

# Solid Waste Management & Resource Recovery

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# Hazardous Waste Treatment

## √ Definition of hazardous waste:

"Anything which, because of its quantity, concentration, or physical, chemical or infectious characteristics may cause, or significantly contribute to, and increase in mortality; or cause an increase in serious irreversible, or incapacitating reversible illness; or pose a substantial present or potential hazard to human health and the environment when improperly treated, stored, transported, or disposed of, or otherwise managed." (EPA)

## √ Treatment of hazardous waste:

- We create large volumes of waste, yet only < 5% is landfilled worldwide. The rest is treated in some way (ex situ or in situ)
- Methods of treatment (no resource recovery or recycling)
  - Volume reduction (physical/chemical/biological treatment)
  - Thermal destruction (incineration)
  - Land disposal
  - Stabilization / Fixation

# Hazardous Waste Treatment

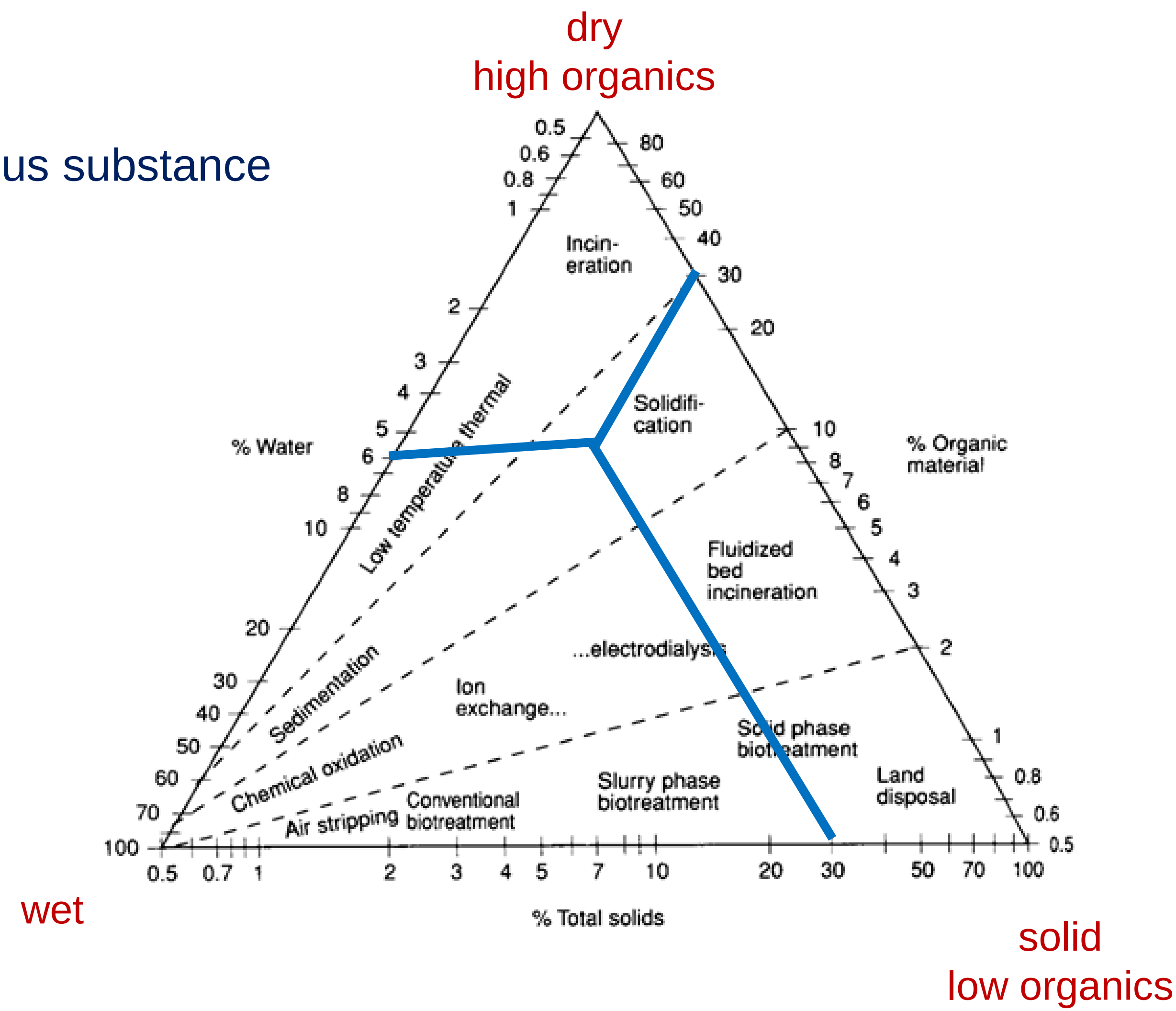
- Goal of all methods:
  - create less hazardous substance
  - reduce volume
  - reduce mobility

- Example:

  Waste composition:

  - %TS = 30
  - %OM = 30
  - $\%H_2O = 6$

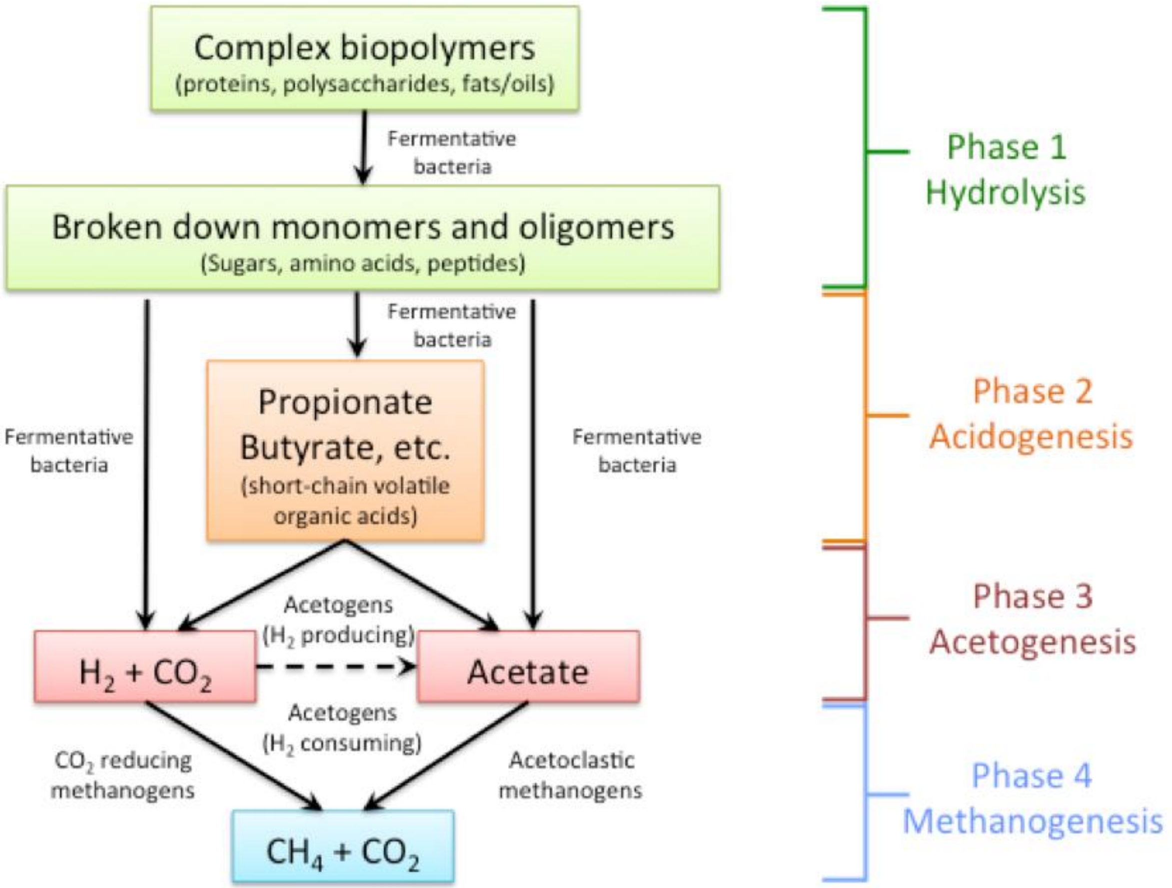
  → Solidification



# Anaerobic Digestion

## √ Anaerobic digestion

- **Anaerobic digestion refers to the process in which microorganisms break down biodegradable substrates under anaerobic conditions, producing biogas**




**Source: BEEMS Module B7 - Anaerobic Digestion**

# Anaerobic Digestion

# Incineration

- Effective for organics in soils, slurries, sludges, liquids
- Not effective for high water content waste
- Can destroy pathological wastes, carcinogens, mutagens
- Metals that volatilize below 2000°F are problematic (Pb)
- Efficiency
  - destruction and removal efficiency

    (DRE) = (In-Out)/In x 100%
- RCRA (The Resource Conservation and Recovery Act) requires 99.99 efficiency for most organics.
  99.9999 (six nines) required for dioxin, dibenzofurans, PCBs
- Combustion efficiency controlled by
  - combustion temperature
  - combustion time
  - mixing or turbulence
  - oxygen available

# Incineration

- Two widely used designs:

  - *Liquid injection incinerator*

    spray fuel in wastes with atomizing nozzle

    combust at very high temperature

  - *Rotary kiln incinerator*

    handles more types of wastes (liquid, solids, sludges, drummed waste)

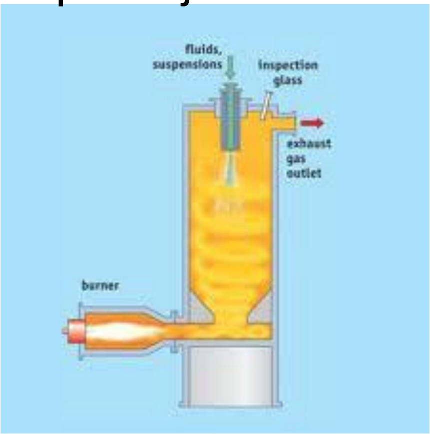
    waste fed to rotating chamber where combustion occurs

    any remaining gas burnt in secondary chamber

- Problems with incineration
  - If combustion is not complete, can form odors, CO, HCl, particulates
  - hazardous ash to dispose of

# Incineration

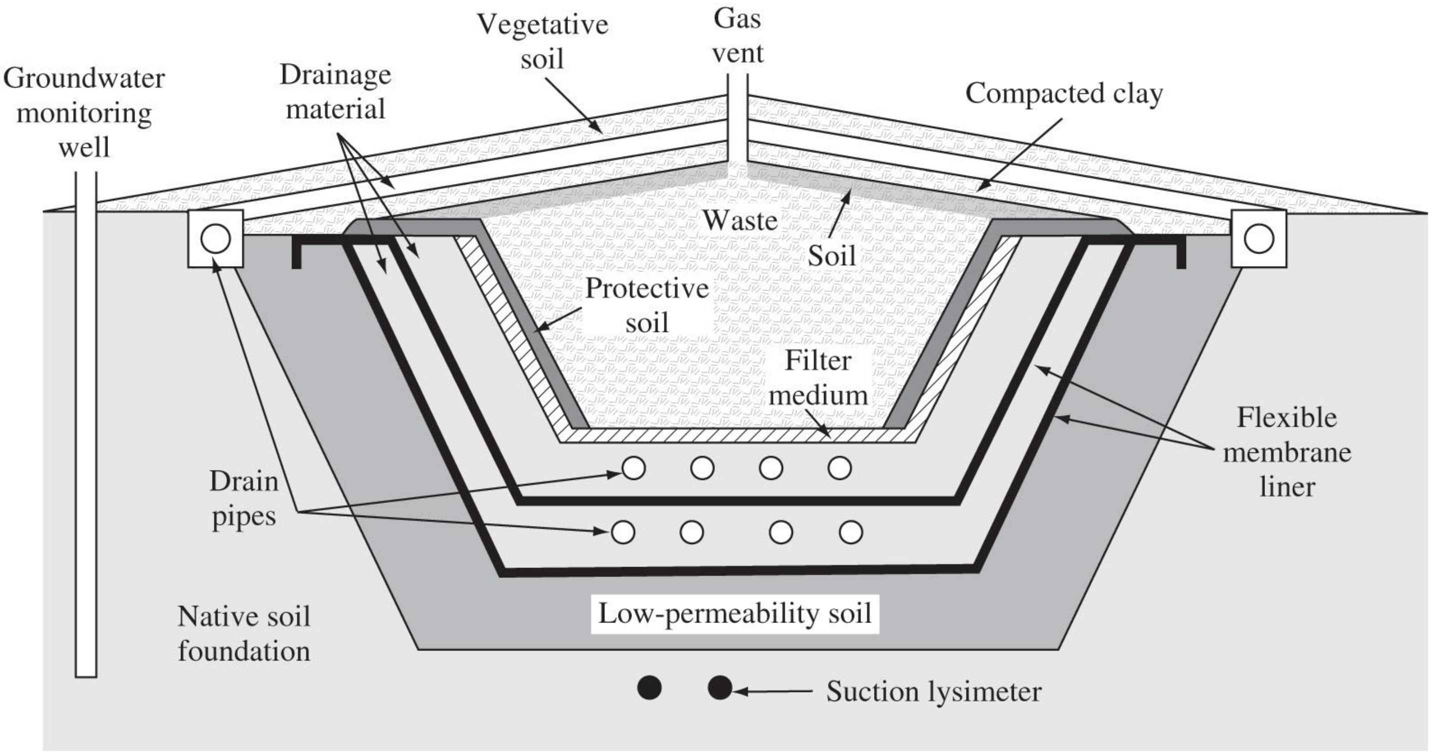
Liquid Injection Incinerator




Rotary Kiln Incinerator

# Land Disposal

- Landfills segregate wastes and cover with soil.
- Double liner systems prevent leachate from entering groundwater.
  - Liners usually made of flexible membrane, e.g., polyvinyl chloride, polyethylene, or rubber material
- Leachate collected and pumped to surface for above-ground treatment.
- Monitor groundwater around the landfill

