Aalto University
School of Arts, Design
and Architecture

Eco-Auditing:
Assessing sustainability impacts in design

Spring 2023 / Teaching Period III
Thursdays 12.1., 19.1. & 26.1. (13:15–16:30)

Teacher: Tatu Marttila

19.1.2023

Course schedule

First contact day: Thursday 12.1. (13:15–16:30):

- Basics of lifecycle design and material selection
- Familiarizing with Edupack material selection tools
- Introducing project ideas

Second day: Thursday 19.1. (13:15–16:30):

- Basics of eco-auditing and lifecycle impact assessment
- Familiarizing with Edupack eco-auditing tool
- Project work status (& tutoring for project work)

Third day: Thursday 26.1. (13:15–16:30):

- Project report guidelines & examples
- Project work status

Final project work reports

Final reports on project work due 20.2. (period III end):

- Around 5-7 pages (or more) PDF document with:
  - Description of the project idea
  - Assessment of focus materials (system boundaries, material inventory, life phases)
  - Description of the eco-auditing process/comparison
  - Reflection on results
- Can be essay-like document or presentation type
- Some example project reports presented on session 3 (26.1.)
- Upload to course MyCourses after course!

Recap of last week

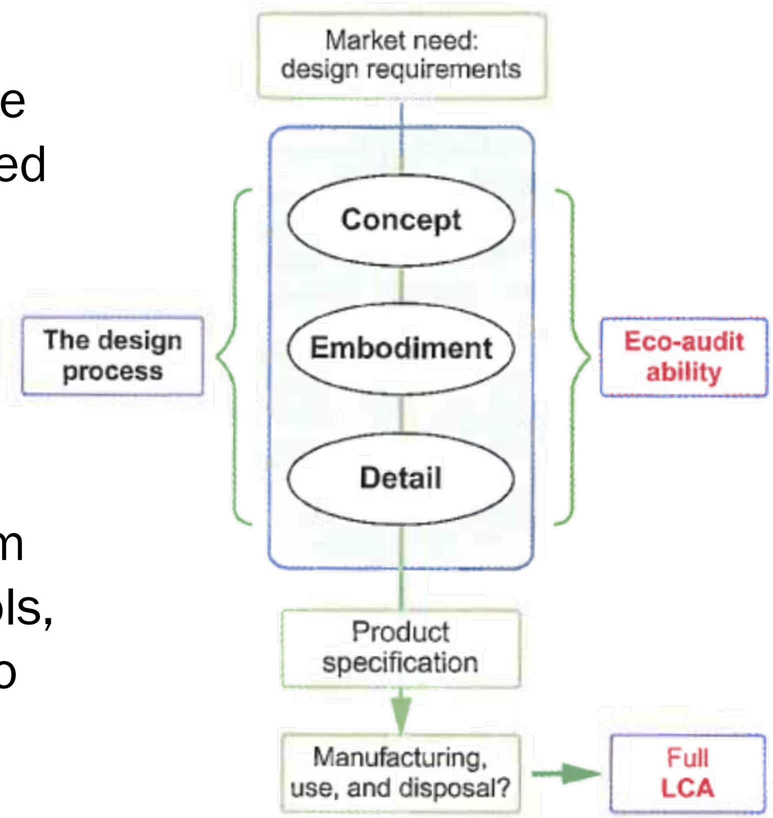
Material impacts and life-cycle design & assessment (LCA)

Life-cycle design & assessment (LCA)

Sustainable design considers product's whole life. It should also include (some type of) assessment of the impacts of its involved material use and production processes, in each different phase of product-life.

<u>One mainly used approach in ecodesign is life-cycle assessment (LCA)</u>

Design tools for life cycle design range from guidelines and checklists to qualitative tools, light-weight eco-auditing tools and finally to full-scale quantitative LCA research, often made by specialized consults.



Life-cycle assessment – process:

Life-cycle assessment (LCA) is carried out in the following four phases:

1) Definition of goal and scope, the aims for improvement, and the system with its boundaries;
2) Creation of an inventory of the inputs and outputs in selected dimensions depending on LCA approach or method used;
3) Assessment of life cycle impacts, which include the estimation of effects of studied inventory;
4) Interpretation that is reflecting three other phases continuously.

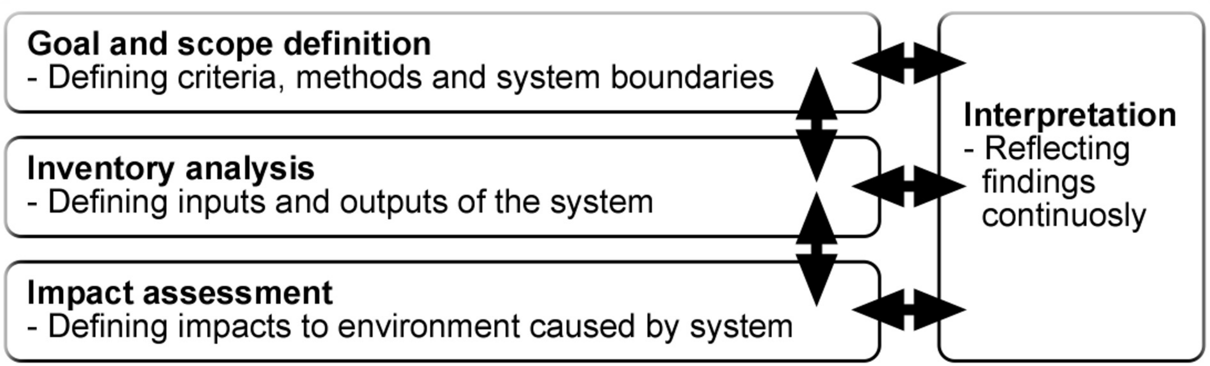


Figure 2. The process of LCA (according to ISO 14040 and ISO 14044).

Simplified life-cycle assessment (SLCA)

The methodologies used in LCA process can be divided in approaches utilizing quantitative, semi-quantitative or qualitative life-cycle assessment methods and data. (Wenzel, H. 1998)

Simplified, or streamlined LCA (SLCA) is divided also in semi-quantitative and qualitative strategies, including input-output tools and matrix approaches.

Commonly, SLCA tools often emphasize general values over specific numbers from a specific assessment. Many of them can also combine quantitative and qualitative aspects

Example – META matrix:

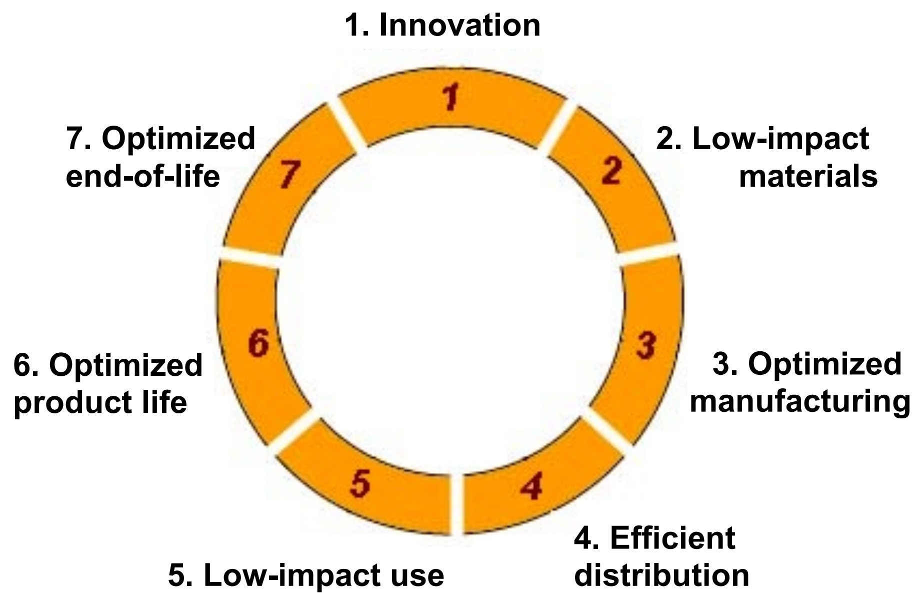
Impact category	Material production	Manufac-turing	Use-phase	End-life	Transport
M-Materials					
E-Energy					
T-Toxicity					
A-Socio-cultural					

Eco-design strategy wheel

1. Define the product idea, product concept or existing product that will be analyzed. (evaluate existing system or your concept)

2. Systematically score the product on each dimension of the strategy wheel, linked to life phases of the product.

3. Consider the optimization options for each of the dimensions, paying special attention to those where the current design scores badly.



