MEBS6020 Sustainable Building Design

http://www.hku.hk/bse/MEBS6020/

Energy and Environmental Design (II)

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- Life cycle assessment
- Evaluation methods
- Life cycle costing
- Carbon audit

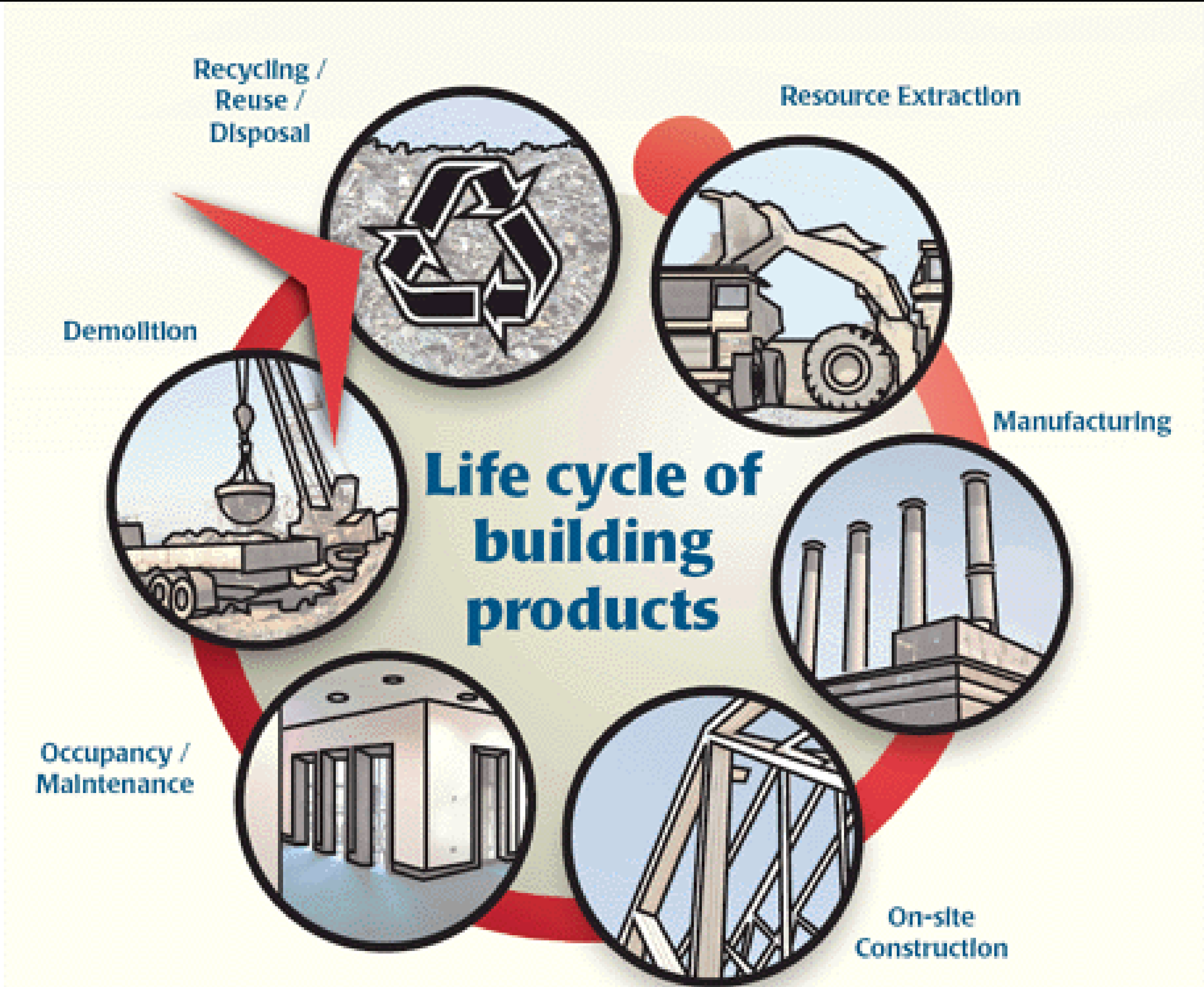
Cradle-to-Grave

Life cycle assessment

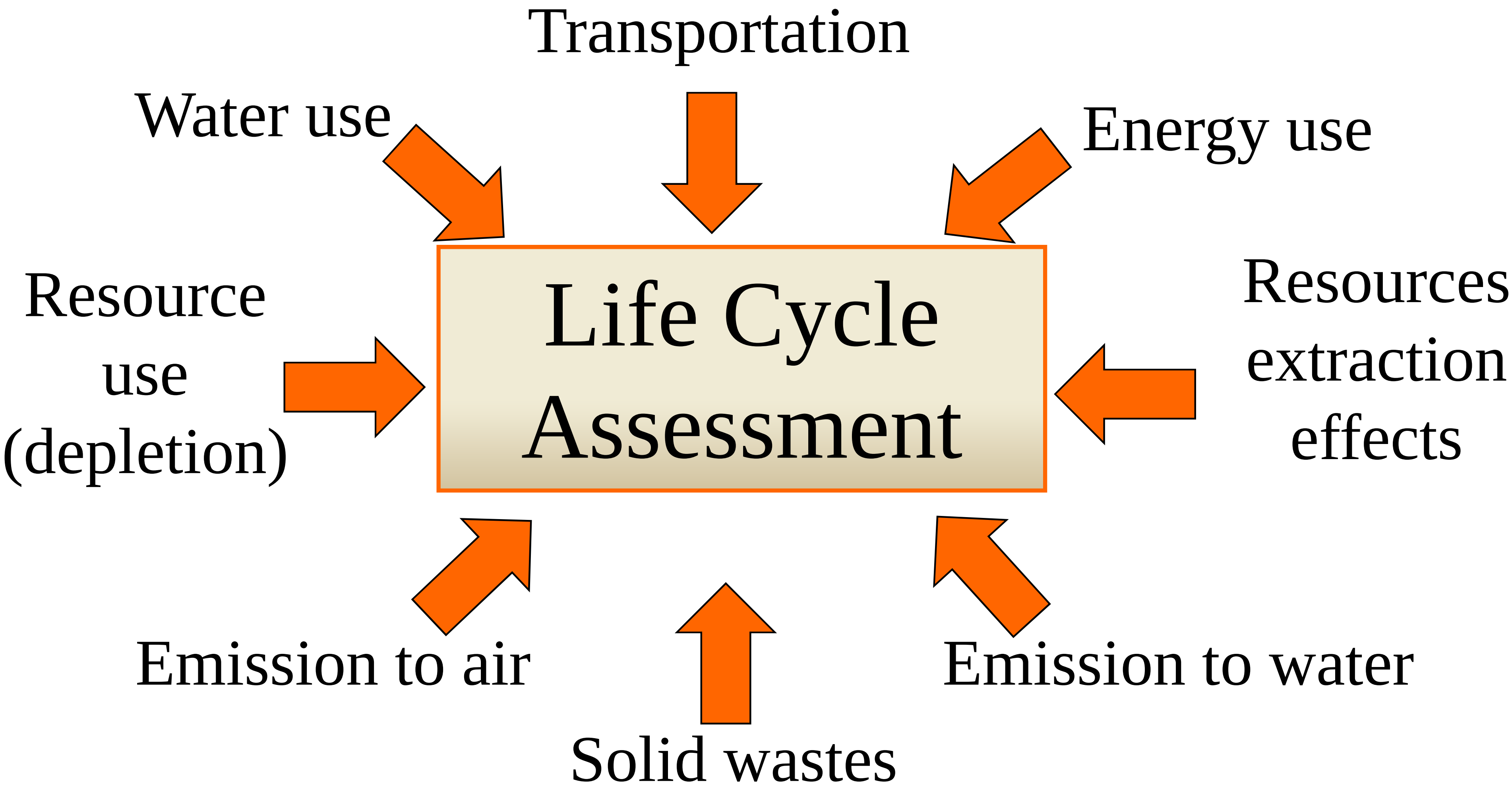
- Sustainable building design is still evolving
  - The need to put emphasis on performance outcomes and the trend toward more requirements rather than point-based alternatives
  - Use Life Cycle Assessment (LCA) to determine the embodied environmental effects of materials
- However, the LCA tools currently available are not widely utilized by most stakeholders
  - Therefore, need to promote education & training

Life cycle assessment

- According to ISO 14040, LCA is
  - “*A compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle*”
- Also called “cradle-to-grave” analysis
- Embodied effects include:
  - Resource use (raw materials, land, water, energy)
  - Emissions to air, water and land



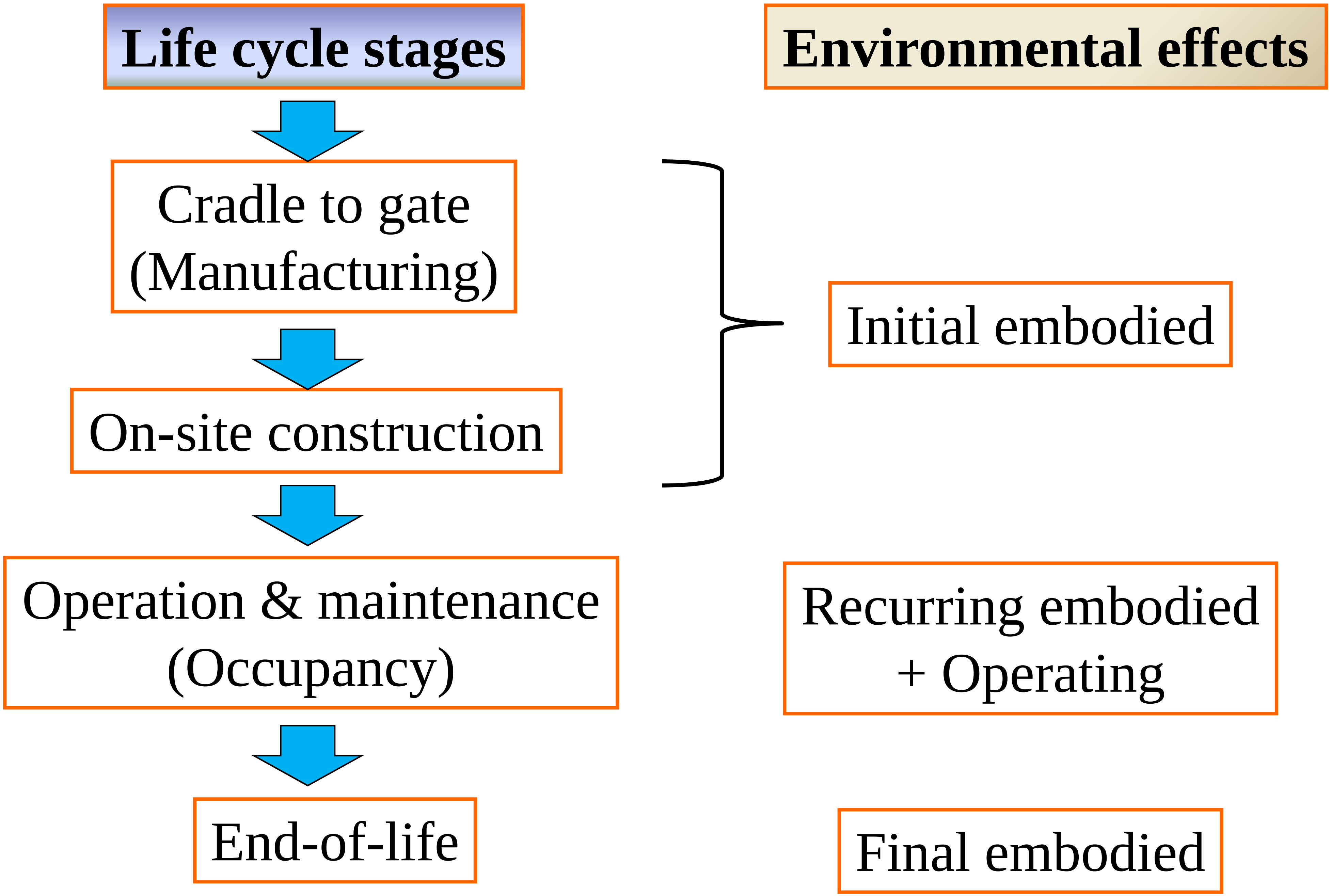
(Source: Athena Institute, www.athenasmi.org)



LCA: a methodology for assessing the life cycle environmental performance of products and processes

