Life Cycle Assessment (LCA)

Theory & Practice

COST ACTION Training School
Tampere – June 2017

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ActInPak

COST
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

COST is supported by the EU Framework Programme Horizon 2020

COST Action FP1405

Active and intelligent fibre-based packaging – innovation and market introduction **(ActInPak)**

ActInPak is a pan European (COST) network of the leading experts in active and intelligent packaging of over 150 institutes, universities and companies from 37 countries. Main goal of action is to develop a knowledge-based network on sustainable, active and intelligent fibre-based packaging in order to facilitate its introduction on the market.

http://www.actinpak.eu
http://www.cost.eu/COST_Actions/fps/Actions/FP1405
https://www.linkedin.com/groups/COST-FP1405-ActInPak-8254568/about

COBRO – PACKAGING RESEARCH INSTITUTE

State, self-supporting research institution subordinated to the Ministry of Economy, founded in 1973.

Member of:

- World Packaging Organisation,
- International Association of Packaging Research Institutes,
- Polish Chamber of Packaging,
- European Bioplastics.

- Packaging R&D Department:
  - ✓ Packaging and Environment Department
  - ✓ Laboratory for Packaging Materials and Consumer Packaging Testing
- Laboratory for Transport Packaging Testing
- Certification Centre
- Standardization Department
- *Packaging Spectrum* Magazine

Sustainable Development

To use the traditional definition, sustainable development is:

"development that meets the needs of the present without compromising the ability of future generations to meet their own needs", in other words ensuring that today's growth does not jeopardize the growth possibilities of future generations.

Sustainable development thus comprises three elements - economic, social and environmental - which have to be considered in equal measure at the political level. The strategy for sustainable development, adopted in 2001 and amended in 2005, is complemented inter alia by the principle of integrating environmental concerns with European policies which impact on the environment.

- source: http://europa.eu

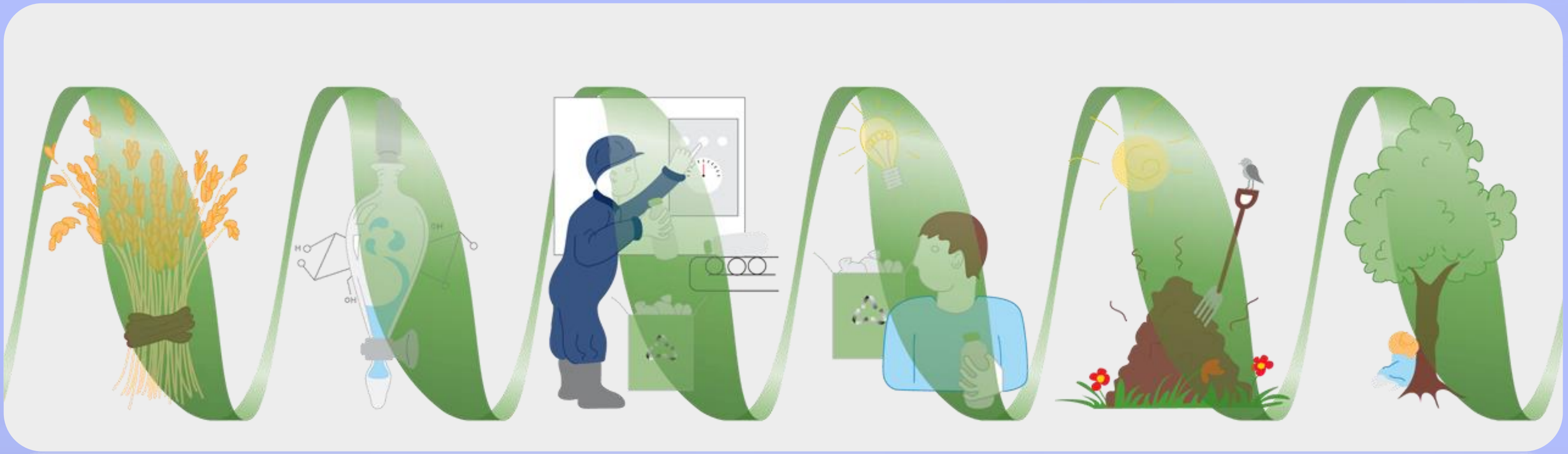
Sustainable Development

Sustainable development is about integrating the goals of a high quality of life, health and prosperity with social justice and maintaining the earth's capacity to support life in all its diversity. These **social, economic and environmental** goals are interdependent and mutually reinforcing. Sustainable development can be treated as a way of expressing the broader expectations of society as a whole.

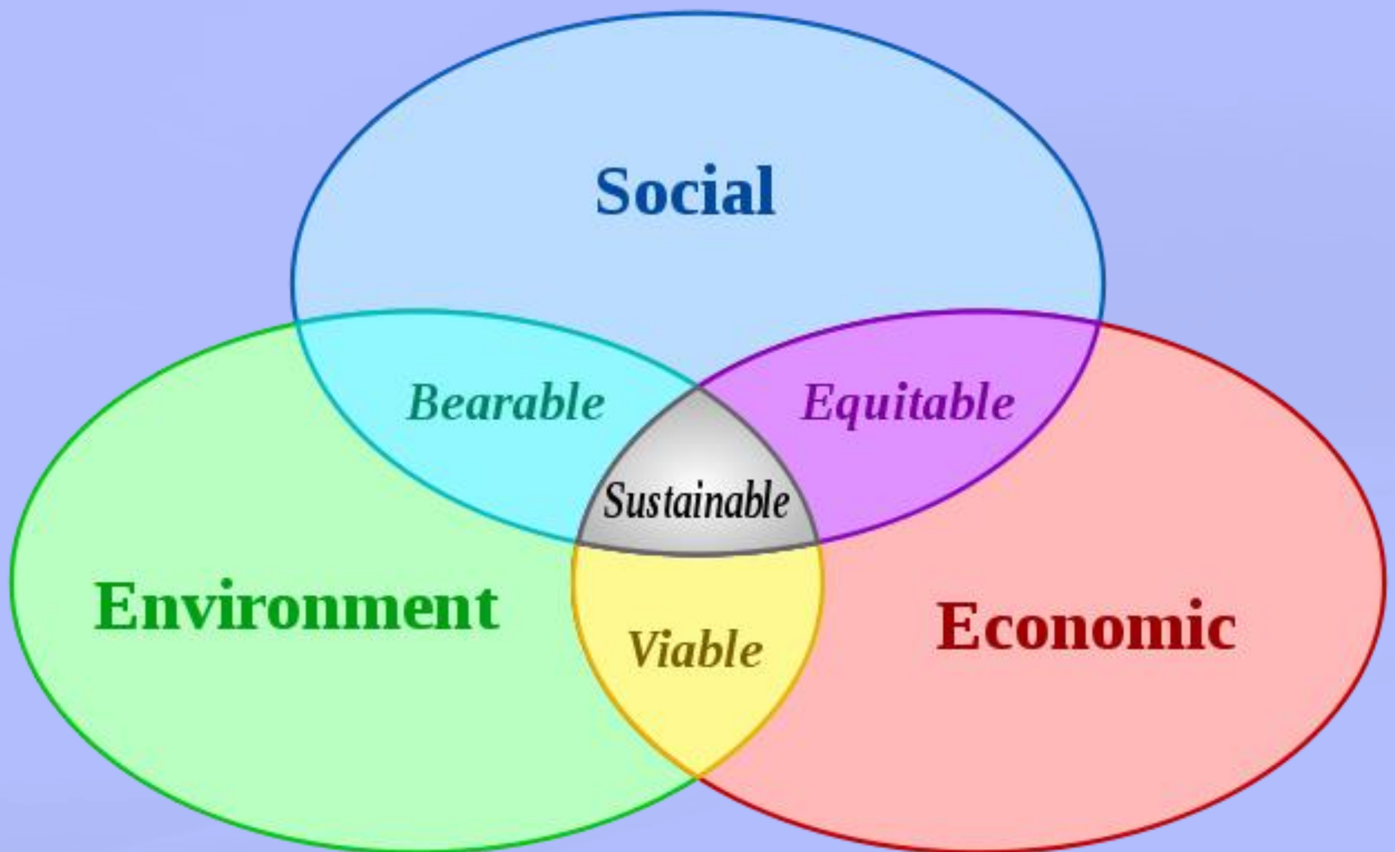
- source: ISO 26000:2010

Sustainable Development

Sustainable development concept for business, consists of taking into consideration widely understood **economic, environmental and social** issues in the **daily and long term operations of a company**.



Sustainable Development

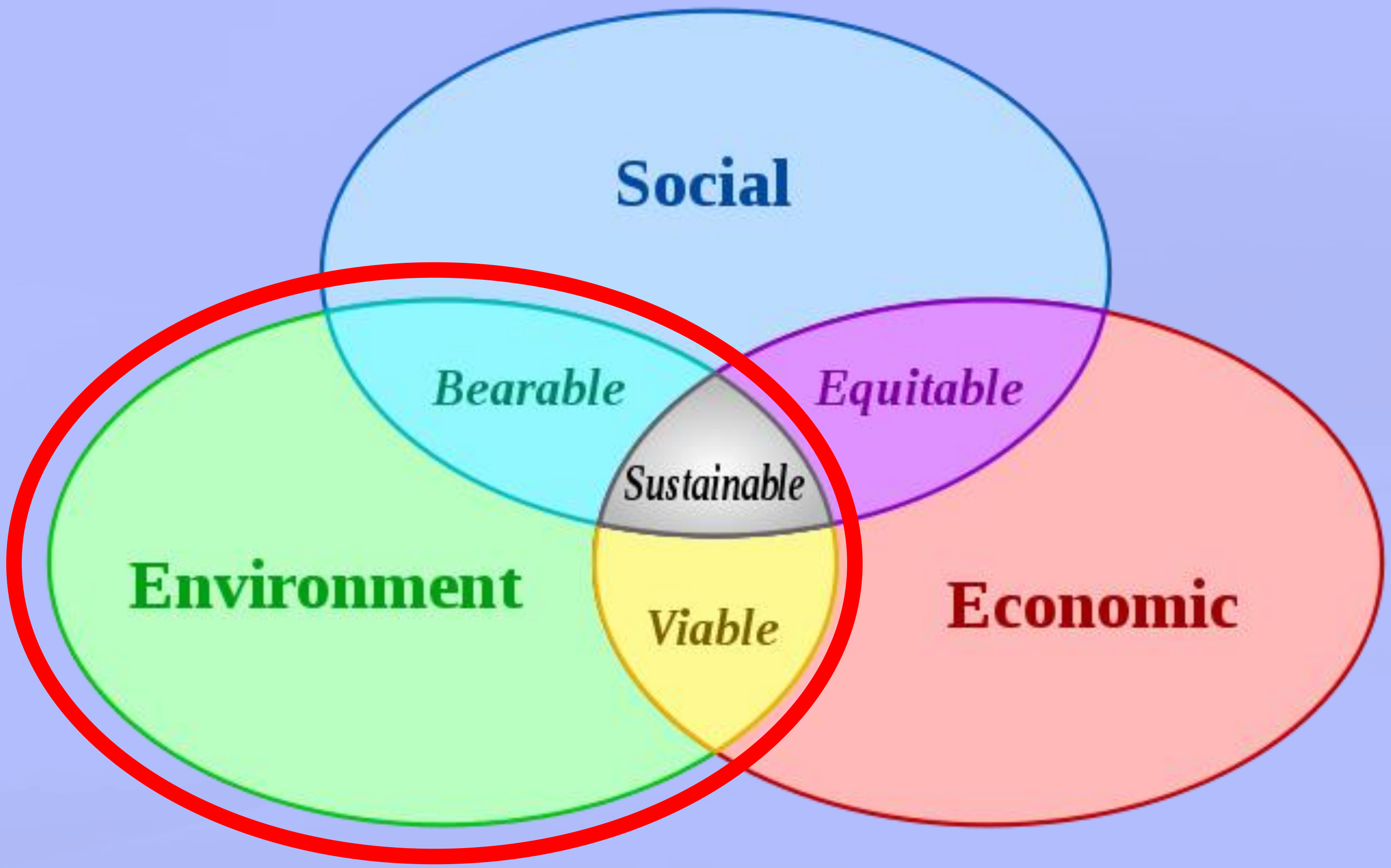


Sustainable Development

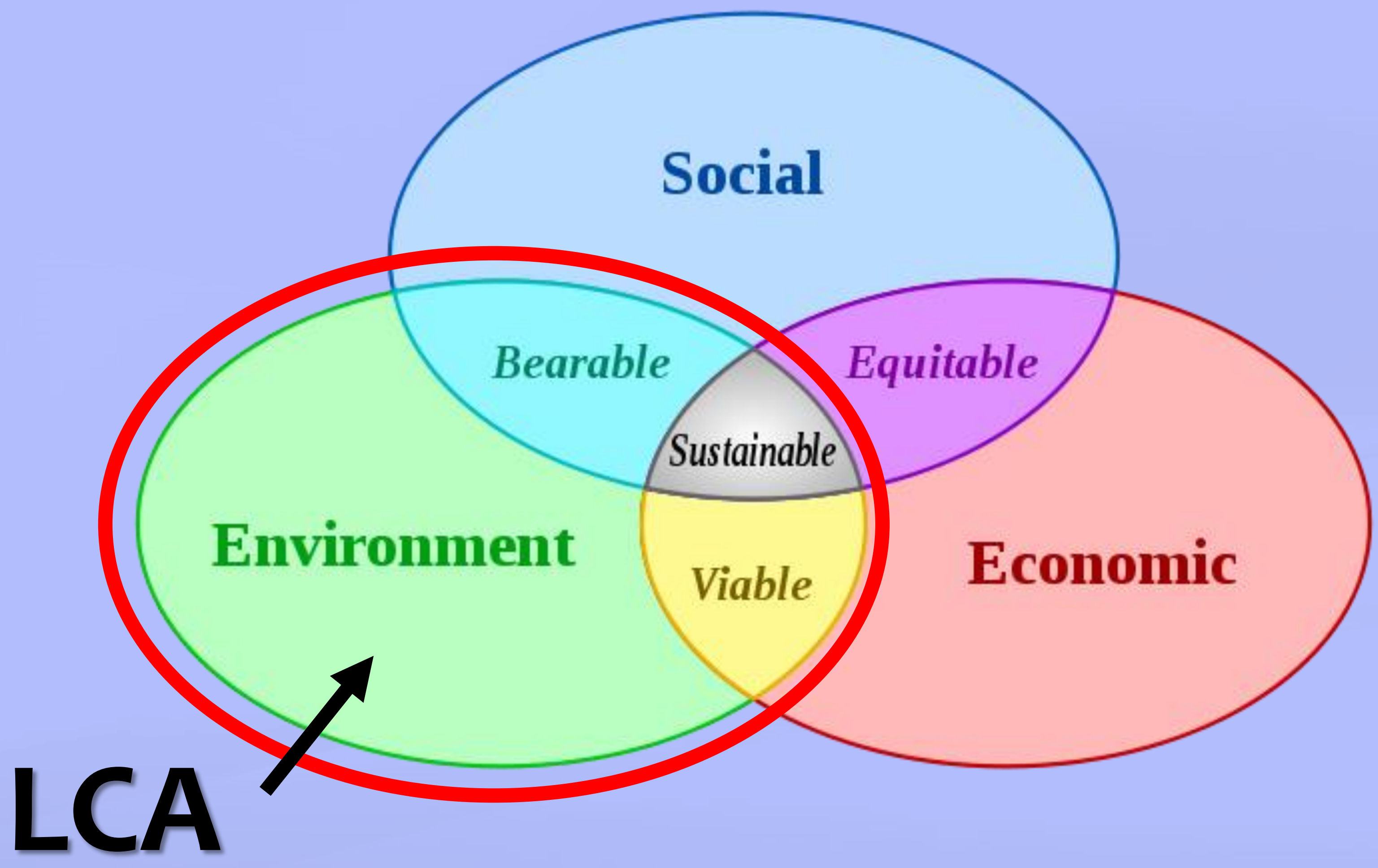
Sustainable development has to be **present in all product life cycle stages**, starting from production process, delivery chain, demand for resources, processing methods, packaging, distribution, usage and waste management including transport.

At the same time sustainable products **should match up or exceed conventional products by functional and quality properties**, fulfil todays environmental protection standards, and also contribute to waste management system.

Sustainable Development

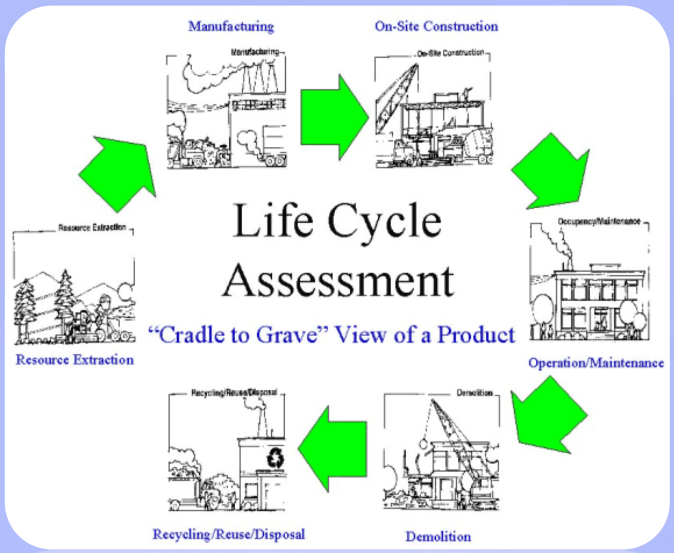


Sustainable Development



What is LCA ??

- LCA = Life Cycle Assessment
- The most popular sustainability assessment tool
- Can be used to assess products, value chains, processes, whole companies, economy and even socio-cultural implications
- Its main goal is to assess the aspects of environmental impacts in whole life cycle of selected subject matter.



What is LCA ??

- LCA consists of different criteria of evaluation in all life cycle stages of a selected product.
- Environmental influence of every life cycle process of a chosen product is quantitatively recorded in different impact categories
- **LCA method can be used to rate and compare a product with another products with similar functionality.**

What is LCA ??

Input:
What we have taken from the environment

Life:
Detailed Biography and Family Tree of our product

Output:
What we are leaving behind - emissions

LCA as a description of reality

LCA is used to *model* **complex** reality

+

Each *model* **simplifies** the reality

=

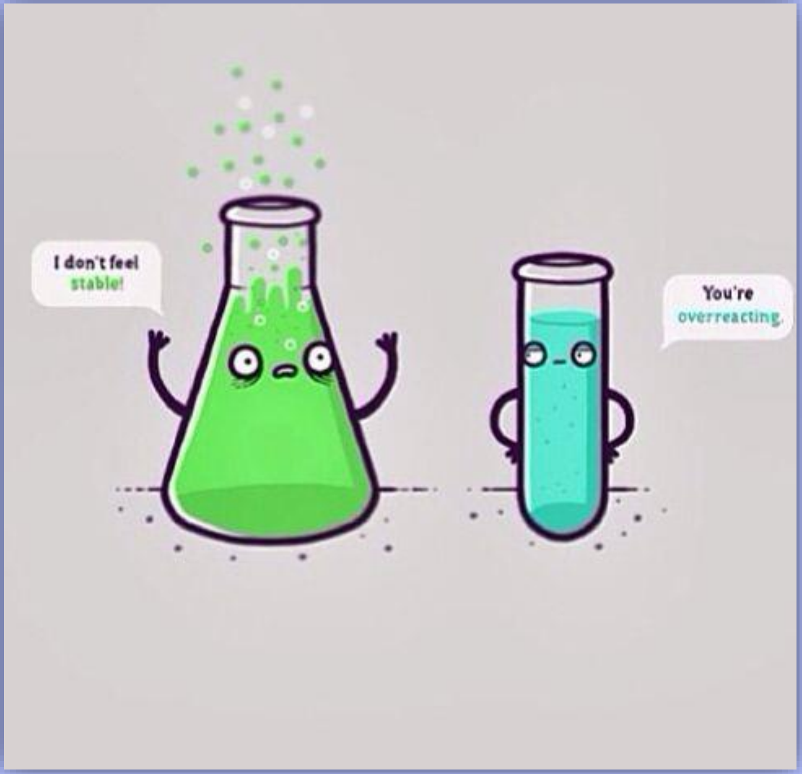
Contradiction – simplification distorts the reality

Main goal of LCA – minimise this distortion

LCA Science

Comprehensiveness

- Attempt to cover all attributes or aspects of natural environment, human health and resources!
- Therefore, include a wide range of potential environmental impacts in LCA studies
- **Coverage of every conceivable impact not possible**



Source: *Life Cycle Assessment (LCA) Learning Module Series*

LCA Science

Priority of scientific approach to characterize impacts:

- First: Natural science
- Next: Social or economic science or International convention
- Last: Value choices (opinion, preferences)

Source: *Life Cycle Assessment (LCA) Learning Module Series*

How to use LCA

- Internal LCA – used by enterprises
  - ‘knowing your product’, identification of ‘hot spots’, strategic management goals
  - Marketing / Benchmarking
  - PR
  - Preparation for legislation changes, arguments for lobbying
- External LCA – full public reports
  - Published by public institutes/research institutes
  - Need to be peer reviewed
  - Not often used by enterprises due to bad experiences in the ‘90 (benchmarking backfire)

Why use LCA??

- Consumer demands
- Information request from business clients (e.g in the supply chain)
- External pressure from society stakeholders (e.g. NGOs) and civil society
- Increasing attention from financial stakeholders
- Green Public Procurement programs of public administrations
- Requirements from policy-makers (e.g. WEEE and RoHS European Directives)

Why use LCA??