Ecodesign strategy wheel by TU Delft

Granta Edupack program

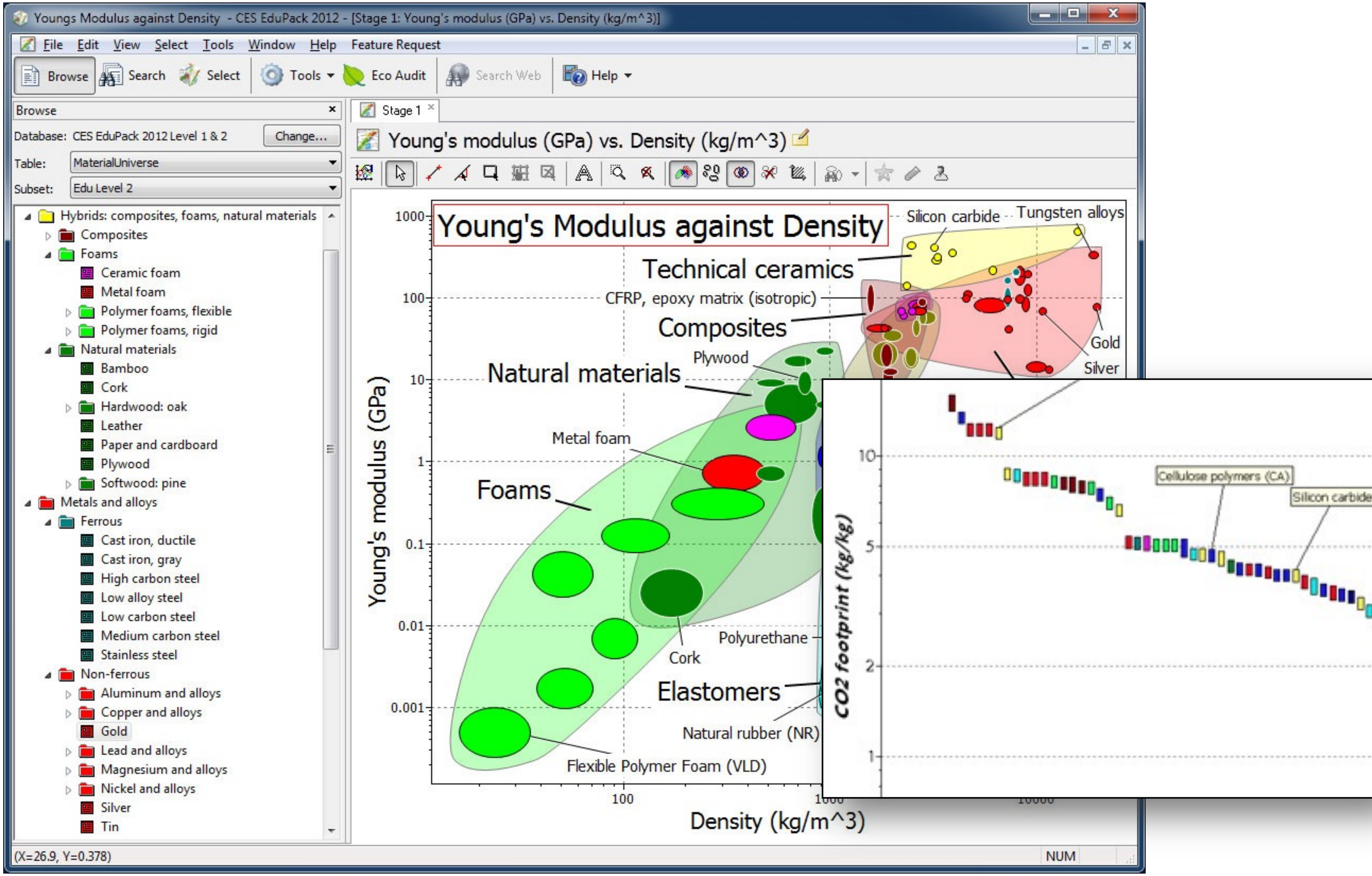
Granta's Edupack Tool (previously CES Edupack, Cambridge Engineering Selector) is a program with database that have information tables on legislation & regulations, materials, processes, nations and even many producers.

It can be used to easily find information and compare different materials and to assist in material selection.

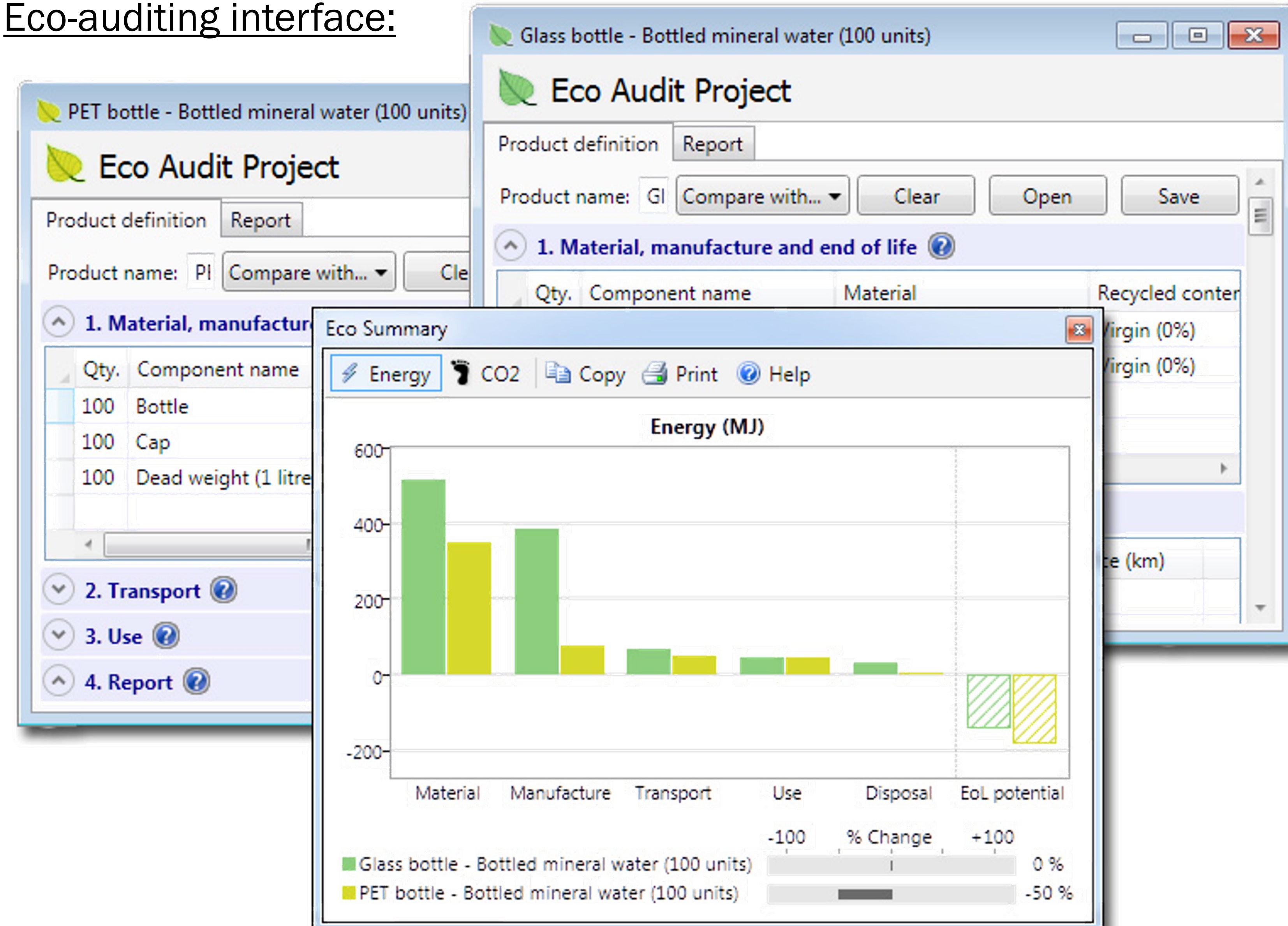
It can be also used to assess products' impacts on both environmental and to some extent on societal dimensions (or system parts like service elements).

On Aalto computers!

Material selection interface:



Eco-auditing interface:



19.1.
Eco-Auditing course:

Assessing sustainability & Eco-auditing with Edupack

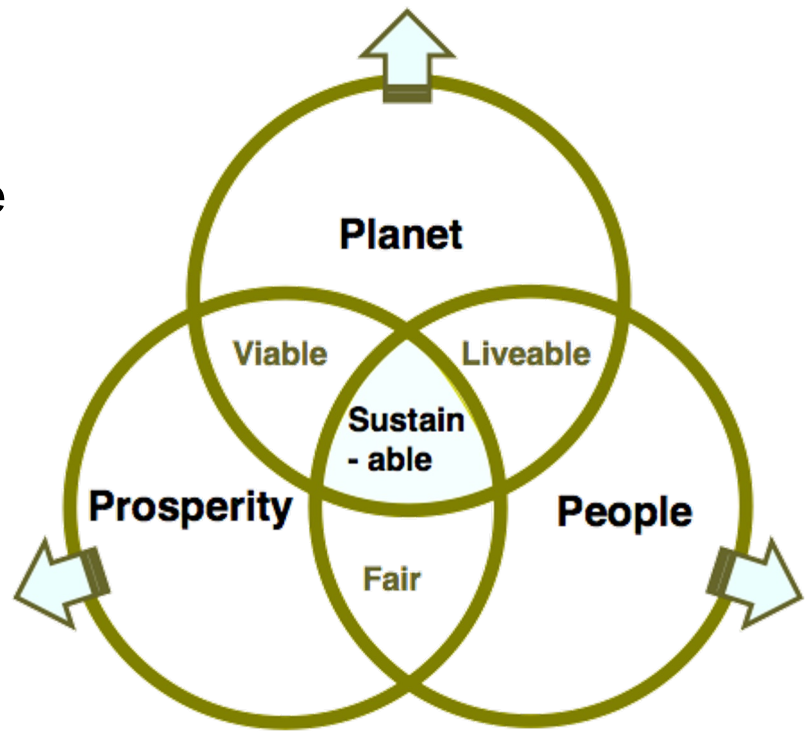
Sustainability – complex to assess…

Prioritization: "Sustainability" vs. "Sustainable development"?