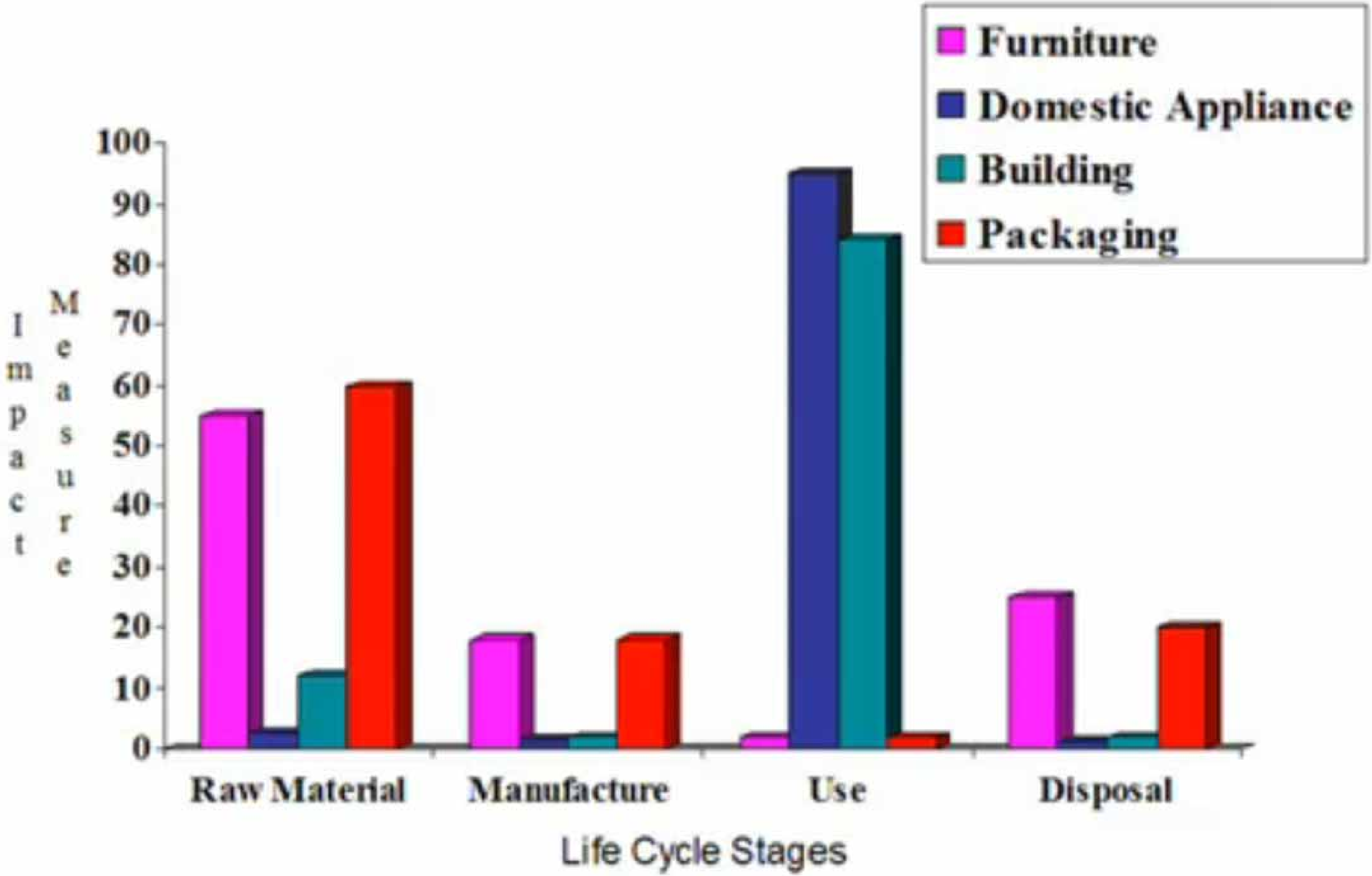
(Source: Athena Institute, www.athenasmi.org)

Life cycle stages and effects



(Source: Athena Institute, www.athenasmi.org)

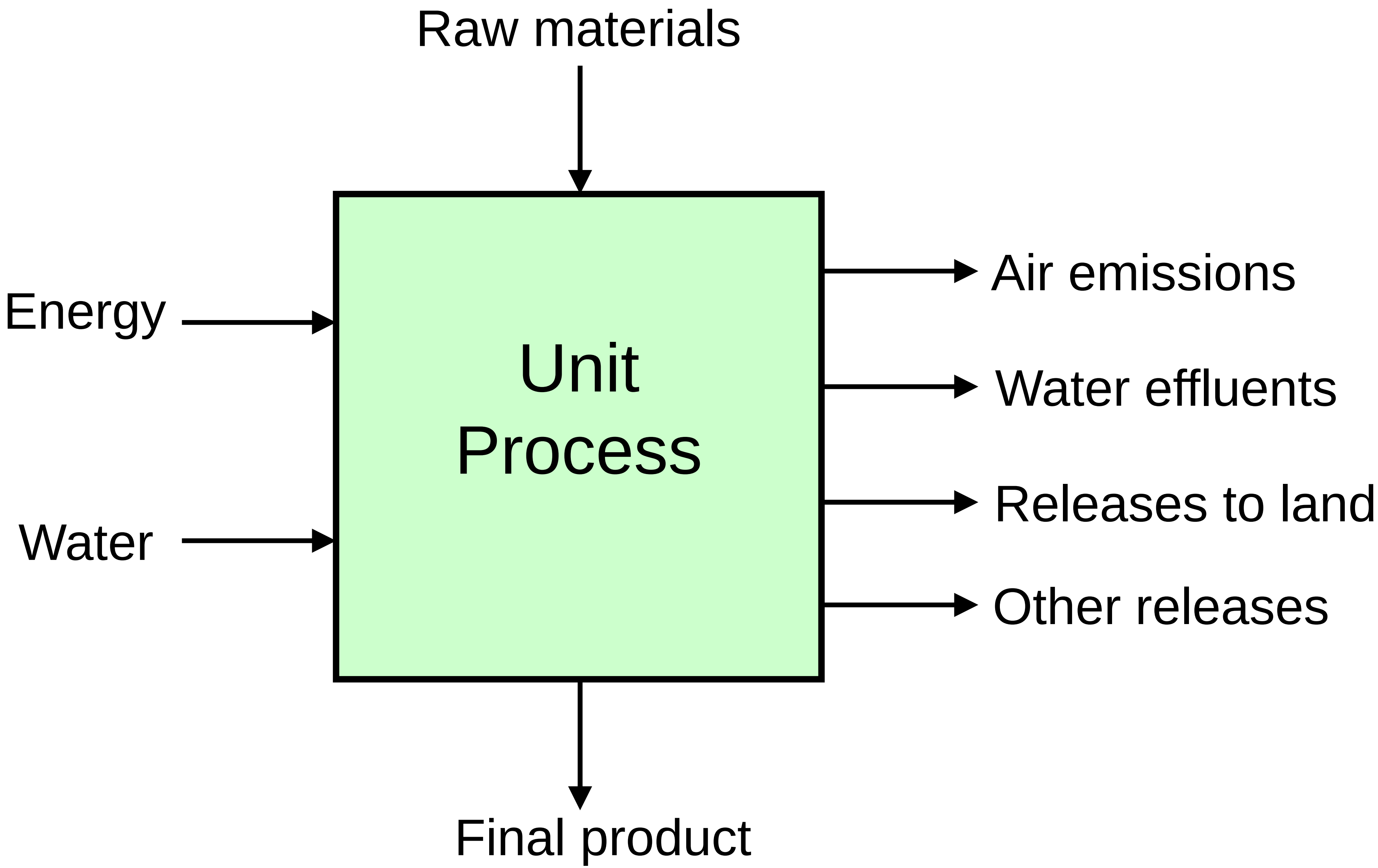
Understanding basic life cycle archetypes



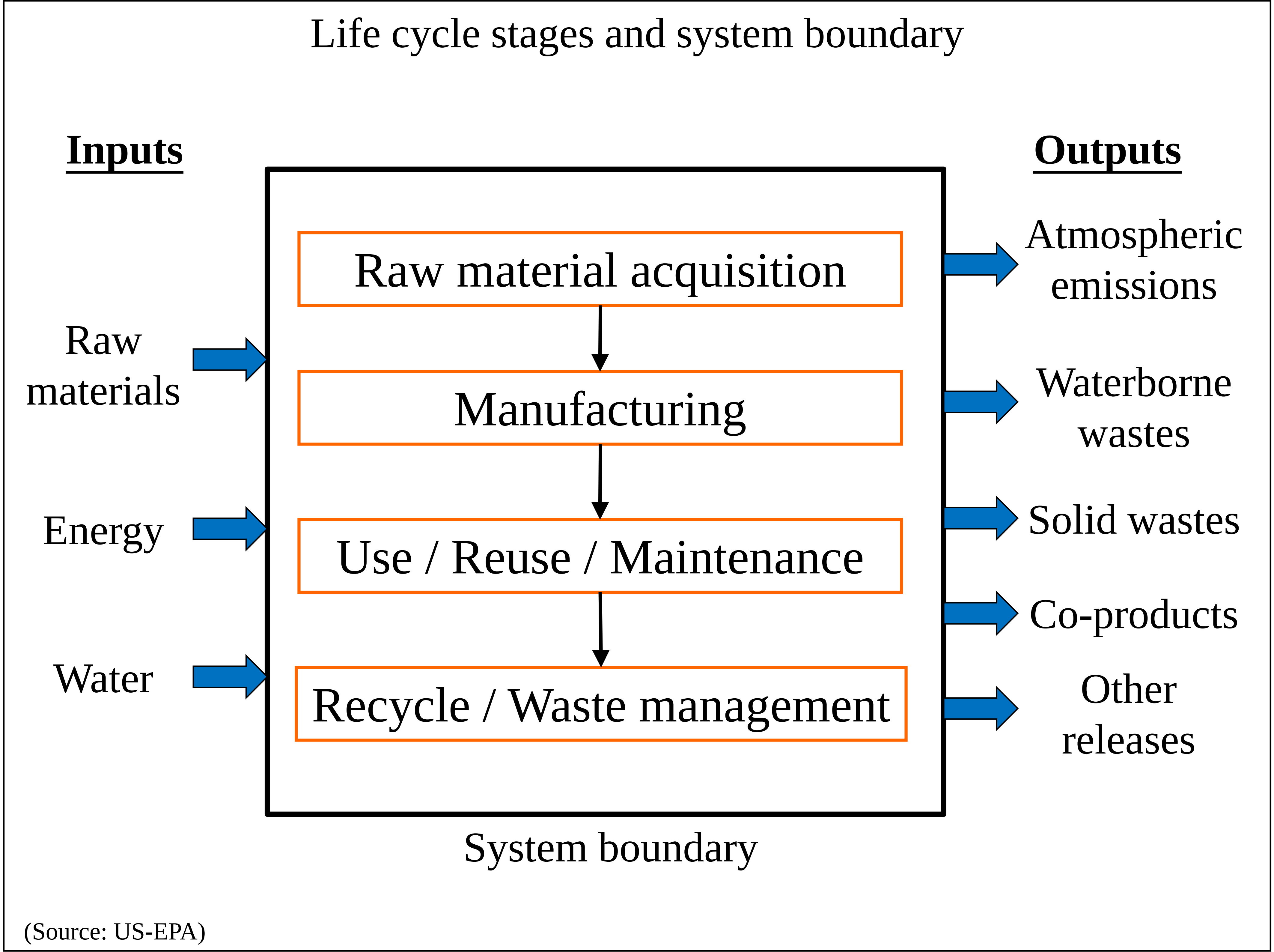
(Source: Professor Tim Grant, RMIT University)

Life cycle assessment

- LCA considers the environmental loadings that can result from the manufacture, use, and disposal of a product
  - It expresses the results in energy units, mass units of pollutants, potential impacts, and other units
- Three major LCA impact assessment phases:
  - (a) Inventory
  - (b) Impact indicators
  - (c) Impact assessment (valuation/weighting)



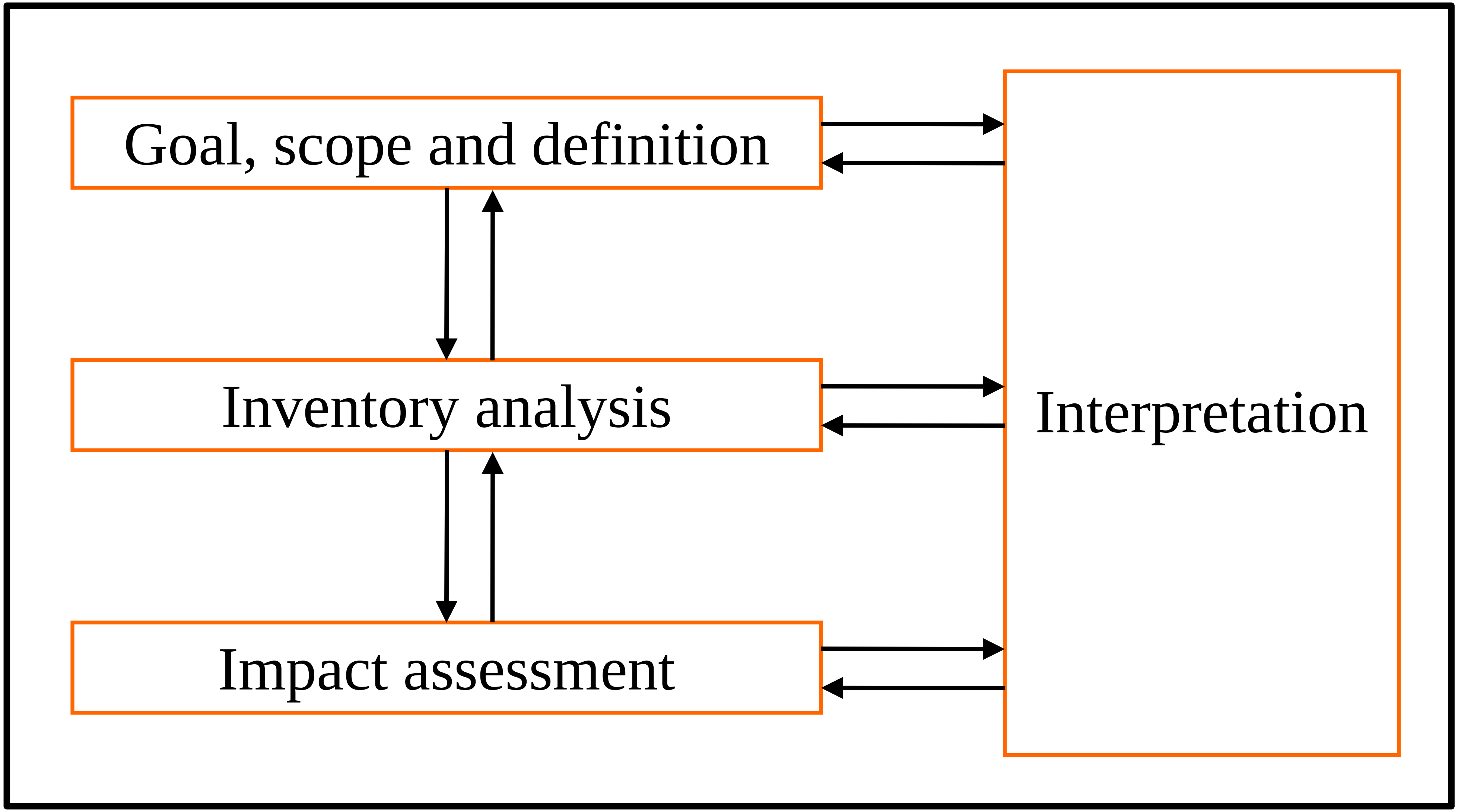
Inventory analysis model for life-cycle assessment