Competitive advantage in emerging or new green markets

- Final consumers
- Business clients
- Public administrations

Better image

- Consumers and clients
- Financial stakeholders
- NGOs and civil society
- Legislators

Influence regulations and pre-normative processes

LCA Standards

- 2 main standards:
  - EN ISO 14040 – main concept
  - EN ISO 14044 – details

International Organization for Standardization

- Other relevant standards:
  - EN ISO 14020 series – Environmental labels and declarations
    - 14021 – Type II
    - 14024 – Type I
    - 14025 – Type III
  - 14064 – GHG emissions
  - 14067 – Carbon Footprint calculation

LCA Standards

ISO 14040 contains general information on:

a. Goal and scope of LCA
b. LCI phase
c. LCIA phase
d. Interpretation phase

Phases of an LCA

e. Reporting and critical review
f. Limitations
g. Relationship between phases
h. Conditions for use of value choices and optional elements

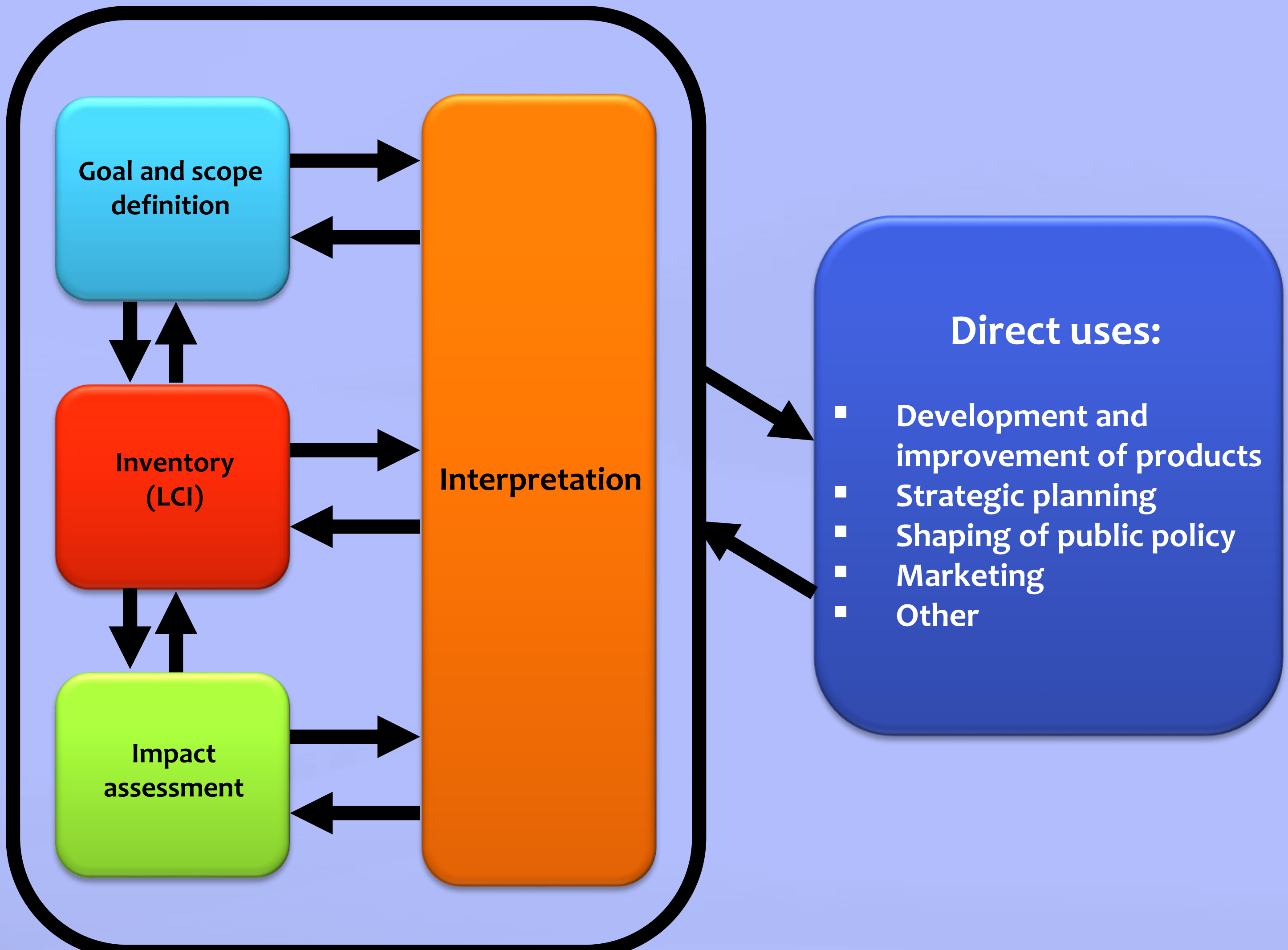
Normative references: Need to use 14044 to apply 14040

Source: *Life Cycle Assessment (LCA) Learning Module Series*

LCA CEN Reports

- 2 CEN Reports for packaging:
  - CR 12340:1996 – Recommendations for LCI of packaging systems
  - CR 13910:2009 – Criteria and methods for packaging LCA

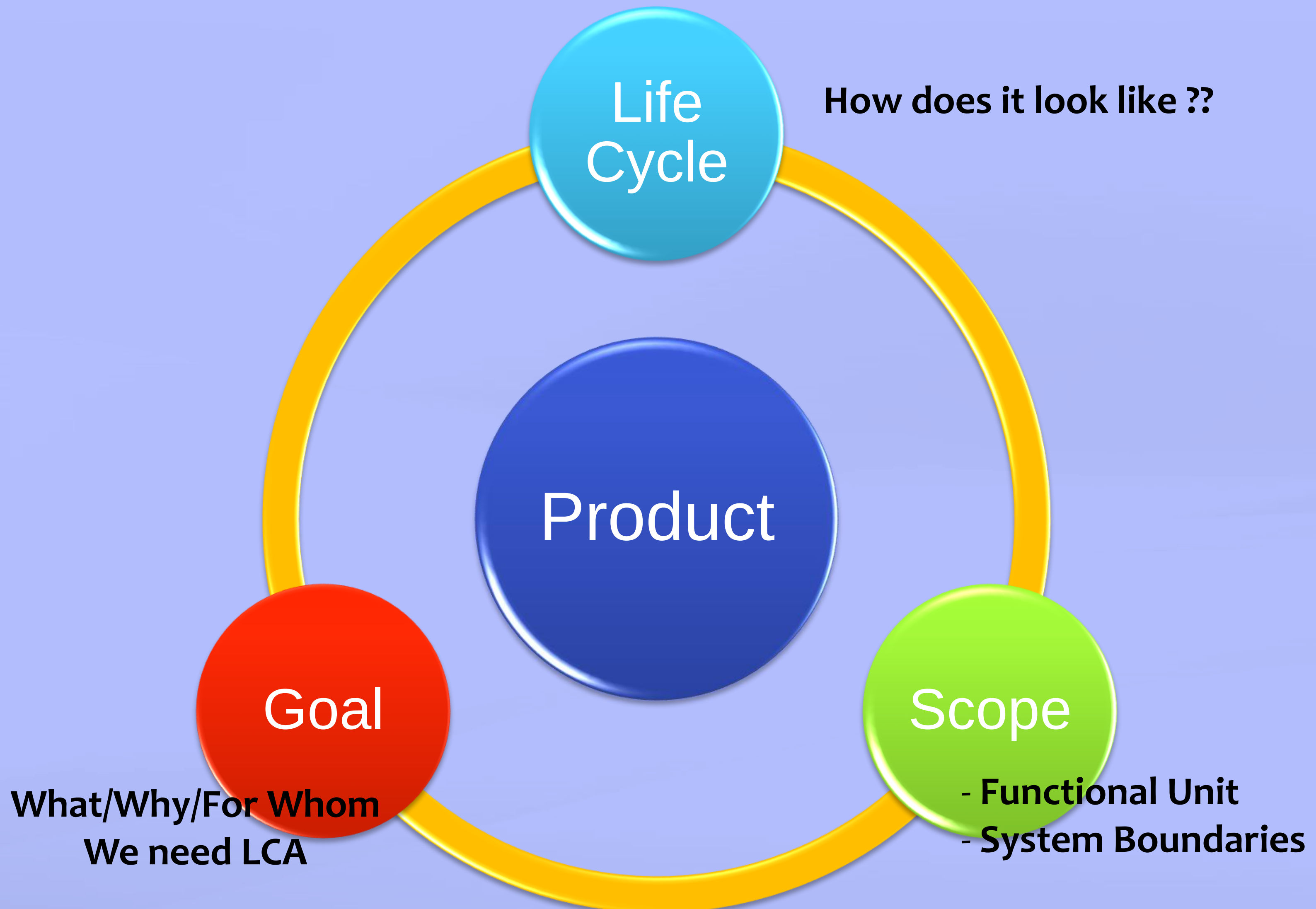
LCA in 4 steps



LCA Principles

- Guidance for product, process, or product element selection
- Entire life cycle environmental burden between stages and processes
- Relative to a functional unit
  - Functional unit is a quantified amount of function obtained from the product or process
  - Light bulb functional unit might be 1,000,000 lumen-hours of light
  - Bus functional unit might be 10,000 passenger-kilometers traveled
- Only environmental considerations addressed
- Economic, social, and other aspects could be considered with other tools
- Iterative process where each phase uses results of other phases
  - For example: goal and scope can and should be updated during analysis of other stages

Step 1 – Goal and Scope



LCA Example Workshop

Goal

Goal statement is the first component of an LCA and guides much of the subsequent analysis

Goal must state:
Intended use
Reasons for study
Audience
Whether comparative and disclosed to public

Scope

Scope provides background information, details methodological choices, and lays out report format

Scope includes:
Product system
Functions of systems
Functional unit
System boundary
Allocation procedures
Impact categories, assessment method and interpretation type

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Step 1 – Goal and Scope

- Goal statement is the first component of an LCA and guides much of the subsequent analysis
- <u>Goal must state:</u>
  - Intended use
  - Reasons for study
  - Audience
  - Whether comparative and disclosed to public

Step 1 – Goal and Scope

Target groups:

External stakeholders

- Final consumers
- Business clients
- Financial stakeholders
- Public administrators and policy makers
- Civil society and society stakeholders
- Suppliers

Internal stakeholders

- Shareholders
- Employees and management

Step 1 – Goal and Scope

- **Function and functional unit**
  - Define the functional characteristics of the product system
  - Functional unit for amount of function achieved, useful as a reference measure
- **System boundary**
  - Define which processes are included in the study
  - Helpful to include a process flow diagram
- **LCIA methodology**
  - State which impact categories and category indicators are used
  - State which impact characterization methodology is used
- **Inventory Data**
  - Obtain either from direct measurement of processes or from secondary sources (or a mix of the two)
  - Include inputs and outputs to air, water, and soil

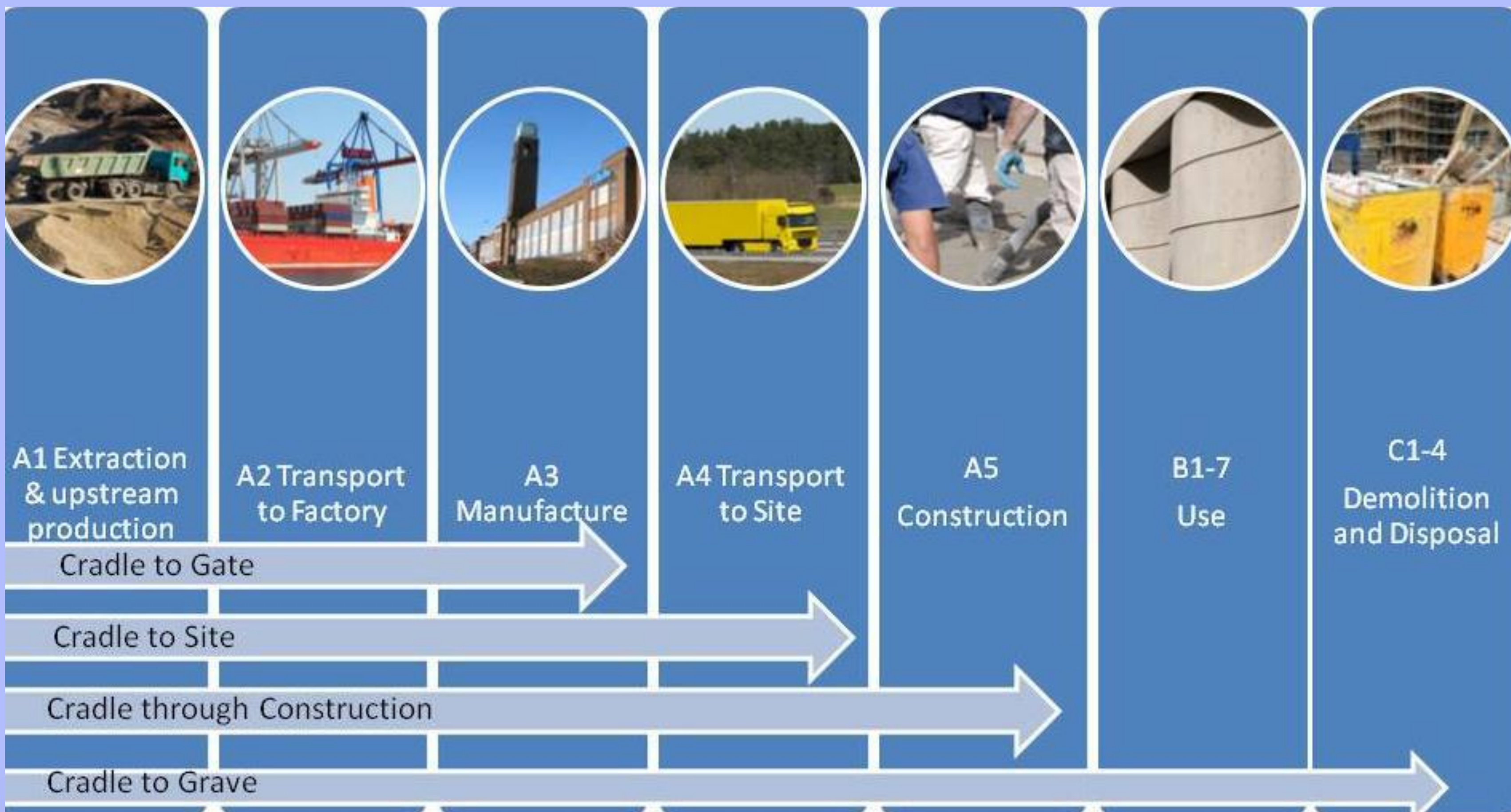
Step 1 – Goal and Scope

- **Data quality**
  - Address age, geographic coverage, technology coverage, precision, completeness, representativeness, consistency, reproducibility, sources, minimum length of time to collect, and uncertainty.
  - For missing data a zero value, non-zero value, or a calculated value from similar technology should be used and explained.
- **Comparisons between systems**
  - Use the same functional unit, system boundaries, data quality, allocation, and impact assessment procedures (if not possible, identify differences)
  - For publicly disclosed studies must include a critical review and the LCIA phase
- **Critical Review**
  - State whether or not a critical review will be conducted
  - Define how, and by whom, the critical review will be carried out

Step 1 – Goal and Scope

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Step 1 – Goal and Scope



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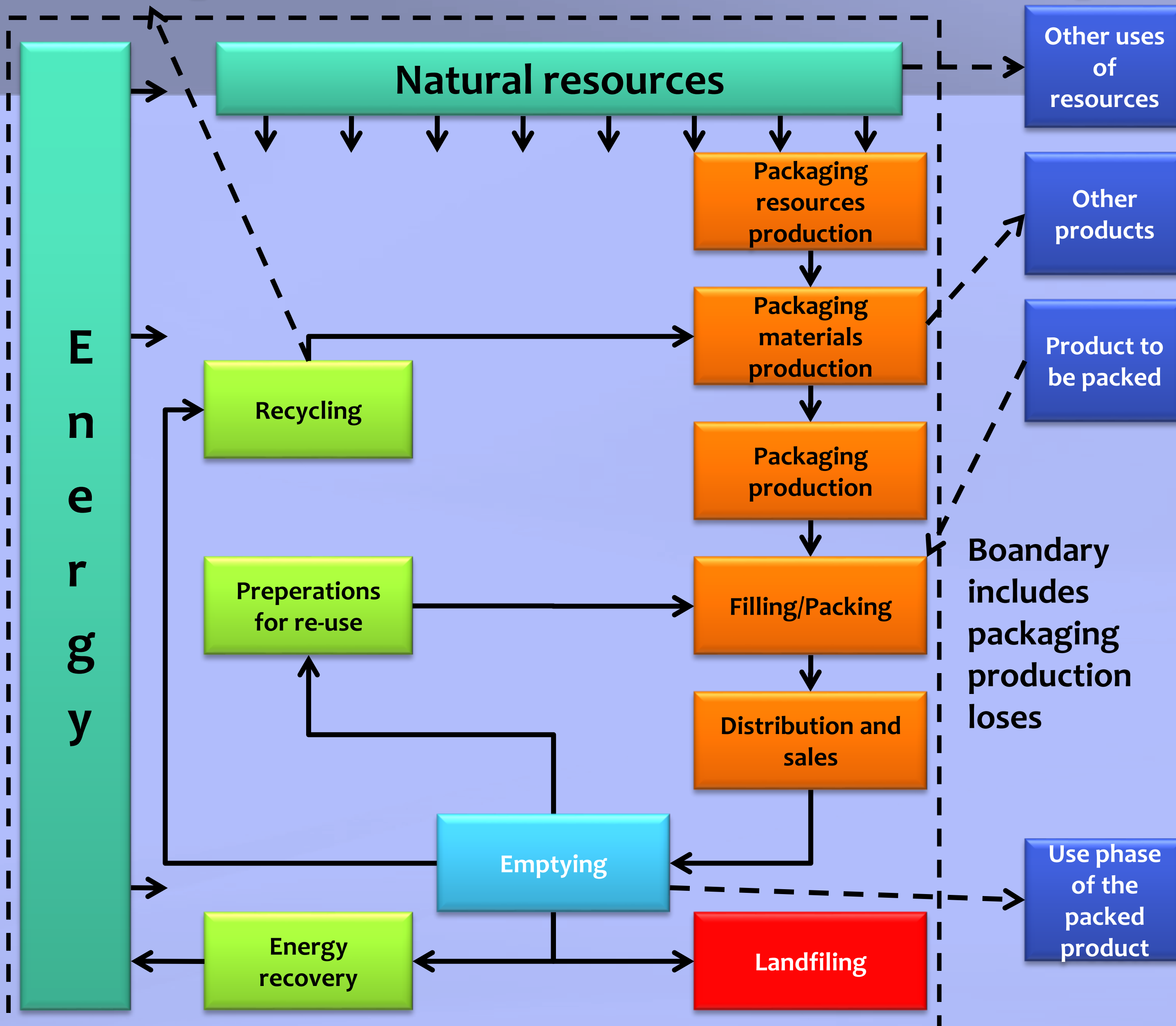
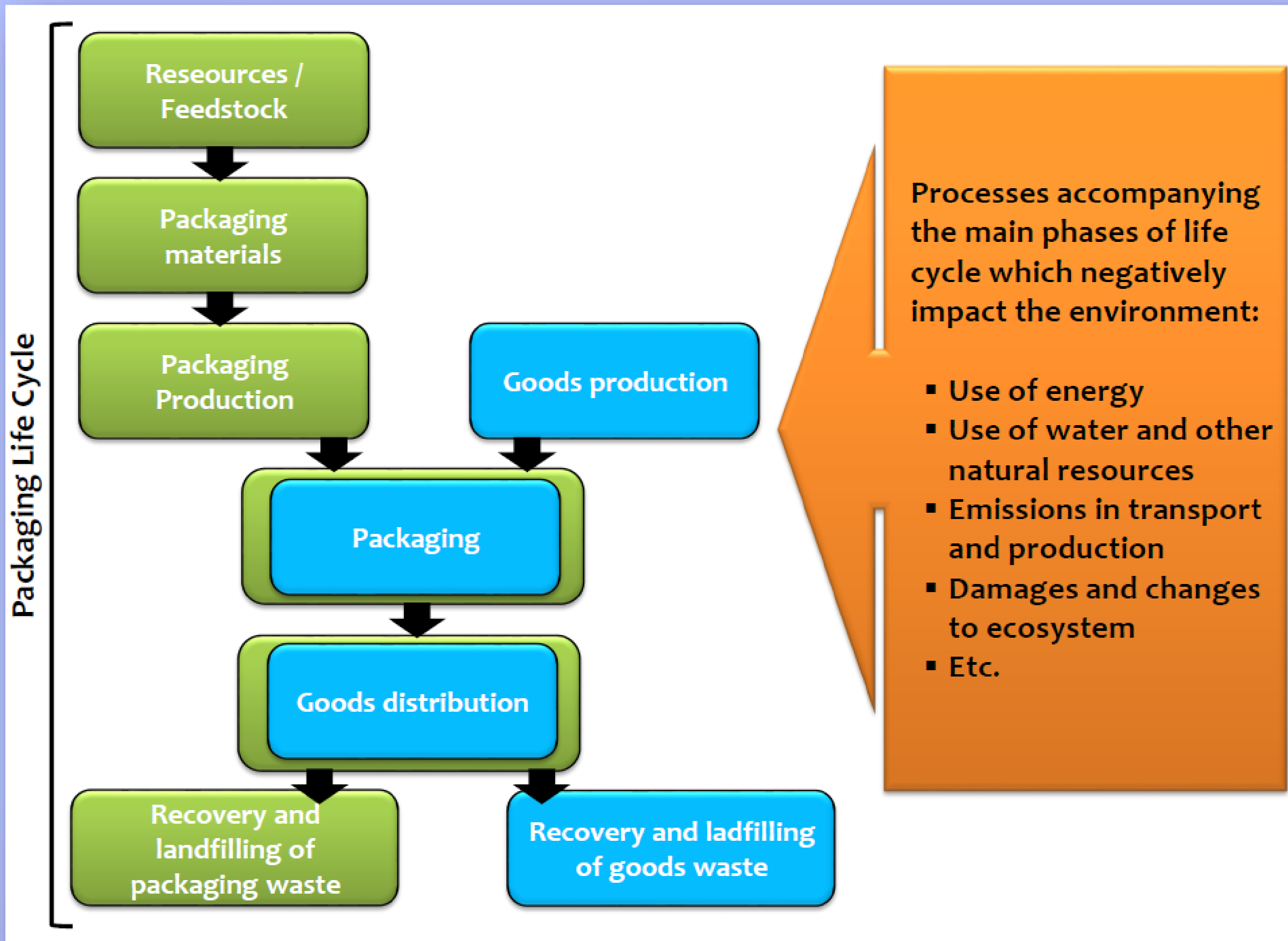
Step 1 – Goal and Scope



Boandary includes packaging production loses

Step 1 – Goal and Scope



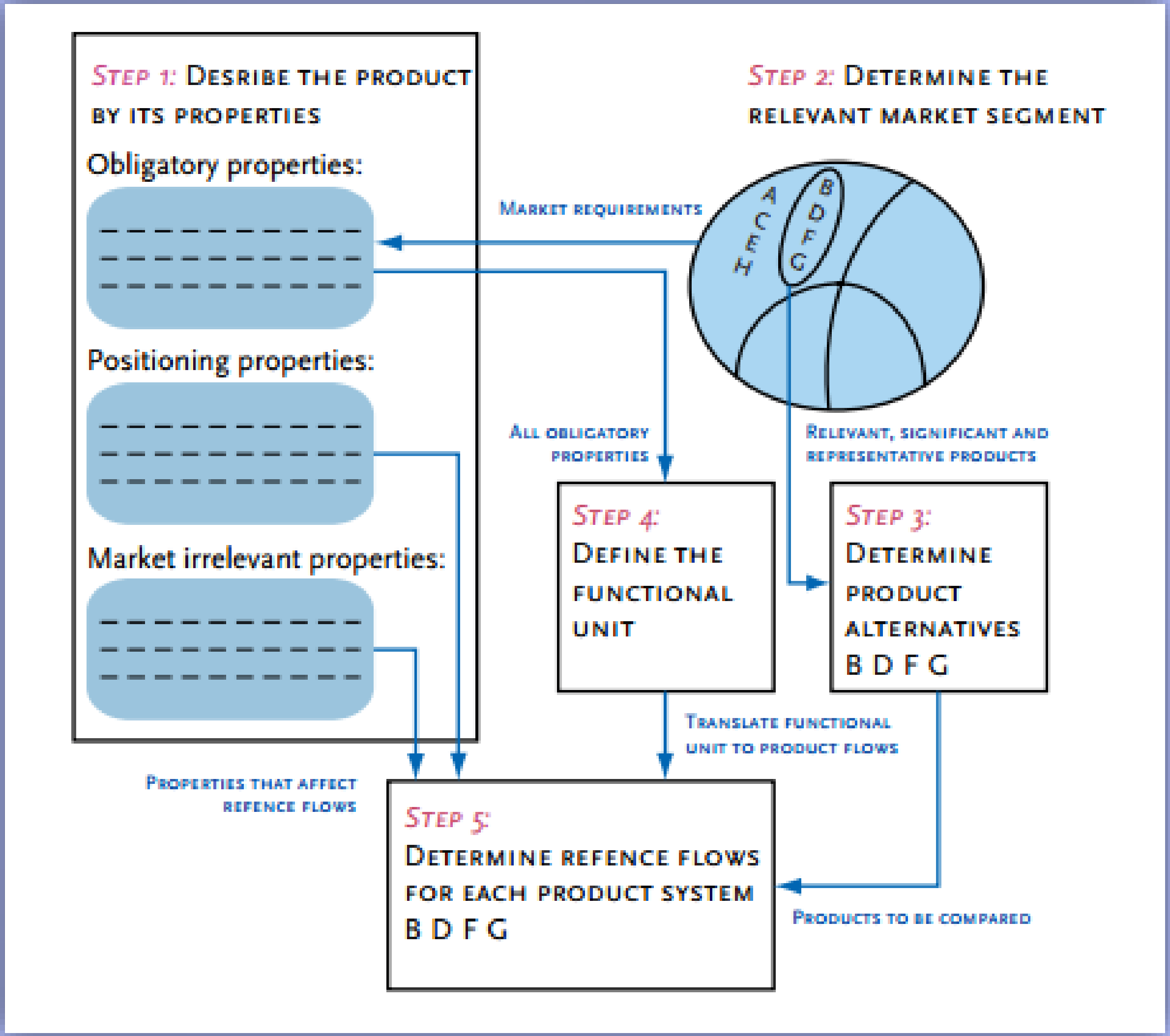
Step 1 – Goal and Scope

Functional Unit

- Unit of reference
- Quantitative system effect – unit has to measure same effect when comparing 2 or more products
- All data should be referenced to the functional unit

Step 1 – Goal and Scope

Functional Unit



Function

- What the product(s) or process(es) is designed to do
- Often intuitive
  - However, function must be stated to make it unambiguous
- Important to help define the system and functional unit

Generate Light

Transport People

House Students

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Functional Unit Definition

“Quantified performance of a product system for use as a reference unit.”