Reporting:

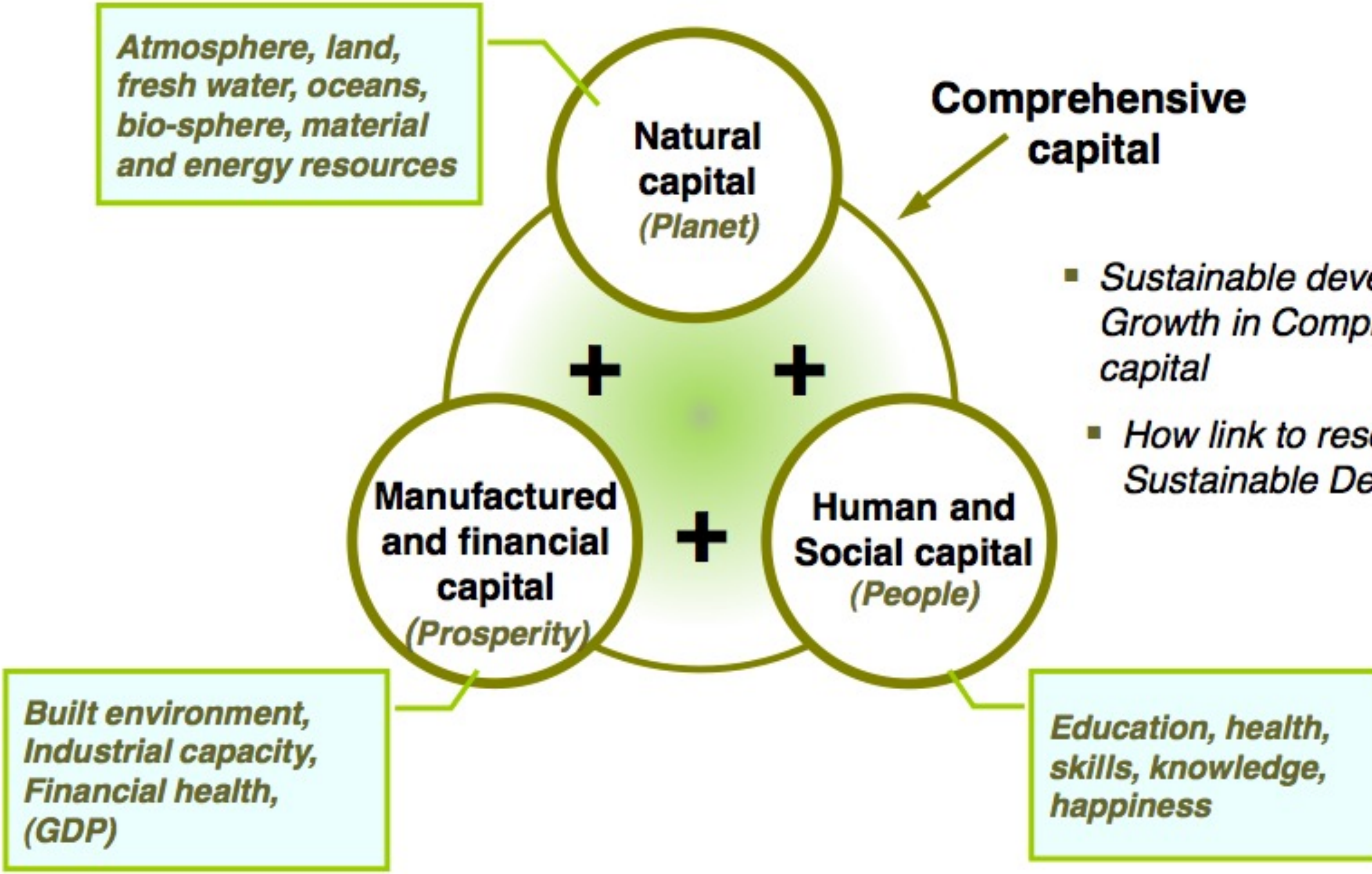
- Financial bottom line
- Social / ethical performance
- Environmental performance

Decouple the circles
– unpack their meaning…



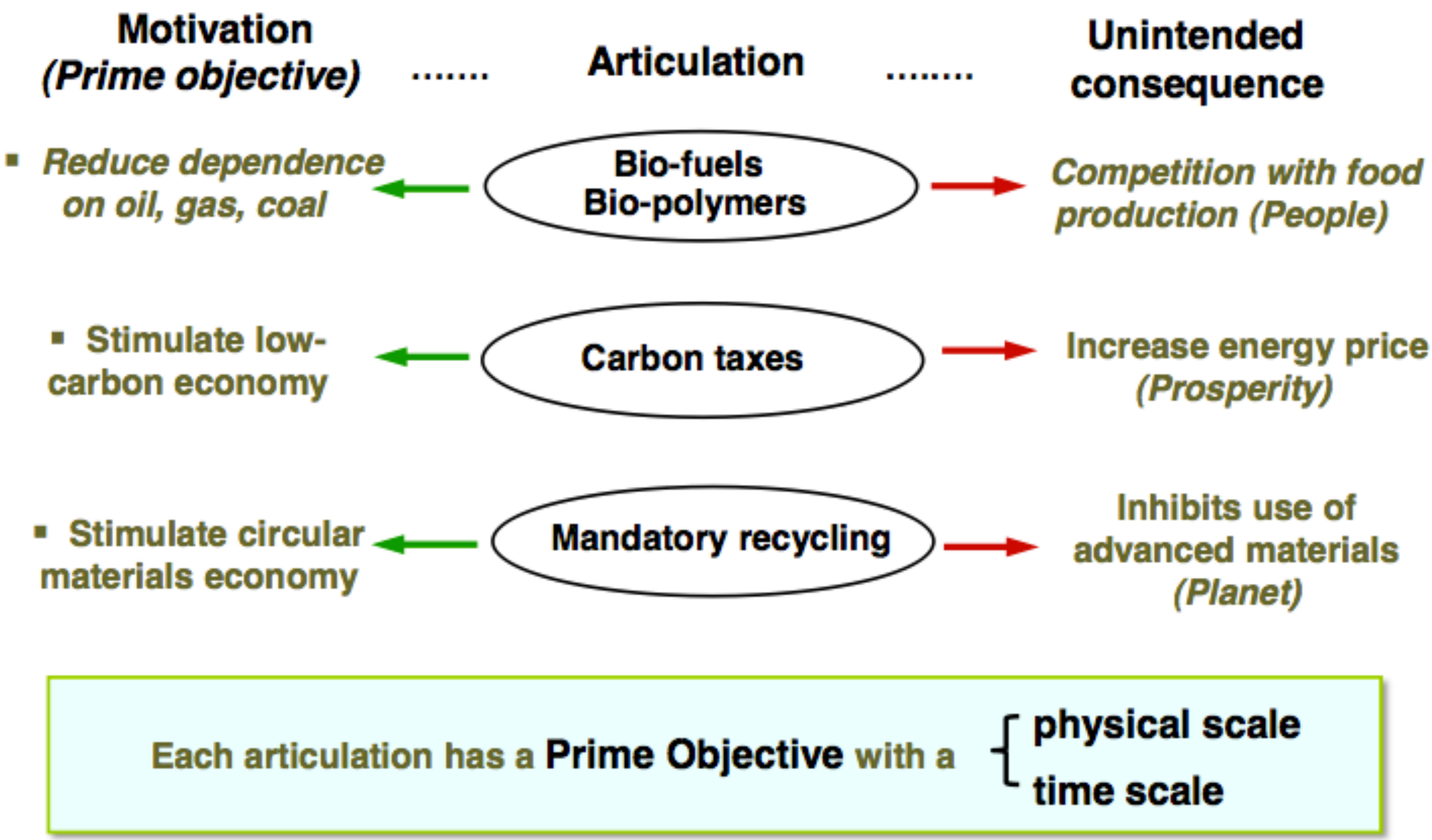
Source: Ashby et al. (2012) Materials & SD

Growing comprehensive capital:



- *Sustainable development = Growth in Comprehensive capital*
  - *How link to research on Sustainable Development?*