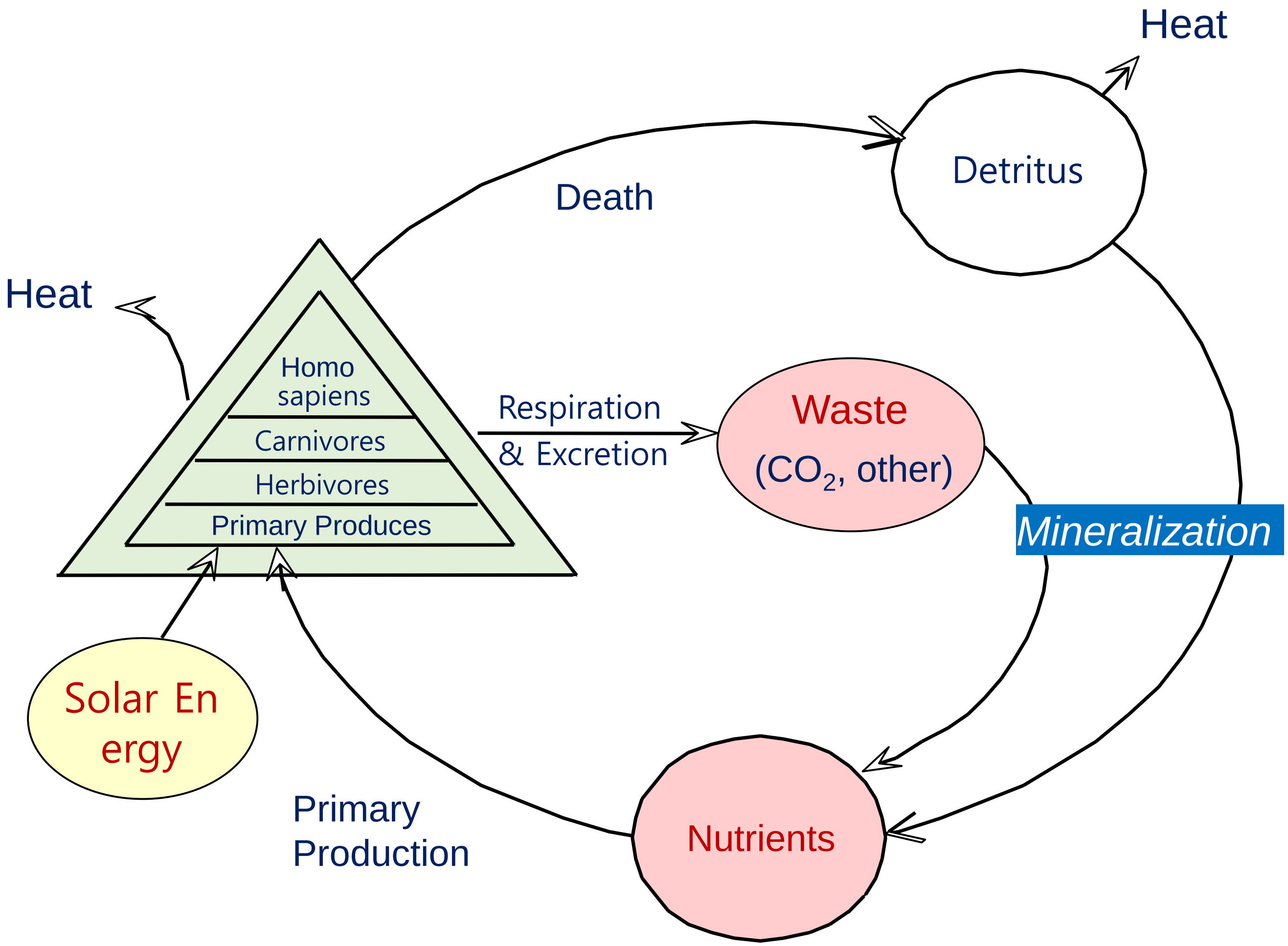


# Land Disposal

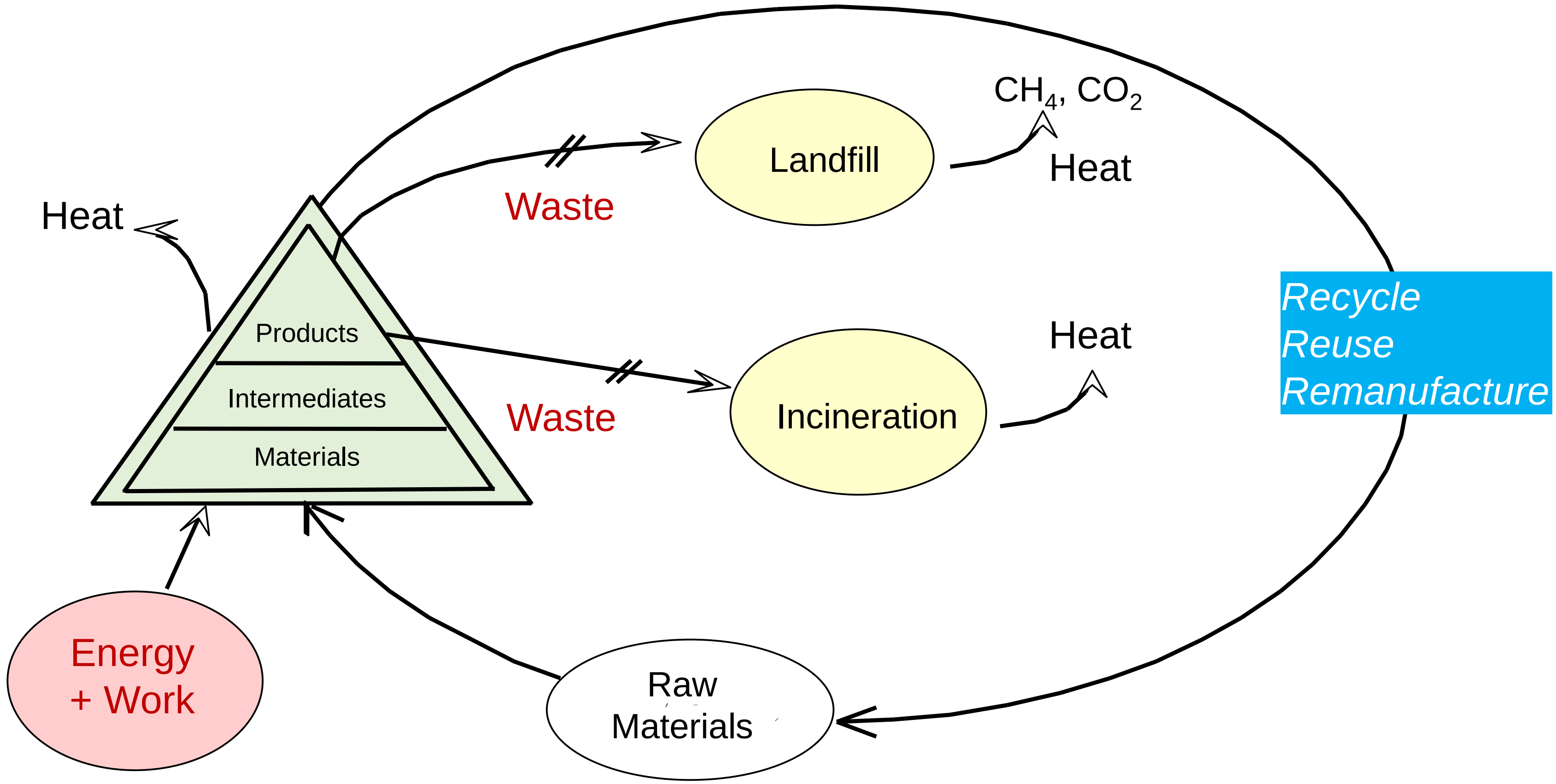
# Industrial Ecology

- It is a multidisciplinary framework to design and operate industries as if they were living entities interacting with ecosystems.
- Seeks to attain a balance between economic gains and ecological and global interests.
- It is the science behind sustainable development.