Life cycle stages and system boundary
Inputs
Outputs
Raw materials
Energy
Water
Raw material acquisition
Manufacturing
Use / Reuse / Maintenance
Recycle / Waste management
Atmospheric emissions
Waterborne wastes
Solid wastes
Co-products
Other releases
System boundary
(Source: US-EPA)

Life cycle assessment

- LCA components and approach
  - 1) Goal, scope and definition
    - Defines purpose of study, sets boundaries
  - 2) Life cycle inventory (LCI)
    - Provides inventory of input/output data
  - 3) Life cycle impact assessment (LCIA)
    - Assess the magnitude and significance of the impacts
  - 4) Life cycle interpretation
    - Provides conclusions and recommendations (areas for improvement)

Life cycle assessment framework

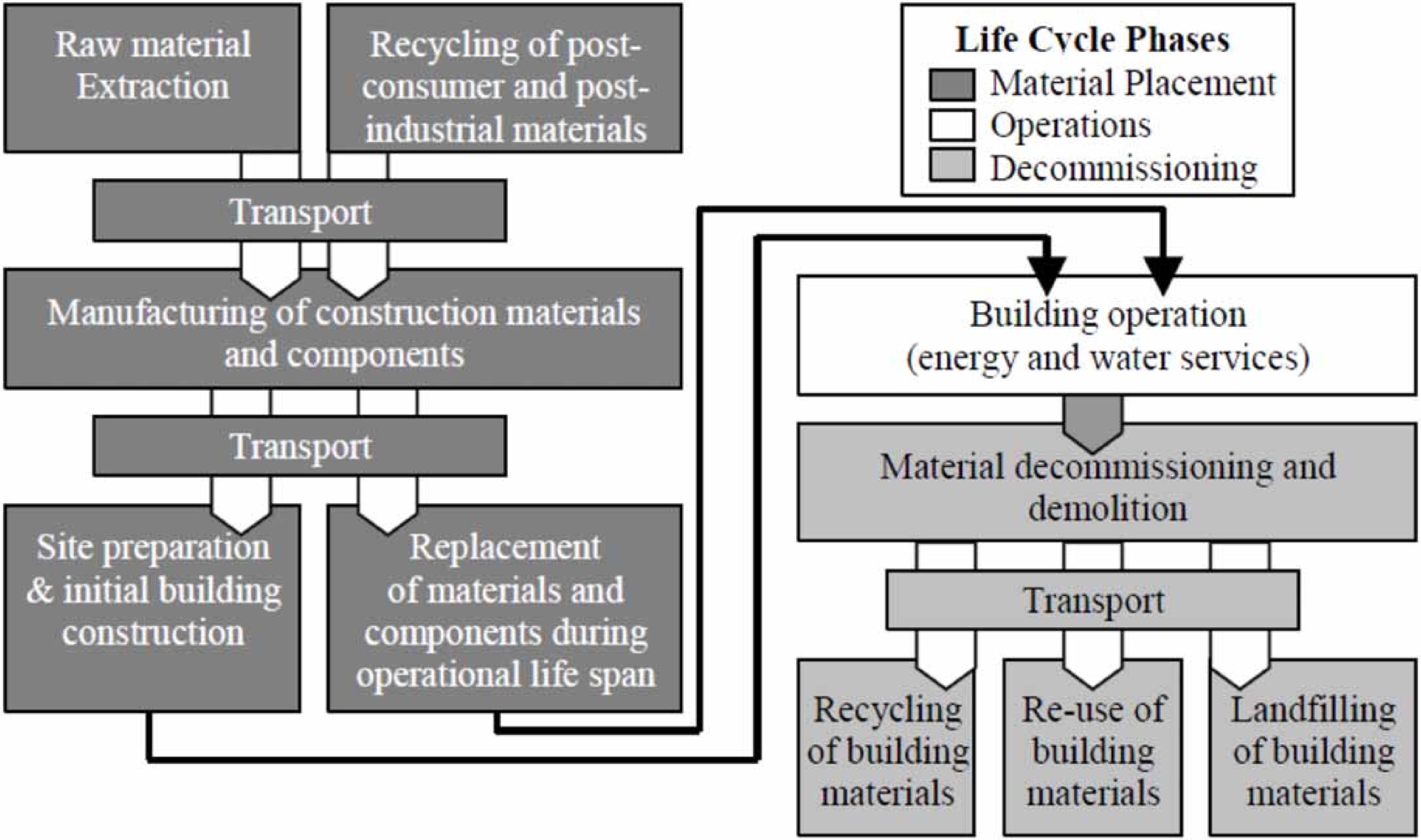


(Source: US-EPA)

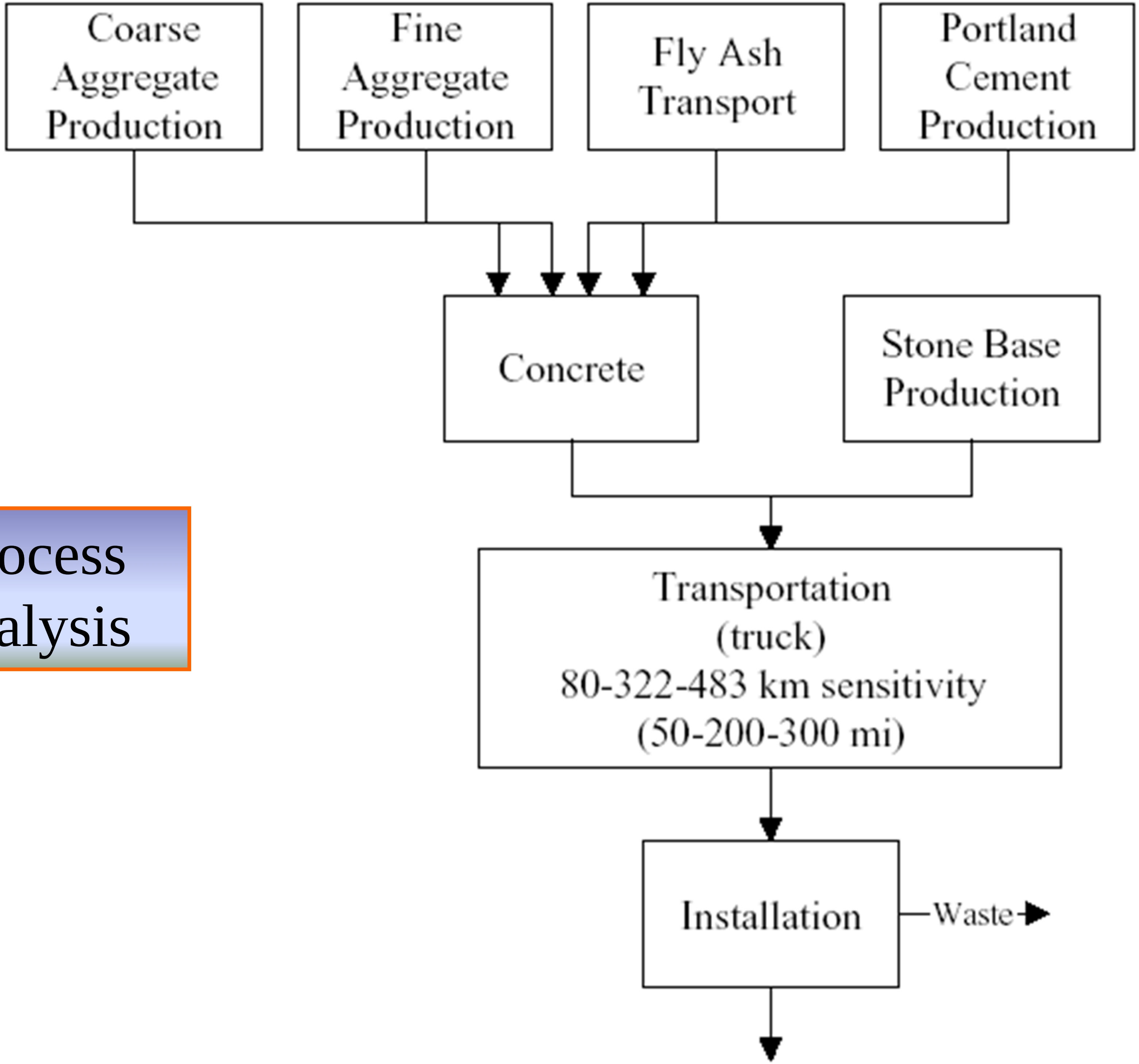
Life cycle assessment

- Key steps to interpret the results of the LCA
  - 1. Identification of the significant issues based on the LCI and LCIA
  - 2. Evaluation which considers:
    - Completeness check
    - Sensitivity check
    - Consistency check
  - 3. Conclusions, recommendations, and reporting