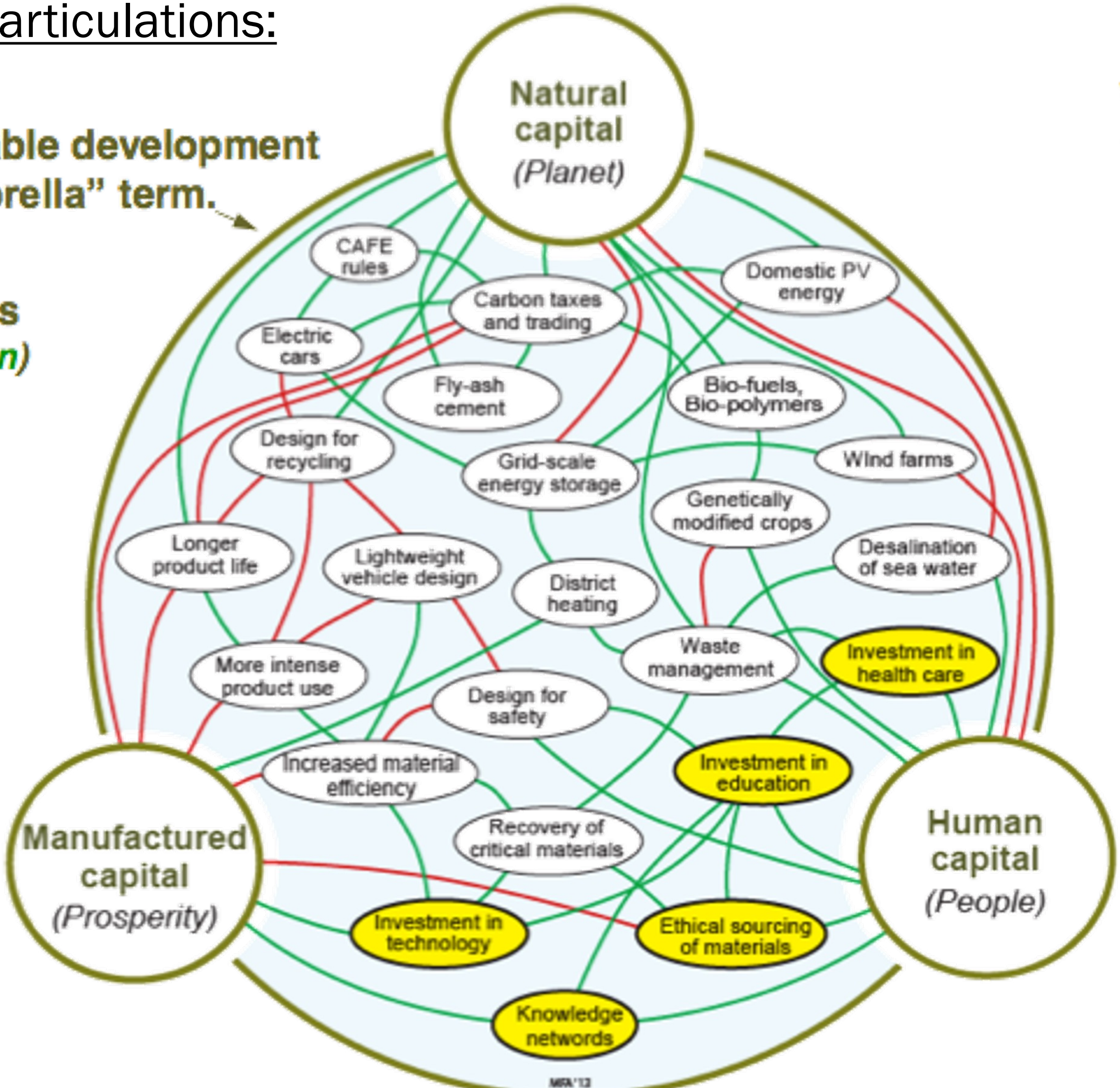
Several actions/techs ("articulations") claim to support sustainability:



Source: Ashby et al. (2012) Materials & SD

Map of articulations:

- **Sustainable development is an "Umbrella" term.**
- **Conflicts** *(red, green)*

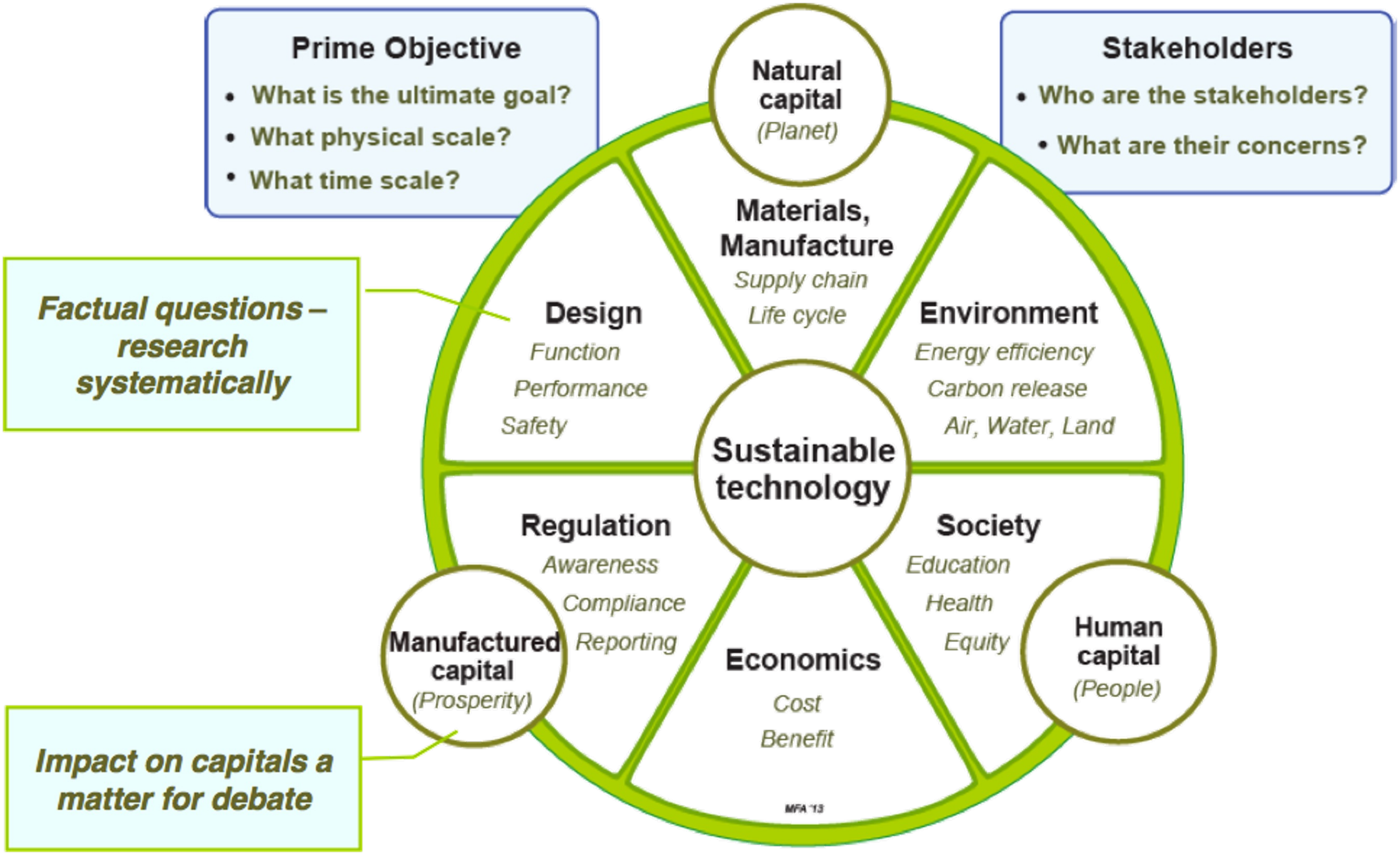


What can we distil from this picture? Group under:

- **Materials**
- **Design**
- **Environment**
- **Regulation**
- **Society**
- **Economics**