# Natural Ecology

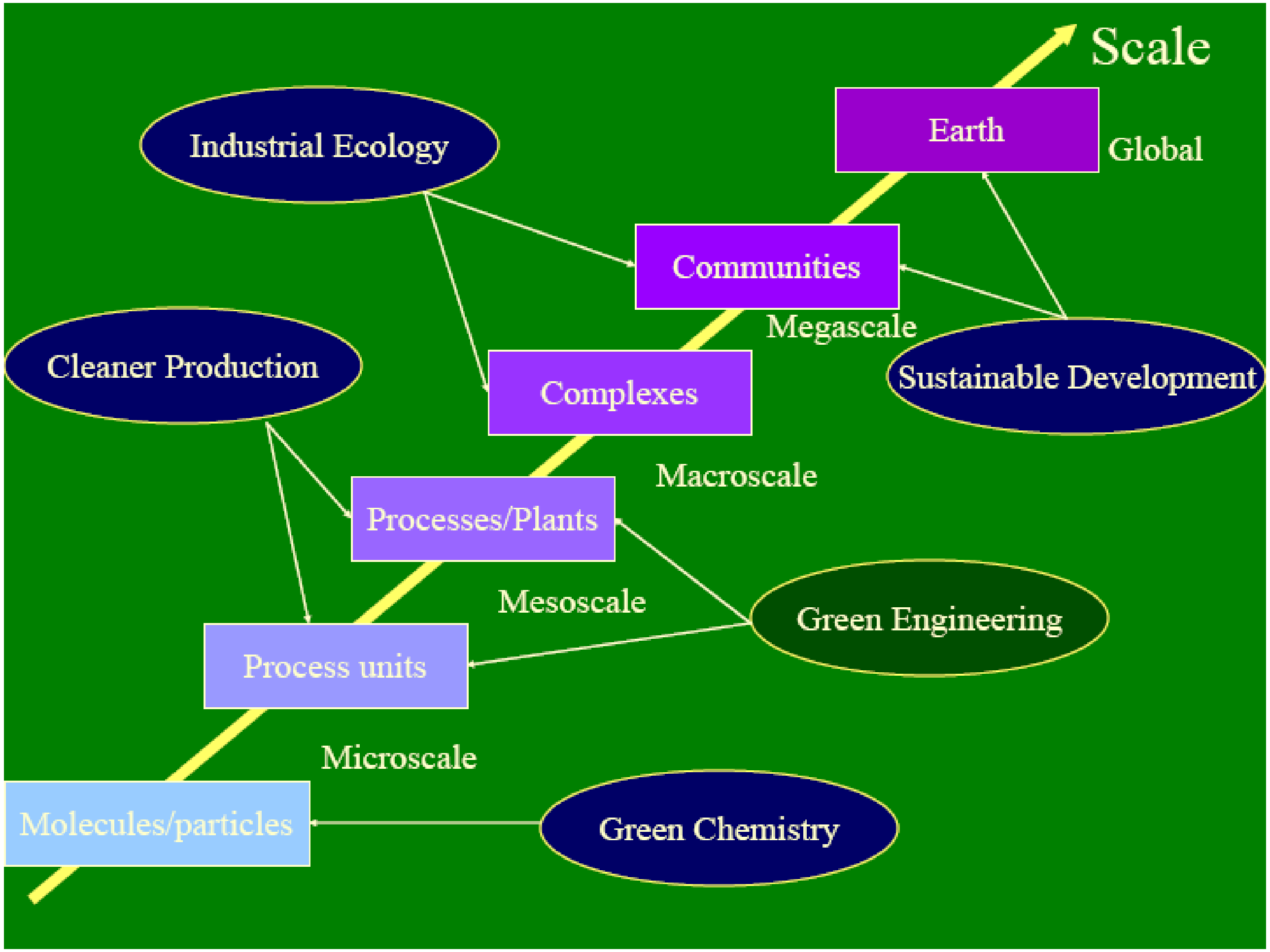


# Industrial Ecology

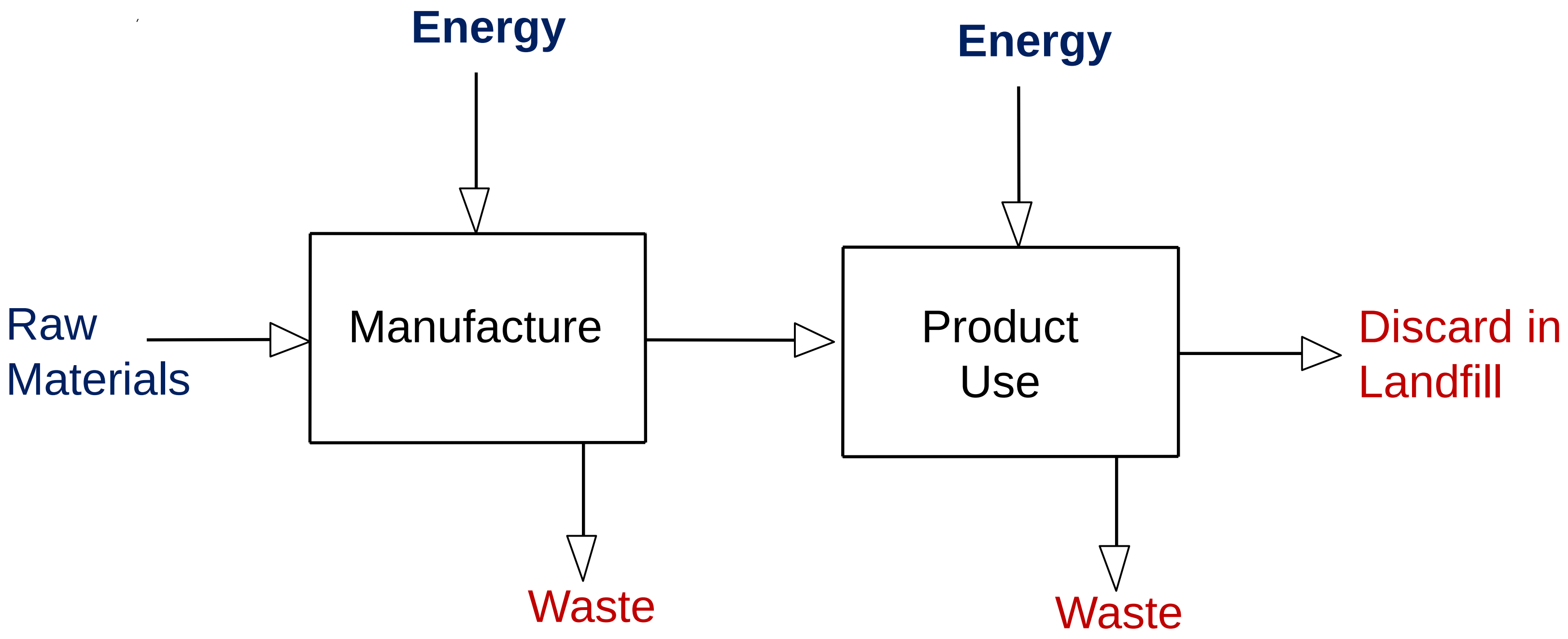


# Industrial Ecology

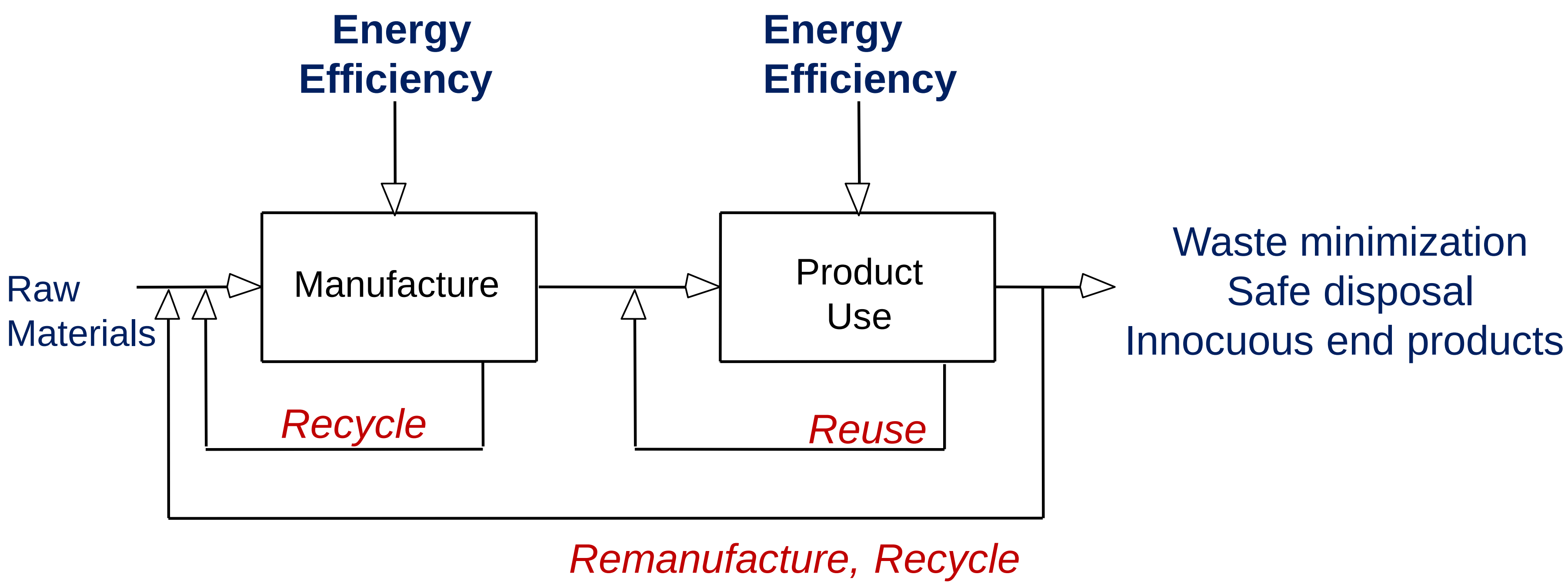
- Industrial ecology is a systems-level approach implemented on larger scales than green chemistry and green engineering



# Conventional Design



# Green Ecology



# Green Engineering

## √ The 12 Principles of Green Engineering

1. Inherent rather than circumstantial

   (all energy and material inputs and outputs should be inherently non-hazardous)

2. Prevention rather than treatment
3. Design for separation and purification of wastes
4. Maximize mass, energy, space and time efficiency
5. “Out-pulled” rather than “input-pushed” through the use of energy and materials
6. View complexity as an investment when making design choices on recycle, reuse or beneficial disposition

# Green Engineering

7. Target durability rather than immortality

8. Need rather than excess

   (don’t design for unnecessary capacity – avoid “one size fits all”)