Life cycle phase diagram

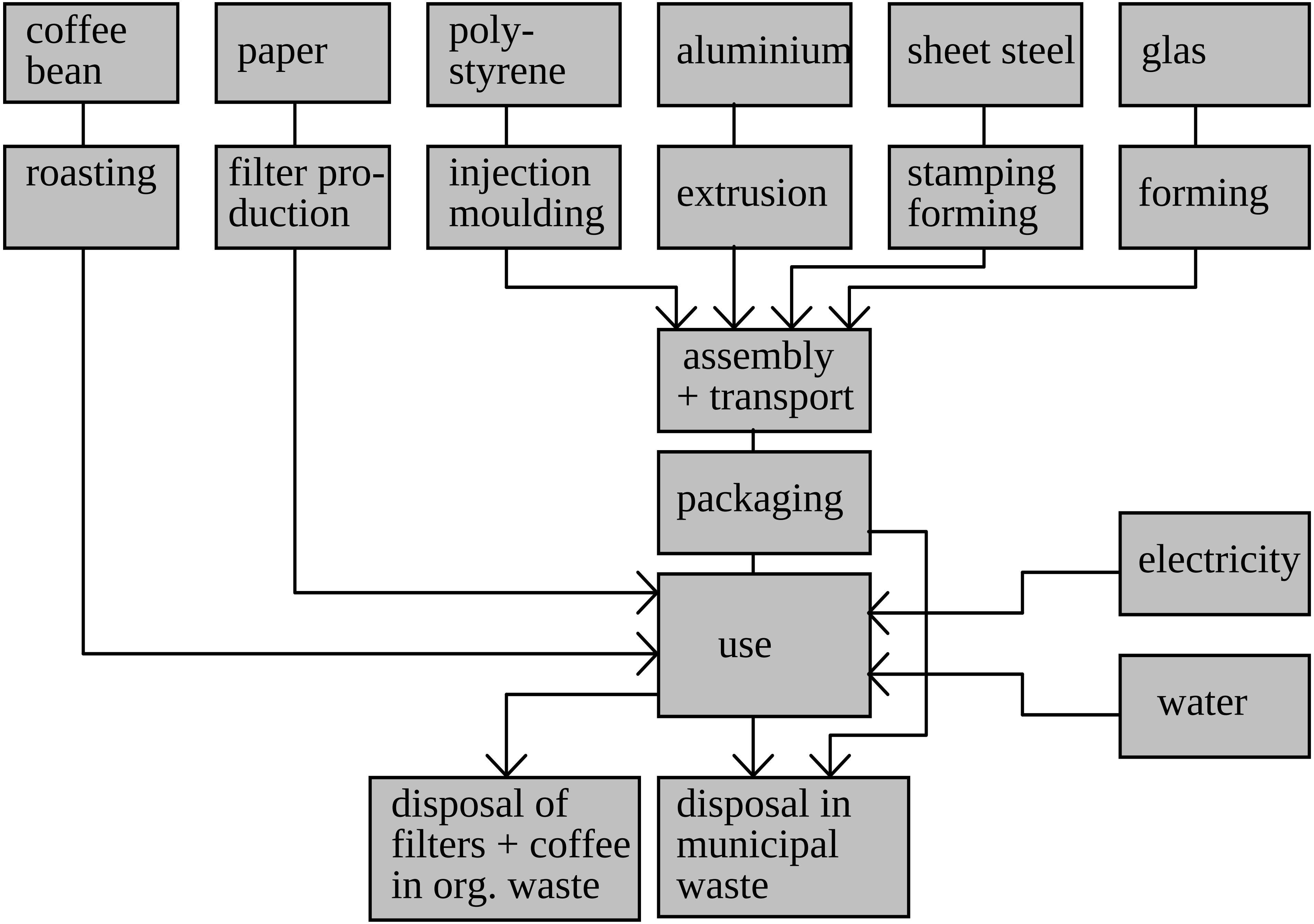


LCA example – concrete paving flow chart



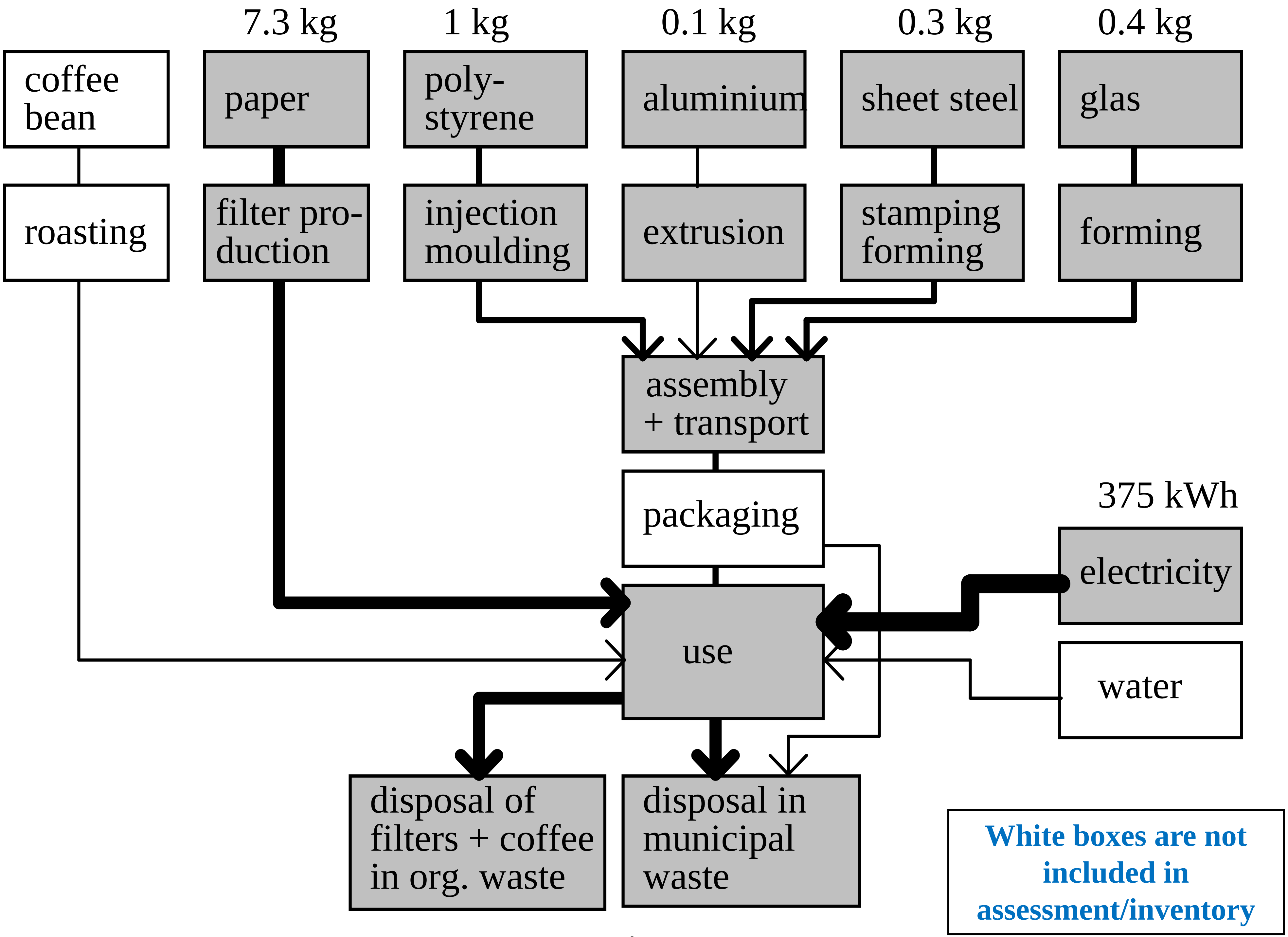
Process analysis

Example: Simplified process tree for a coffee machine's life-cycle



(Source: Systems Realization Laboratory, Georgia Institute of Technology)

Example: Coffee machine life-cycle inventory



(Source: Systems Realization Laboratory, Georgia Institute of Technology)

Life cycle assessment

- Environmental performance indicators:
  - Fossil fuel depletion
  - Other non-renewable resource use
  - Water use
  - Global warming potential
  - Stratospheric ozone depletion
  - Ground level ozone (smog) creation
  - Nutrification (excess nutrients)/eutrophication (oxygen deficiency) of water bodies

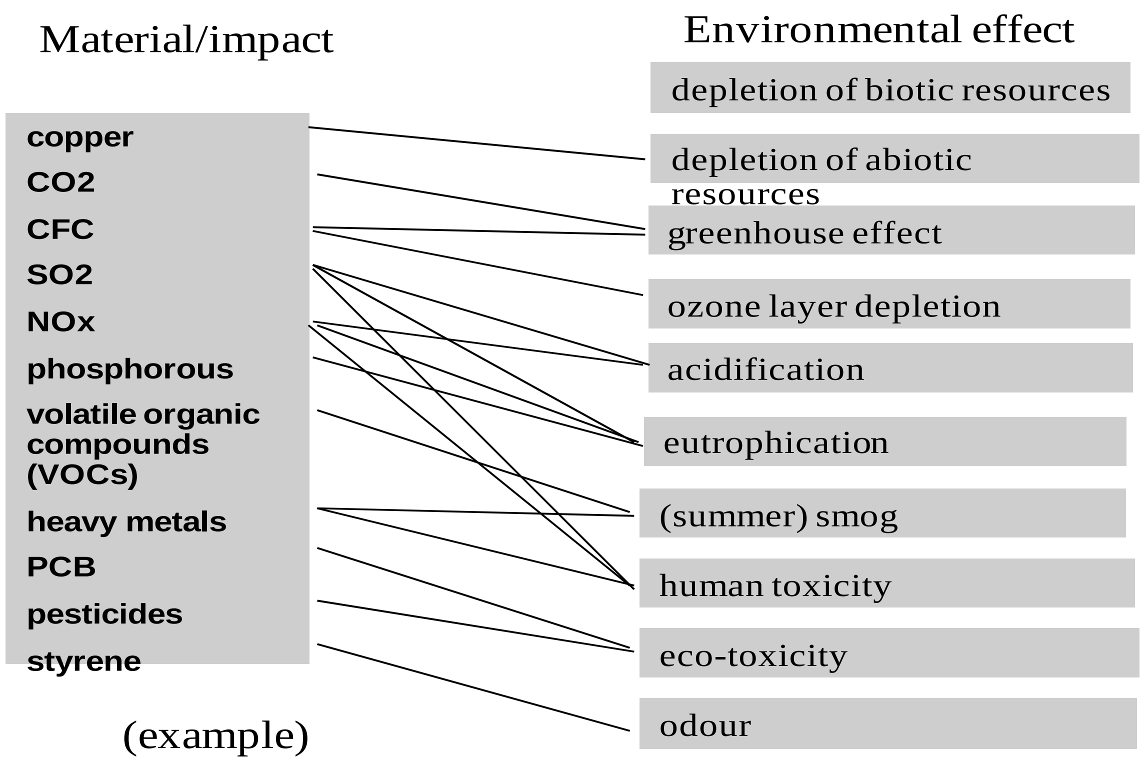
Life cycle assessment

- Environment. performance indicators: (cont'd)
  - Acidification and acid deposition (dry and wet)
  - Toxic releases to air, water, and land

- The indicators do not directly address the ultimate human or ecosystem health effects, but provide good measures of environmental performance

Life cycle assessment

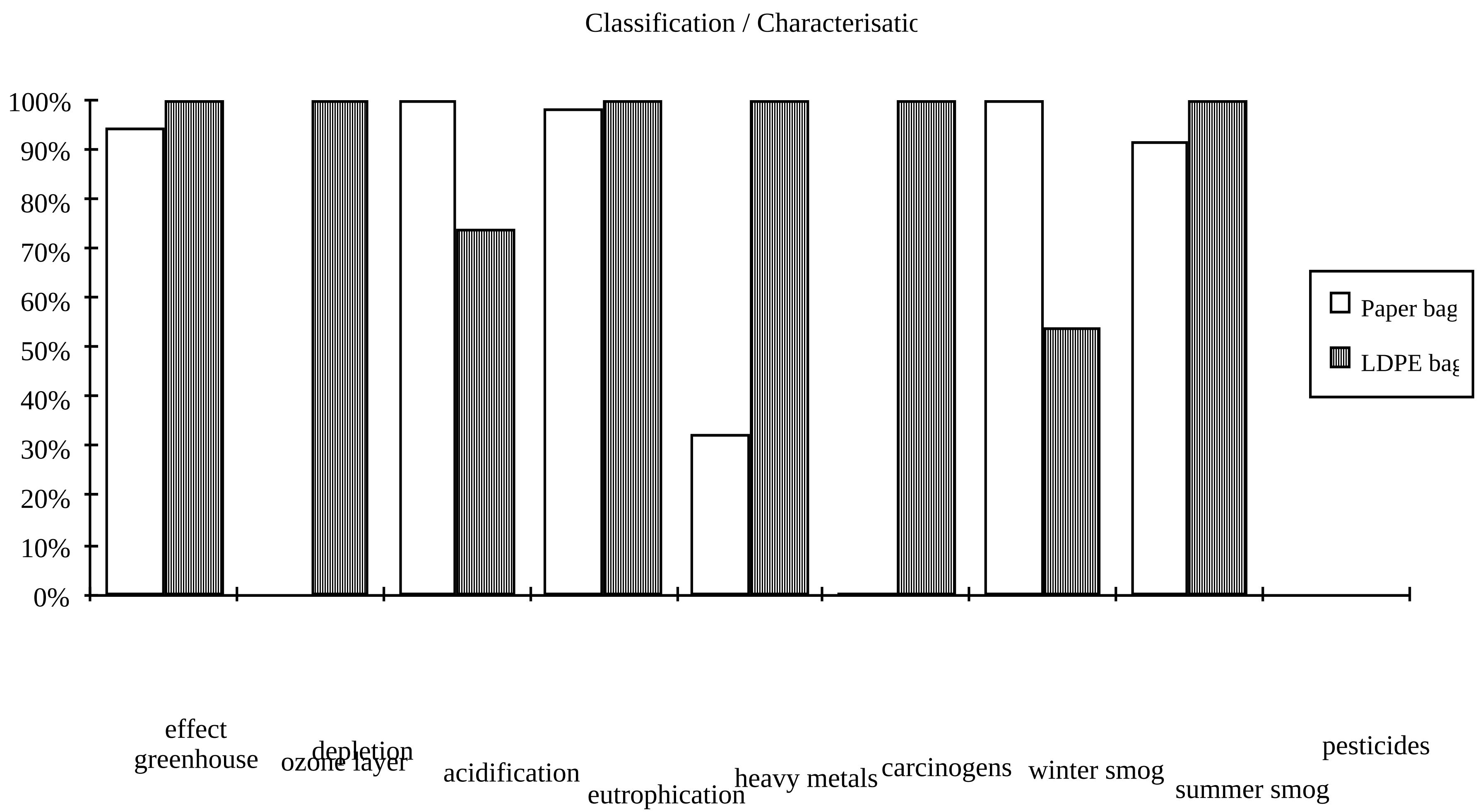
- LCA impact assessment:
  - It focuses on characterizing the type and severity of environmental impact more specifically



Weighting of effect?

There are different ways to assess and weigh the environmental effects.

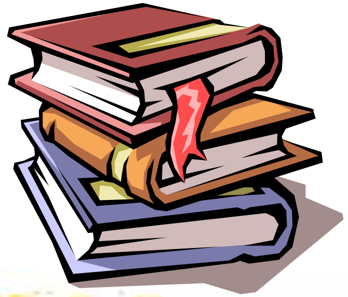
Example: Plastic versus paper bag classification



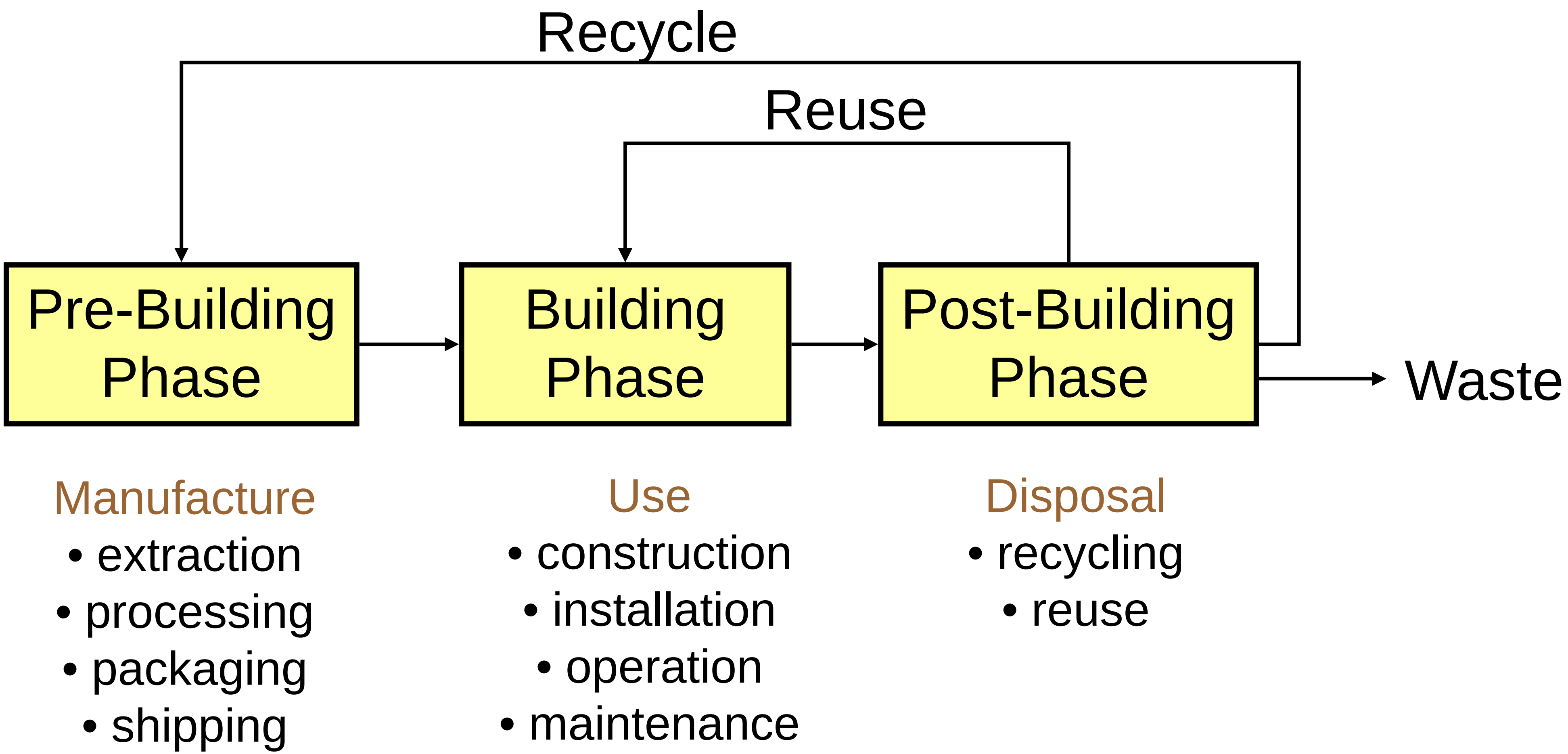
- The paper bag causes more winter smog and acidification, but scores better on the other environmental effects.
- The classification does not reveal which is the better bag. What is missing is the mutual weighting of the effects.