Functional Unit

- Functional unit defines what quantity of the product's function is achieved to cause the environmental impacts identified
  - Light bulb functional unit might be 1,000,000 lumen-hours of light
  - Bus functional unit might be 10,000 passenger-kilometer
  - Dormitory building functional unit might be house 200 students for one year

For 20 Million lumen-hours

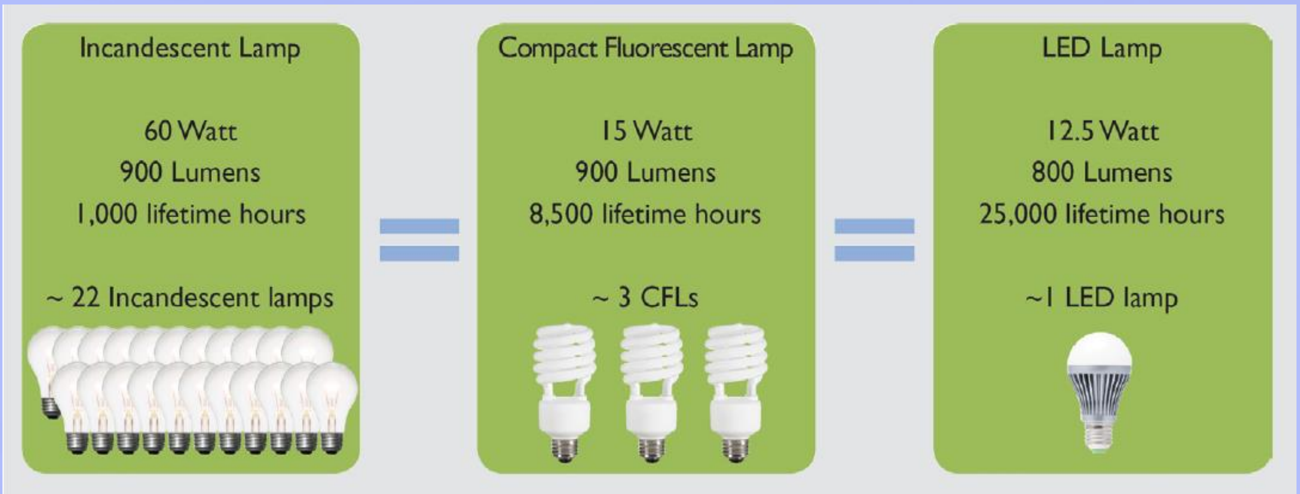


Figure credit: U.S. Department of Energy. "Life Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products."

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Functional Unit

- Some consider correct determination of functional unit the highest priority in LCA
- Must be "clearly defined and measurable"
- Especially important in comparative studies to ensure fair comparison
- Value not particularly important
  - Unit is very important
- Best to set functional unit before collecting data (though not required)
  - Can always change it later
- Product life time should be considered later when applying functional unit

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Functional Unit

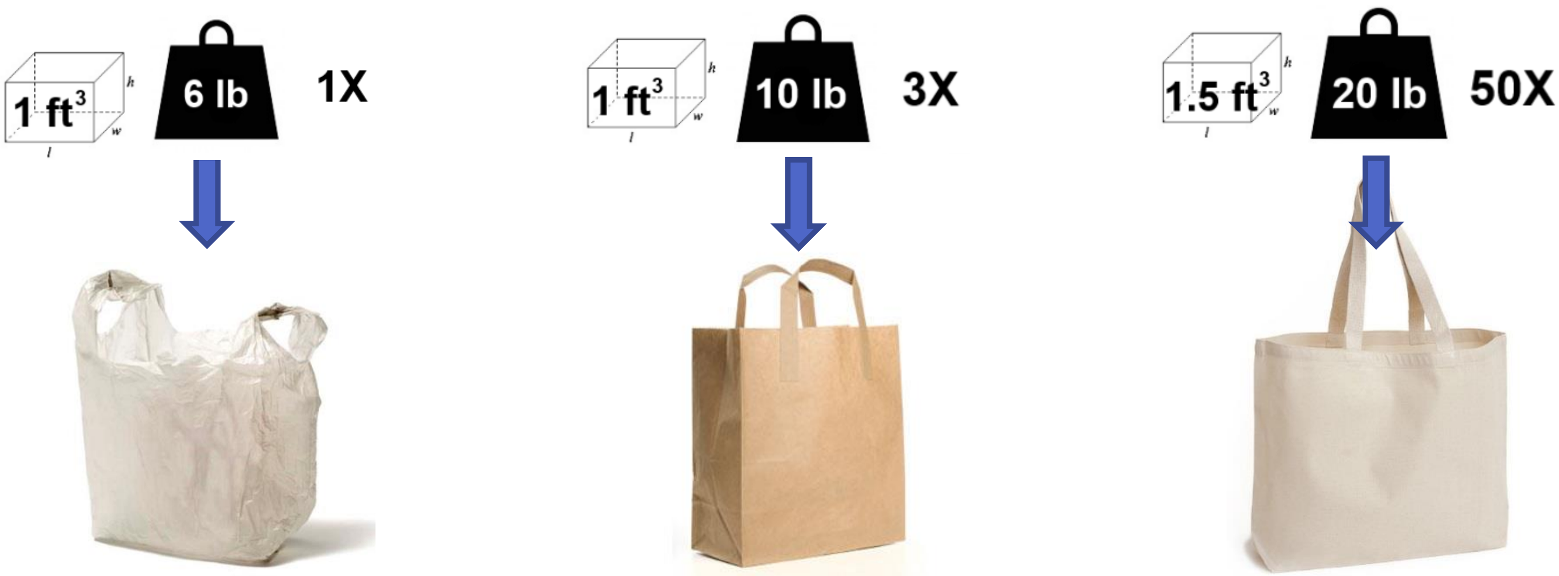
Situation: Comparing an LED, CFL, and incandescent bulb

Example statement: The function of the compared product systems is to provide lighting in residential applications. The functional unit is defined to be twenty million lumen-hours of light, with a wavelength between 450-600 nm, provided. This functional unit was chosen because lumen-hours is a common unit of cumulative illumination measurement, twenty million lumen-hours represents approximately one LED lamp's illumination over its full life time, and the wavelength range represents visible light appropriate for home illumination.

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Functional Unit

- Shopping bag comparing paper, plastic, and cloth
  - Functional unit could be to carry a certain volume or a certain weight of groceries a certain number of times (i.e. 5 kg of groceries on 10 trips)



Source: *Life Cycle Assessment (LCA) Learning Module Series*

Step 1 – Goal and Scope

Functional Unit

Functional Unit examples:

- Paint: 20 m^2 area coverage for 20 years
- Ice-cream: kcal / mass / leisure time
- Beverage packaging: volume of beverage
- Public transport: person-kilometer
- Packaging waste: kg
- Shopping bags: 5 kg of shopping carried for 500 meters
- Hand towels: 10 000 washed hands

Step 2 - LCI

Data collection – depends on the goals and scope of our research.

- What shall be taken into account:
  - System boundaries
  - Geography
  - Time of data collection
  - Functional Unit
  - Allocation methods
  - But most importantly: **Time and Money!!**

Step 2 - LCI

1. Consider goal and scope
2. Prepare for data collection
3. Collect data
4. Validate data
5. Relate data to unit process and allocations (reuse, etc.)
6. Relate data to functional unit
7. Aggregate data
8. Refine system boundary
9. Revise, repeat as needed

Already done if data from literature

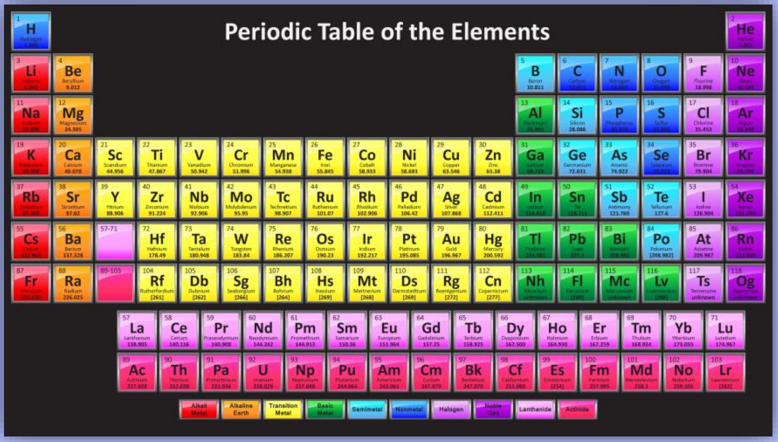
Already done if using database

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Step 2 - LCI

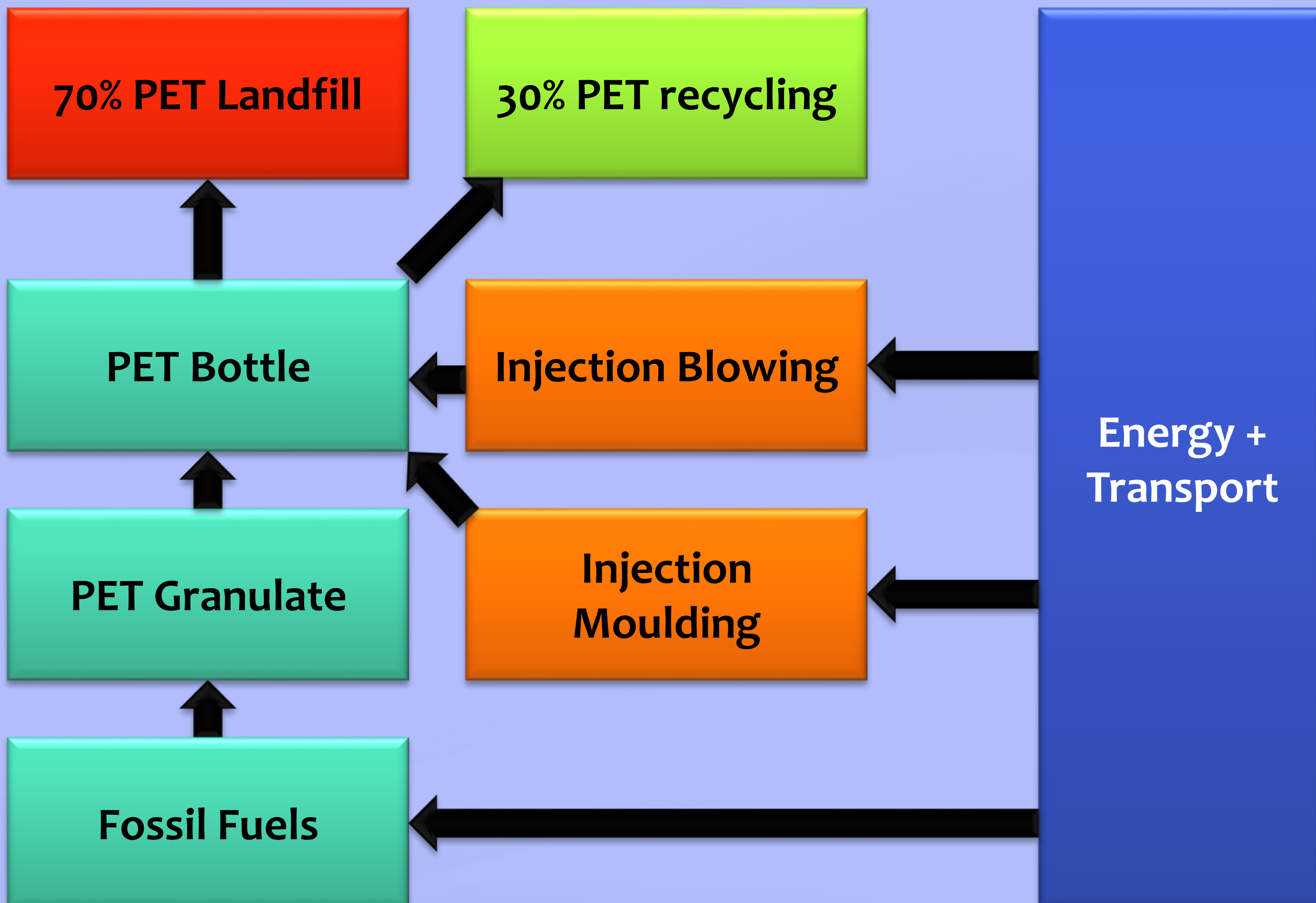
Step 2 effect – Process Tree

- Process Tree includes all LCI results in the form of inputs and outputs emissions from and to soil, atmosphere, water etc.
- Examples of quantitative results of LCI: CO2, CFC, P, SO2, NOx, DDT used/emitted during different stages of life cycle.



Step 2 – Process Tree

PET bottle – recycling 30%



Step 2 – Process Tree

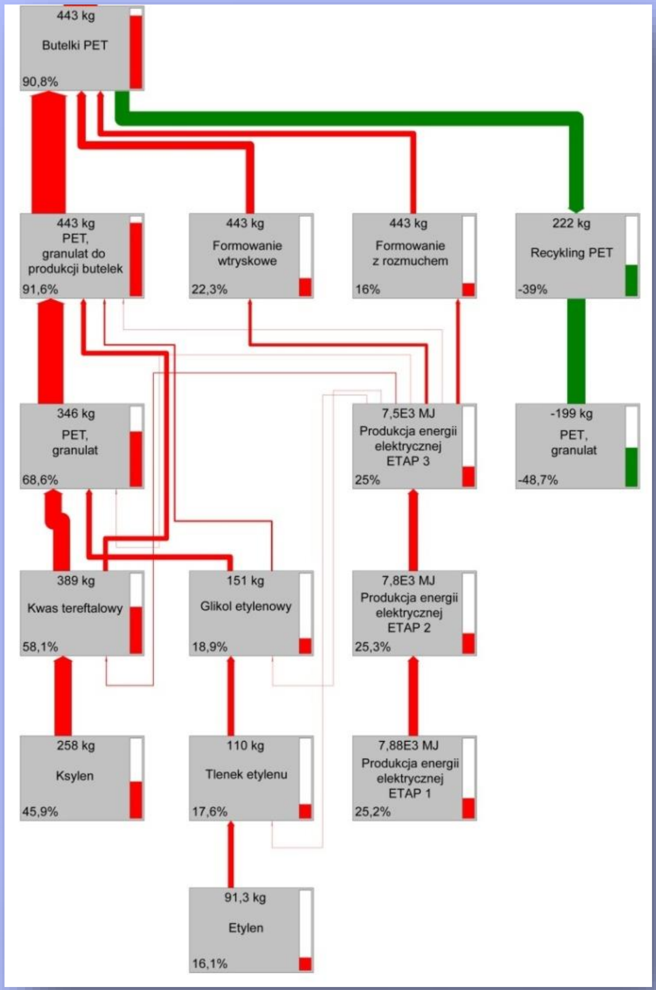
PET bottle – recycling 30%

C:\Users\Gtancx\Desktop\[[SIMAPRO BACKUP]]\DARMSTADT; BIO BASED PACKING LYON 09 - [Analyse Butelka PET - 30% odpadów poddane recyklingowi]

No	Substance	Compartment	Unit	Total	Butelka PET - 30% odpadów poddane
1	Volume occupied, reservoir	Raw	m3y	22,3	22,3
2	Water, turbine use, unspecified natural origin	Raw	m3	9,39E3	9,39E3
3	Gas, natural, in ground	Raw	m3	508	508
4	Water, cooling, unspecified natural origin/m3	Raw	m3	72,6	72,6
5	Gas, natural, 35 MJ per m3, in ground	Raw	m3	16	16
6	Water, river	Raw	m3	8,13	8,13
7	Water, unspecified natural origin/m3	Raw	m3	7,29	7,29
8	Gas, petroleum, 35 MJ per m3, in ground	Raw	m3	3,12	3,12
9	Gas, mine, off-gas, process, coal mining/m3	Raw	m3	2,64	2,64
10	Water, well, in ground	Raw	m3	2,1	2,1
11	Water, salt, ocean	Raw	m3	1,42	1,42
12	Wood, soft, standing	Raw	l	188	188
13	Water, lake	Raw	l	175	175
14	Wood, hard, standing	Raw	l	80,5	80,5
15	Water, salt, sole	Raw	l	76,9	76,9
16	Volume occupied, underground deposit	Raw	l	1,28	1,28
17	Volume occupied, final repository for low-active radioactive waste	Raw	cm3	33,6	33,6
18	Volume occupied, final repository for radioactive waste	Raw	cm3	8,51	8,51
19	Wood, primary forest, standing	Raw	cm3	5,59	5,59
20	Wood, unspecified, standing/m3	Raw	cm3	2,8	2,8
21	Water, process and cooling, unspecified natural origin	Raw	m3	-2,03	-2,03
22	Gas, natural, feedstock, 35 MJ per m3, in ground	Raw	m3	-38,3	-38,3
23	Gas, natural, 36.6 MJ per m3, in ground	Raw	m3	-47,9	-47,9
24	Radon-222	Air	kBq	5,96E5	5,96E5
25	Radioactive species, unspecified	Air	kBq	5,02E5	5,02E5
26	Noble gases, radioactive, unspecified	Air	kBq	2,84E5	2,84E5
27	Krypton-85	Air	kBq	4,59E4	4,59E4
28	Hydrogen-3, Tritium	Water	kBq	1,45E4	1,45E4
29	Radioactive species, unspecified	Water	kBq	4,61E3	4,61E3
30	Hydrogen-3, Tritium	Air	kBq	177	177
31	Radium-226	Water	kBq	69,4	69,4
32	Xenon-133	Air	kBq	63,7	63,7
33	Strontium-90	Water	kBq	41,3	41,3
34	Carbon-14	Air	kBq	29,9	29,9
35	Radioactive species, Nuclides, unspecified	Water	kBq	28,8	28,8

Step 2 – Process Tree

PET bottle – recycling 30%



Step 3 – Impact Assessment

- LCI results, while interesting, do not give us any specific information about the environmental impact of a particular product
- LCI results should be interpreted and characterised into impact categories
- There are many characterisation methods available, many of them with normalisation and weighting options

LCIA

Impact Category

"Class representing environmental issues of concern to which life cycle inventory analysis results may be assigned"*

simply:

Types of environmental issues that could be caused by the inputs and outputs of the product or process being analyzed

Classes of Impact Categories

Human Health

Ecosystems

Resources

Common Emissions Impact Categories

Some can be partitioned further into:

- Air
- Water
- Soil

- Acidification Potential (AP)
- Ecotoxicity Potential (ETP)
- Eutrophication Potential (EP) (Also: Nutrification)
- Global Warming Potential (GWP) (Also: Climate Change)
- Human Toxicity Cancer Potential (HTCP) (Also: Human Health Cancer)
- Human Toxicity Non-Cancer Potential (HTNCP) (Also: Human Health Non-Cancer)
- Human Health Criteria Air Potential (HHCAP) (Also: Human Health Particulates)
- Stratospheric Ozone Depletion Potential (OPD) (Also: Ozone Layer Depletion)
- Smog Creation Potential (SCP) (Also: Photochemical Ozone Creation)

Other impact categories

- (Ionizing) Radiation Potential
- Ecosystem Damage Potential
- Abiotic Resource Depletion Potential
- Biotic Resource Depletion Potential
- Fossil Fuel Depletion Potential
- Energy Use
- Land Use
- Water Use
- Landfill Use
- Nuisance-related Impacts (odor, sound, etc.)
- Indoor Air Quality

Step 3 – Method example

CML 2000

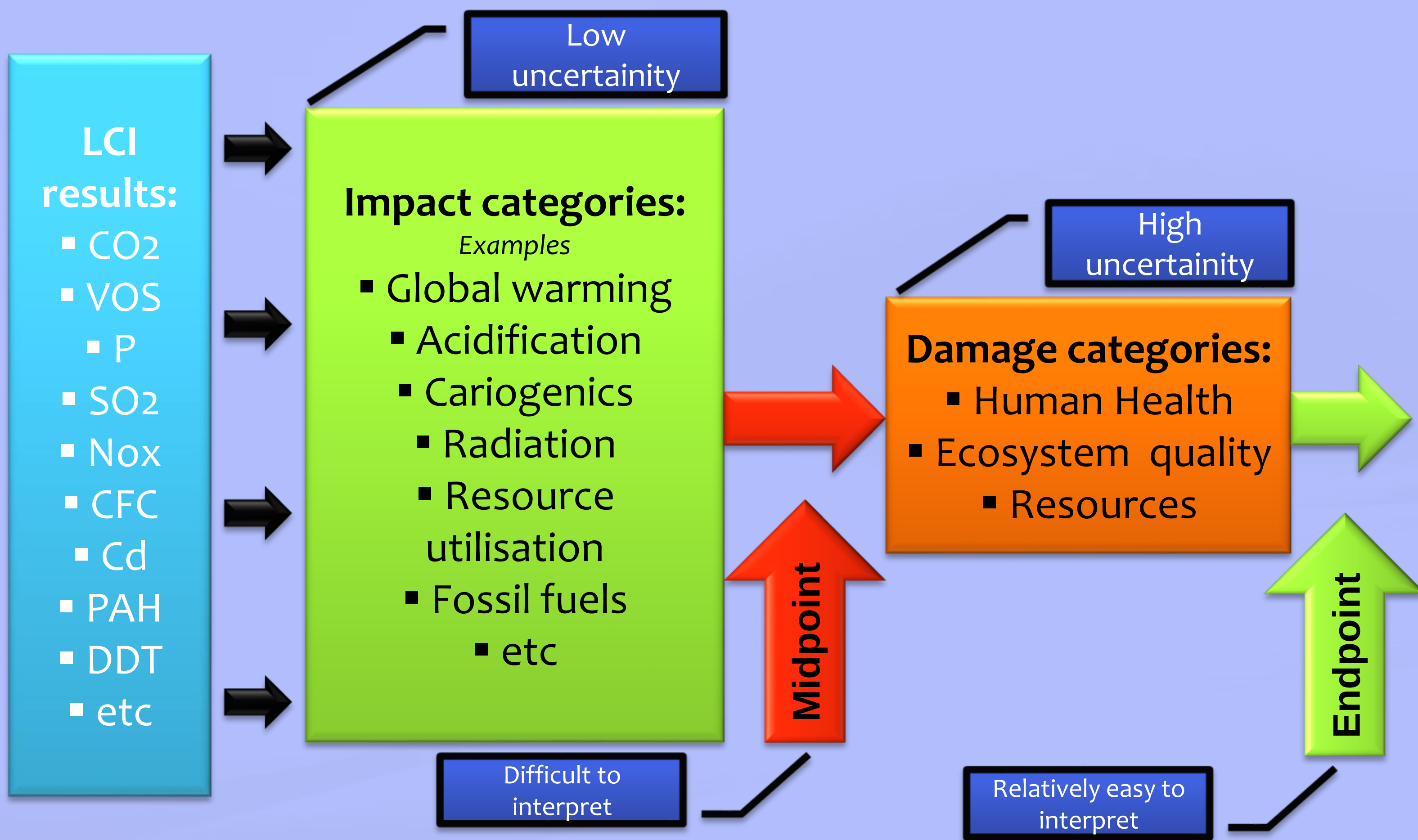
LCI result	Climate change	Acidification	Human toxicity
1000 gr CO2	x 1 = 1000		
10 gr. CH4	x 23 = 230		
10 gr. SO2		x 1 = 10	x 9.6E-2 = 0.96
5 gr. NOx		x 0.7 = 3.5	x 1.2 = 6
1E-7 gr dioxine			x 1.3E9 = 130
Total	1230	13.5	136.96

CO2-eq.