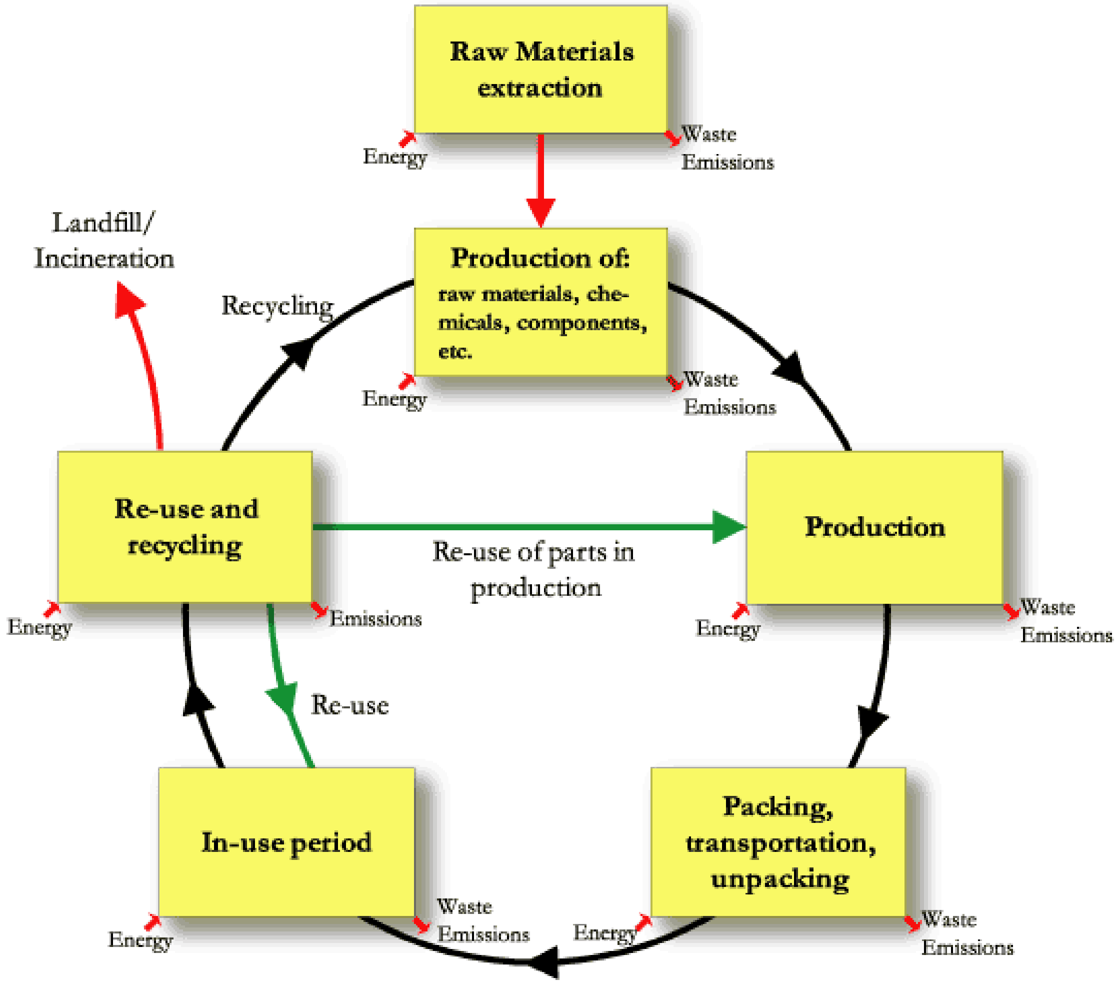
9. Minimize material diversity to strive for material unification and promote disassembly + value retention

10. Integrate local material and energy flows (interconnectivity, system of systems)

11. Design for commercial “afterlife”

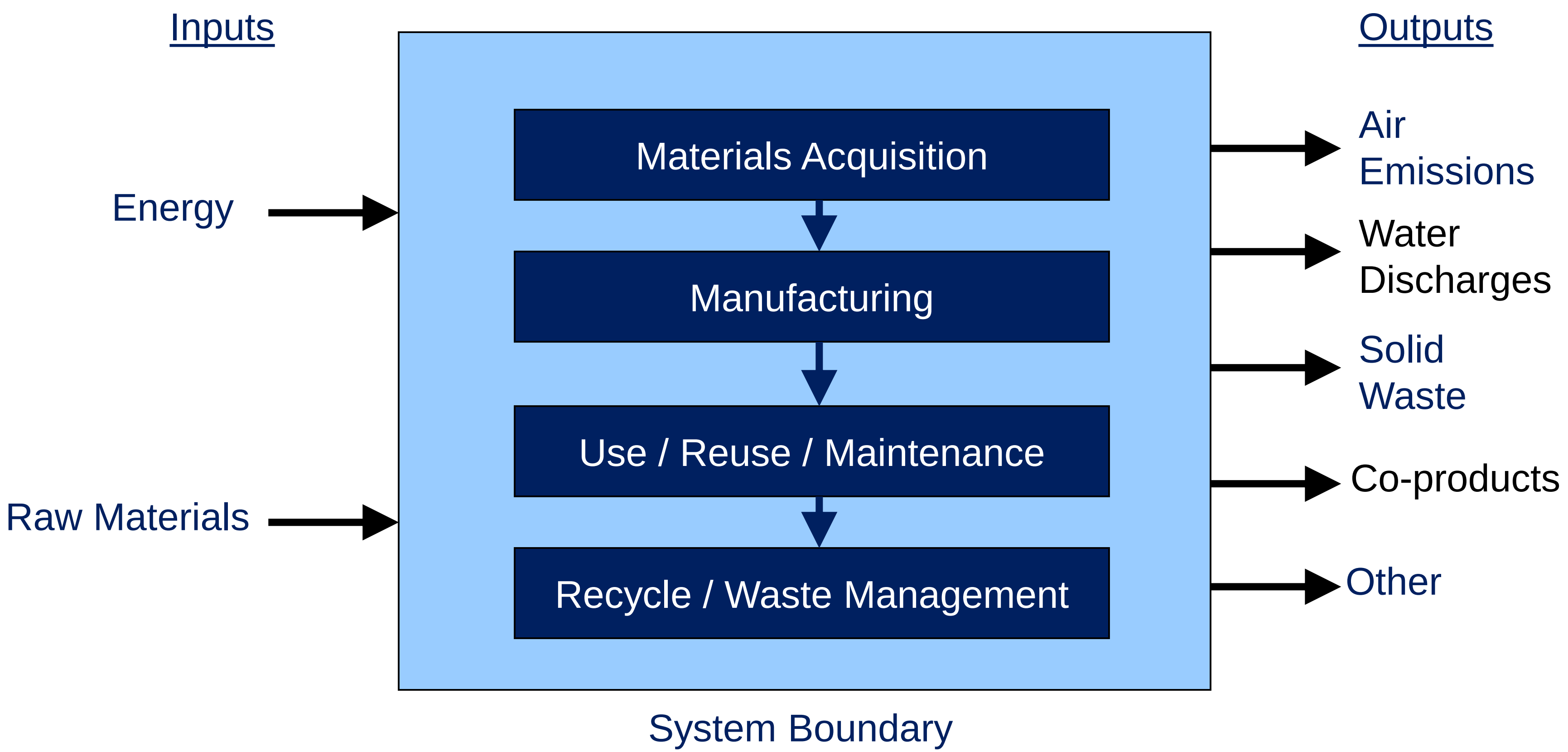
12. Use renewable & readily available inputs through life cycle