(Source: Systems Realization Laboratory, Georgia Institute of Technology)

Useful References

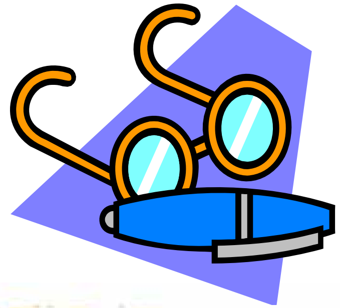


- ISO 14040:2006 Environmental Management – Life Cycle Assessment –Principles and Framework
- ISO 14044:2006 Environmental Management – Life Cycle Assessment – Requirements and Guidelines



Three phases of building material life cycle

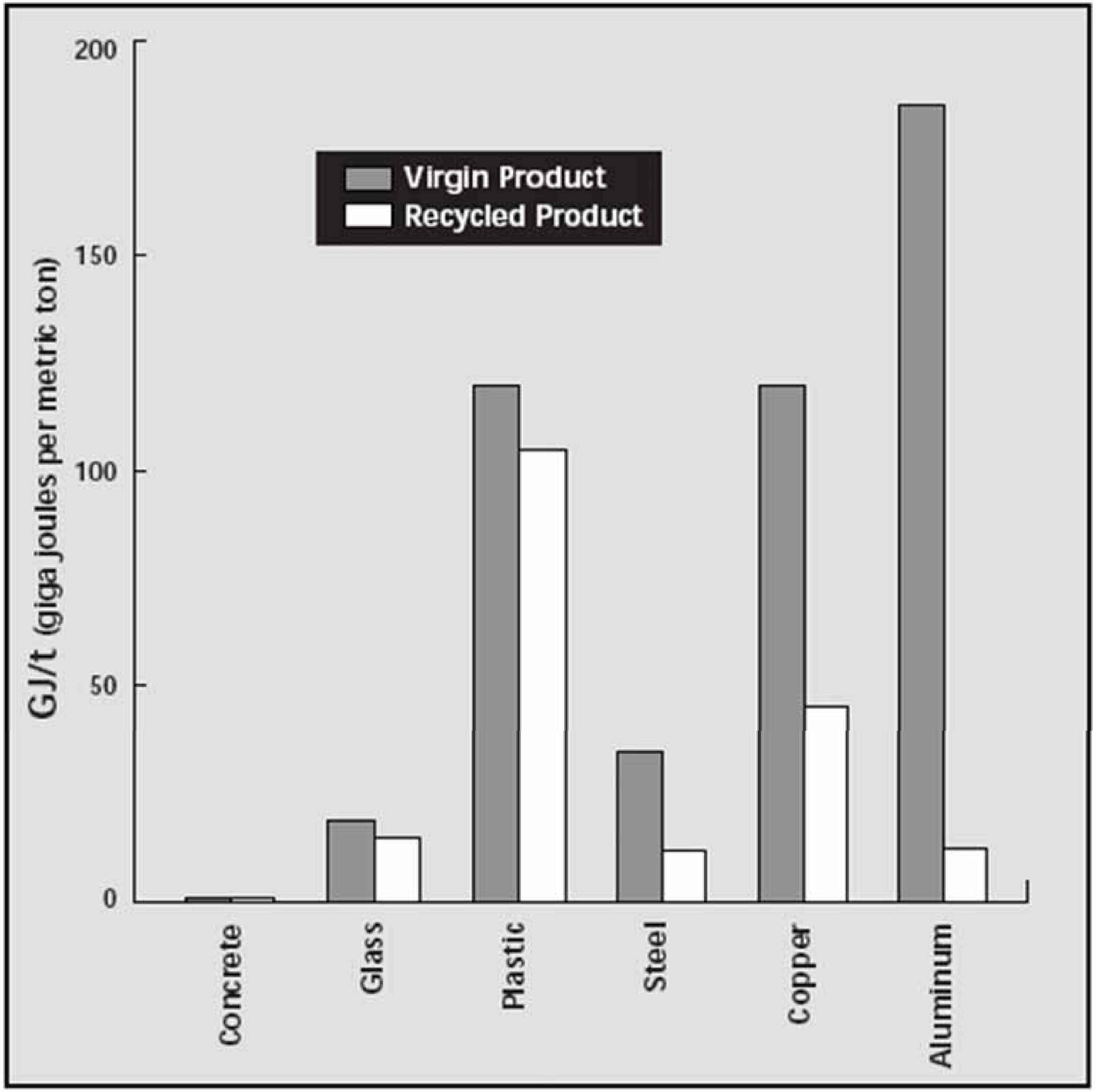
Evaluation methods



- Pre-building phase
  - Materials acquisition & preparation
    - Land degradation & depletion of resources
  - Manufacturing & fabrication
    - Energy & water use
    - Fugitive emissions
    - Water pollution
  - Distribution & transport
    - Fuel use & air pollution

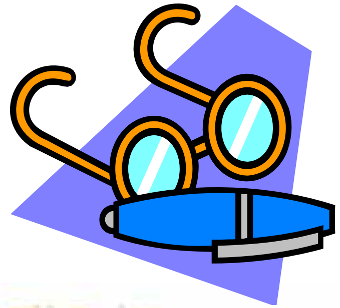
Energy efficiency by mode of transport

	kJ/tonne-km
Truck	2,128
Railroad	248
Barge (on river)	287
Ship	123

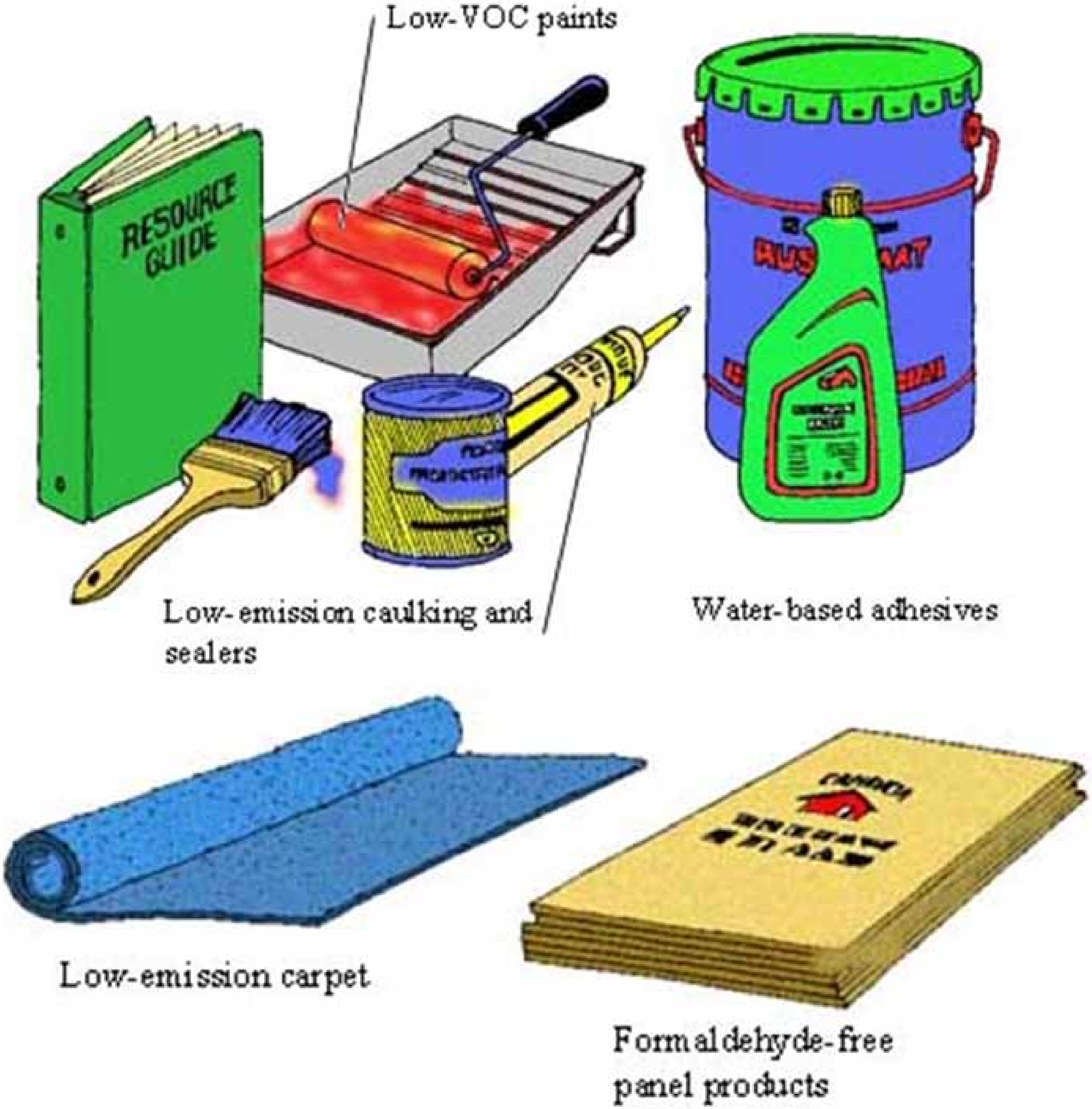


Embodied energy of virgin and recycled products

Evaluation methods

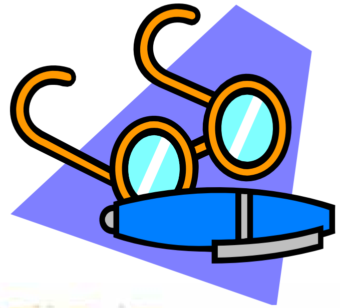


- Building phase
  - Construction & installation on site
    - Noise, waste & pollutants from construction site
  - Maintenance & repair
    - Energy & water use
    - Maintenance & operation requirements
  - Use & operation of the building
    - Effects on indoor air quality & occupants' health

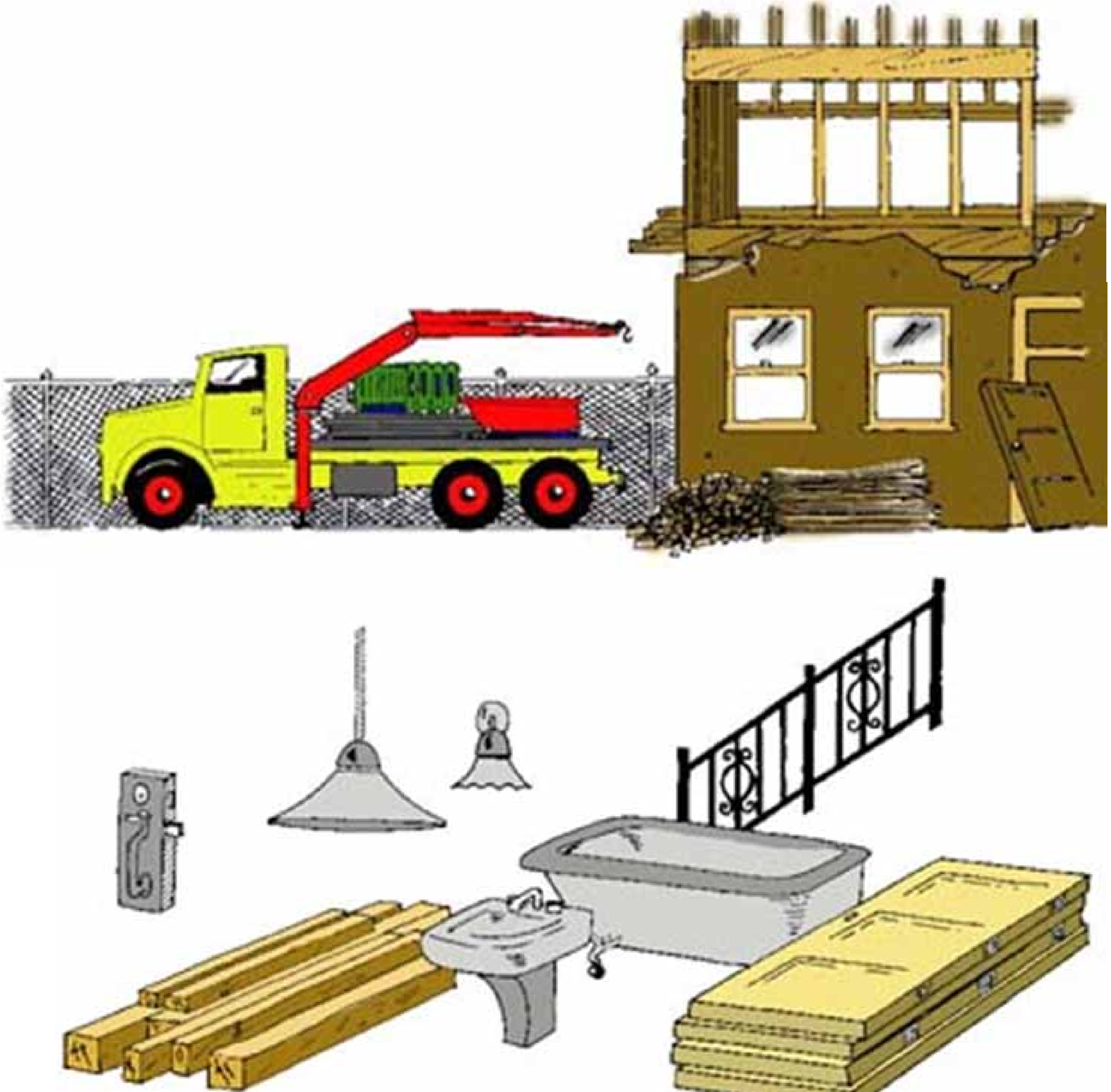


Enhance indoor air quality and minimise health effects

Evaluation methods

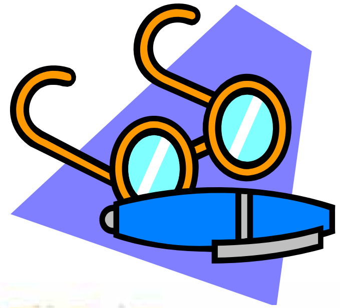


- Post-building phase
  - Demolition
    - Noise, air & water pollution during demolition
  - Disposal
    - Need for transportation, landfil, etc. for the waste
  - Reuse or recycling
    - Energy & water use
- “De-construction”
  - Building disassembly & materials salvage