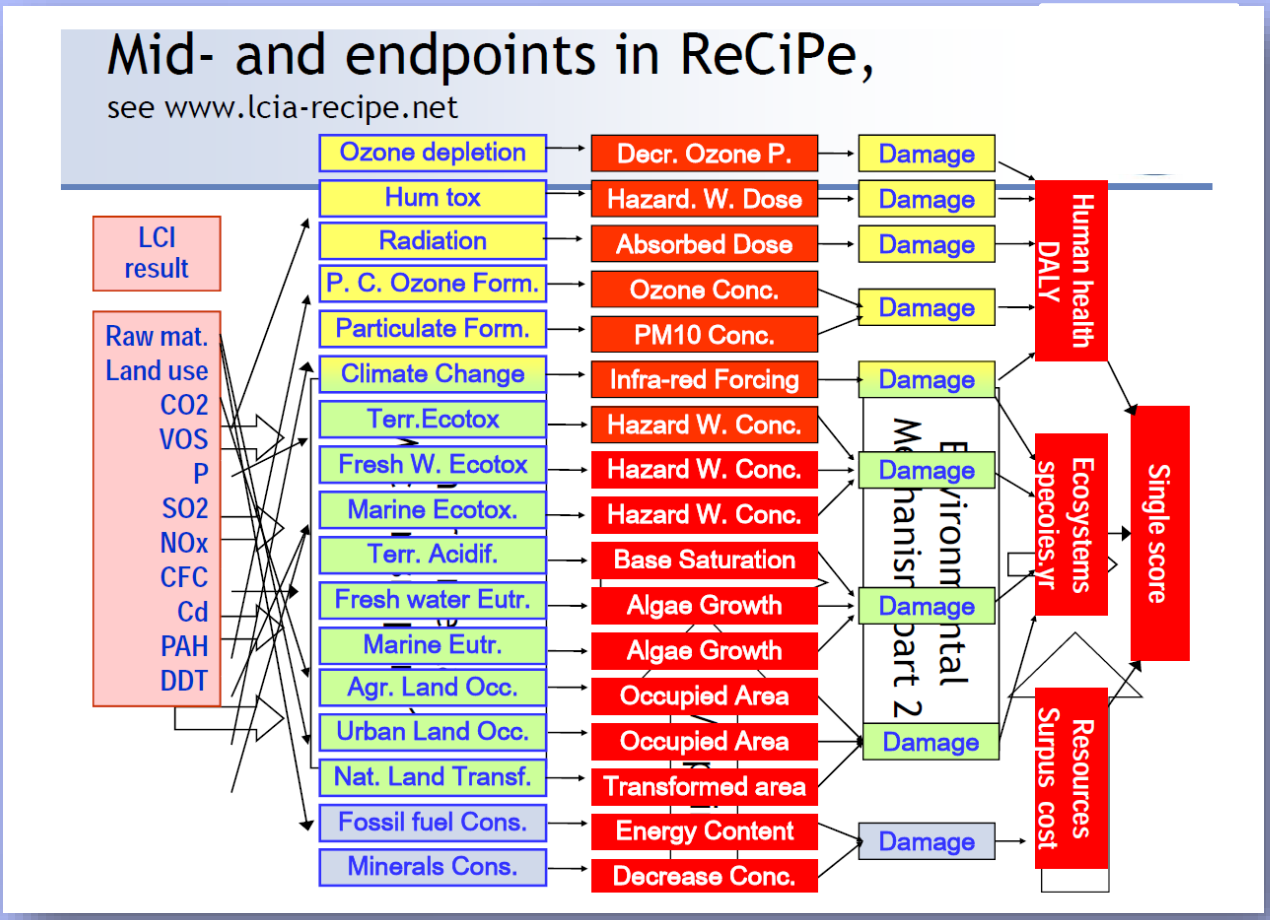
SO2-eq.

Human toxicity potentials

Step 3 –
Midpoint and Endpoint in a method



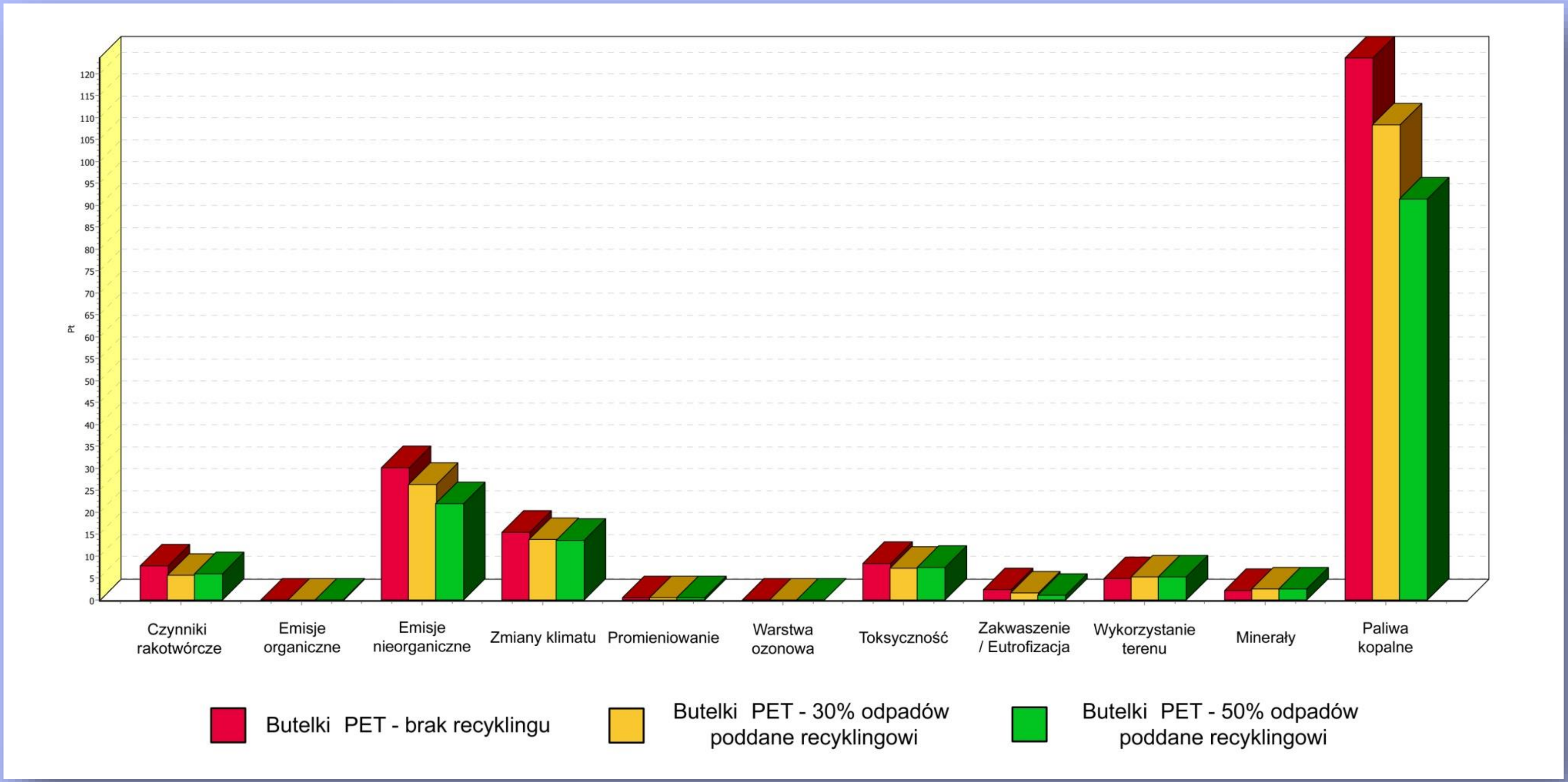
Step 3 –
Midpoint and Endpoint in a method



Step 3 – Impact Assessment

3 PET bottles – No recyling / recycling 30% & recycling 50%

Method: Eco-indicator 99



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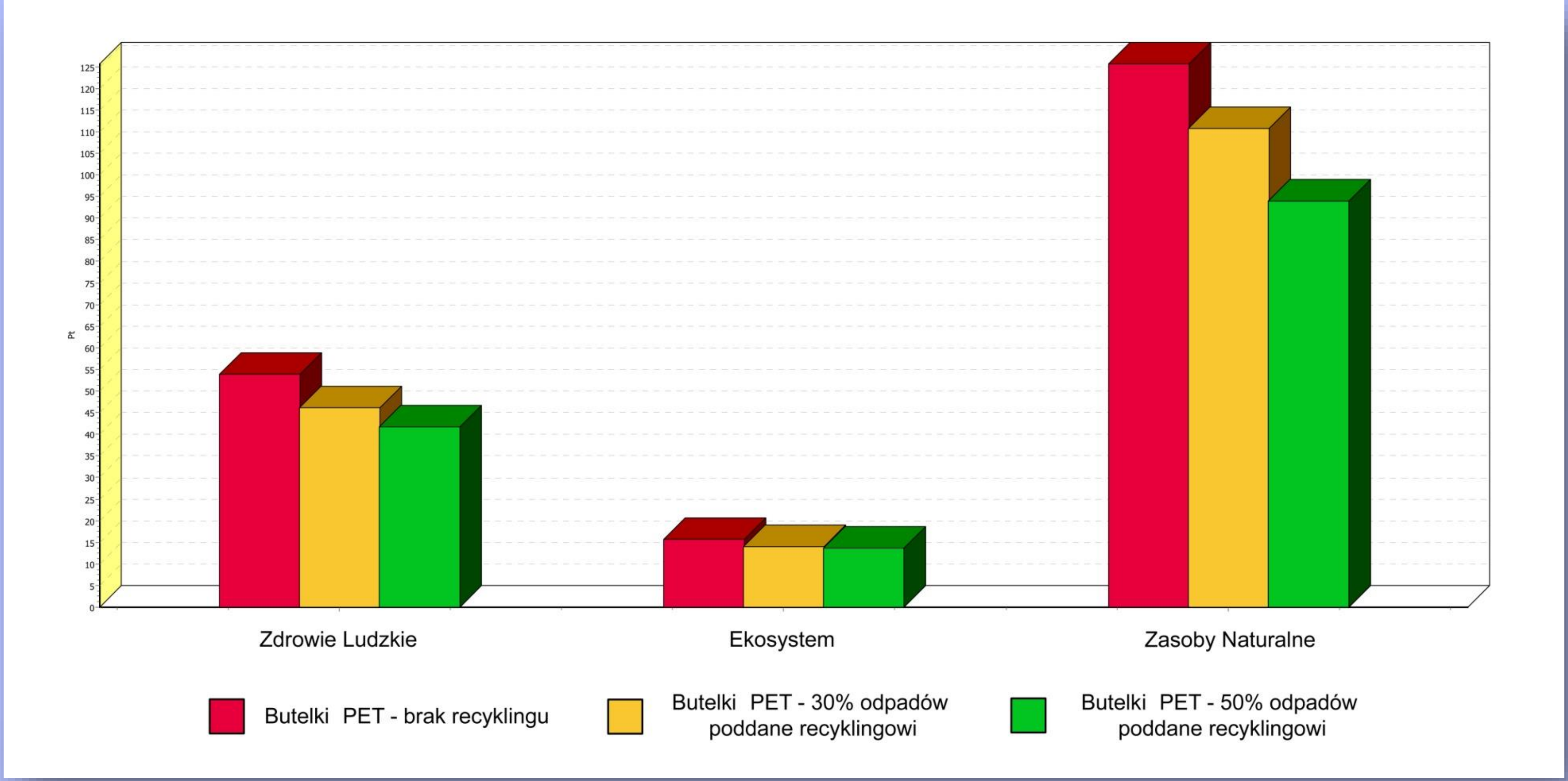

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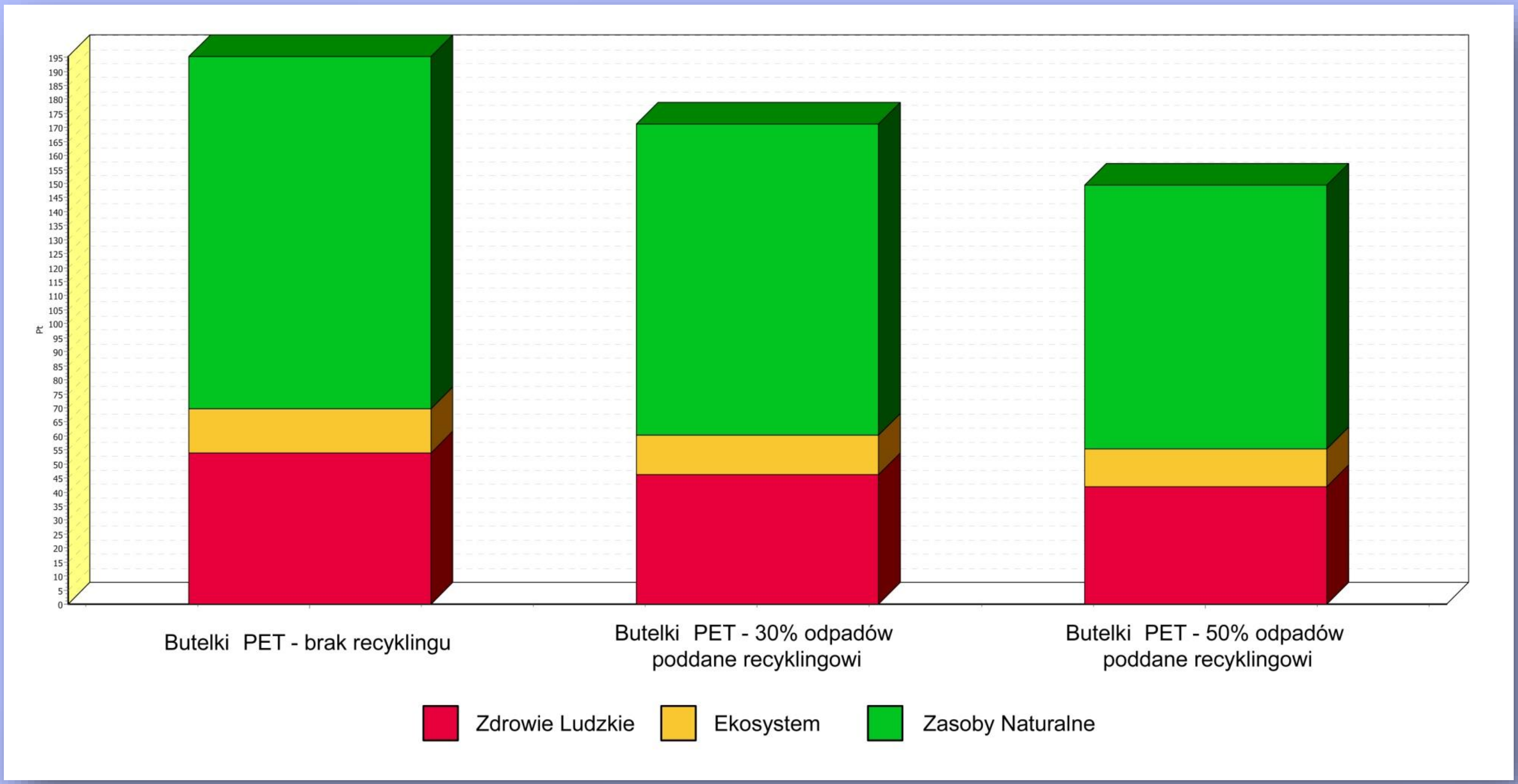


Step 4 - Interpretation

Continually ongoing during assessment to help guide other phases

Discussion of inventory analysis and impact assessment results in LCA study

Can be modeled as **conclusions and recommendations** to the decision maker

Should be consistent with and **based on goal and scope** of the study

Should **reflect the various uncertainties** inherent in LCA including:

- LCA is based on a relative approach using a functional unit
- Impacts are “potential”

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Step 4 - Interpretation

ISO 14044 standard recommends that before drawing conclusions and preparing a report from 3 previous steps, following elements should be checked:

- Check consistency of results with goal and scope definitions
- Check processes with highest environmental impact
- Check for anomalies (use best judgment)
- Check whether the method is consistent with assessed product
- Some methods omit substances present in the LCI – check whether the number of omitted substances influence the result by choosing a different method
- LCA is not objective, therefore it is helpful to check how the LCA results are dependent on our choices throughout the process.
- Perform uncertainty and sensitivity analysis where logical and possible. Prepare few scenarios.

Limitations of LCA

- "Not a complete assessment of all environmental issues" because only those identified in the goal and scope are considered
- LCI can rarely, if ever, include every single process and capture every single input and output due to system boundaries, data gaps, cut-off criteria, etc.
- LCI data collected contains uncertainty
- Characterization models are far from perfect
- Sensitivity and other uncertainty analyses are not fully developed

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Critical Review

- Necessary component for comparative studies disclosed to the public
- Verifies process and consistency with principles
  - Not an endorsement
  - Does not verify or validate goals
- Can improve credibility of study
- Critical review process defined in goal and scope!
- External independent chair person and at least two other members

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Summary Features of an LCA

- **Systematic procedure** for **environmental assessment** through product or process life cycle
- **Functional unit basis for comparisons** differs from many other environmental management techniques
- **Amenable to data confidentiality needs** and proprietary matters
- **Open to update** based on new science and developing techniques
- Not overly restrictive
- Impacts identified are all expressed as **POTENTIAL**
- LCIA converts LCI results to environmental issues based on characterization factors
- **Systematic approach to identify, check, evaluate and present information based on goal and scope**
- **Iterative process with continual interpretation**
- May **link to other environmental management techniques**

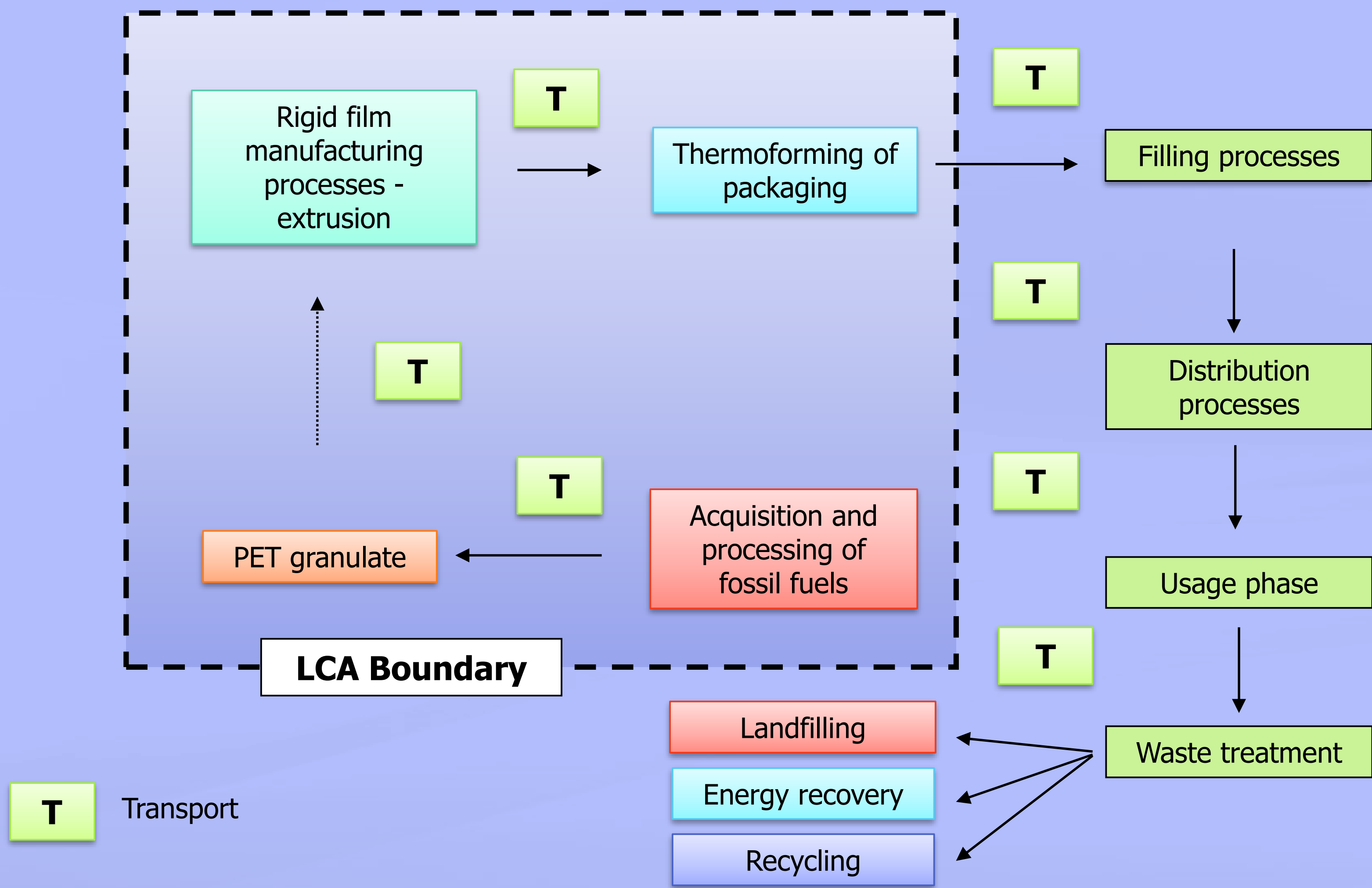
Source: *Life Cycle Assessment (LCA) Learning Module Series*

Example

Cheery tomato container from the following materials :