# Life Cycle Assessment (LCA)



# Life Cycle Assessment (LCA)

√ **Life cycle Inventory: Data gathering**



# Life Cycle Assessment (LCA)

- Following completion of the Life Cycle Inventory (LCI), the Impact Assessment begins:

**Step 1:**

Select and Define Impact Categories

***Description of impact categories***

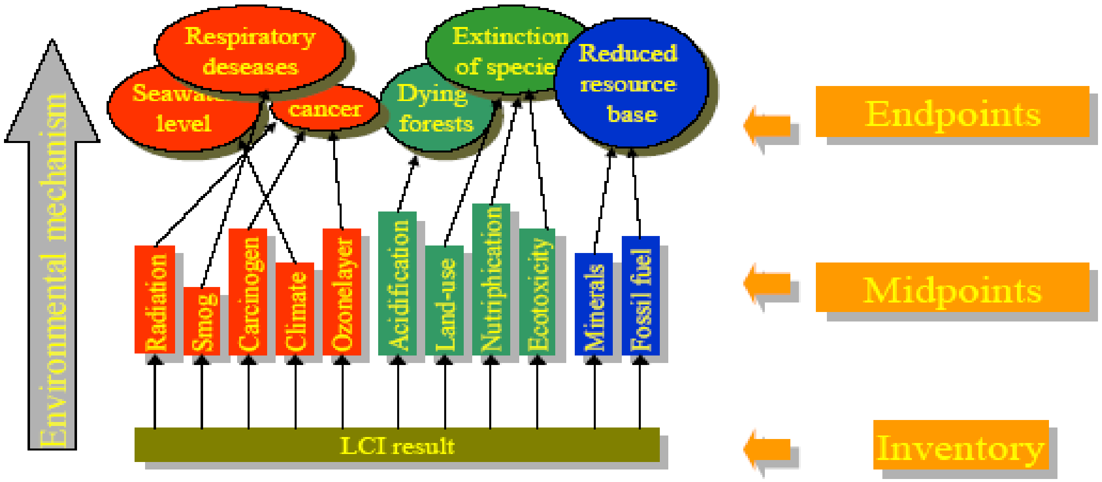
The different impact categories mentioned in the preliminary ISO list supplemented with relevant other categories e.g. "work environment" will be described briefly below with examples on potential effects:

- abiotic resources
- biotic resources
- land use
- global warming
- stratospheric ozone depletion
- ecotoxicological impacts
- human toxicological impacts
- photochemical oxidant formation
- acidification
- eutrophication
- work environment

# Life Cycle Assessment (LCA)

**Step 2**: Classification

- Determine if the impacts are proportional (dependent) or additive (independent).
- Organize and if possibly combine the LCI results into impact categories/ endpoints.




*General overview of the structure of an impact assessment method. The LCI results are characterised to produce a number of impact category indicators. According to ISO, one must document the environmental relevance of each indicator by describing the link to the endpoints. Endpoints can be selected by the practitioner, as long as the reasons for including or excluding endpoints are clearly documented.*

# Life Cycle Assessment (LCA)

**Step 3:** Characterization

- Impact characterization uses science-based conversion factors, called characterization factors, to convert and combine the LCI results into representative **indicators of impacts to human and ecological health**.
- Characterization factors also are commonly referred to as equivalency factors.

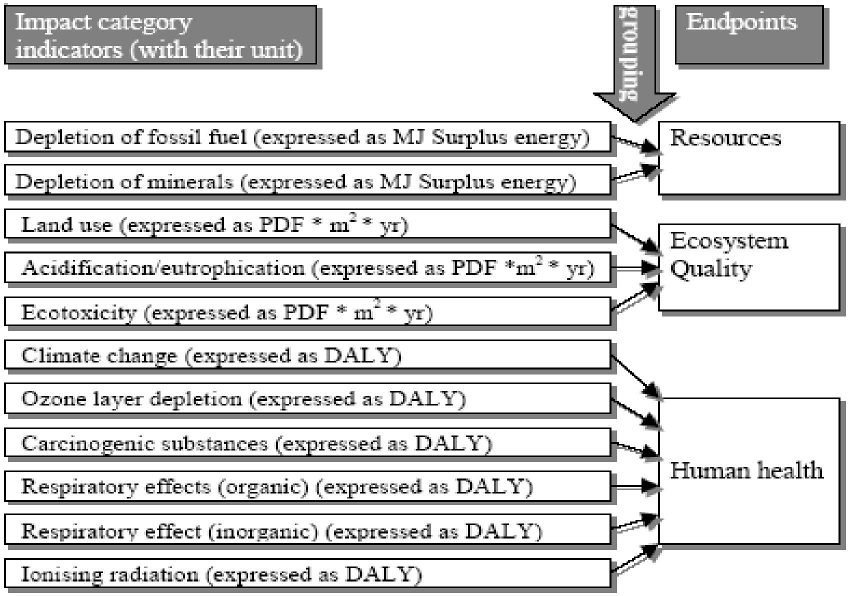



*Illustration of the grouping option on the Eco-indicator99 method. This procedure allows to reduce the number of impact categories to just three instead of 11 without subjective weighting*