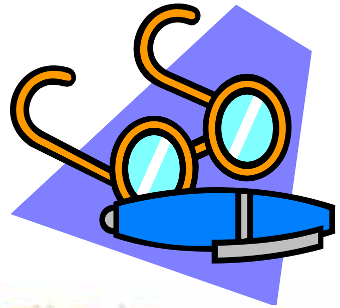
Separate recyclables from demolition and reuse salvaged materials

Evaluation methods



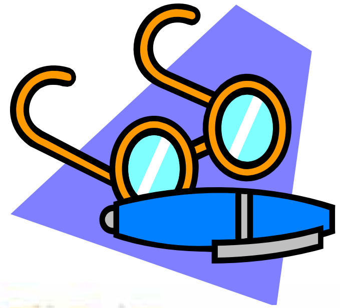
- Criteria in material selection:
  - Resource quantity (use less & more efficiently)
  - Reused materials (salvaged & reused)
  - Recycled content (post- & pre-consumer waste)
  - Renewable materials (e.g. sustainable forestry)
  - Local content and reduced transportation
  - Life-cycle cost & maintenance requirements
  - Resource recovery & recycling
  - Effects on health & indoor air quality

Evaluation methods



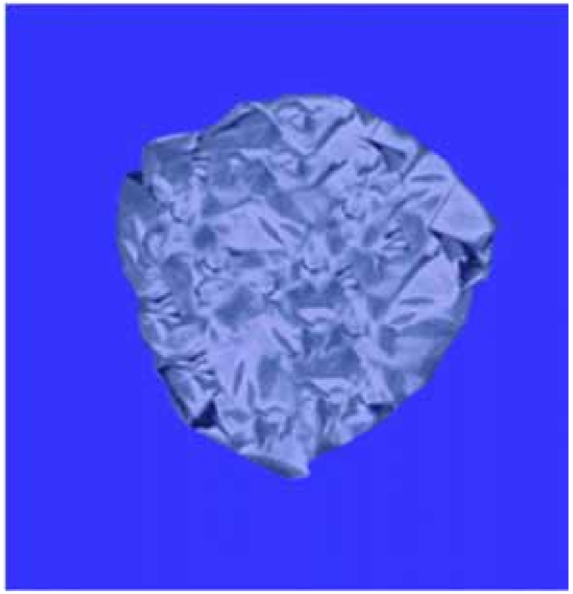
- Important considerations
  - Not just replace one material by another
  - Need to consider how the material is used
  - May require cultural change in design and in using the new materials
- Product to service shift
  - e.g. carpeting service (by Interface, Inc.)
  - Supplier to reuse or recycle the materials

Evaluation methods



- Evaluate building materials
  - Collect as much information as possible
  - Make judgements & assumptions if needed
- Basic questions
  - What is in them?
  - How they are made?
  - Where they come from?
  - How they perform in the building?
  - What happens to them afterwards?

“Waste - a resource in the wrong place”
-- An old Chinese proverb.



The True Cost of Waste

Purchase price & transportation costs of materials

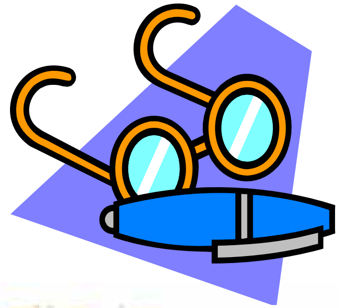
+

Cost of storage, transport & disposal of waste

+

Loss of income from not salvaging waste materials

Evaluation methods



- Examples of LCA analysis software tools
  - ATHENA Impact Estimator and EcoCalculator (Canada), www.athenaSMI.ca
  - BEES (Building for Environmental and Economic Sustainability) Online version (USA)
    - www.bfrl.nist.gov/oae/software/bees/
  - GaBi (Germany), www.gabi-software.com
  - SimaPro (The Netherlands)
    - www.pre.nl/simapro.html

Evaluation methods

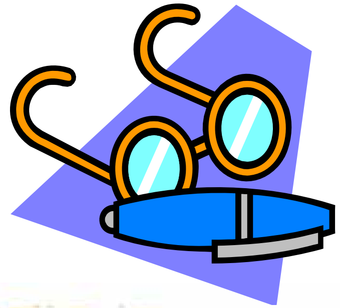
- LCA tools by Athena Institute, http://www.athenaSMI.ca/
  - Impact Estimator (for buildings)
    - Evaluate whole buildings and assemblies based on LCA methodology
  - EcoCalculator (for assemblies)
    - Provides instant LCA results for more than 400 common building assemblies
  - LCA inventory databases
    - Such as structural products and envelope products

Athena Impact Estimator for Buildings

Athena EcoCalculator for Commercial Assemblies

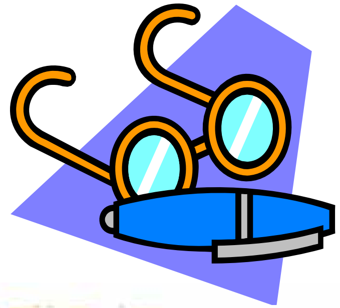
Athena EcoCalculator for Residential Assemblies

Evaluation methods



- Impact Estimator's summary measures format:
  - Embodied primary energy use (consumption)
  - Acidification potential
  - Global warming potential
  - Human health respiratory effects potential
  - Ozone depletion potential
  - Smog potential
  - Aquatic eutrophication potential
  - Weighted resource use

Evaluation methods

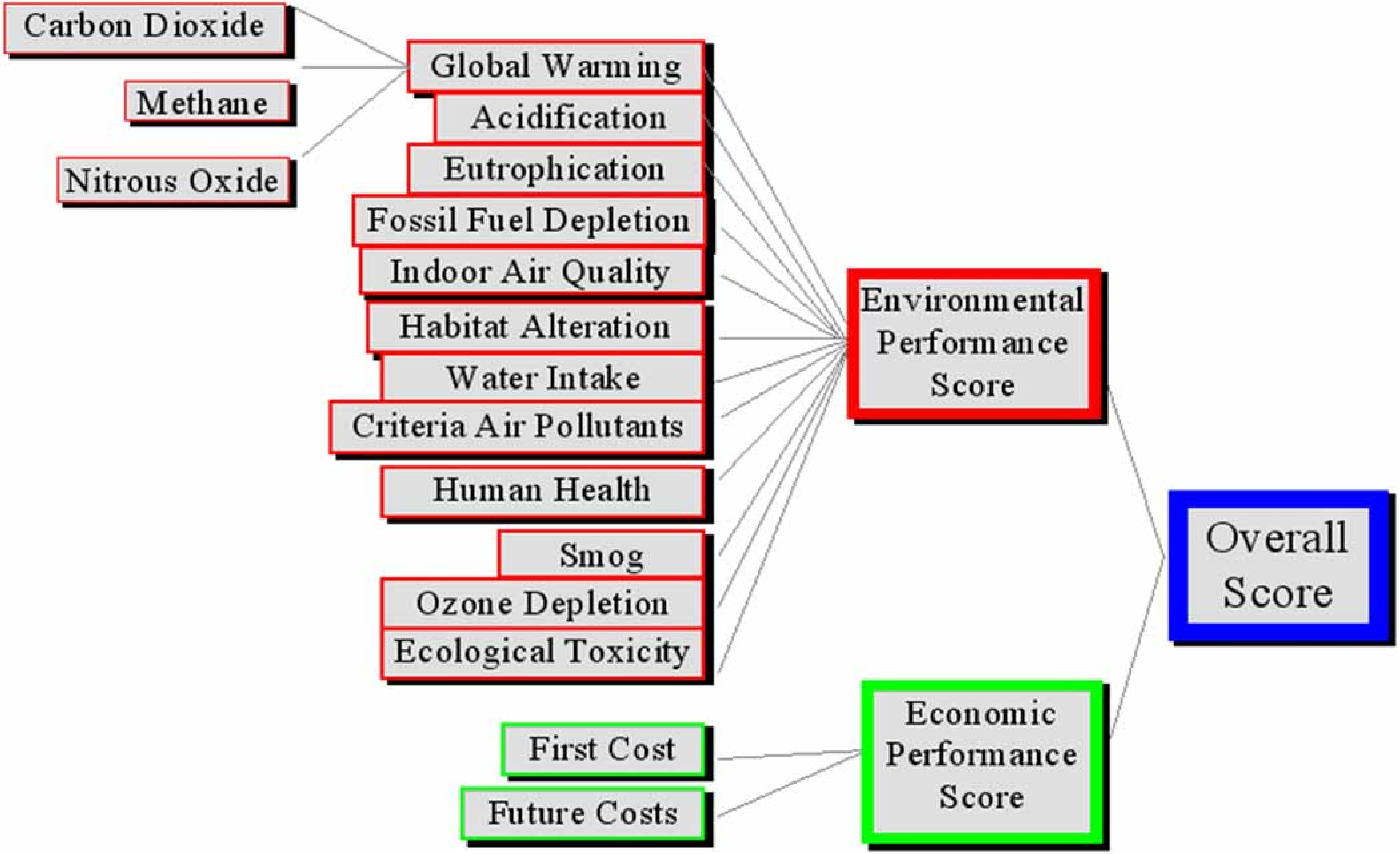


- Impact Estimator's absolute values format:
  - Energy
  - Air emissions
  - Water emissions
  - Land emissions
  - Resource use
- Further information:
  - Impact Estimator for Buildings v. 4 Tutorial
    - www.athenasmi.org/tools/impactEstimator/tutorial.html

Evaluation methods

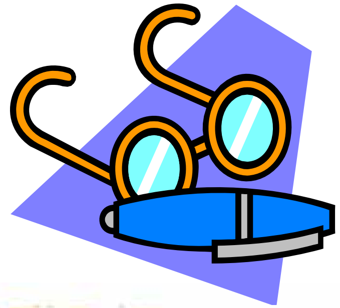
- BEES (Building for Environmental and Economic Sustainability) (USA)
  - http://www.bfrl.nist.gov/oae/software/bees/
  - Developed by Building and Fire Research Laboratory of the National Institute of Standards and Technology (NIST)
  - For measuring the life-cycle environmental and economic performance of building products
  - BEES Online version is available now