Source: Ashby et al. (2012) Materials & SD

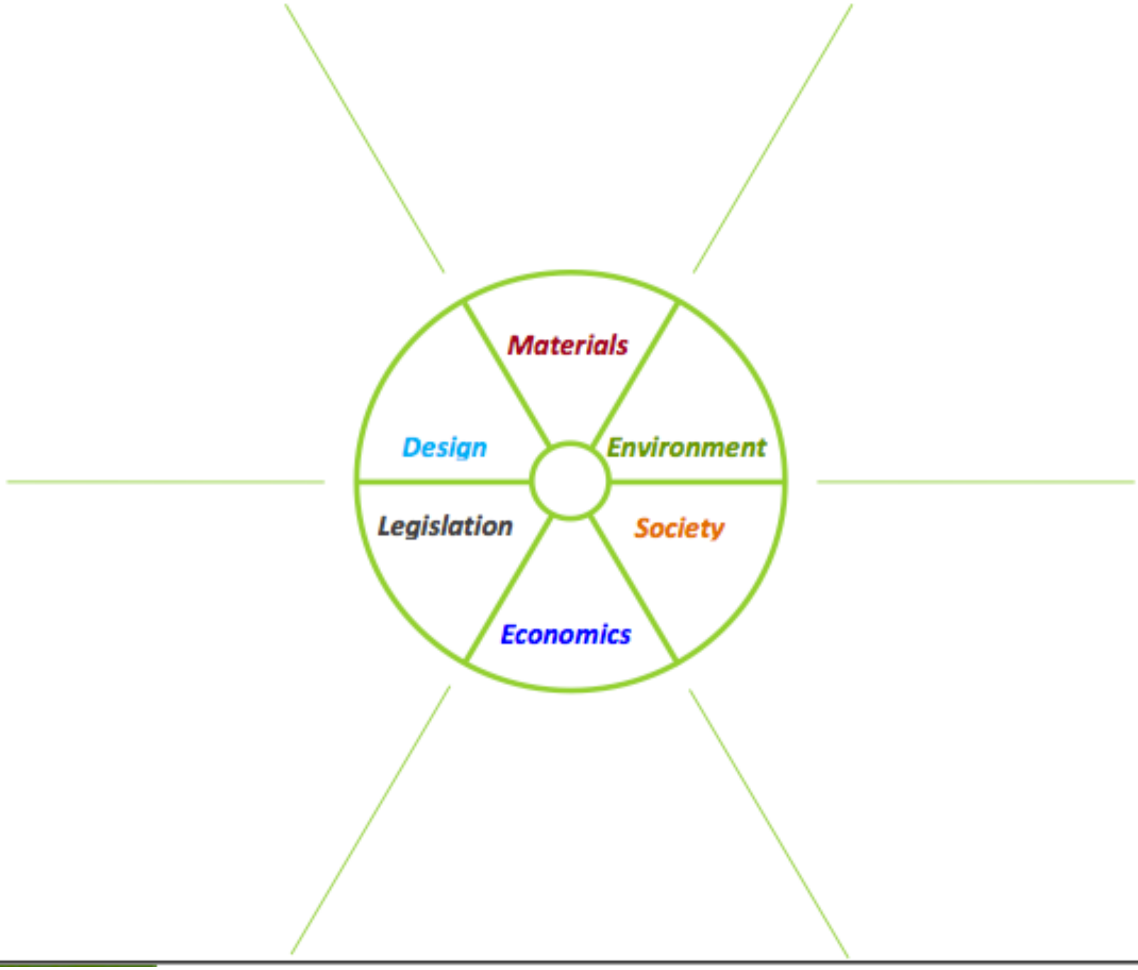
Analysing "articulations":



Source: Ashby et al. (2012) Materials & SD

1. Prime Objective and Scale:

3. Fact - finding



2. Stakeholders

Edupack program: Sustainability assessment

Two main processes with Edupack

Materials selection & information:

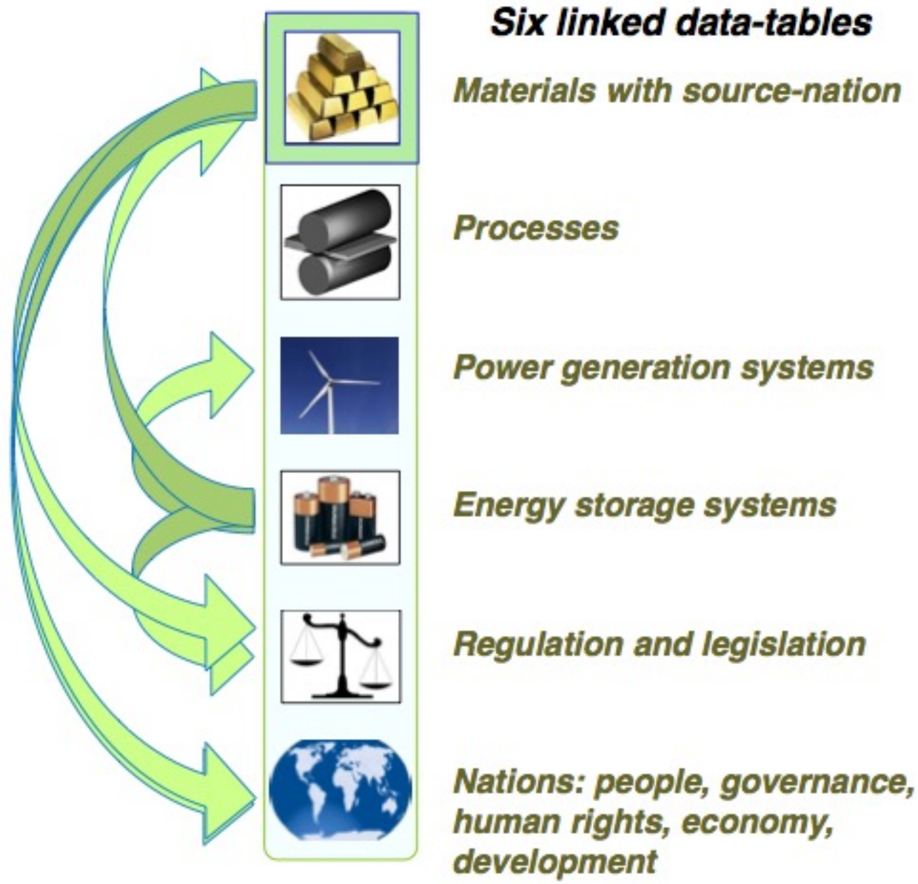
- Materials comparison can be done by combining information from the several different tables considering material qualities and information related to them (eg. Nations of the world –table).

Ecological impacts assessment:

- Products (or system elements) can be assessed with SLCA type of impact-assessment tool (indicating values from data tables)
- Products' assessment values can be compared with each other
- Different scenarios compared with each other…

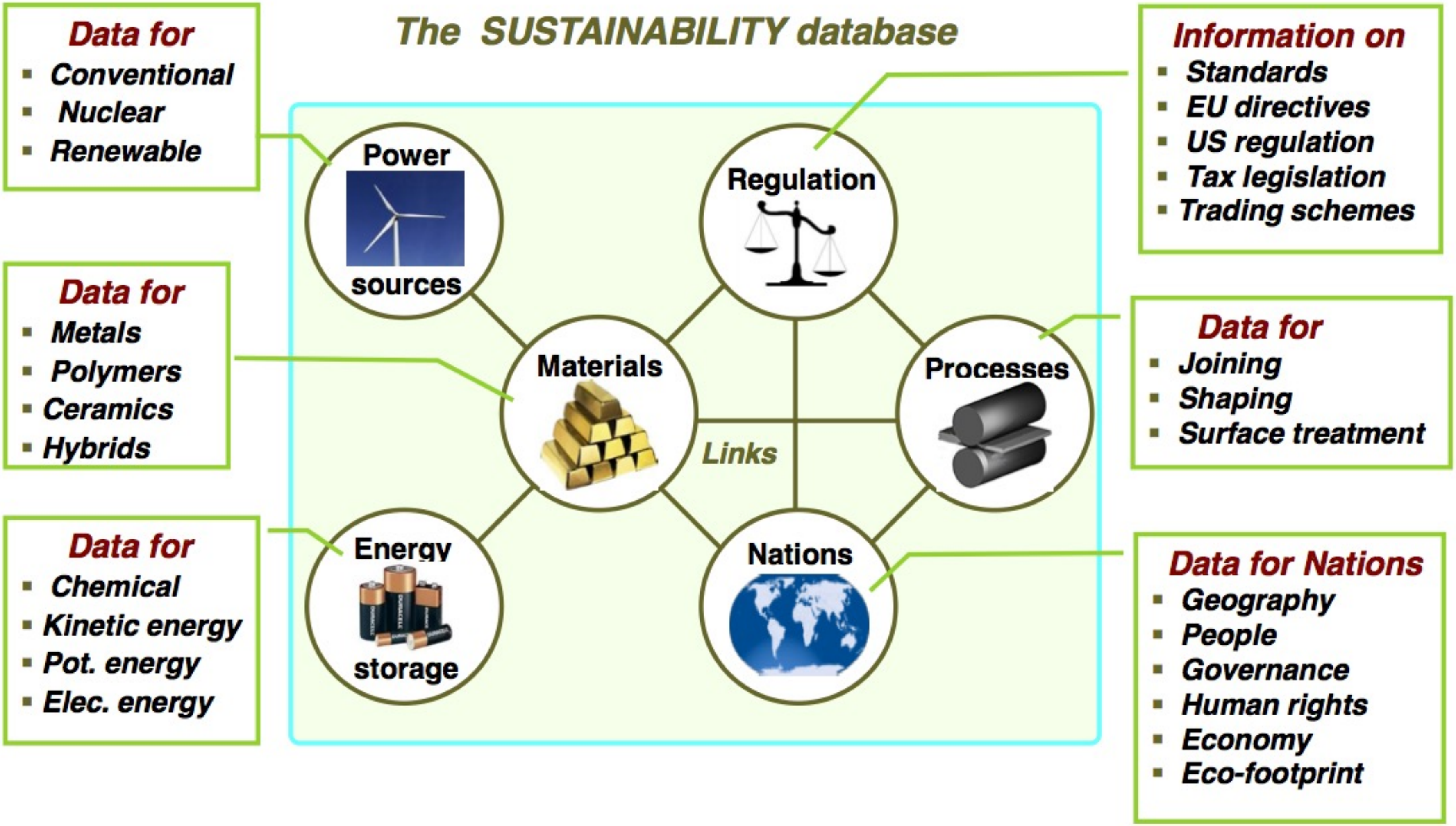
Sustainability assessment with CES Edupack

Expanding materials and processes assessment with energy, legislation and info on nations.



