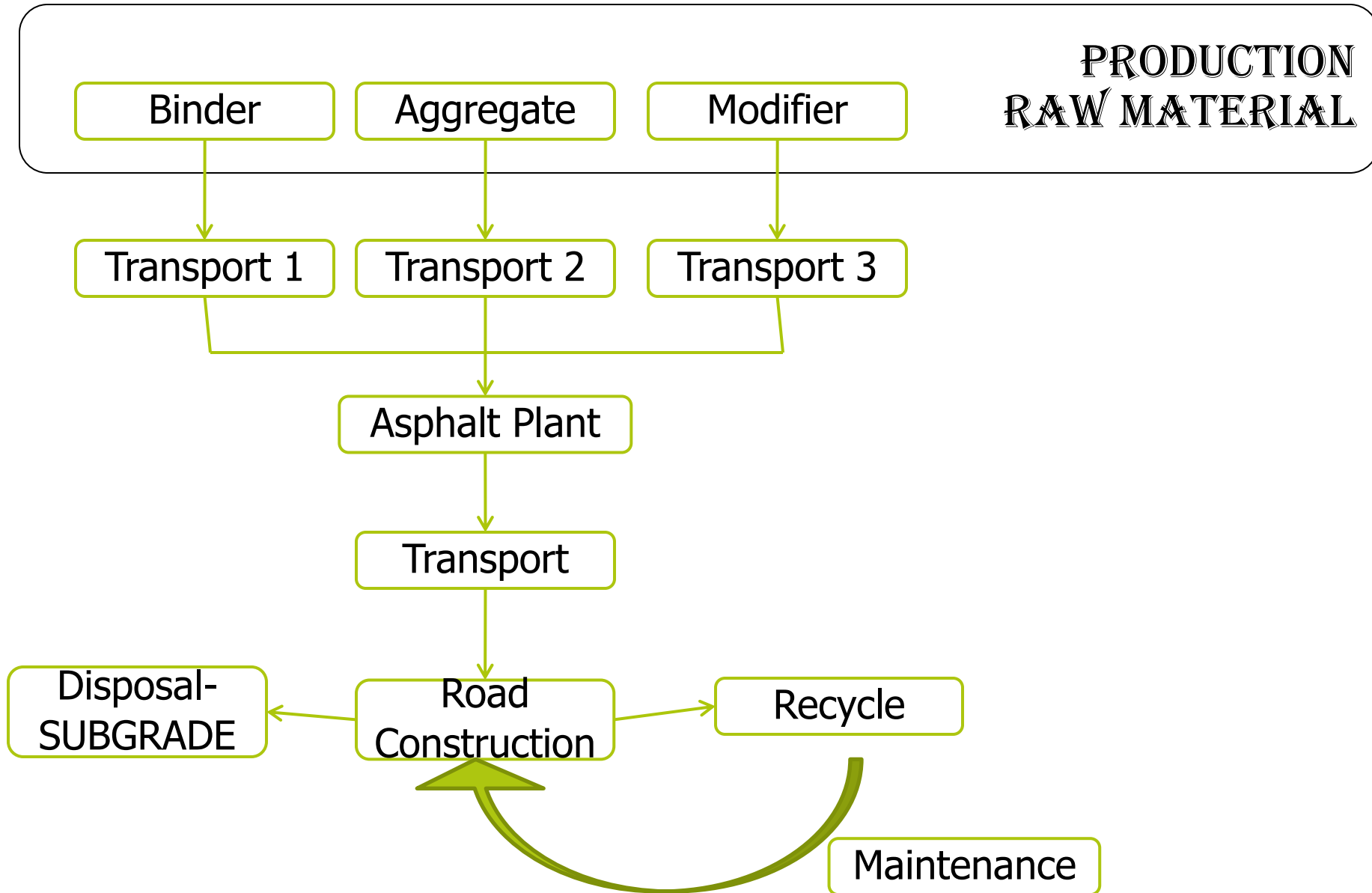
- In an environmental point of view, which materials are best suited for use in Infra-systems?
- How can we build and improve the Infra-system to be more environmental friendly?
- Does the Infra-system serve for a long time before the end of its functional life?
- How do we dismantle the Infra-system (Recycle or Bury in the ground)?

Stages of Life Cycle (Kendall and Santero)

- Evaluates a product or system throughout its entire *life cycle*



PRODUCTION RAW MATERIAL



Disposal



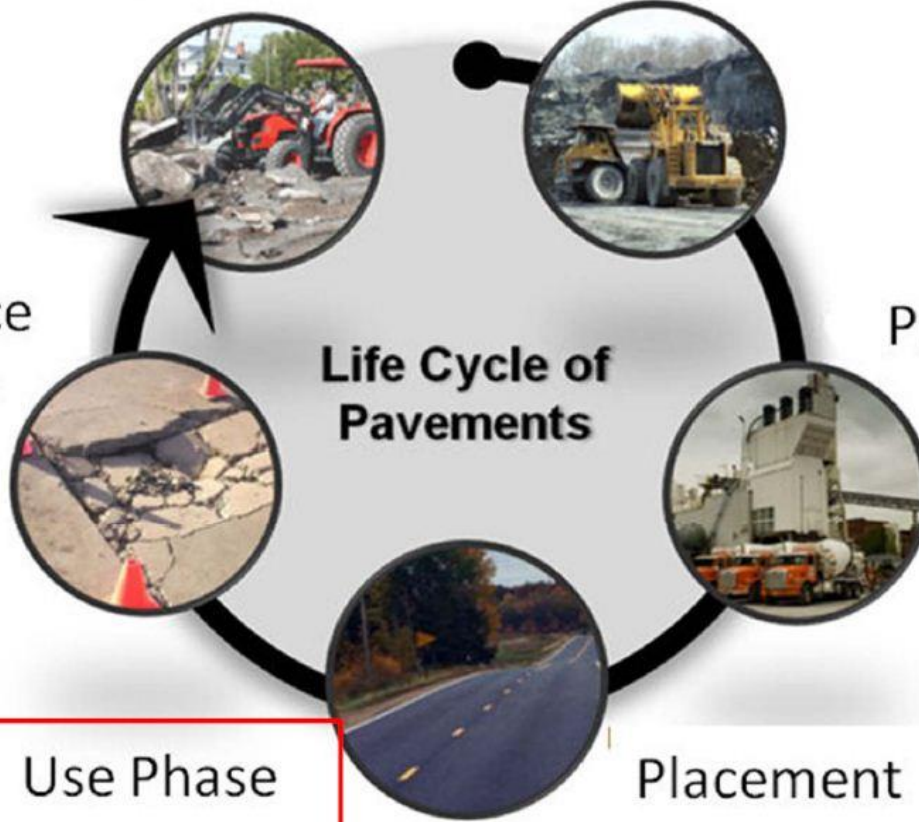
Recycling

Resource Extraction

Maintenance and Rehab

Processing

Life Cycle of Pavements



Use Phase

Placement

→ Roadway lighting, lane closures, etc.

- A method or a tool for characterizing and quantifying environmental sustainability
- Applies a “cradle-to-grave” perspective when analyzing products or systems
- Measures inputs and outputs of a product or a system
 - ✓ Example inputs: energy, water, materials
 - ✓ Example outputs: air emissions, waste
 - ✓ Can be categorized into *impact categories*
- General standards set by ISO 14040 series
 - ✓ Provides general LCA guidance, but lacks detailed information necessary for individual products and systems