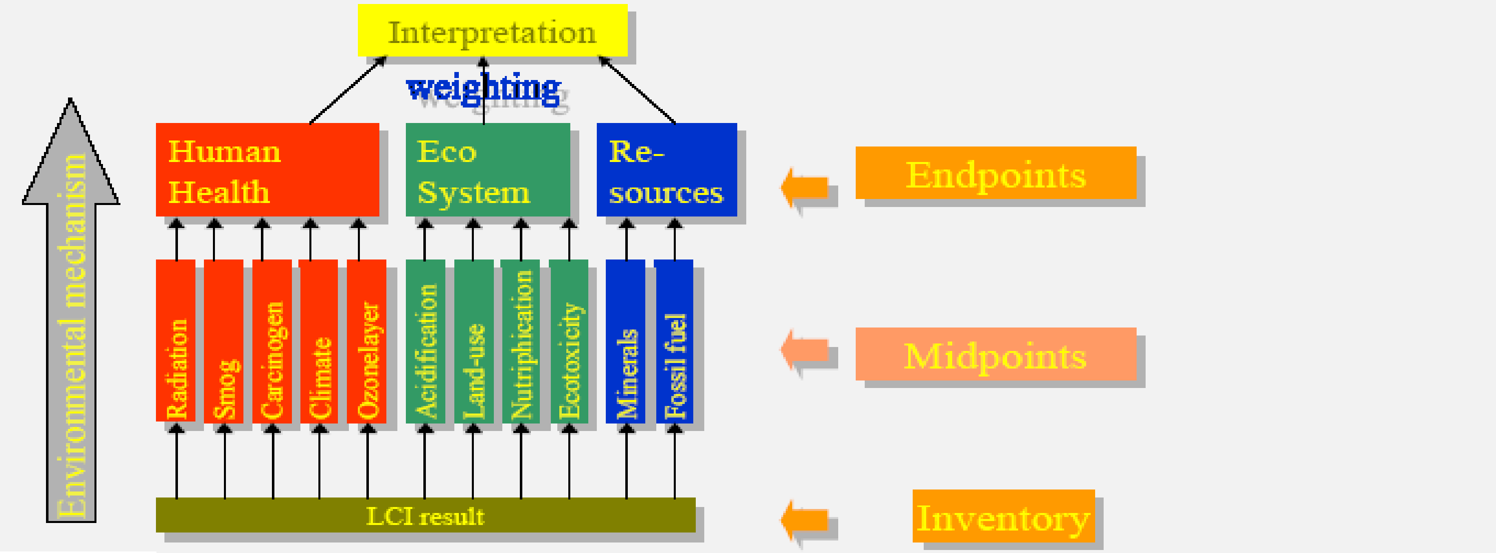
**Step 4:** Normalization (common units)

**Step 5:** Grouping

# Life Cycle Assessment (LCA)

**Step 6:** Weighting

- The weighting step (also referred to as valuation) of an LCIA assigns weights or relative values to the different impact categories based on their perceived importance or relevance.
- Weighting is important because the impact categories should also reflect study goals and stakeholder values.




*Schematic overview of the methodology proposed by Goedkoop & Spriensma. The environmental models for each impact category are extended up to endpoint level, as the impact category indicators that relate to the same endpoint have a common unit, these indicators can be added. In the case of ecotoxicity, the endpoint is Ecosystem Quality, expressed as Potential Disappeared Fraction of plants*

# Green Options for Existing Processes

- Eliminate or replace product (life cycle assessment)
- Eliminate or minimize hazardous substance use (mass balance)
- Minimize energy use
- Dematerialization (minimize weight and/or volume, combine various functions into one product, make fewer different styles, minimize/take back packaging, Moore's Law: the speed of a chip doubles every 2 years)
- Increase efficiency and economic life
- Redesign for reuse, remanufacture, or easy repair
- Reflect environmental cost in the price of the product

# Sustainability

√ **Some definitions:**

- Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. - *Brudtland Report*

- Maintaining or improving the material and social conditions for human health and the environment over time without exceeding the ecological capabilities that support them - *EPA NRMRL*

- Leaders that consider the impact of decisions on the seventh generation into the future. This way, they proceed cautiously, thinking of what effect their decisions will have on the welfare of their descendants.
  \- *Haudenosaunee Culture*

# Un-sustainability = Overload

Limited natural resources on earth +

Increasing rate of consumption +

Disproportionate use by wealthy minority =

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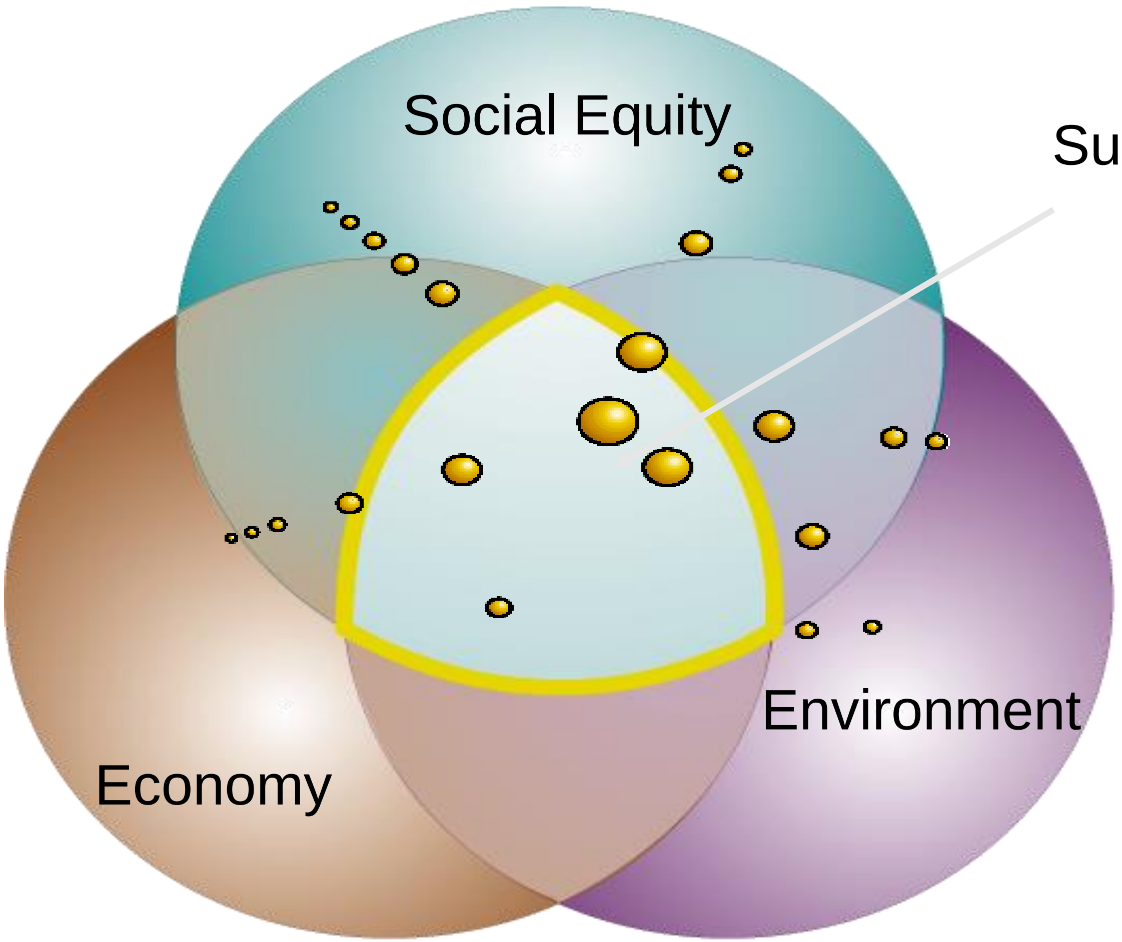
Intragenerational + Intergenerational Inequity

# Sustainability = Triple Bottom Line




Sustainable Solutions