Source: Ashby et al. (2012) Materials & SD

Datatables to assist sustainable design process:



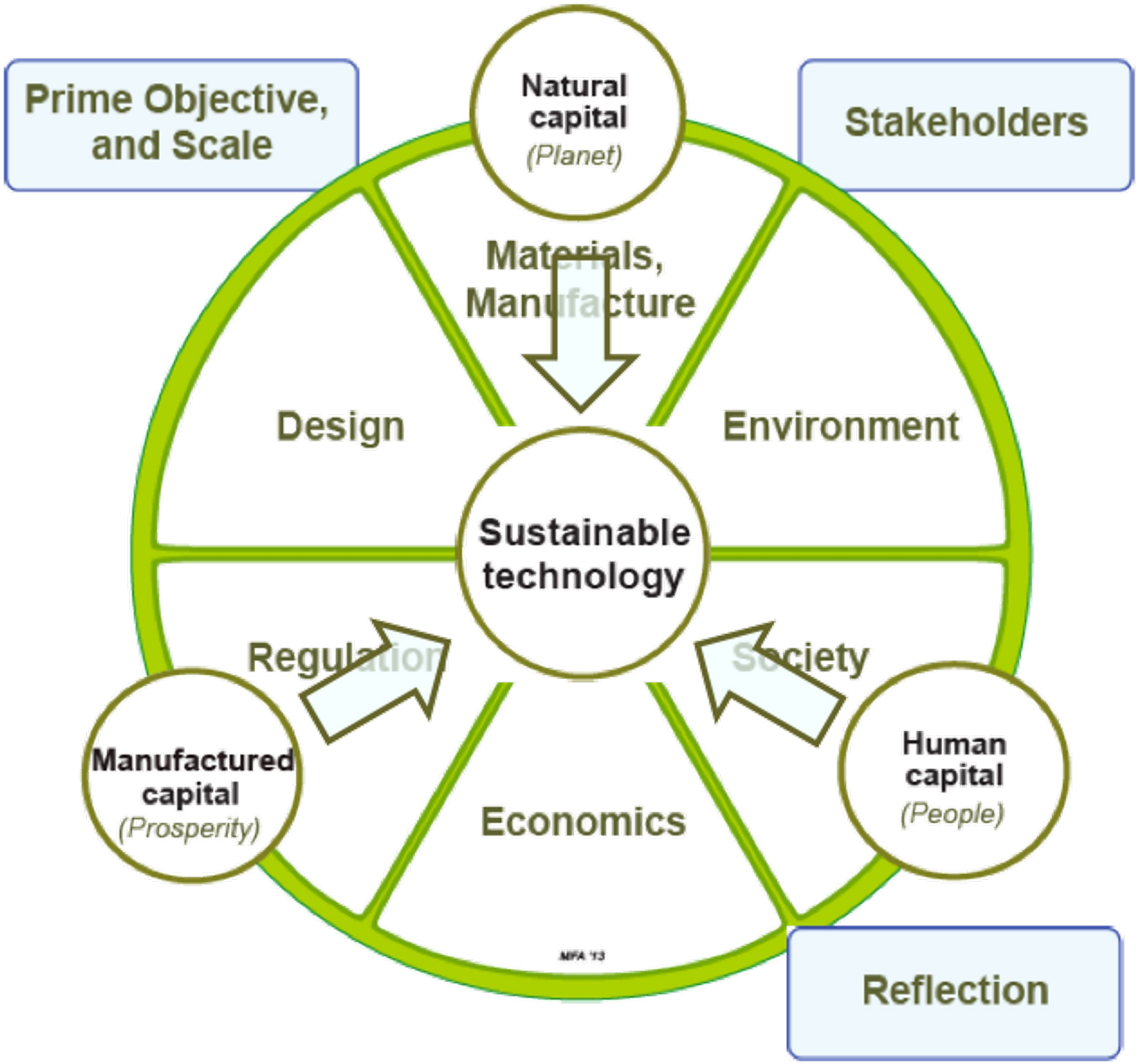
Source: Ashby et al. (2012) Materials & SD

Assessment process for sustainable design

Steps to assess sustainability of designs:

1. Identify prime objective for design action (product/service/process etc.)
2. Define system boundaries for the assessment
3. Review stakeholders and both production system and product components
4. Perform “fact-finding” on stakeholders and components (Materials & Manufacturing; Environment; Society; Economics; Regulation; Design)
5. Integration back into communicative message (Natural capital; Manufactured capital; Human capital)

Assessing sustainability potential:



Step 1: Clarify Objective

Step 2: Stakeholders

Step 3: Fact finding
- *objective*

Step 4: Integration
- *subjective*

Step 5: Reflection

Source: Ashby et al. (2012) Materials & SD

The larger process:

Source: Ashby et al. (2012) Materials & SD

Edupack program:
Eco-auditing tool

Eco-auditing with Edupack

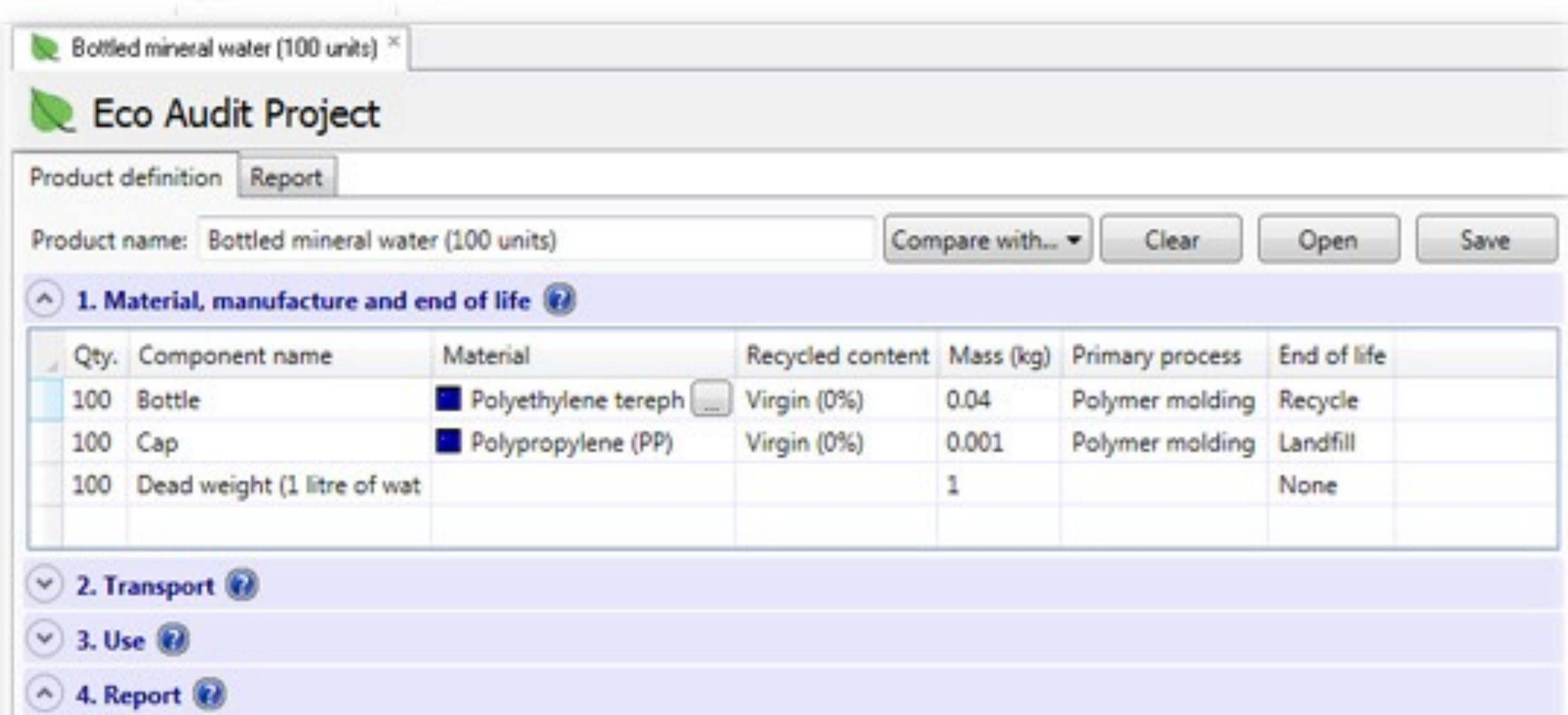
The Eco Audit Tool calculates the energy used and CO2 produced during five key life phases of a product (material, manufacture, transport, use and end of life) and identifies which is the dominant phase.

This is the starting point for eco-aware product design, as it identifies which parameters need to be targeted to reduce the eco-footprint of the product.