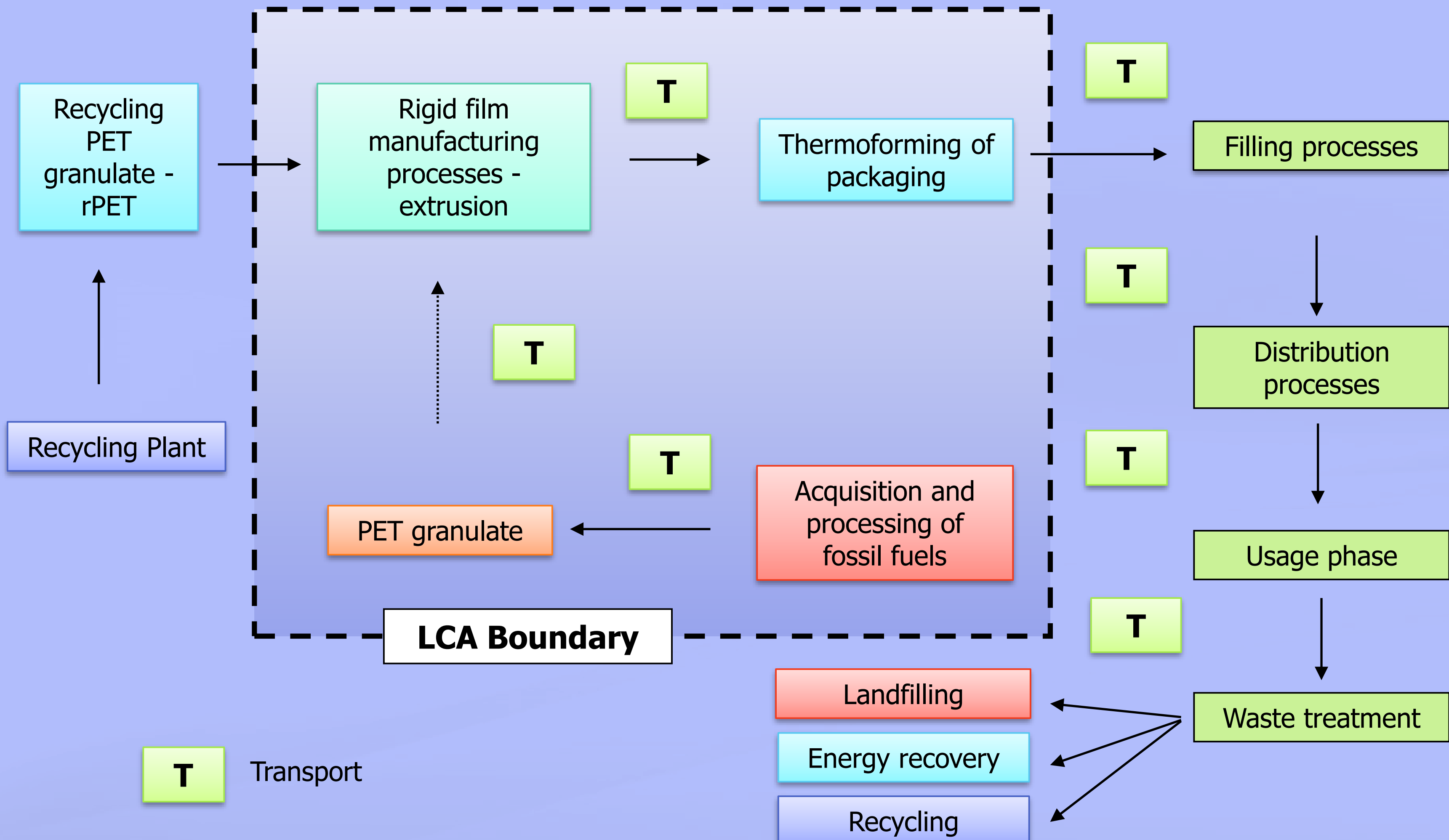
1. PP
2. PET
3. rPET
4. PLA

Example



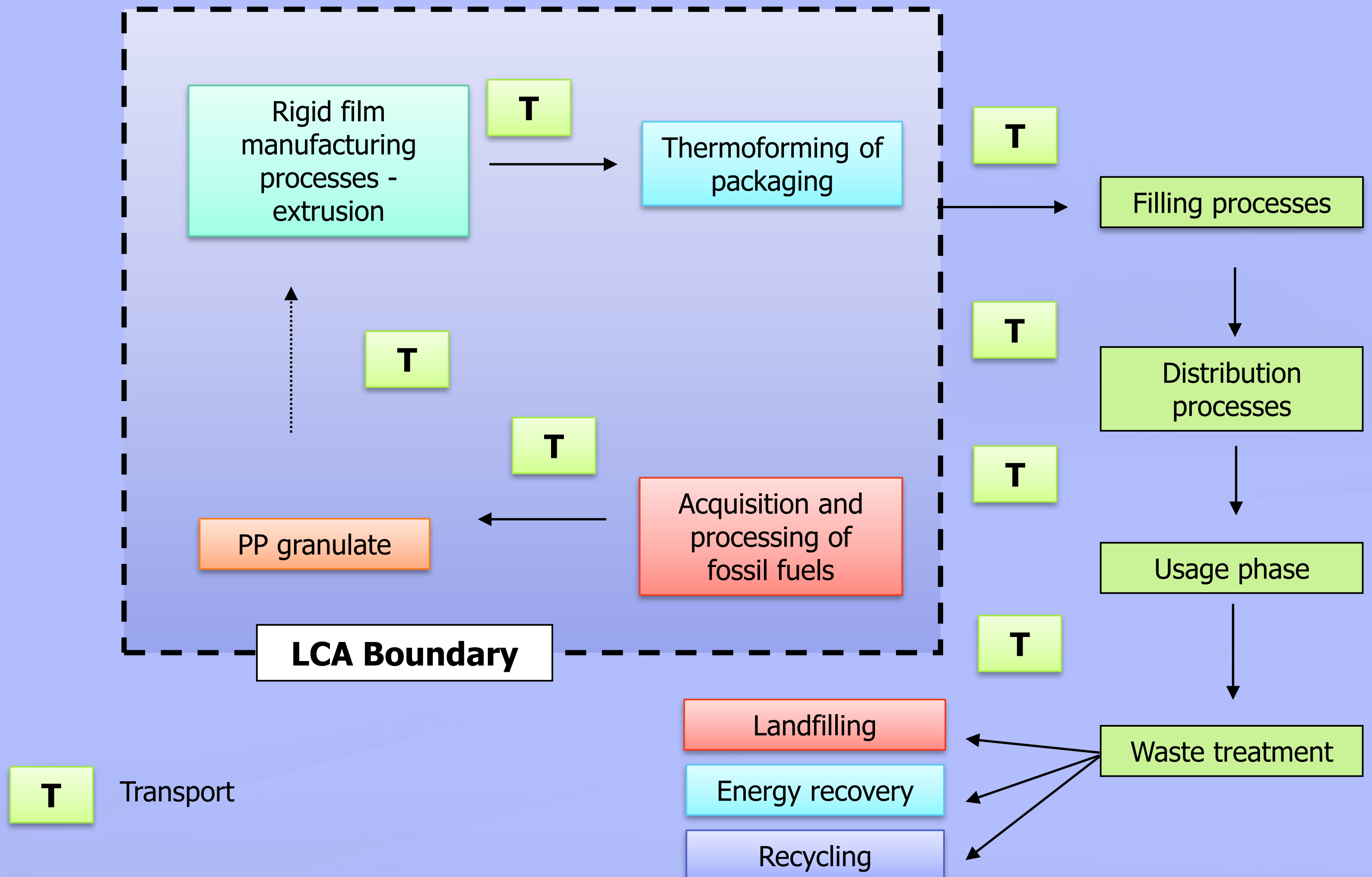
Rigid film manufacturing processes - extrusion
T
Thermoforming of packaging
T
Filling processes
T
Distribution processes
T
T
PET granulate
T
Acquisition and processing of fossil fuels
Usage phase
LCA Boundary
T
Landfilling
Waste treatment
Energy recovery
Recycling
T
Transport

Example



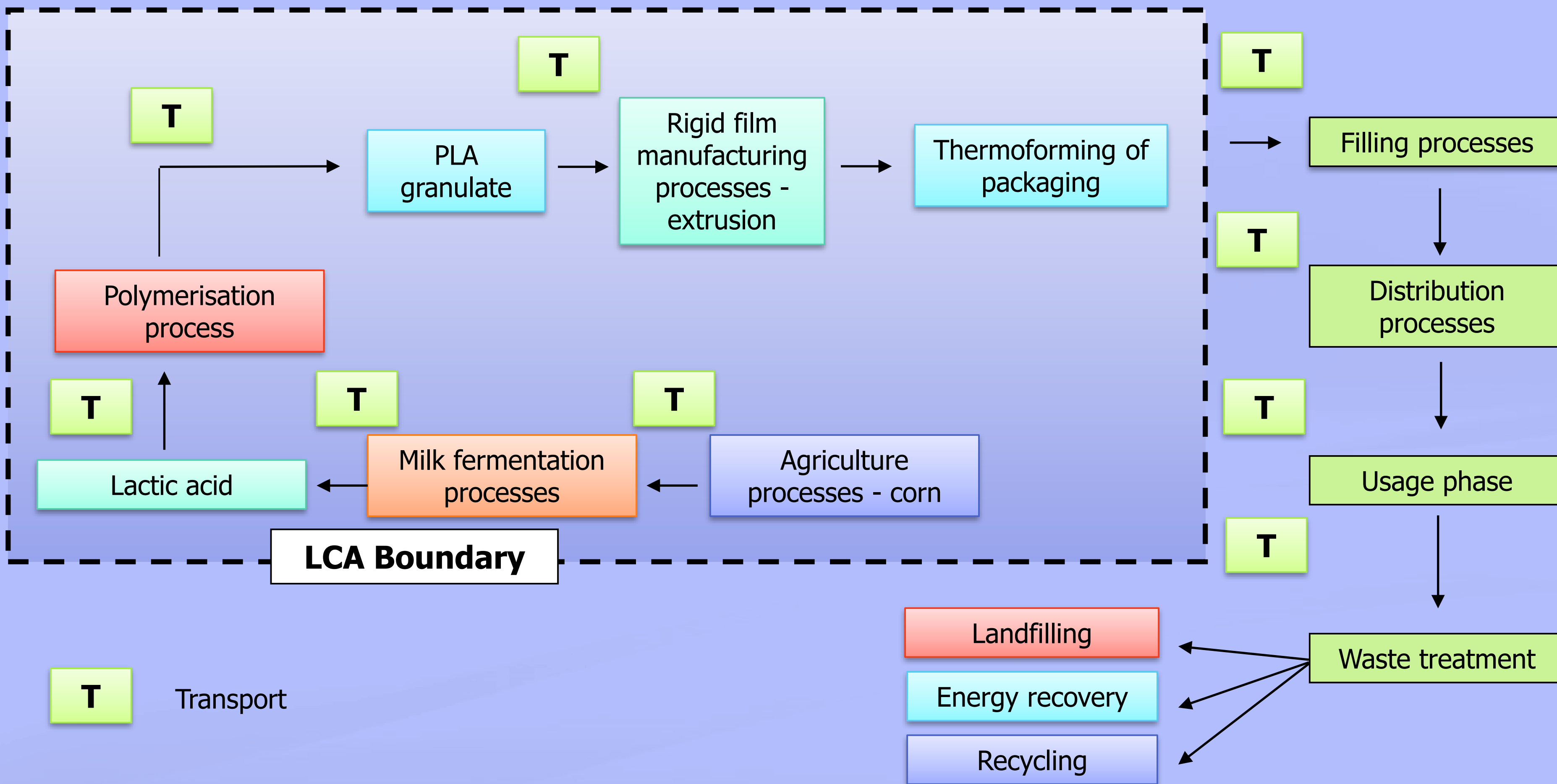
Recycling PET granulate - rPET
Rigid film manufacturing processes - extrusion
T
Thermoforming of packaging
T
Filling processes
T
Distribution processes
T
T
Recycling Plant
T
PET granulate
Acquisition and processing of fossil fuels
T
Usage phase
T
LCA Boundary
Waste treatment
Landfilling
Energy recovery
Recycling
T
Transport

Example



Rigid film manufacturing processes - extrusion
T
Thermoforming of packaging
T
Filling processes
T
T
Distribution processes
T
T
Acquisition and processing of fossil fuels
PP granulate
Usage phase
LCA Boundary
T
Landfilling
Energy recovery
Recycling
Waste treatment
T
Transport

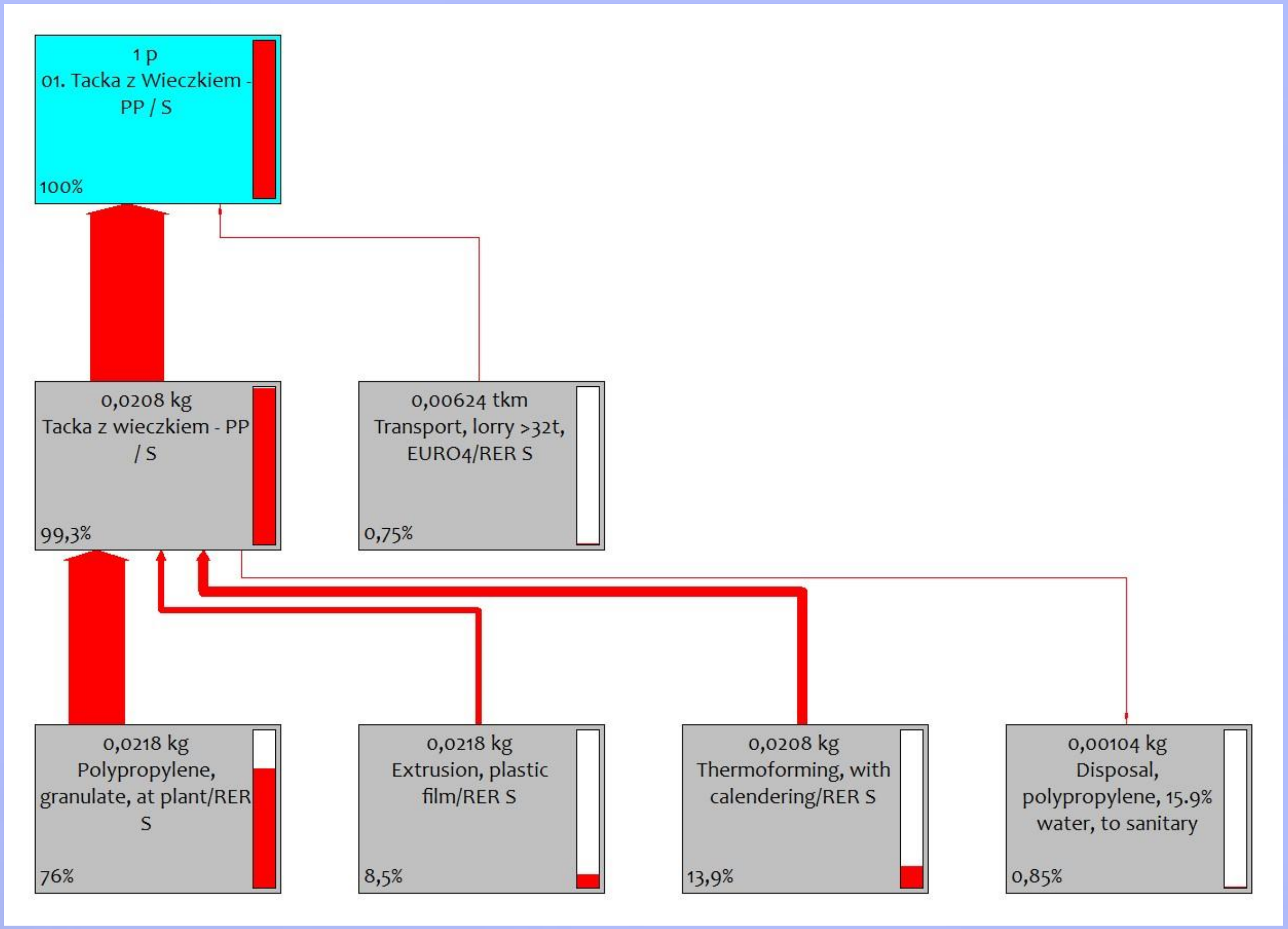
Example



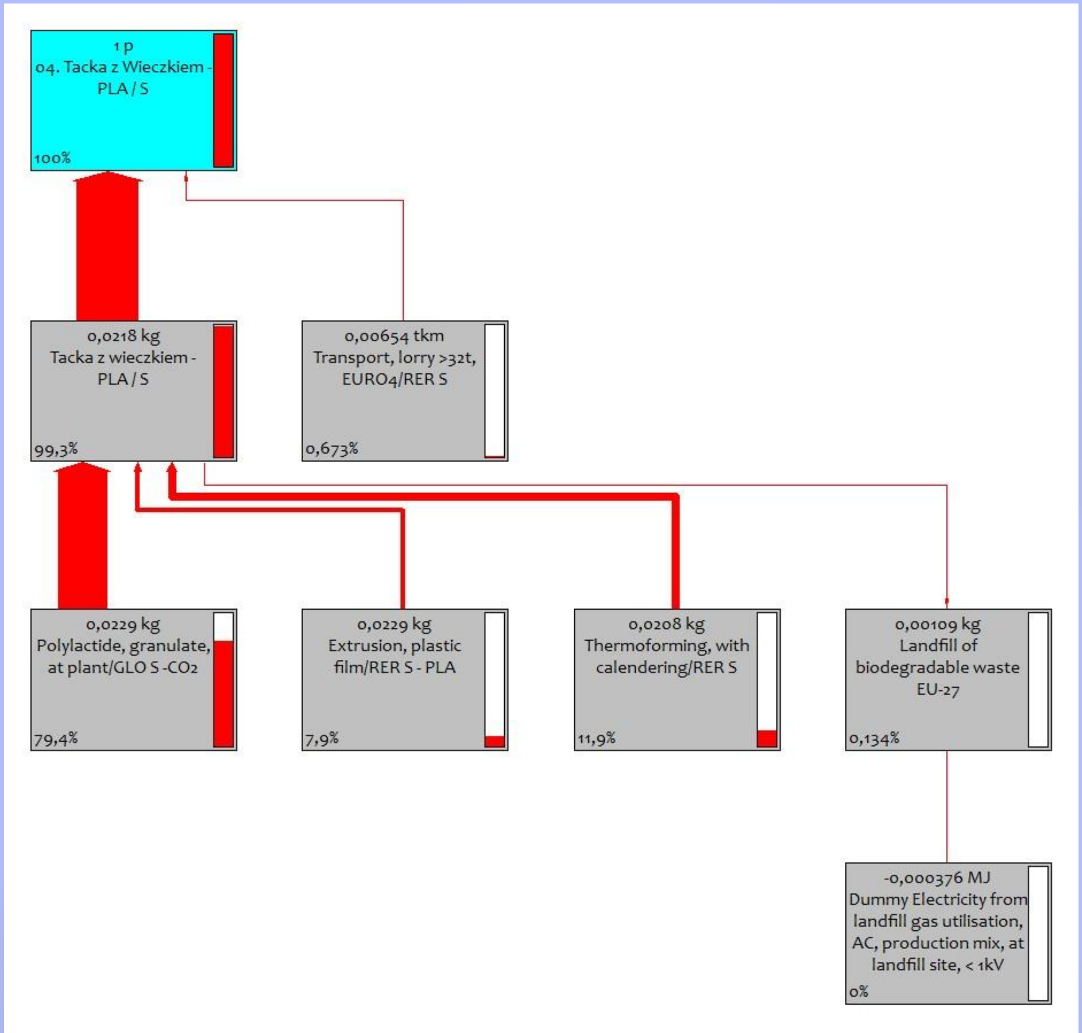
T
PLA granulate
Rigid film manufacturing processes - extrusion
Thermoforming of packaging
Polymerisation process
Lactic acid
Milk fermentation processes
Agriculture processes - corn
LCA Boundary
Filling processes
Distribution processes
Usage phase
Waste treatment
Landfilling
Energy recovery
Recycling
T
Transport