BEES (Building for Environmental and Economic Sustainability) Model



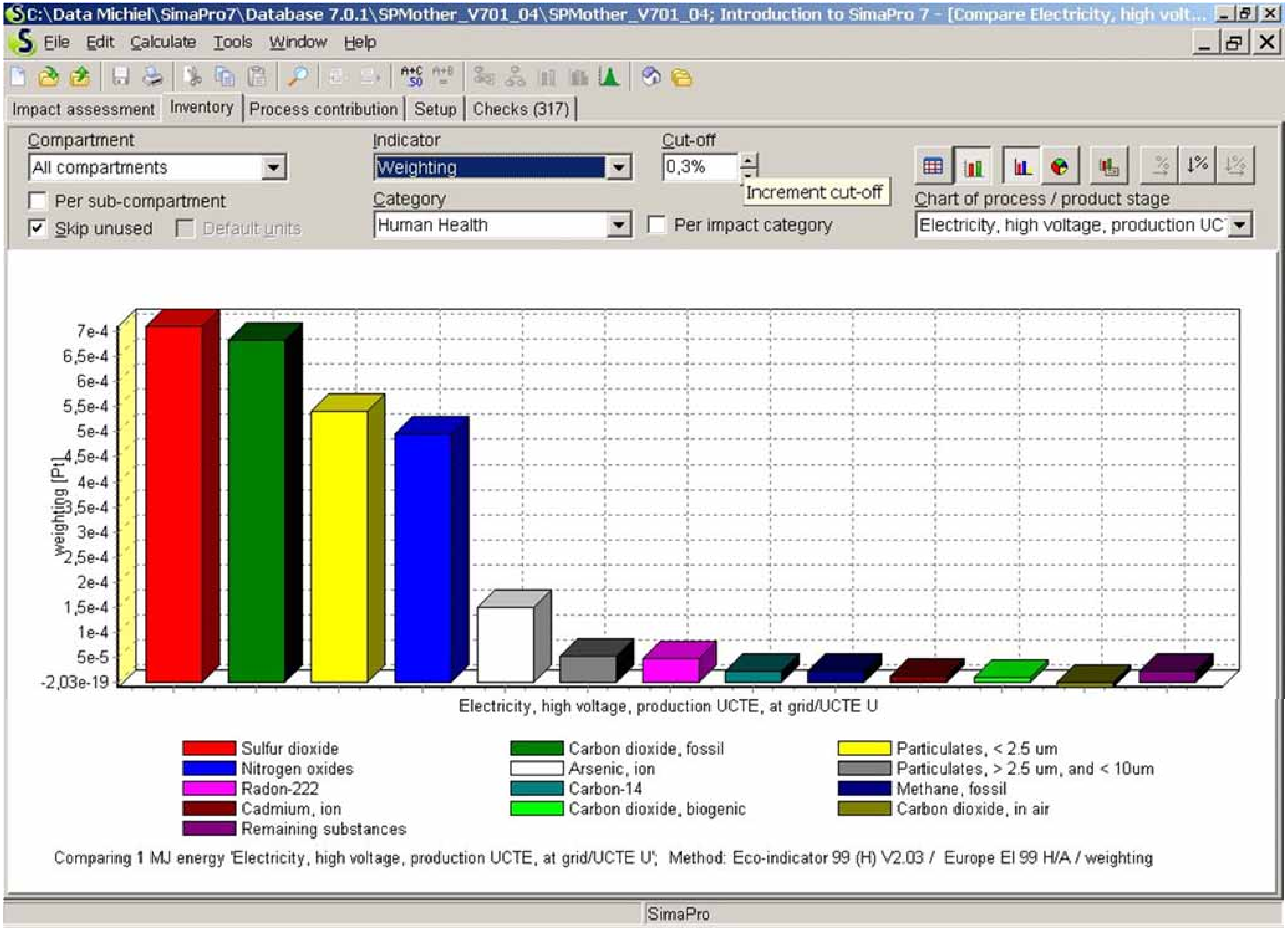
(Source: www.bfrl.nist.gov/oae/software/bees)

Evaluation methods



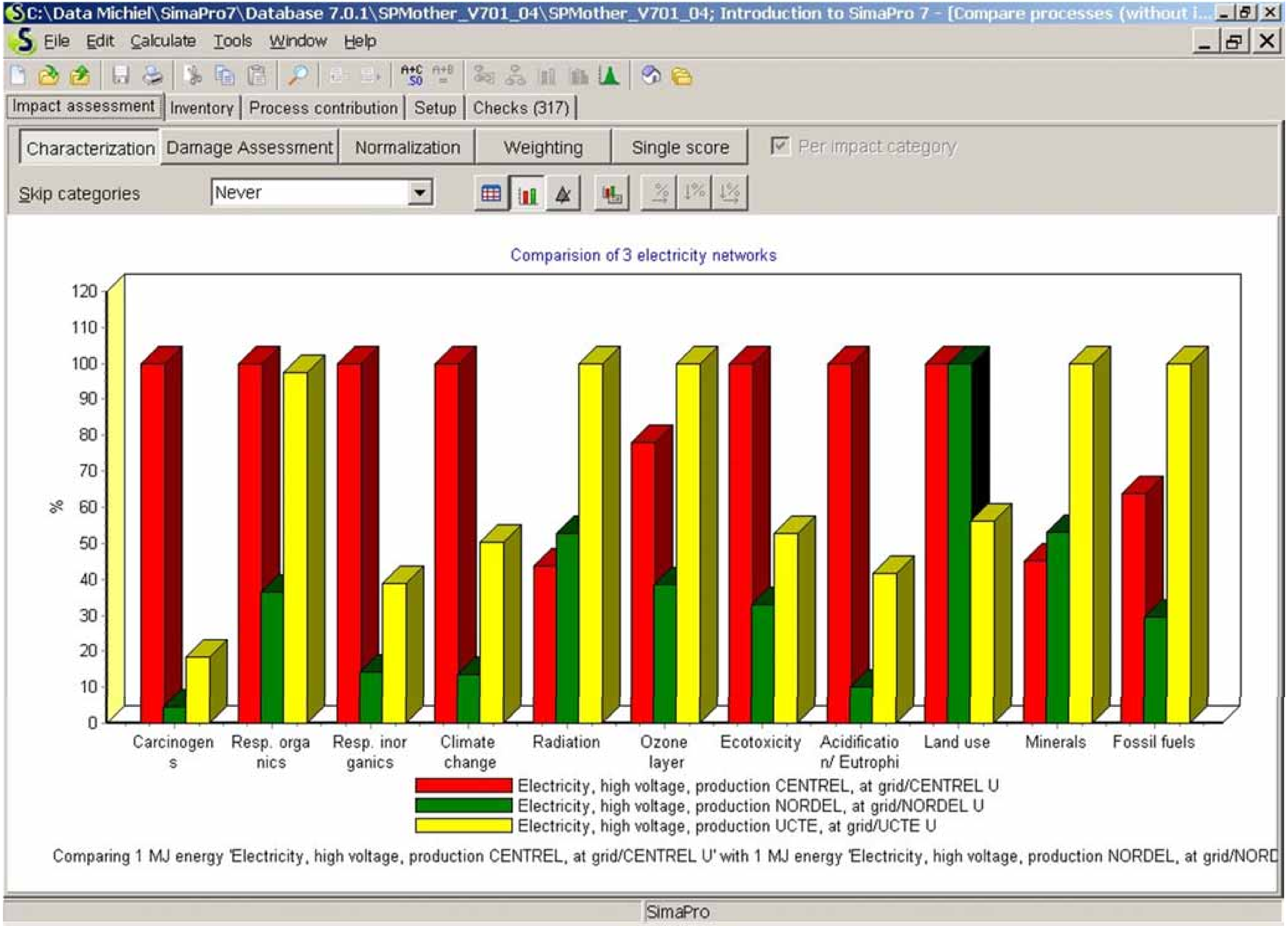
- SimaPro LCA software (by PRé Consultants)
  - http://www.pre.nl/simapro.html
  - Tool to collect, analyze and monitor the environmental performance of products, processes and services
  - Follow the ISO 14040 series recommendations
  - SimaPro inventory databases
  - SimaPro 7 introduction
    - www.pre.nl/webdemo/new/EN/SimaPro_Intro_EN.html

Features of SimaPro



(Source: www.pre.nl/simapro/)

Compare models in SimaPro



(Source: www.pre.nl/simapro/)

Life cycle costing

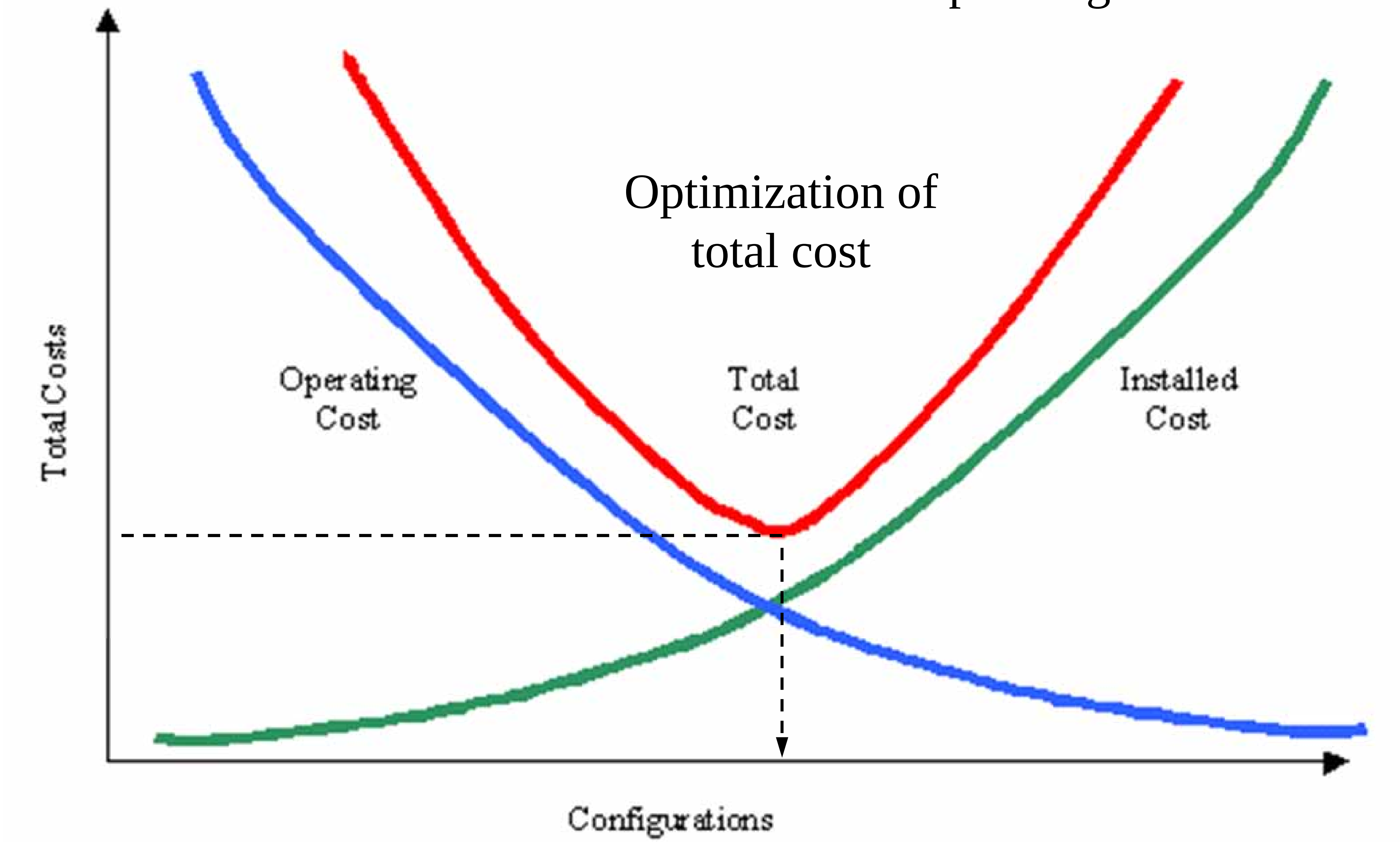
- Life-cycle costing (LCC)
  - Analyses the design of building or building systems including initial costs, maintenance costs, repair costs, energy & water costs, and other significant costs over the assumed life of the facility or system
  - Combines all costs into net annual amounts, discounts them to present value, and sums them to arrive at total LCC

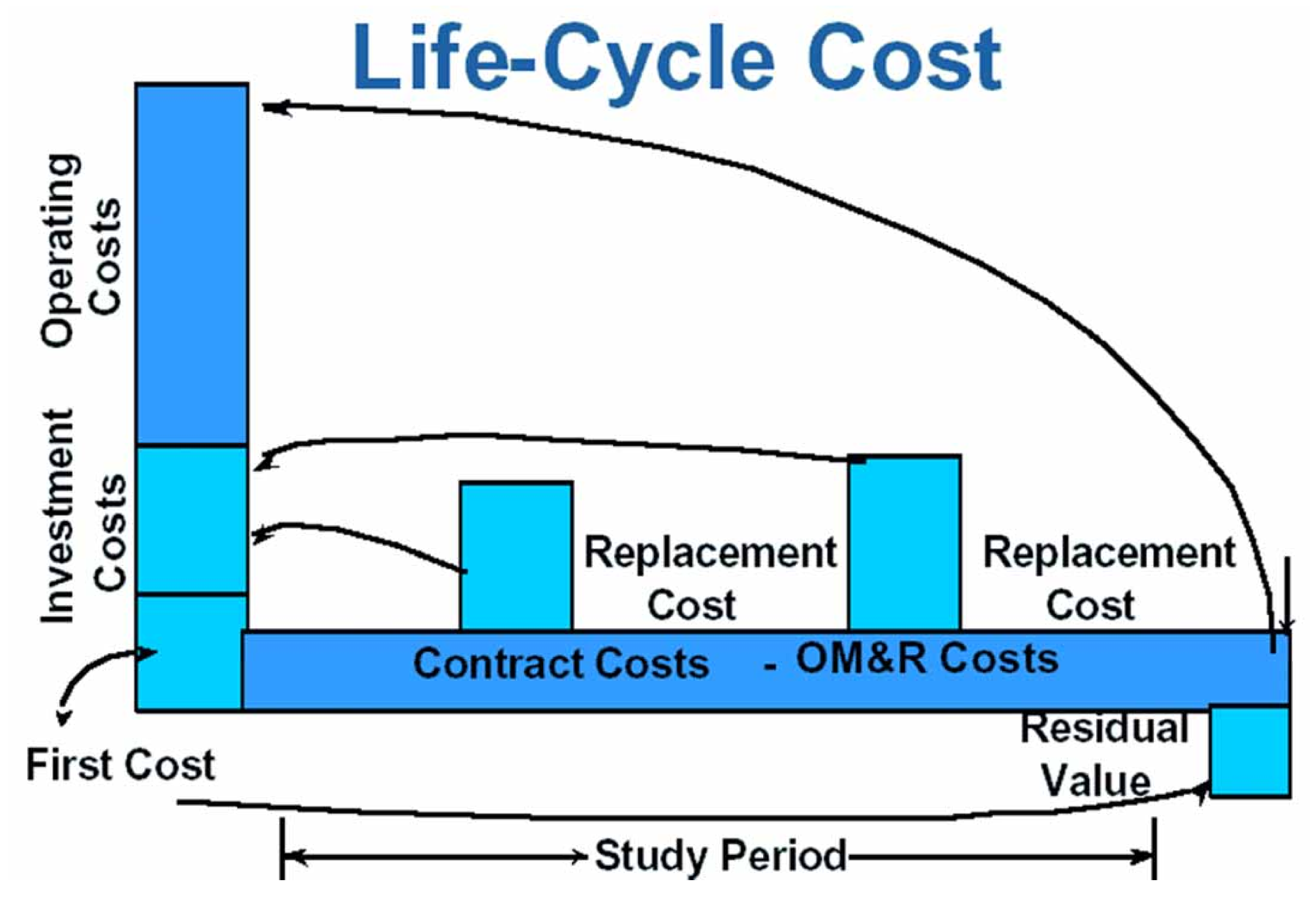
Life cycle costing

- LCA is that it is not the same as LCC
- The two methodologies are complementary, but LCC focuses on the dollar costs of building and maintaining a structure over its life cycle, while LCA focuses on environmental performance
- Performance is measured in the units appropriate to each emission type or effect category