In 'material selection' terminology, the result of the eco audit forms the objective for the product design. This objective is dependent on both the dominant phase and the product application. For example, when the use phase is dominant, the objective for a car would be to minimize mass, whereas for a boiler, it would be to minimize thermal loss

Eco-auditing with Edupack:
Material, manufacture and end of life

The first part of eco-audit is a product definition with a list of components and their mass & materials, involved processes and end of life.



Eco-auditing with Edupack:
Bill of Materials

The first section of the product definition allows entry of the 'bill of materials' for the product, with each line representing an individual component. There is no limit on the number of components that can be added.

1. Quantity
2. Component name
3. Material
4. Recycled content
5. Mass
6. Primary process
7. End of life

Eco-auditing with Edupack:
Primary Processing Techniques

The primary process options display the processes that are applicable to the material selected.

This information, and associated data, is extracted from the material's datasheet.

Depends on the level of database used. On some levels also more options (secondary processing; finishing options).

Eco-auditing with Edupack:
End-of-life

This option displays all viable end of life options for the selected material.

Of the seven options the validity of the first four, 'Landfill', 'Combust for energy recovery', 'Recycle' and 'Downcycle' is determined by the associated status flag on the material's datasheet.

The remaining 'Re- manufacture', 'Reused' and 'None' options, which are not specified on the datasheet, are added as viable options for all materials.

'None' applies to components that have no end of life costs (for example, building foundations that are left in the ground).

End of life options and primary processes:

End of life option	Applicable materials
Landfill	All non-toxic materials
Combust (for energy recovery)	All organic-based materials with a heat of combustion value >5 MJ/kg
Downcycle	All
Recycle	All unfilled: metals / glasses / thermoplastics /TPEs Particulate filled thermoplastics Particulate & whisker reinforced metals (All ceramics / thermosets / elastomers / natural organic / natural inorganic materials and all fiber reinforced materials are marked as non-recyclable)
Re-manufacture	All
Reuse	All
None	All

Material	Process
Metals	Casting
	Extrusion, foil rolling
	Rough rolling, forging
	Wire drawing
	Metal powder forming
	Vaporization
Polymers & elastomers	Polymer molding
	Polymer extrusion
Technical ceramics	Incl. in material value
Non-technical ceramics	Incl. in material value
Glasses	Glass molding
Composites	Casting
	Autoclave molding
	Filament winding
	Compression molding
	Resin spray-up
	Resin transfer molding (RTM)
Natural materials	Incl. in material value
Electrical components	Incl. in material value

Eco-auditing with Edupack: Transport

The second part of the product definition is the transportation phase. This relates to the transport of the finished product from the source of manufacture to the customer.

Each line in the table relates to one stage of the journey. There is no limit on the number of stages that can be added. For each stage, three parameters are defined: stage name, transport efficiency, and distance.

The transport efficiency is specified through the 'transport type' dropdown menu, which lists the main methods for transporting freight

Eco-auditing with Edupack:
Use phase

The third stage of the product definition is the use phase.

Product life:

Numeric field for specifying the product life, in years. The default value is 1 year.

Country electricity mix:

The 'Country electricity mix' drop-down menu enables the particular mix of fossil and non-fossil fuel of the country of use to be specified. This is split into three main groups: global regions, individual countries, and fossil fuel percentage. The default option is 'World'.

Eco-auditing with Edupack:
Report

The final section of the product definition incorporates two main features. The first is the 'Summary chart', and the second feature is the capability to have a 'Detailed Report'.

This is divided into three sections:

1. Summary page
   – provides an overview of the eco audit, with headline values for each life phase. This enables rapid identification of the dominant life phase
2. Detailed breakdown of energy usage (accessed via 'Energy Details...' link on summary page)
   – provides a component-by-component breakdown of each life phase, enabling the main contributors to the dominant phase to be identified
3. Detailed breakdown of CO2 footprint (accessed via 'CO2 Details...' link on summary page)
   – similar to above, except for CO2 footprint.

Exercise 1:
Creating eco-audit

Using EduPack Level 2
with eco and durability properties

Exercise 1:
ECO AUDIT Project, 1/7

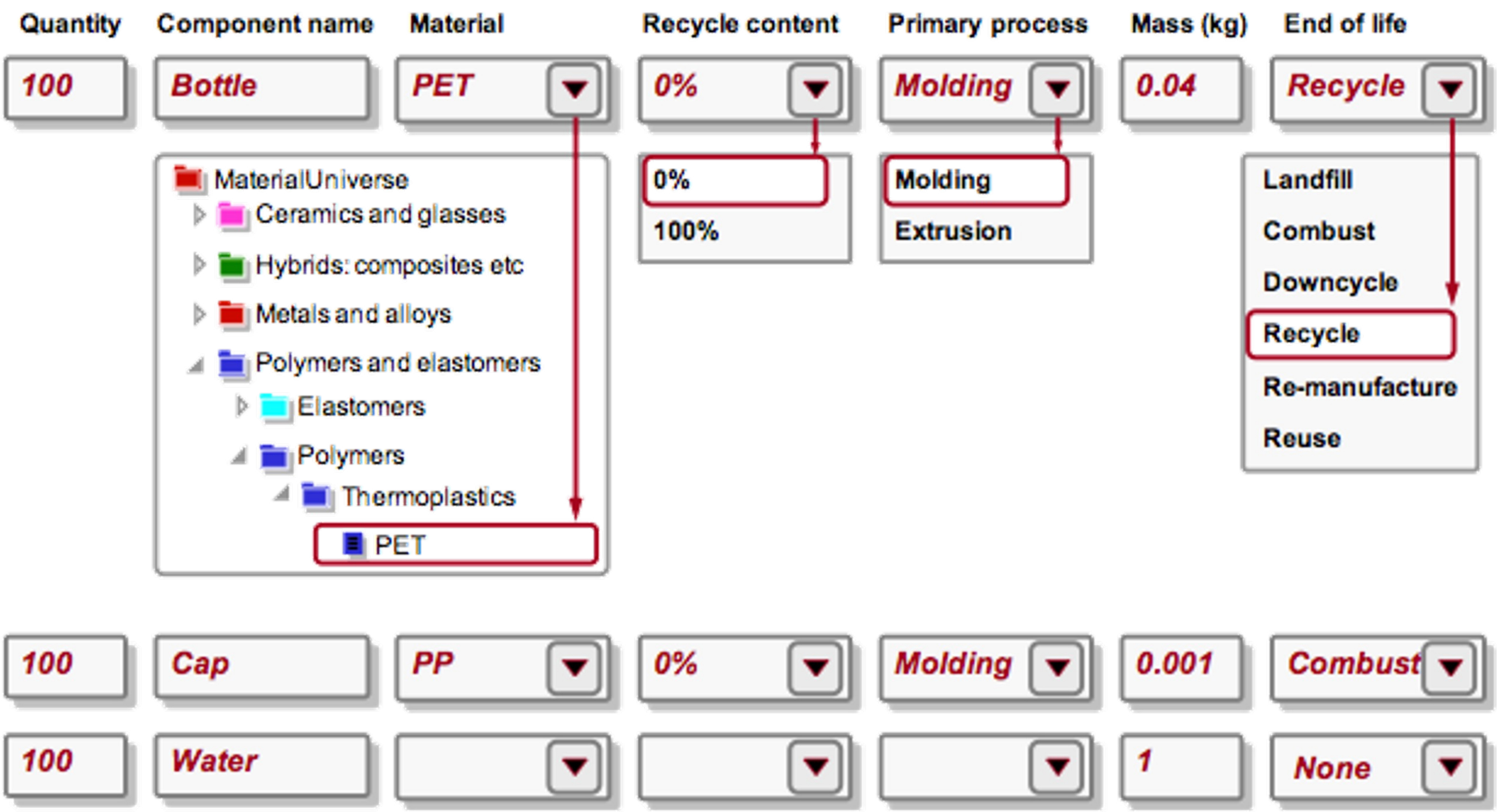
Bottled mineral water is sold in 1 liter PET bottles with polypropylene caps. A bottle weighs 40 grams; the cap 1 gram.

Bottles and caps are molded, filled, and transported 550 km from the French Alps to England by 14 tonne truck, refrigerated for 2 days and then sold.

The overall life of the bottle is one year.