Example

PP container



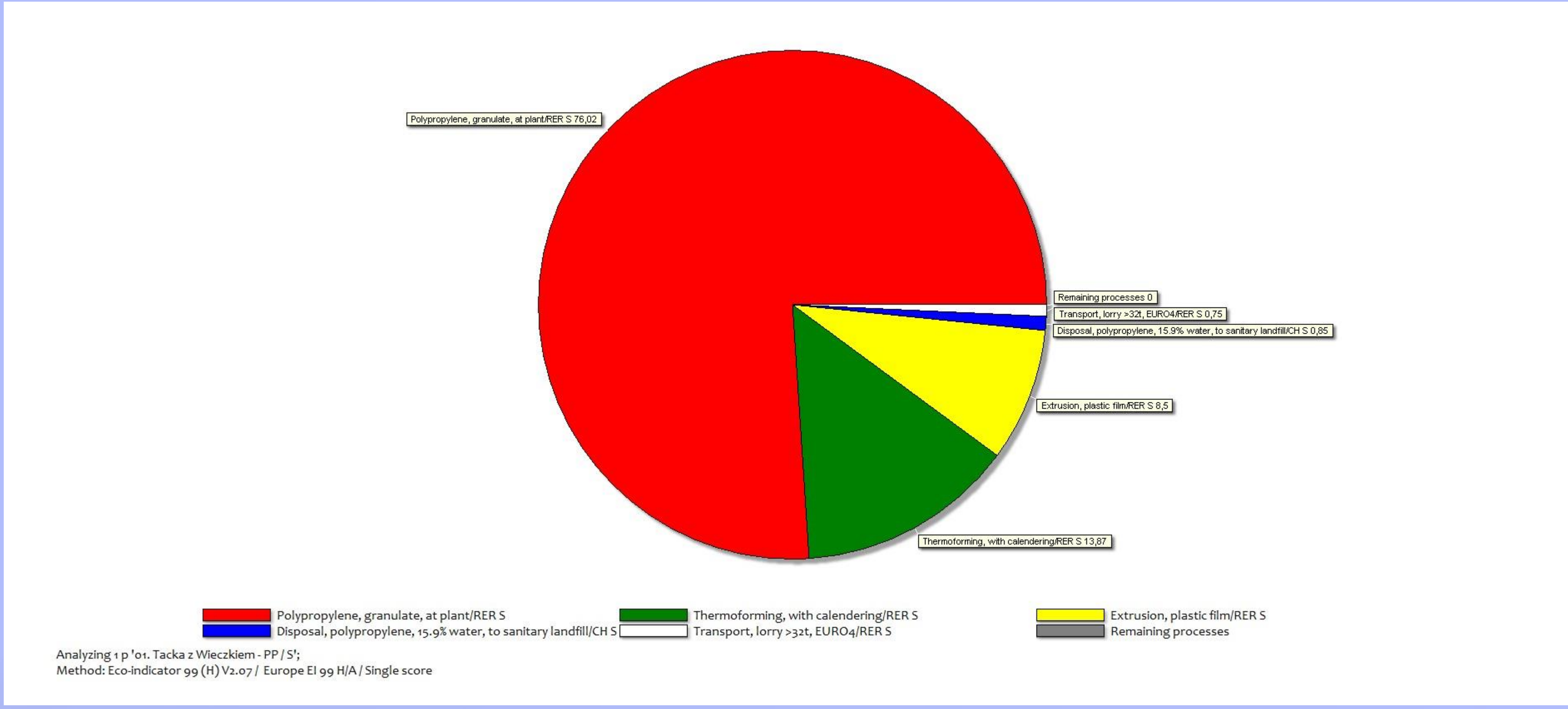
Example



PLA container

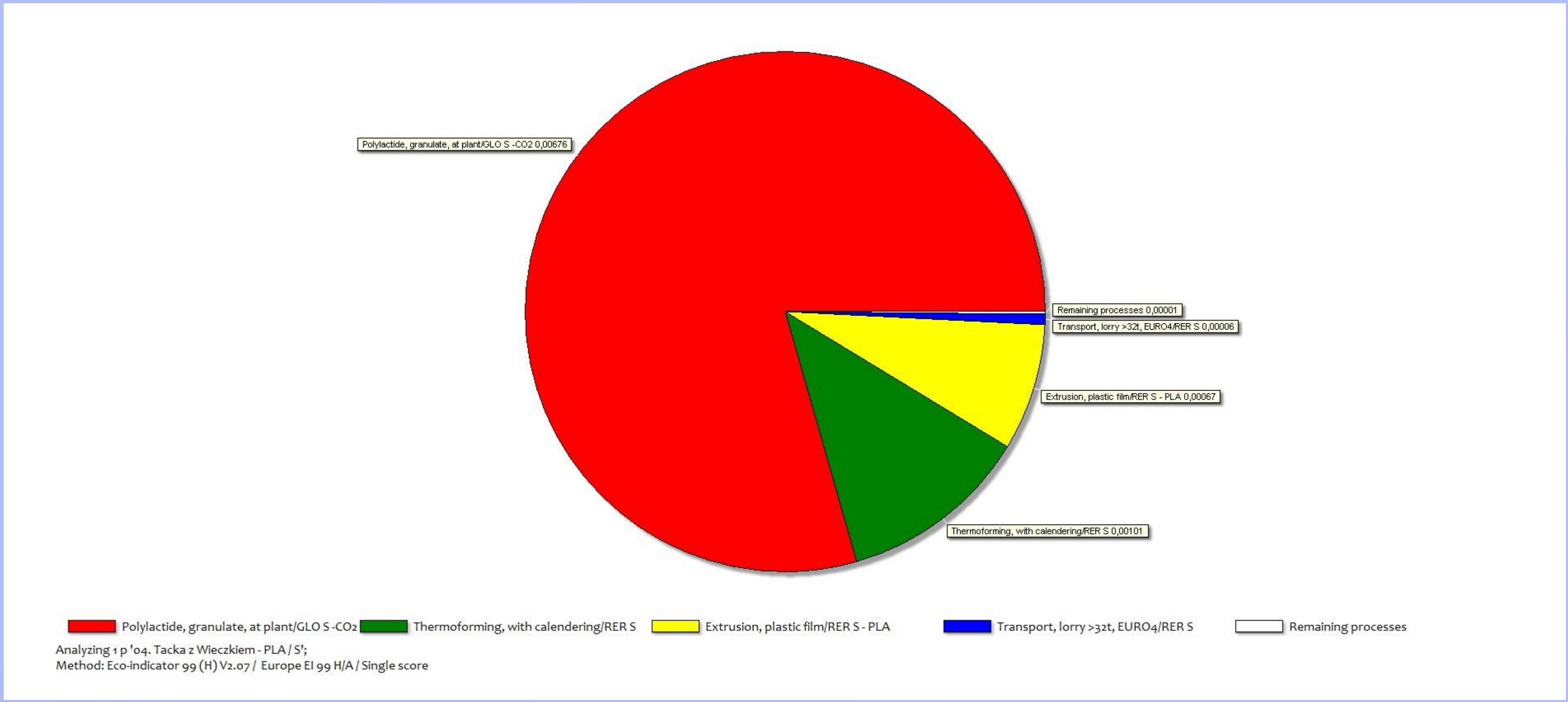
Example

PP container

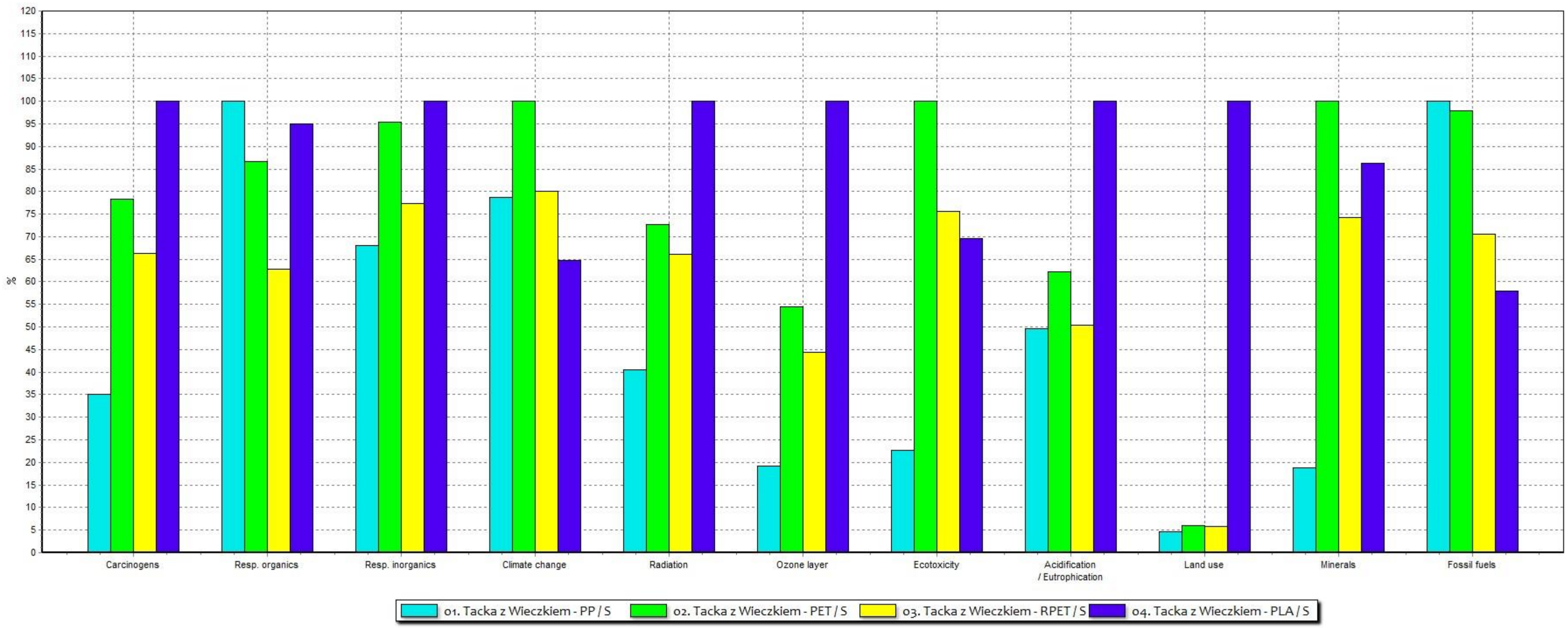


Example

PLA container

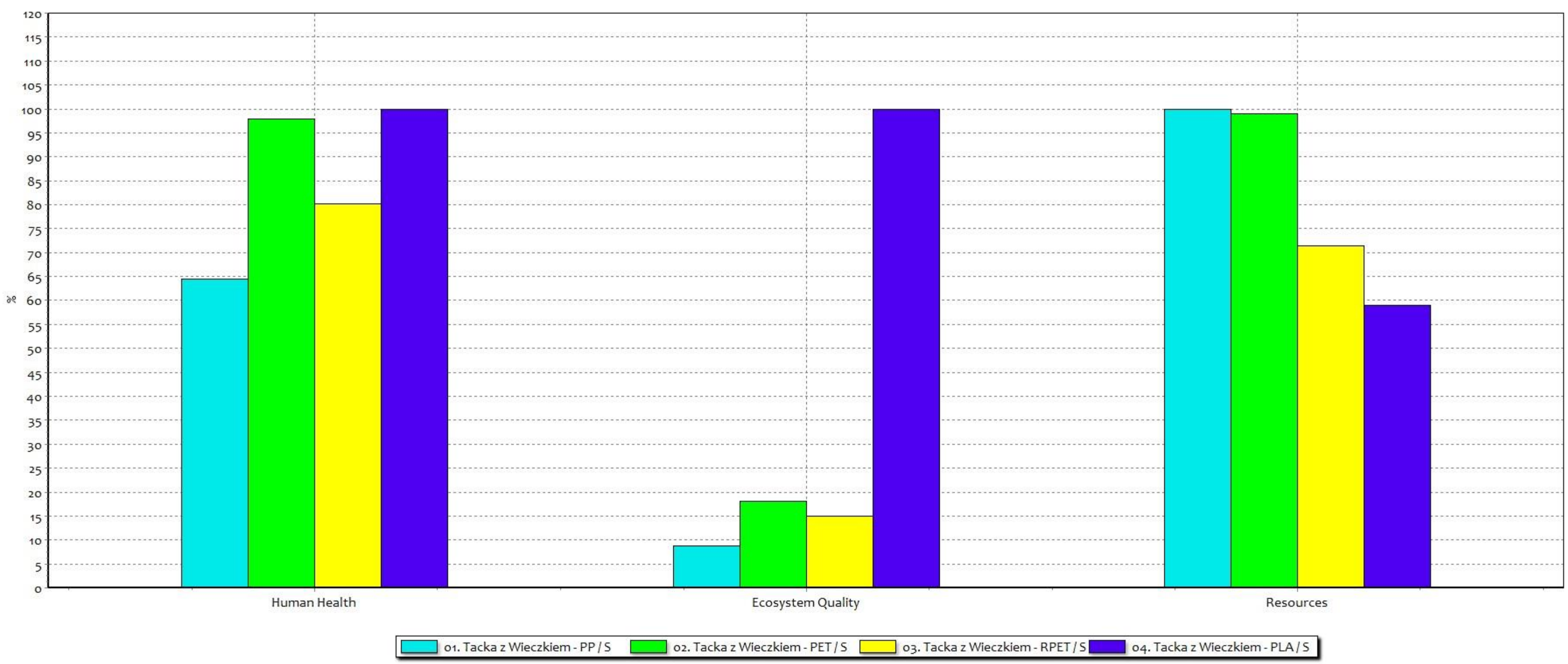


Example



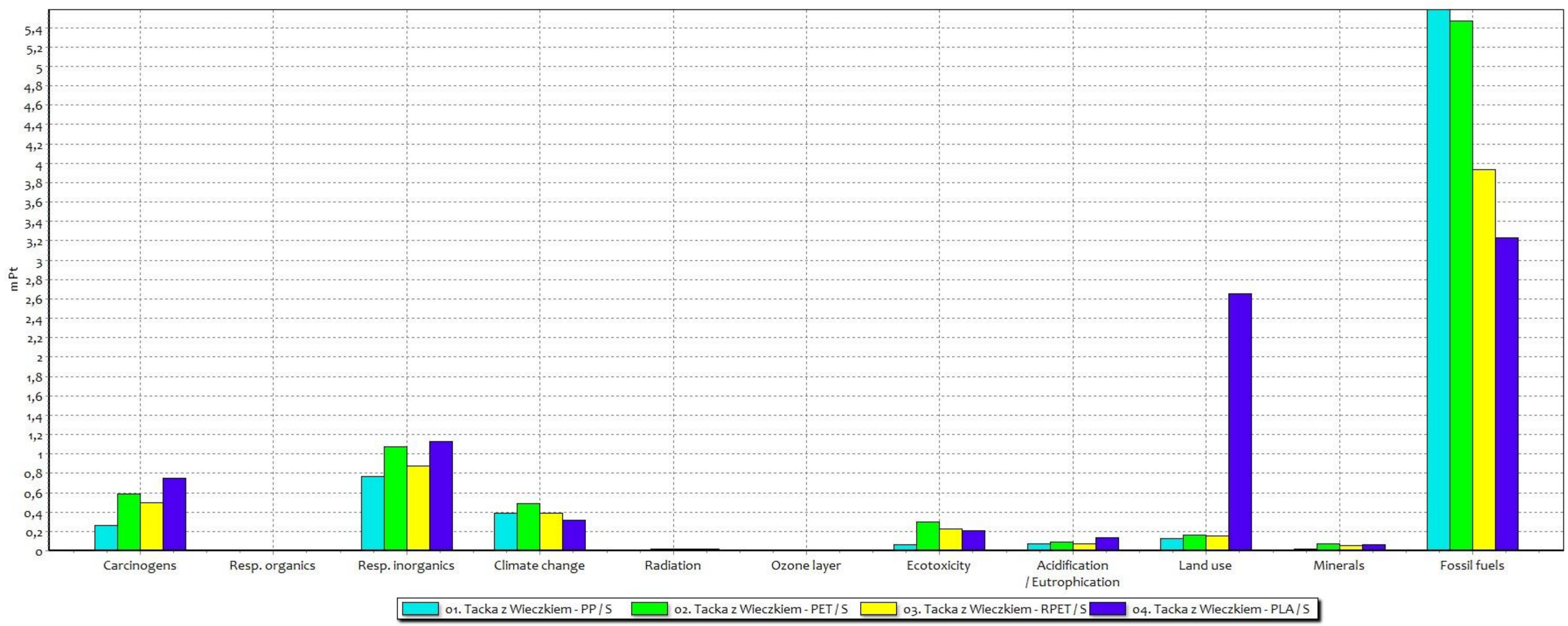
PP PET rPET PLA

Example



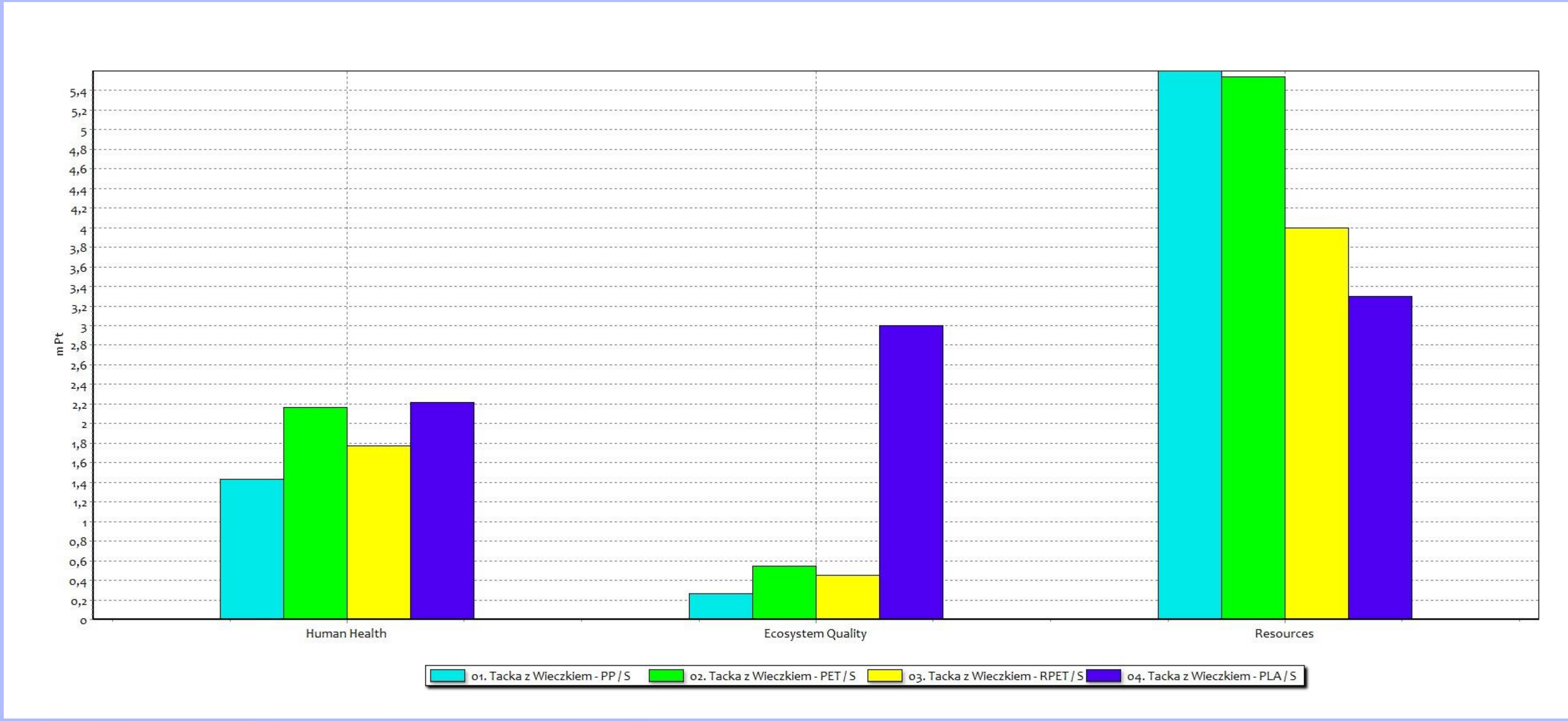
PP PET rPET PLA

Example



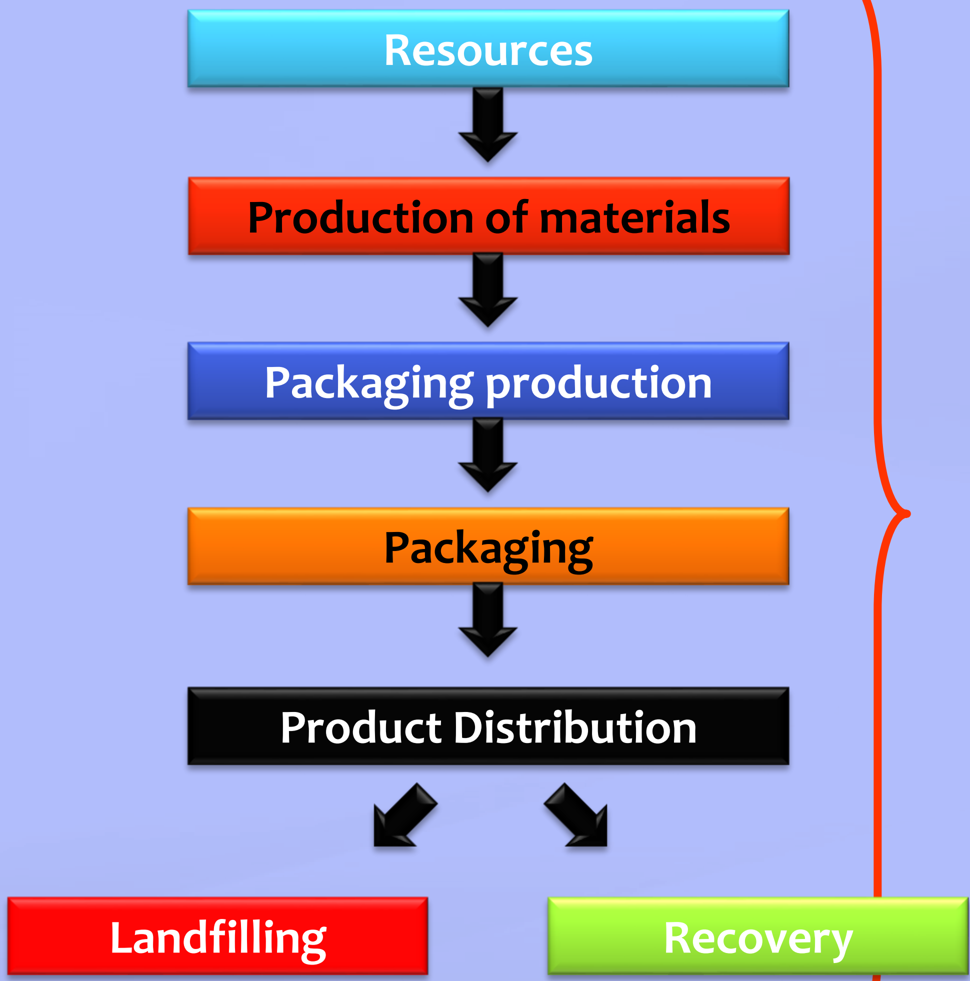
PP PET rPET PLA

Example



mPt
5,4
5,2
5
4,8
4,6
4,4
4,2
4
3,8
3,6
3,4
3,2
3
2,8
2,6
2,4
2,2
2
1,8
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
Human Health
Ecosystem Quality
Resources
01. Tacka z Wieczkiem - PP / S
02. Tacka z Wieczkiem - PET / S
03. Tacka z Wieczkiem - RPET / S
04. Tacka z Wieczkiem - PLA / S

Summary



- Natural resources utilisation
- Environmental damage
- Energy utilisation
- Gas emissions
- Liquid waste
- Solid waste
- Damage impact assessment

COST Action LCA

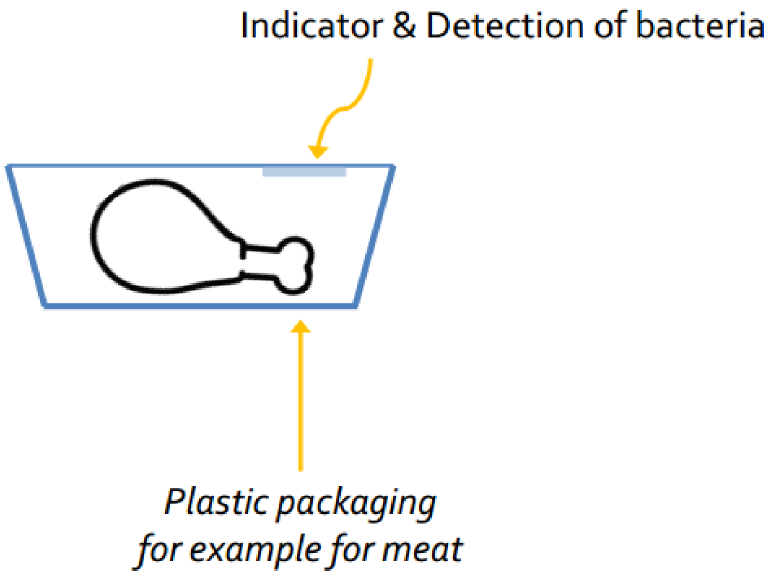
Presentation of demonstrator products

- 3 products - 1 intelligent / 2 active
- Products chosen and agreed upon in previous ActInPak COST action meetings
- Demonstrator products refined for LCA purposes:

1. Intelligent indicator for meat products – assumptions that the indicator is binary – it either shows that the meat is fresh, or not.
2. Packed bread active packaging – bread in active packaging does not have preservatives
3. Fruits/Vegetables active corrugated box – strawberries chosen as the packed product.

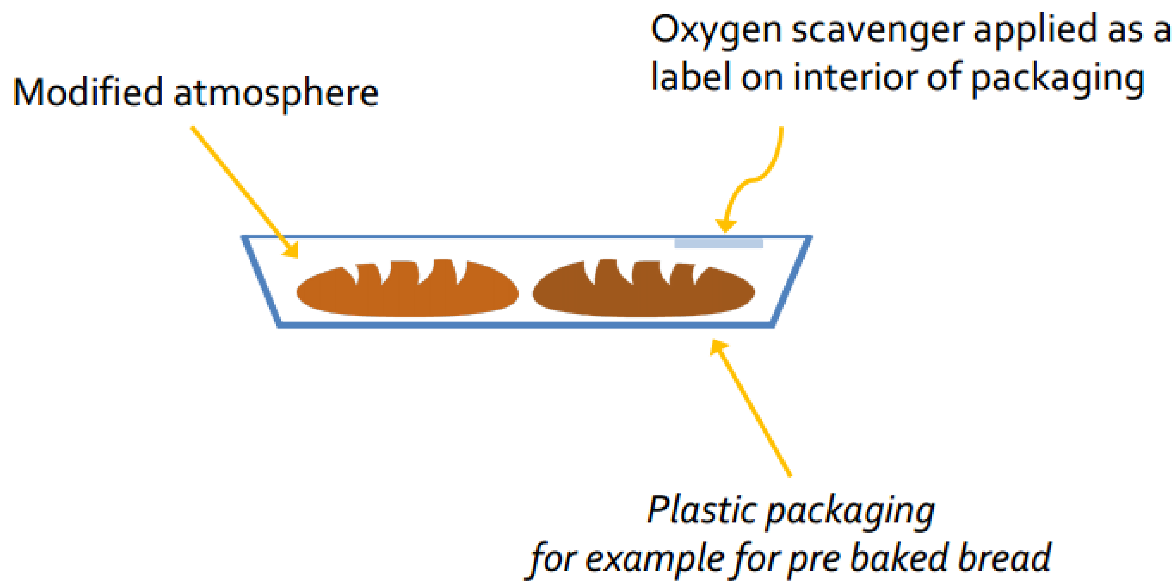
ActInPak Demonstrators

Demonstrator 1 – Intelligent



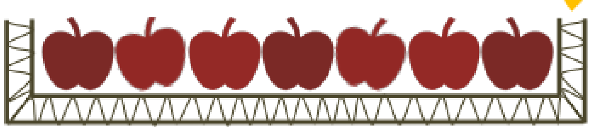
ActInPak Demonstrators

Demonstrator 2 – Active



ActInPak Demonstrators

Demonstrator 3 – Active



Antibacterial / anti mould
Corrugated layer sandwiched
between inner and outer layer

Corrugated box
for example for fruits

COST Action LCA

Discussion on the goal and target group of LCA - *Brain storm in 3 groups*

Common group decision:

Target of the LCA:

Brand Owner / Retailer / Packer

COST Action LCA

Discussion on the scope of LCA for all 3 demonstrator products - *Brain storm in 3 groups*

Common group decision:

Scope of all three LCA's:

Cradle to Grave – Product + Packaging – including three end of life scenarios

COST Action LCA

Discussion on the scope of LCA for all 3 demonstrator products - *Brain storm in 3 groups*

End of life scenarios:

- Recycling heavy
- Mixed
- Landfill heavy

COST Action LCA

Discussion on the functional unit for all 3 demonstrator products - *Brain storm in 2 groups*

1. **Intelligent meat packaging:**
   - ***100 kg of meat consumed***
2. **Active bread packaging:**
   - **100 kg of packed bread sold**
3. **Active strawberries packaging:**
   - **100 kg of strawberries consumed**

COST Action LCA

Intelligent meat packaging:

- ***100 kg of meat consumed***

Assumptions:

- **Packaging with indicator:**
  - Some loss before best before date (due to non optimal storage conditions)
  - Savings after best before date – indicator not activated after x days after best before date = increased consumption
- **Packaging without indicator:**
  - Certain loss after best before date

COST Action LCA

Active bread packaging:

- ***100 kg of packed bread sold***

Assumptions:

- **Packaging with active component:**
  - Bread without preservatives
  - Shelf life is the same as in packaging without active compment
- **Packaging without active component:**
  - Bread with preservatives
  - Shelf life is the same as in packaging with active compment

COST Action LCA

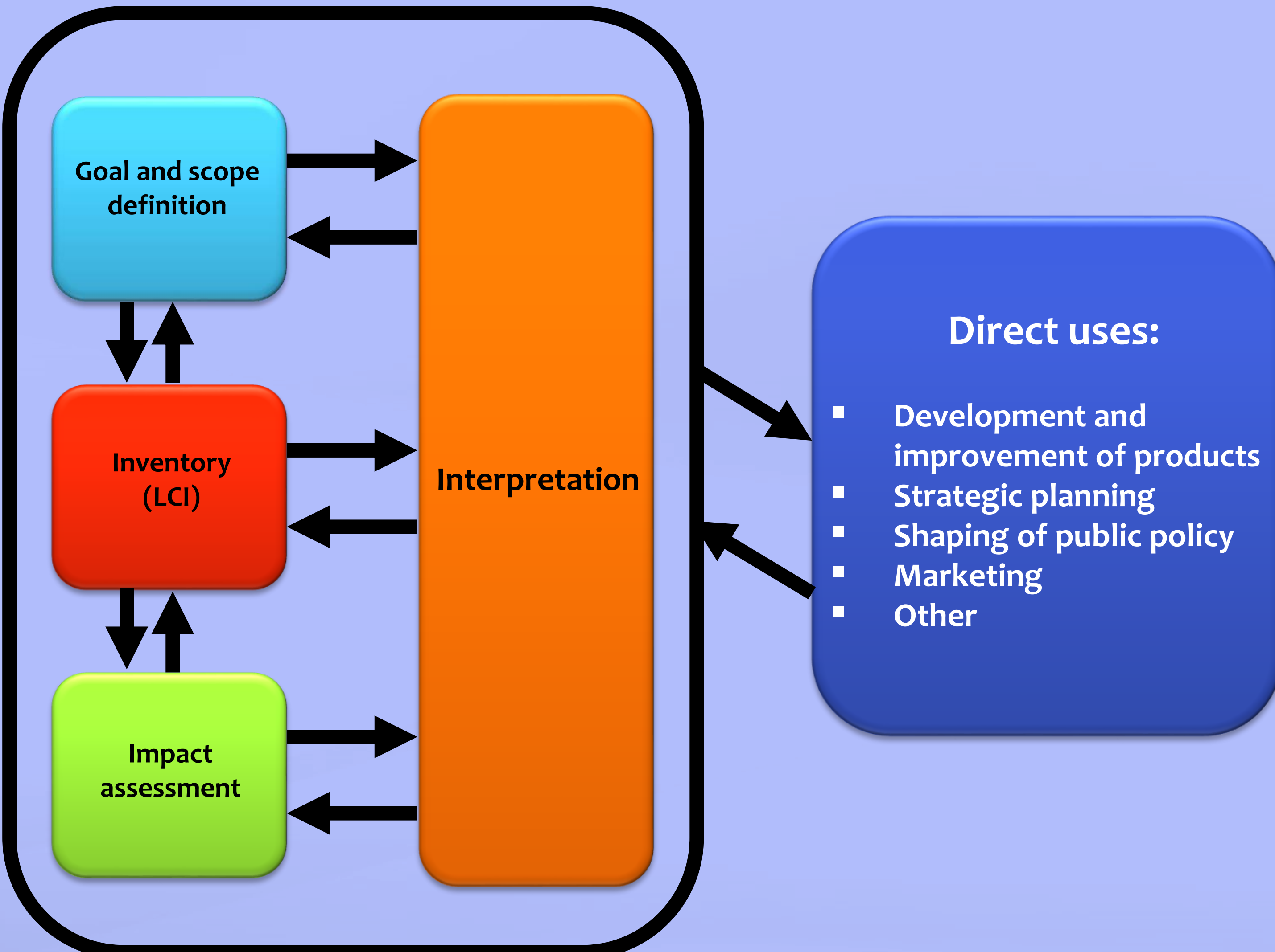
Active strawberries packaging:

- **100 kg of strawberries consumed**

Assumptions:

- **Packaging with active component:**
  - Direct impact on a shelf life- shelf life is longer
- **Packaging without active component:**
  - shelf life is normal

LCA in 4 steps



LCA Example Workshop

LCA Example – Bottled Water

Why would we want to do an LCA of bottled water?