Concept of total cost or life cycle cost

Total cost = Installed cost + Operating cost




Life-Cycle Cost
Operating Costs
Investment Costs
Replacement Cost
Replacement Cost
Contract Costs
- OM&R Costs
First Cost
Residual Value
Study Period

Life cycle costing

- LCC calculation
  - LCC = I + Repl - Res + E + W + OM&R + O
    - LCC = Total LCC in present-value (PV) dollars
    - I = PV investment costs
    - Repl = PV capital replacement costs
    - Res = PV residual value less disposal costs
    - E = PV of energy costs
    - W = PV of water costs
    - OM&R = PV of non-fuel operating, maintenance and repair costs
    - O = PV of other costs (e.g. contract costs)

Cost Considerations for Design

Direct and indirect: initial, life cycle, and environmental

Initial:

Construction: supply and installation

Design

Life cycle:

Daily, weekly and annual maintenance including cleaning, repair, redecoration

Replacement, including removal, waste disposal, replacement

Running cost for energy consuming components

Environmental:

Resource depletion and environmental pollution

Extraction, manufacture, transport, use and disposal: to air, ground and water

Indoor environmental quality

(Source: *A Green Vitruvius: Principles and Practice of Sustainable Architectural Design*)

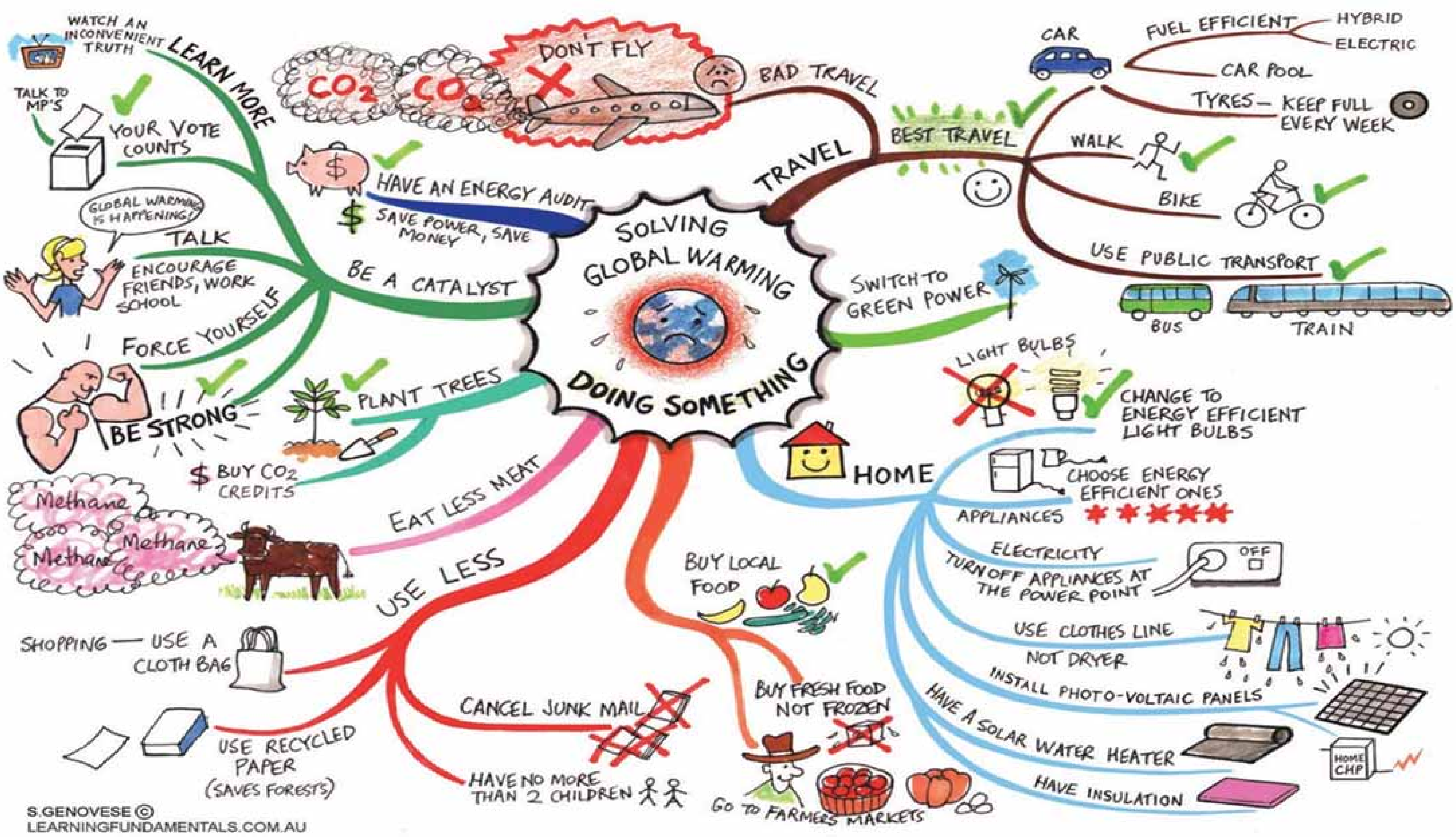
Life cycle costing

- Typical life-cycle cost analysis include:
  - Acquisition costs
  - Financing costs (e.g. interest rate on a loan)
  - Energy savings
  - Equipment replacement costs
  - Operations, maintenance and repair costs
  - Tax implications
  - Impacts of inflation

Life cycle costing

- Basic steps of LCC analysis
  - 1. Gather basic financial data
  - 2. Estimate annual energy costs
  - 3. Estimate first costs
  - 4. Estimate ongoing costs
  - 5. Calculate life-cycle costs
  - 6. Compare life-cycle costs

Solving global warming problems (a mind map)



You can also draw your own mindmap.
(http://en.wikipedia.org/wiki/Mind_map)

Carbon audit

- EPD and EMSD, 2010. *Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings (Commercial, Residential or Institutional Purposes) in Hong Kong*, 2010 Edition, Environmental Protection Department (EPD) and Electrical and Mechanical Services Department (EMSD), Hong Kong
  - www.epd.gov.hk/epd/english/climate_change/ca_guidelines.html

Carbon audit

- Purpose of the guidelines: Assist the building user and managers to:
  - Measure their greenhouse gas (GHG) performance
  - Identify areas of improvement
  - Conduct voluntary programmes to reduce and/or offset emissions
- Voluntary participation and self-reporting
- Compile the GHG inventory

Carbon audit

- Principles to ensure true and fair reporting
  - Relevance
  - Completeness
  - Consistency
  - Accuracy
  - Transparency
- Include 6 types of GHG: CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)

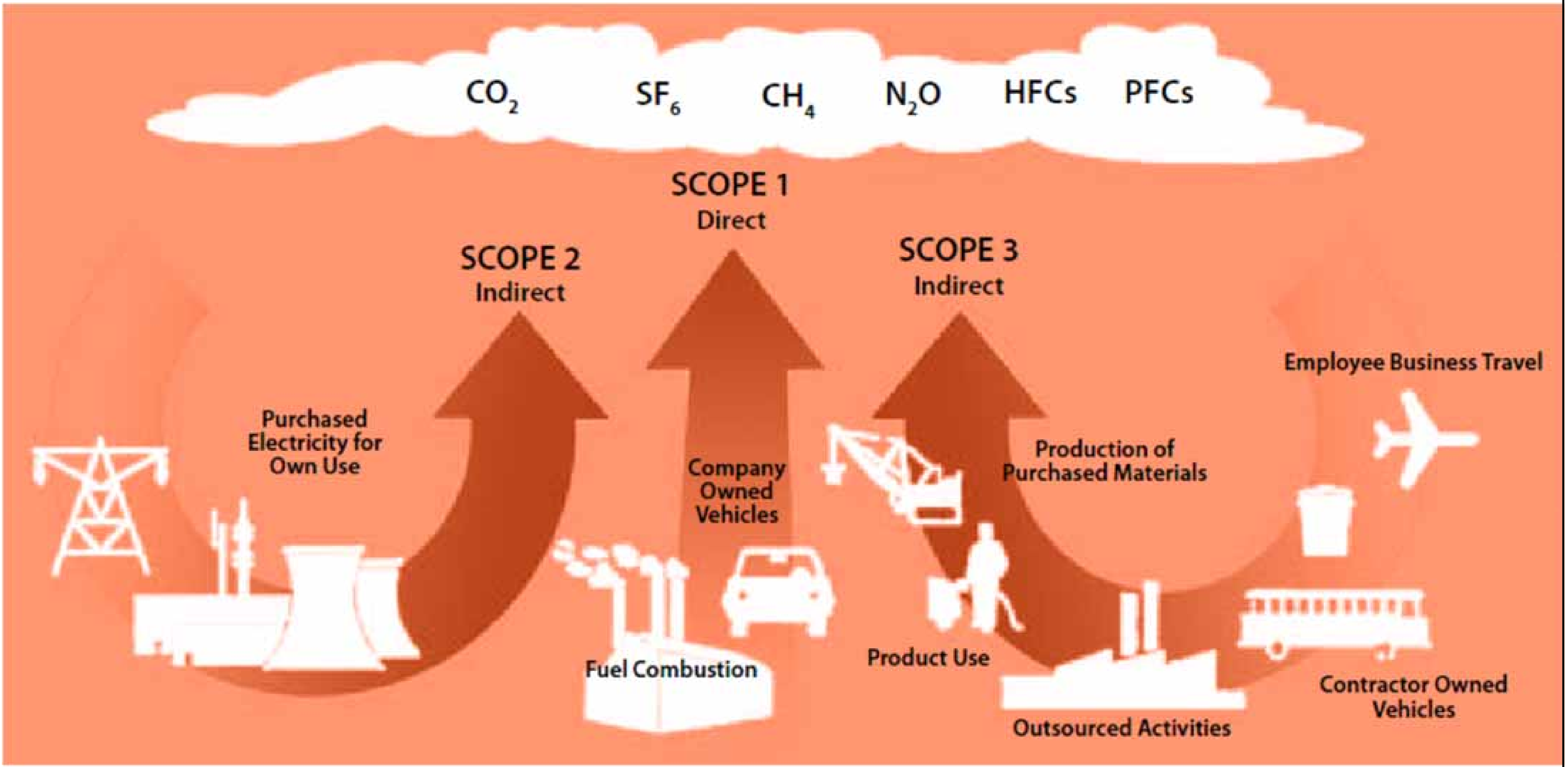
Carbon audit

- Typical steps:
  - 1. Determine the physical boundaries
  - 2. Determine the operational boundaries
  - 3. Determine the reporting period (e.g. one year)
  - 4. Collect necessary data and information and to quantify the GHG performance
  - 5. Prepare the report

Carbon audit

- Physical boundaries (e.g. site boundaries)
- Operational boundaries
  - Operational activities which will result in GHG emissions or removals
  - Scope 1 – direct emissions and removals
  - Scope 2 – energy indirect emissions
  - Scope 3 – other indirect emissions (optional)

Scope of greenhouse gas (GHG) emissions



(Source: UNEP Sustainable Buildings and Climate Initiative, www.unepsbci.org)

Carbon audit

- Scope 1 – direct emissions and removals
  - Combustion of fuels in stationary sources to generate electricity, heat, or steam, e.g. electricity generators, boilers, gas cooking stoves, etc.
  - Combustion of fuels in mobile sources (e.g. motor vehicles and ships), for example, shuttle bus
  - Intentional or unintentional GHG releases from equipment and systems, e.g. HFCs and PFCs from HVAC&R equipment

Carbon audit

- Scope 1 – direct emissions and removals
  - Assimilation of CO_2 into biomass through e.g. planting of trees
  - Any other physical and chemical processing in the physical boundary which will emit or remove GHG. For example, on-site waste or sewage processing facilities

Carbon audit

- Scope 2 – energy indirect emissions
  - Electricity purchased from power companies
  - Towngas purchased from the Hong Kong and China Gas Company
- Scope 3 – other indirect emissions (optional)
  - Methane gas generation at landfill in Hong Kong due to disposal of paper waste
  - GHG emissions due to electricity used for fresh water processing by Water Services Department

Carbon audit

- Scope 3 – other indirect emissions (optional)
  - GHG emissions due to electricity used for sewage processing by Drainage Services Department
  - Other examples of GHG emissions
    - Extraction & production of purchased materials & fuels
    - Transportation of purchased materials or goods, fuels, products, waste, employees, occupants and guests, to and from the concerned buildings
    - Business travel by employees

Carbon audit

- Scope 3 – other indirect emissions (optional)
  - Other examples of GHG emissions (cont'd)
    - Emissions from outsourced activities or other contractual arrangements
    - Use of sold products and services
    - Waste disposal other than those covered in the above list
- Links with international emissions reporting framework, e.g. ISO14064-1

Carbon audit

- Implication to sustainable building design
  - Future green building assessment might include the GHG indicators
  - Building projects that aim at “zero energy”, “zero carbon” or “zero emission” must demonstrate their compliance by carbon audit
  - Possibility of trading off GHG emission and allow carbon trading