~ 15 minutes group work

LCA Example Workshop

Goal

Goal statement is the first component of an LCA and guides much of the subsequent analysis

Goal must state:
Intended use
Reasons for study
Audience
Whether comparative and disclosed to public

Scope

Scope provides background information, details methodological choices, and lays out report format

Scope includes:
Product system
Functions of systems
Functional unit
System boundary
Allocation procedures
Impact categories, assessment method and interpretation type

Source: *Life Cycle Assessment (LCA) Learning Module Series*

LCA Example Workshop

Goal

<u>Goal must state:</u>

Intended use

- *Internal simplified example of LCA for our summer school*

Reasons for study

- *To present the workflow of performing LCA in a workshop format*

Audience

- *Summer school attendees*

Whether comparative and disclosed to public

- *Comparative – not disclosed to public*

Source: *Life Cycle Assessment (LCA) Learning Module Series*

LCA Example Workshop

Scope

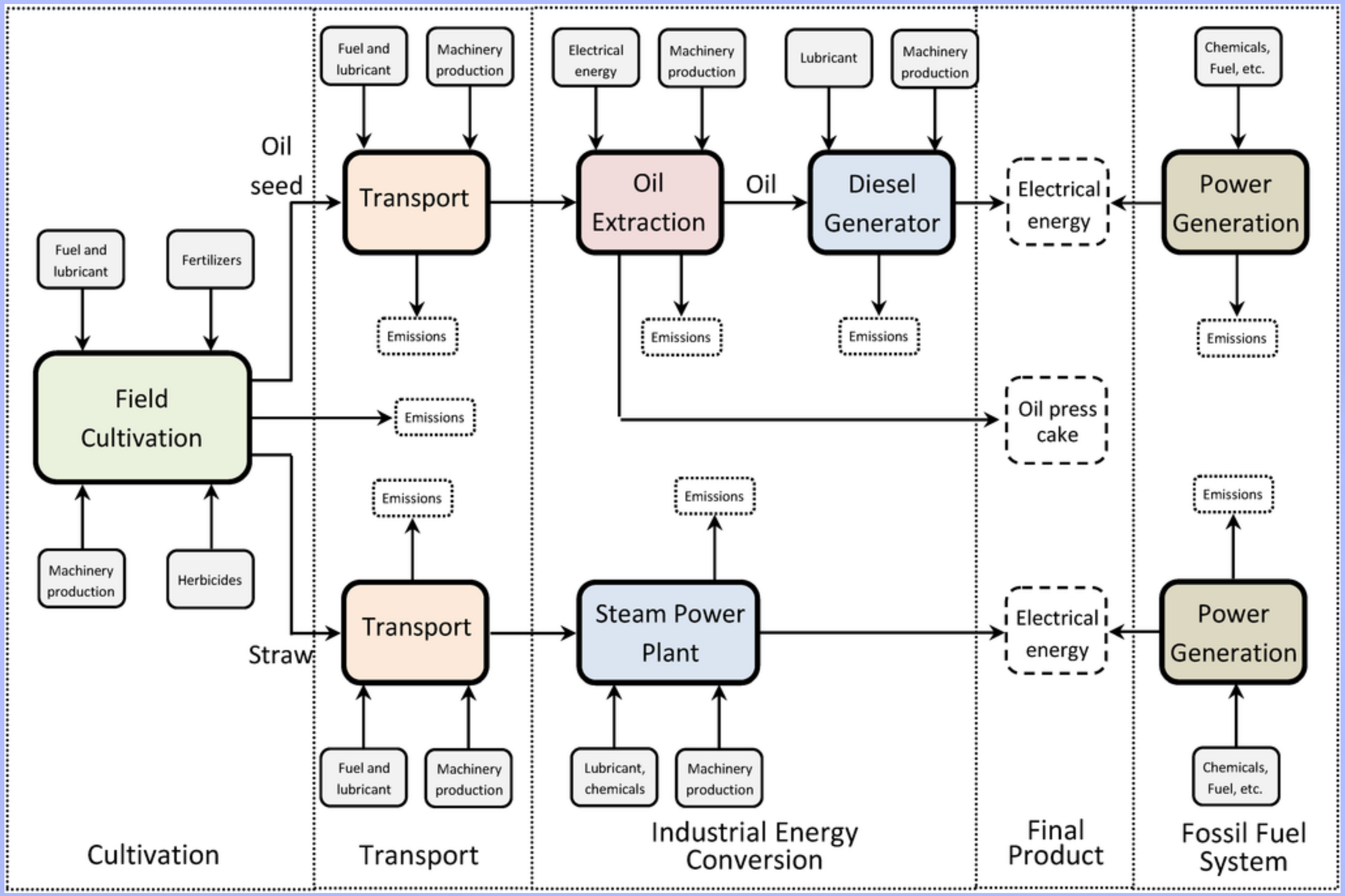
<u>Scope includes:</u>

Product system
Functions of systems
Functional unit
System boundary
Allocation procedures
Impact categories, assessment method and interpretation type

Source: *Life Cycle Assessment (LCA) Learning Module Series*

LCA Example Workshop

Product system

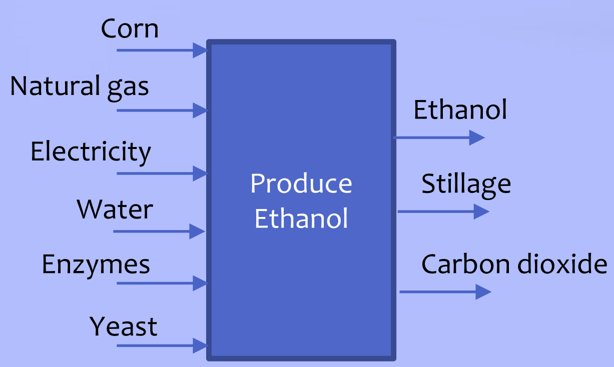


Source: *Life Cycle Assessment (LCA) Learning Module Series*

Process

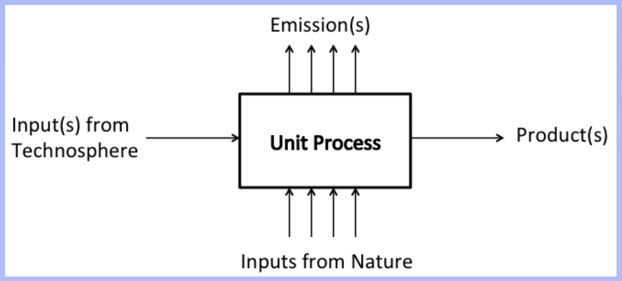
Process

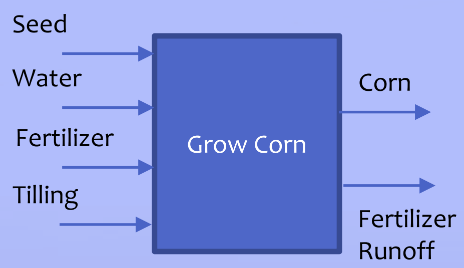
"Set of interrelated or interacting activities that transforms inputs into outputs."



Unit process

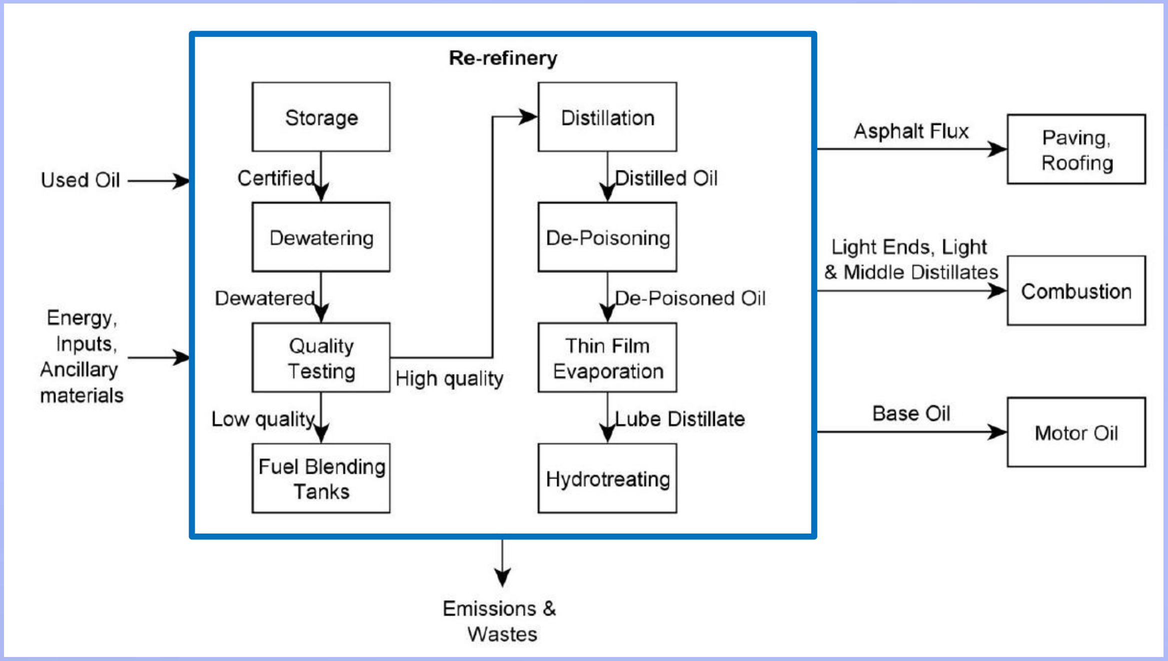
"Smallest element considered in the life cycle inventory analysis for which input and output data are quantified."





Product System

"Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product"



LCA Example Workshop

LCA Example Workshop

Scope

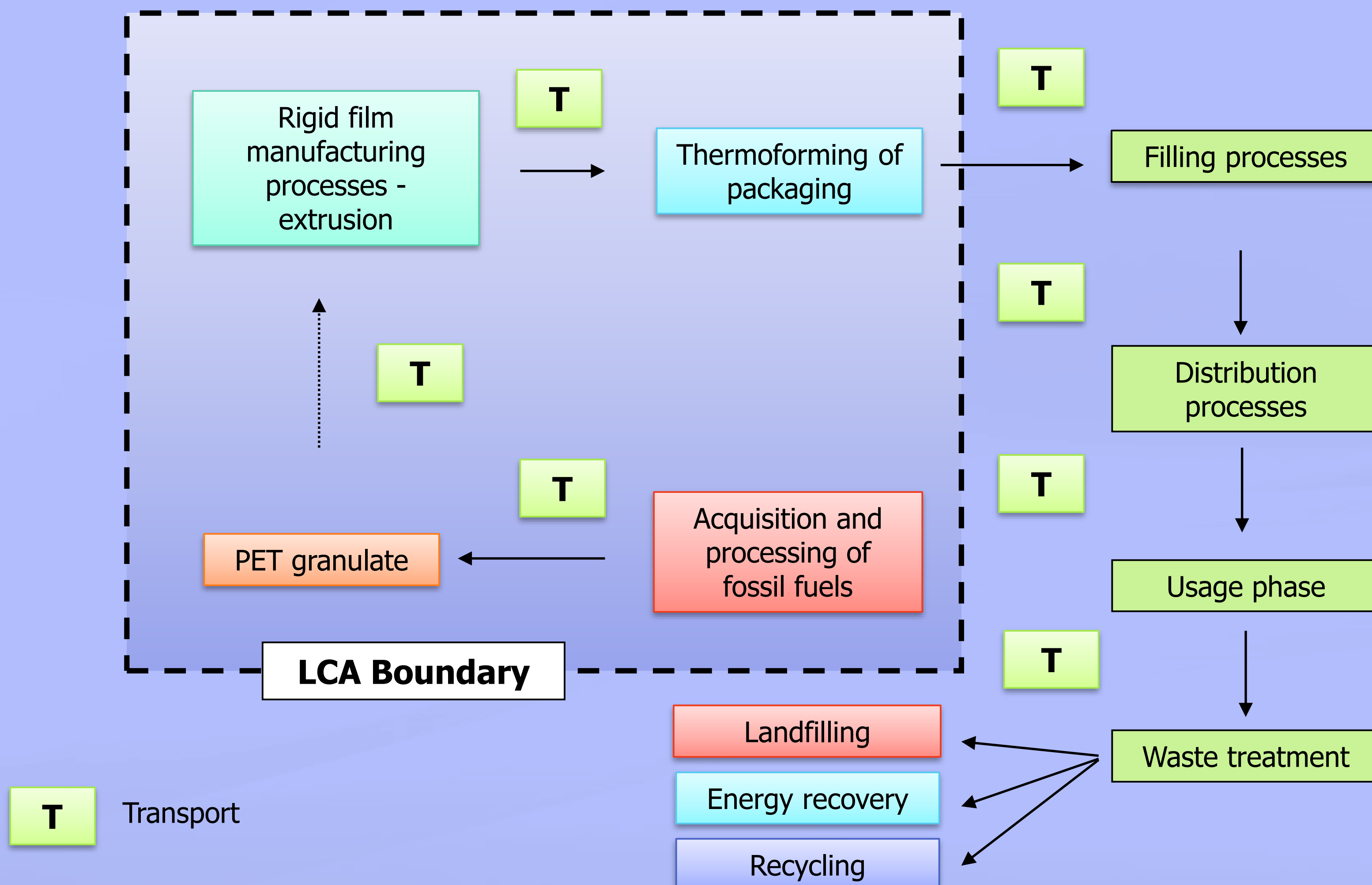
Product system

Draw product system for 2 types of bottled water packaging – BLOCK DIAGRAM

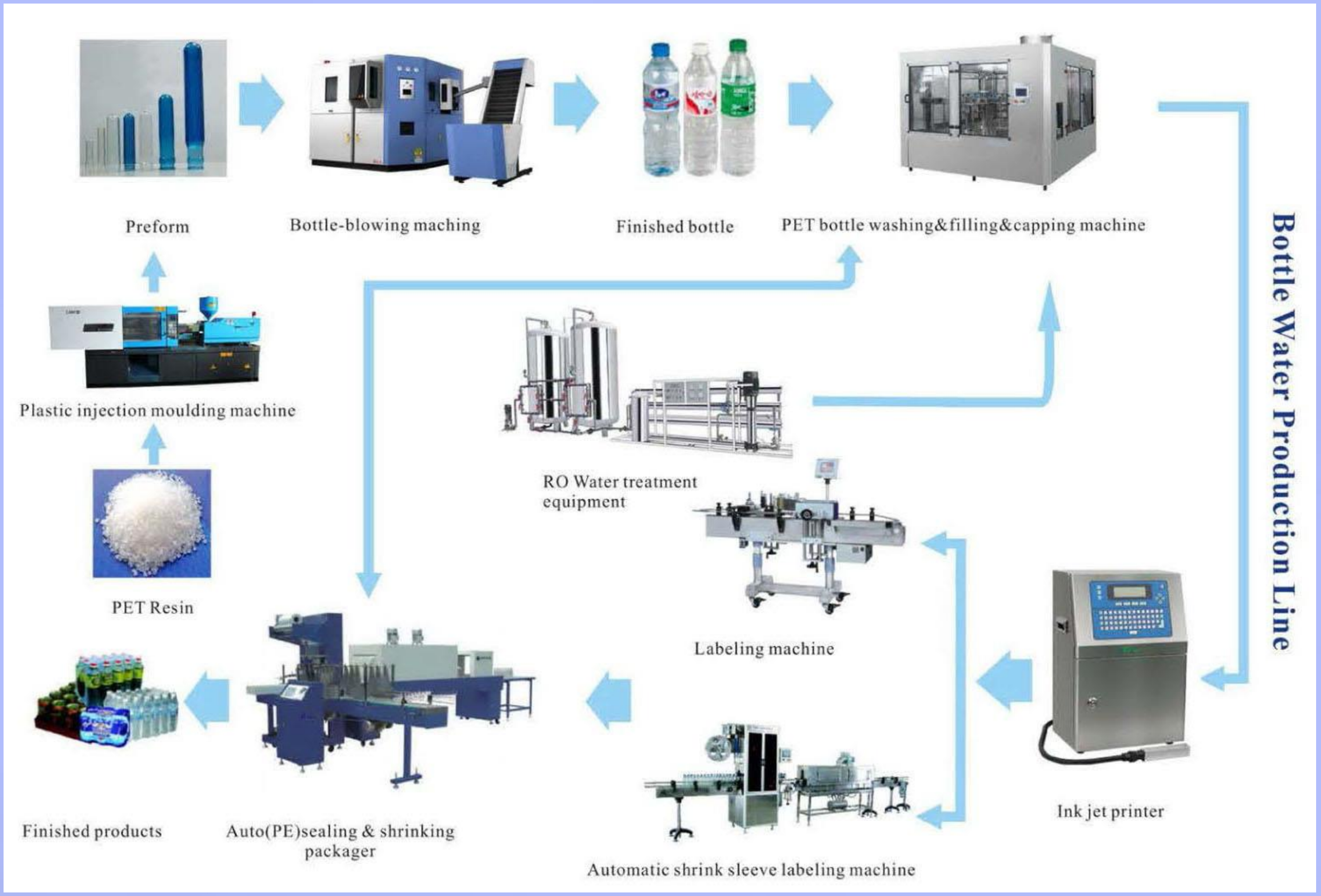
- **Glass bottle**
- **Plastic (PET) bottle**

~ 20 minutes group work

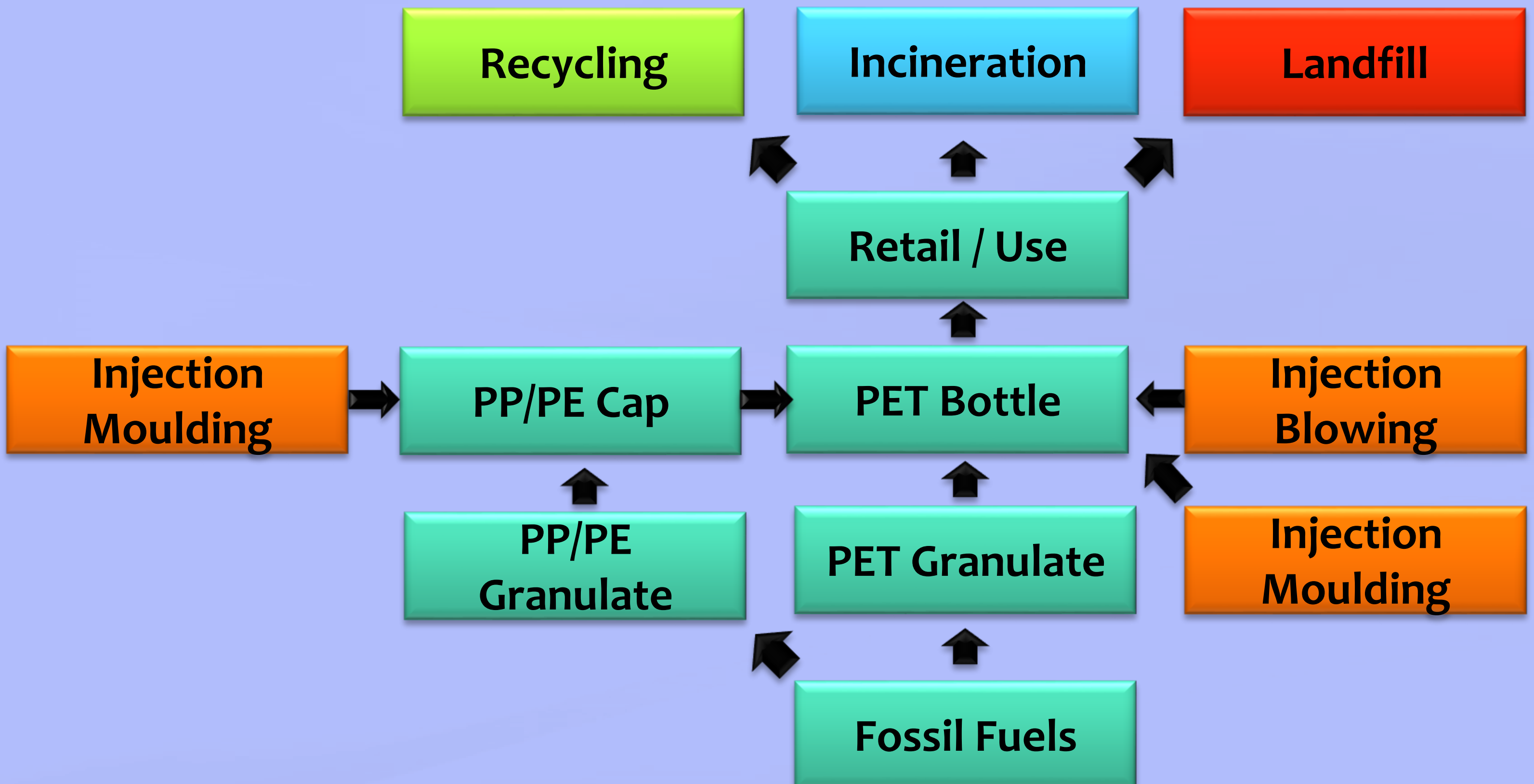
Product System



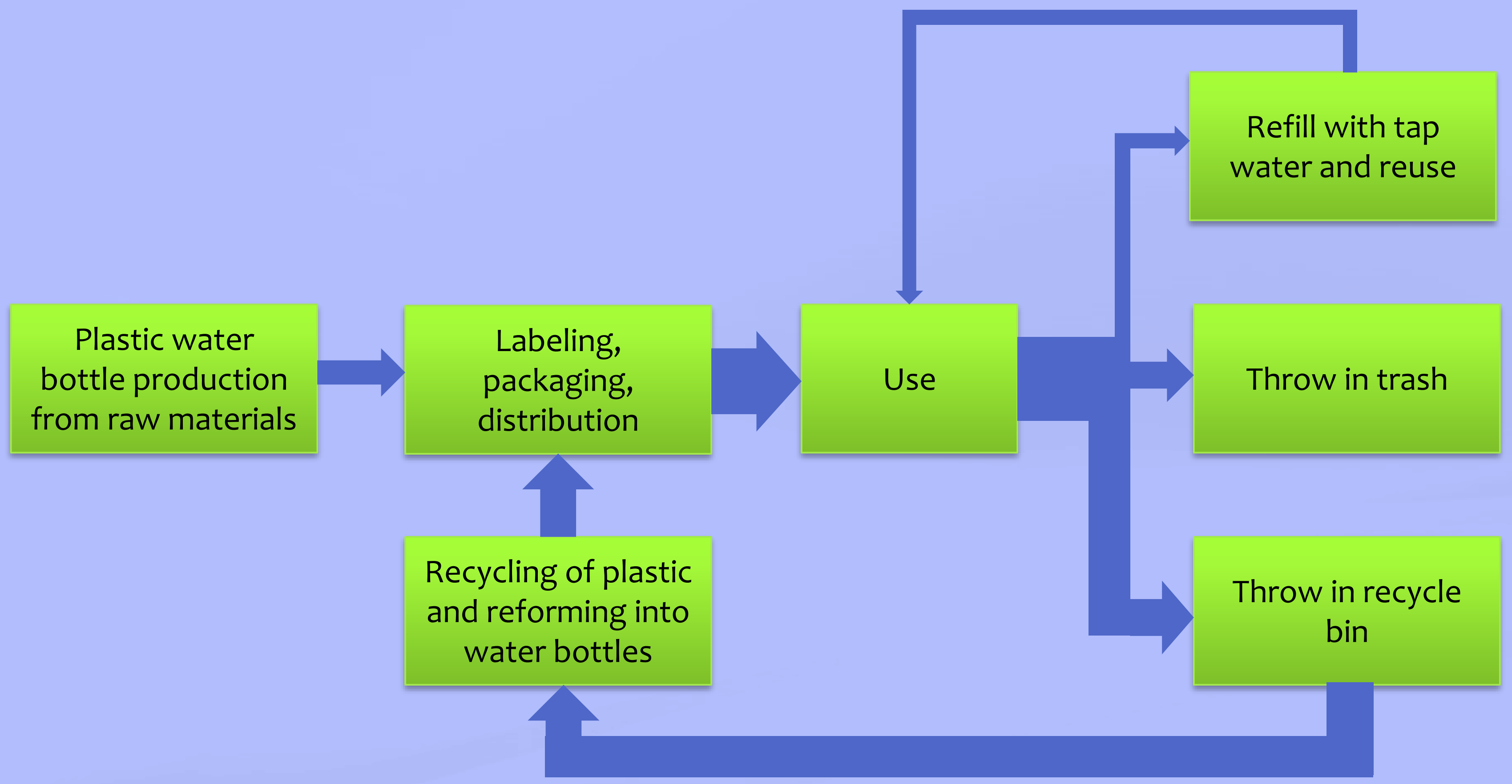
Product System



Product System



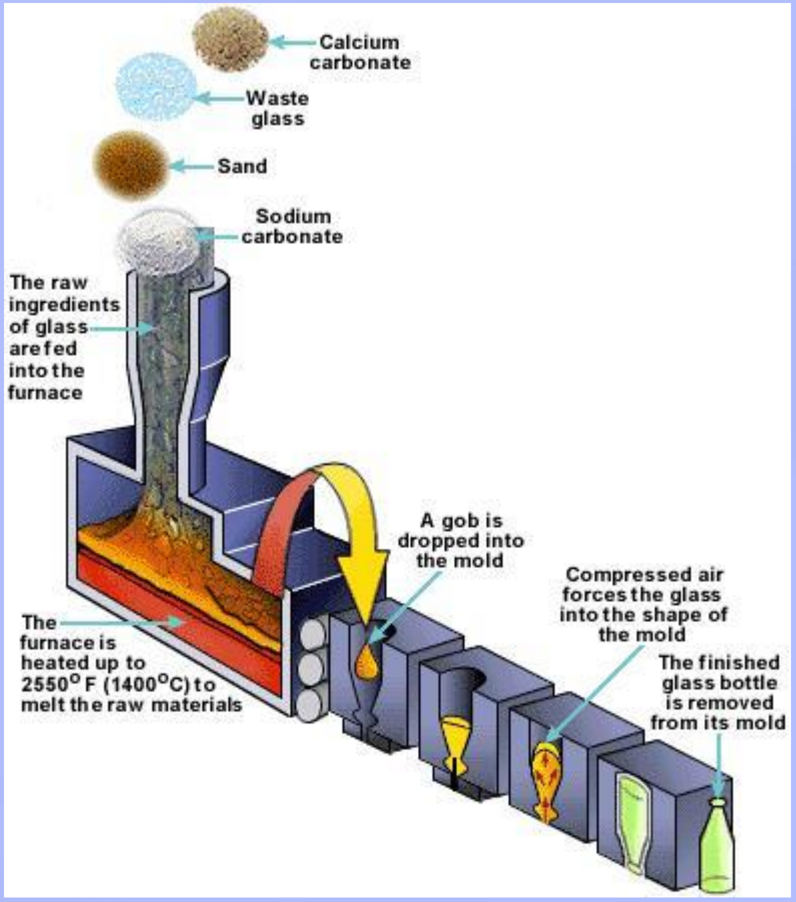
Product System



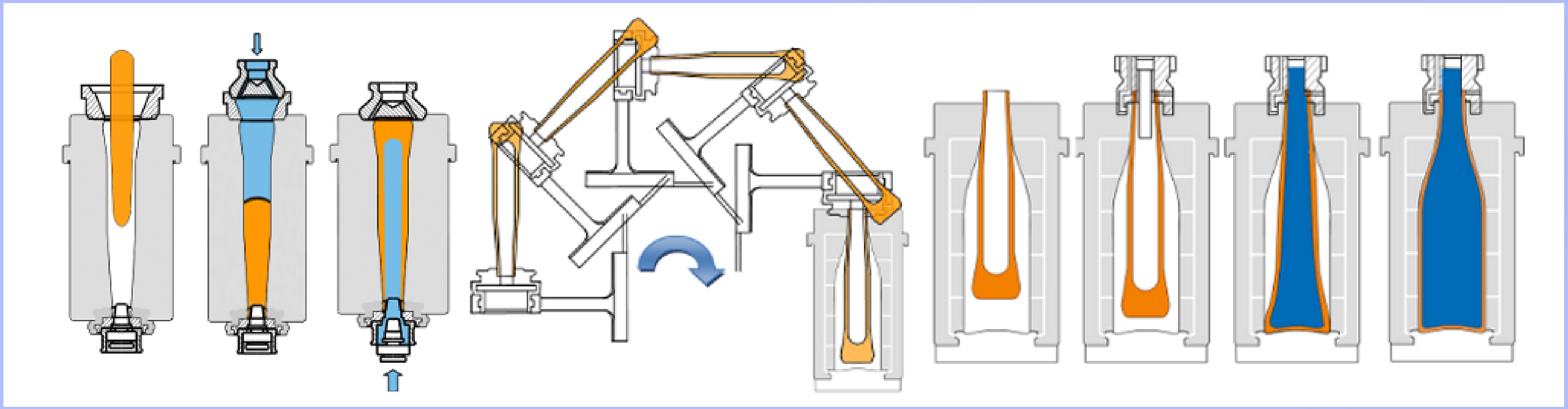
Source: *Life Cycle Assessment (LCA) Learning Module Series*

LCA Example Workshop

Product System



Product System



LCA Example Workshop

Functional Unit

Functional unit = 50,000 passenger-miles traveled

Collect input/output data based on how much of the function is accomplished → Express inputs/outputs in terms of one unit of function → Multiply by value of functional unit

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Functional Unit

<u>Manufacture</u>
1,000 lb steel per car which lasts for 100,000 miles at average occupancy of 1.5 persons

<u>Use</u>
Gaseous emissions:
20 lb CO_2 per gallon of gas, which powers car for 28 miles w/ 1.5 pass

Brake/tire wear:
0.2 lb PM_{10} per 60000 miles w/ 1.5 passengers

<u>Disposal</u>
1,000 lb steel to be recycled per car

Collect input/output data based on how much of the function is accomplished → Express inputs/outputs in terms of one unit of function → Multiply by value of functional unit

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Functional Unit

Manufacture

$$\frac{1000\ lb\ steel}{100{,}000\ mi * 1.5\ pass} = 0.0067\ \frac{lb\ steel}{pass * mi}$$

Use

Gaseous emissions:

$$\frac{20\ lb\ CO_2}{1\ gal\ gas} * \frac{1\ gal}{28\ mi * 1.5\ pass} = 0.48\ \frac{lb\ CO_2}{pass * mi}$$

Brake/tire wear:

$$\frac{0.2\ lb\ PM_{10}}{60000\ mi * 1.5\ pass} = 2.2 \times 10^{-6}\ \frac{lb\ PM_{10}}{pass * mi}$$

Disposal

$$\frac{1000\ lb\ steel}{100{,}000\ mi * 1.5\ pass} = 0.0067\ \frac{lb\ steel}{pass * mi}$$

Collect input/output data based on how much of the function is accomplished → Express inputs/outputs in terms of one unit of function → Multiply by value of functional unit

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Functional Unit

Manufacture

$$0.0067 \frac{lb\ steel}{pass * mi} * 50{,}000\ p * m$$

$$=$$

$$\mathbf{335\ lb\ steel}$$

Use

Gaseous emissions:

$$0.48 \frac{lb\ CO_2}{pass * mi} * 50{,}000\ p * m$$

$$=$$

$$\mathbf{24{,}000\ lb\ CO_2}$$

Brake/tire wear:

$$2.2 \times 10^{-6} \frac{lb\ PM_{10}}{pass * mi} * 50{,}000\ p * m$$

$$=$$

$$\mathbf{0.11\ lb\ PM_{10}}$$

Disposal

$$0.0067 \frac{lb\ steel}{pass * mi} * 50{,}000\ p * m$$

$$=$$

$$\mathbf{335\ lb\ steel}$$

Collect input/output data based on how much of the function is accomplished → Express inputs/outputs in terms of one unit of function → Multiply by value of functional unit

Source: *Life Cycle Assessment (LCA) Learning Module Series*

LCA Example Workshop

Scope

Functional unit

What functional unit for bottled water should we choose??

~ 20 minutes group work

Source: *Life Cycle Assessment (LCA) Learning Module Series*

LCI

Data collection – depends on the goals and scope of our research.

- What shall be taken into account:
  - System boundaries
  - Geography
  - Time of data collection
  - Functional Unit
  - Allocation methods
  - But most importantly: **Time and Money!!**

LCI

Already done if using database

1. Consider goal and scope
2. Prepare for data collection
3. Collect data
4. Validate data
5. Relate data to unit process and allocations (reuse, etc.)
6. Relate data to functional unit
7. Aggregate data
8. Refine system boundary
9. Revise, repeat as needed

Already done if data from literature

Source: *Life Cycle Assessment (LCA) Learning Module Series*

Data

PET Bottle		**Glass Bottle**	
PET Bottle	17,27 [g]	Glass Bottle	165,3 [g]
Plastic Cap	2,73 [g]	Metal Cap	1,44 [g]
Label	0,88 [g]	Label	0,4 [g]

LCIA

- LCI results while interesting do not give us any specific information about the environmental impact of a particular product
- LCI results should be interpreted and characterised into impact categories
- There are many characterisation methods available, many of them with normalisation and weighting options

Step 3 – Method example

CML 2000

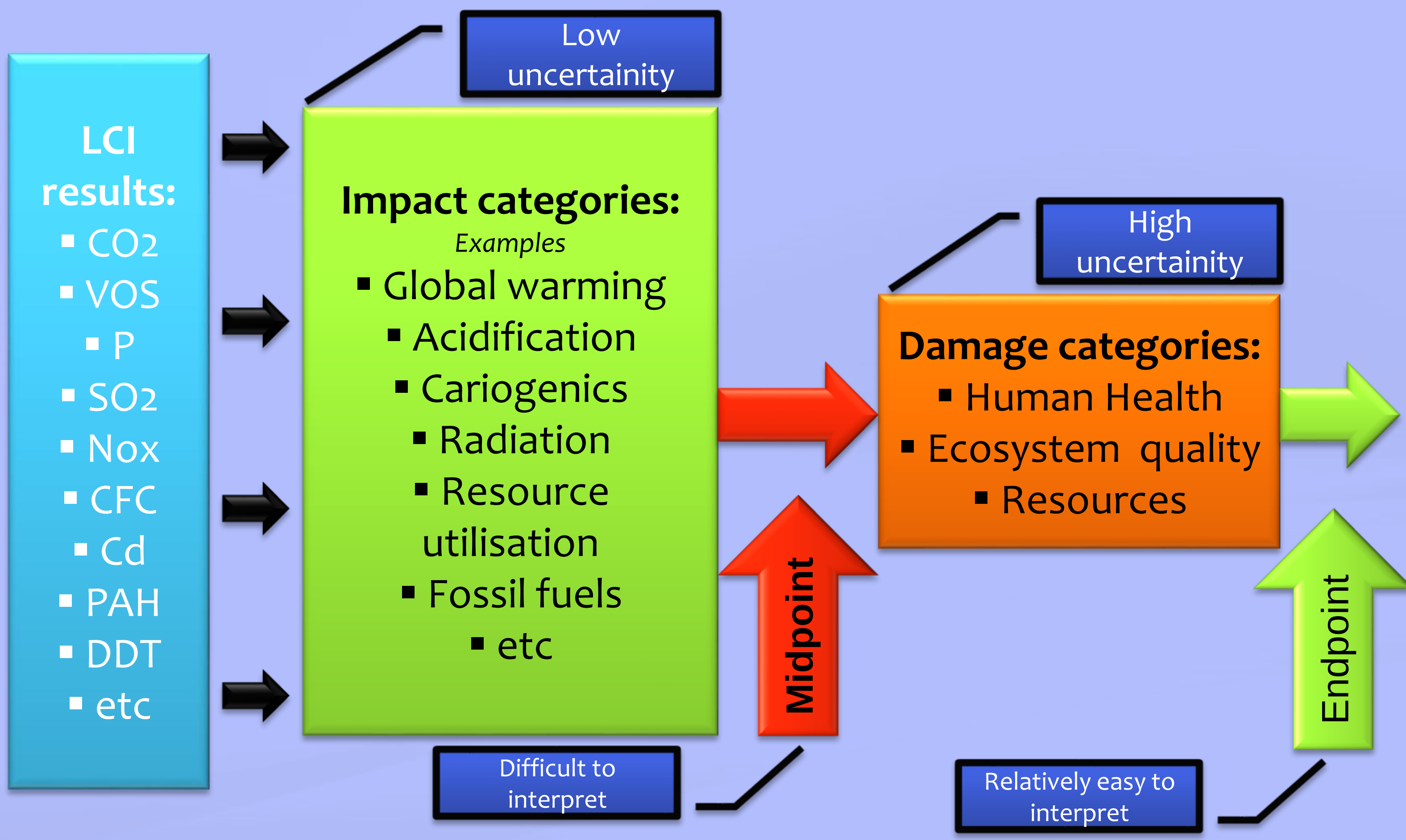
LCI result	Climate change	Acidification	Human toxicity
1000 gr CO2	x 1 = 1000		
10 gr. CH4	x 23 = 230		
10 gr. SO2		x 1 = 10	x 9.6E-2 = 0.96
5 gr. NOx		x 0.7 = 3.5	x 1.2 = 6
1E-7 gr dioxine			x 1.3E9 = 130
Total	1230	13.5	136.96

CO2-eq.

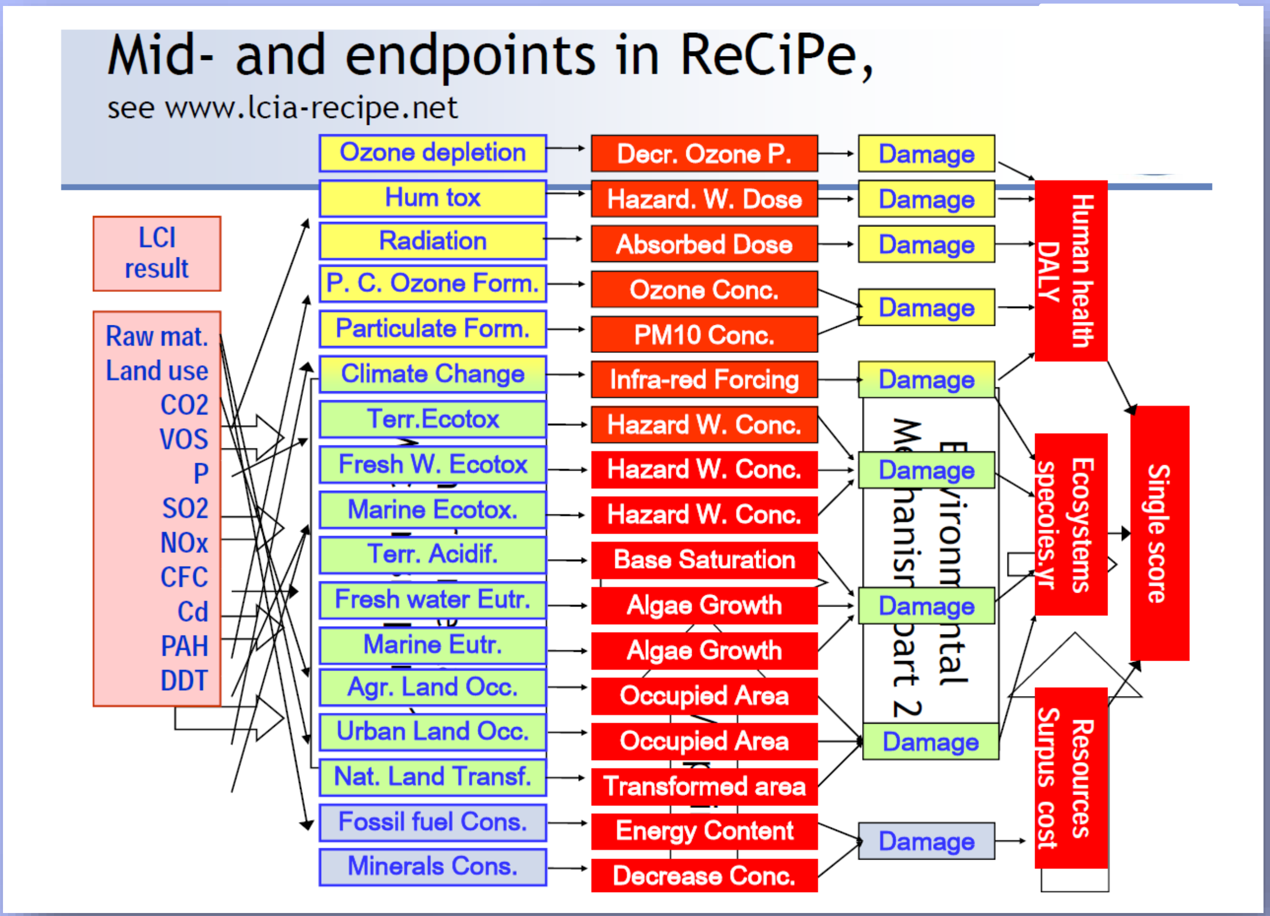
SO2-eq.

Human toxicity potentials

Step 3 –
Midpoint and Endpoint in a method



Step 3 –
Midpoint and Endpoint in a method

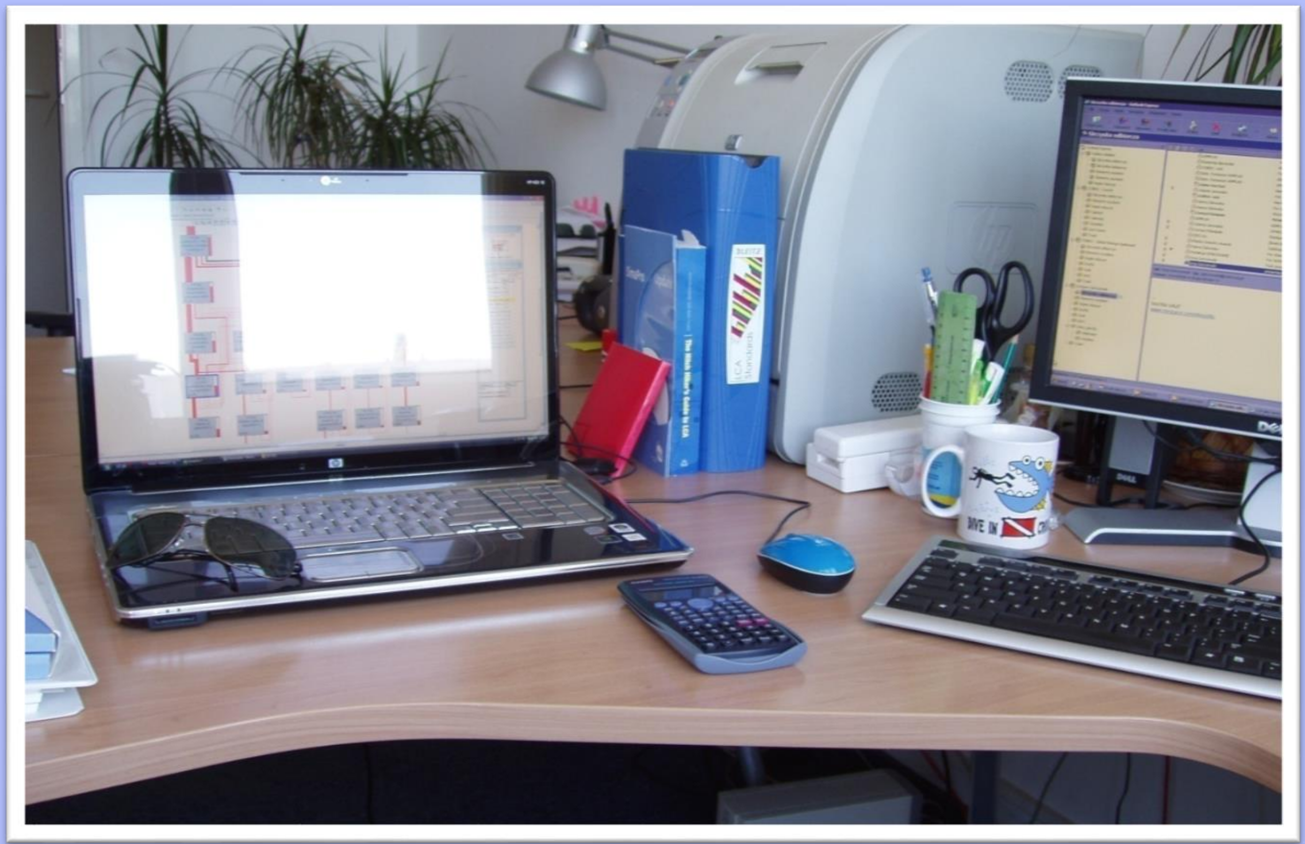


Step 4 - Interpretation

ISO 14044 standard recommends that before drawing conclusions and preparing a report from 3 previous steps, following elements should be checked:

- Check consistency of results with goal and scope definitions
- Check processes with highest environmental impact
- Check for anomalies (use best judgment)
- Check whether the method is consistent with assessed product
- Some methods omit substances present in the LCI – check whether the number of omitted substances influence the result by choosing a different method
- LCA is not objective, therefore it is helpful to check how the LCA results are dependent on our choices throughout the process.
- Perform uncertainty and sensitivity analysis where logical and possible. Prepare few scenarios.

Thank you!!



LCA Workstation