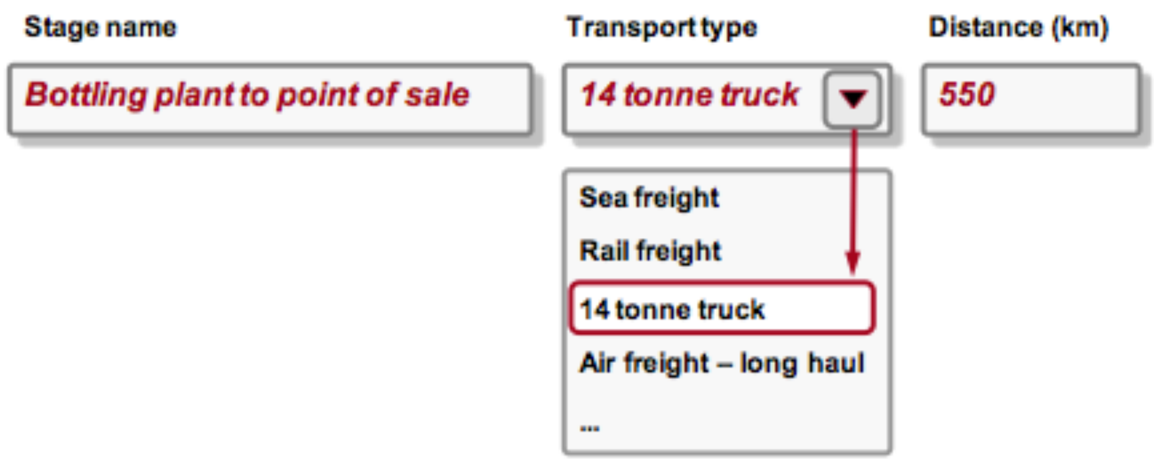
Exercise 1:
ECO AUDIT Project, 2/7

1. Bill of materials, primary processing techniques and end of life:



Exercise 1:
ECO AUDIT Project, 3/7

2. Transportation from site of manufacture to point of sale:



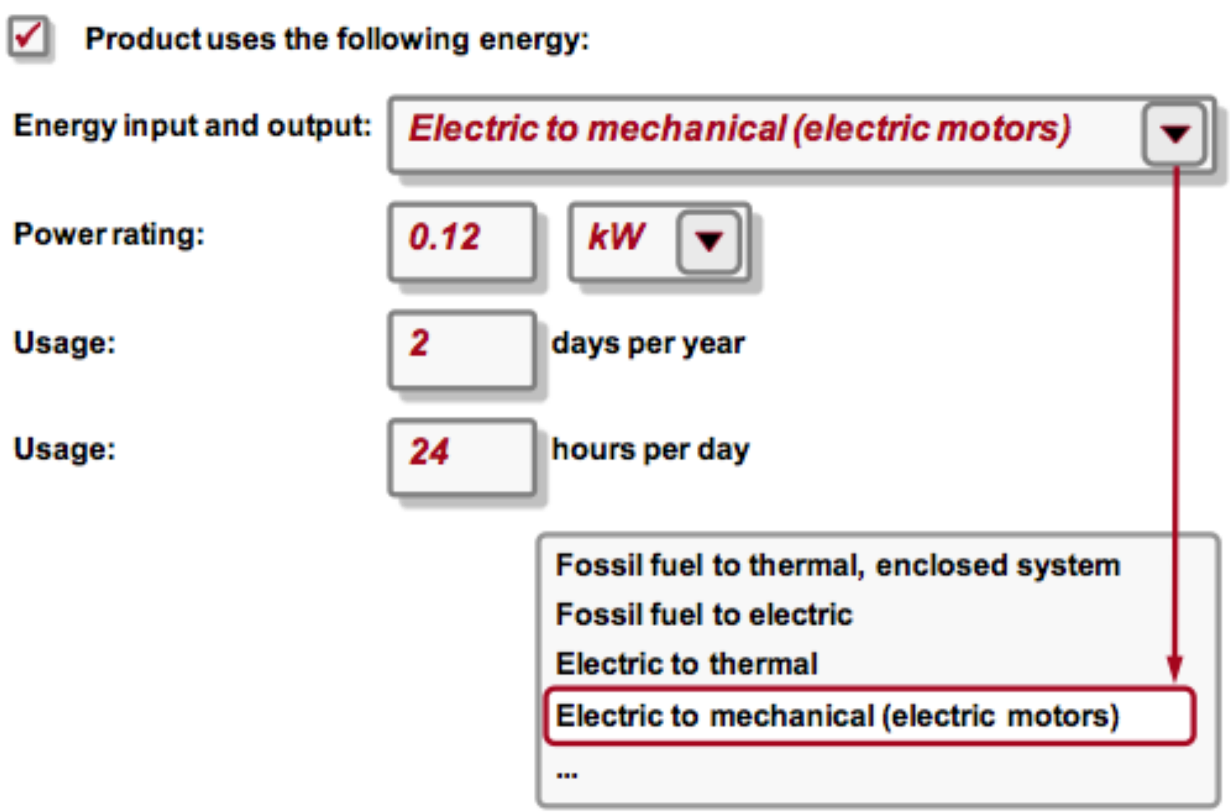
Exercise 1:
ECO AUDIT Project, 4/7

3. Use – product life and location of use:

Exercise 1:
ECO AUDIT Project, 5/7

3. Use – static consumption:

Energy used to refrigerate product at point of sale (average energy required to refrigerate 100 bottles at 4° C = 0.12 kW)

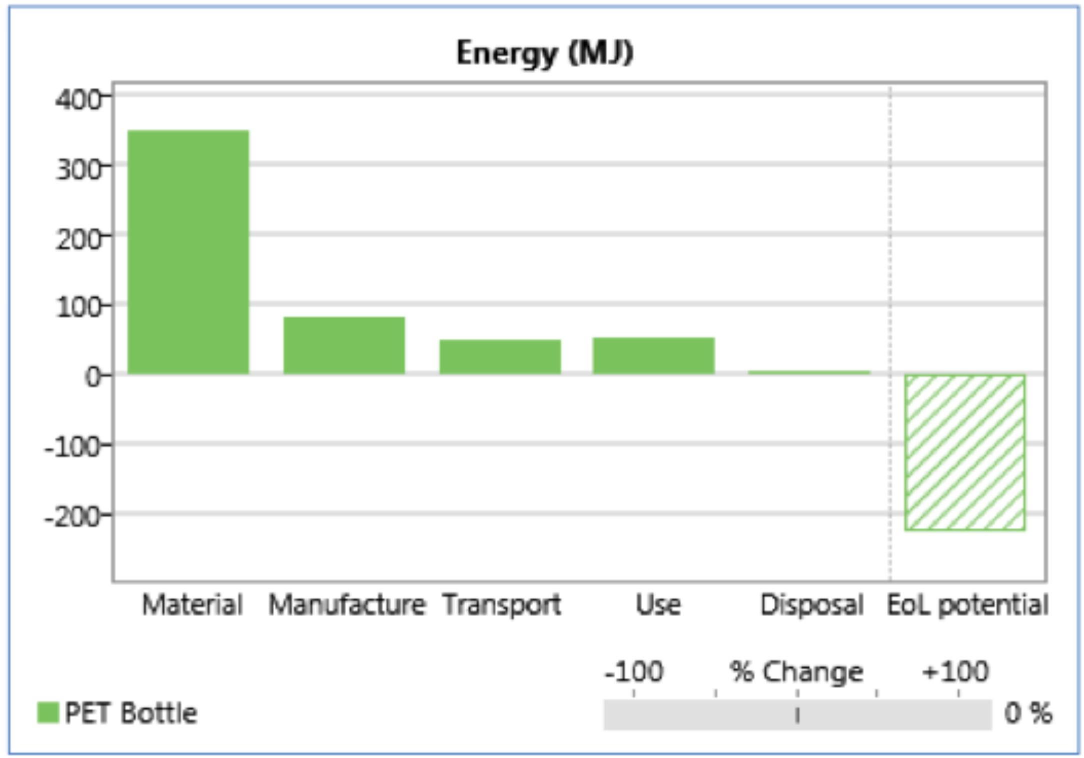


Exercise 1:
ECO AUDIT Project, 6/7

4. Report:

Summary chart enables rapid identification of the dominant life phase. View energy usage or CO2 footprint.

(Click on the Material life phase bar in the summary chart for guidance on strategies to reduce its impact.)



Exercise 1:
ECO AUDIT Project, 7/7

4. Report:

Detailed report provides a component by component breakdown of each life phase, enabling the main contributors to the dominant phase to be identified…

5. Reflection:

What remained outside assessment?

Edupack: Mitigating impacts

Strategies for reducing environmental impact

Having identified the dominant life phase and component/s that contribute most to a product's environmental impact (using the Eco Audit tool), the next step is to identify the correct strategy for reducing that impact.

The appropriate strategies are highly dependent on both the type of product and the dominant life phase.

Guidance on what impact reduction strategies, and material indices, to consider is accessed by clicking on the dominant life phase bars in the Summary chart.

The strategies for reducing the environmental impact are related to each life phase:

1. Material phase
2. Manufacture phase
3. Transportation phase
4. Use phase
5. Disposal and end-of-life phase

Improvement Strategies:
1. Material phase

Aim

- Minimize embodied energy or CO_2 footprint per unit of function.

Actions

- Select material with lowest embodied energy and CO_2 footprint per unit of function.
- Use as large a 'recycled content' in the material as possible.
- Use as little material as possible while retaining enough redundancy for safety.

Conflicts

- Watch out for conflict with the Use phase. The material with the lowest direct eco-impact may not be the lightest or the cheapest. Use trade-off methods to resolve the conflict.

Improvement Strategies:
2. Manufacture phase

Aim

- Minimize process energy, CO_2 footprint and waste.

Actions

- Select processes with low energy and CO_2 footprint – deformation processing rather than casting for example.
- Avoid processes with large processing waste – net-shape processes rather than machining from solid for example.

Conflicts

- Check for quality loss on changing process.

Improvement Strategies:
3. Transportation phase

Aim

- Design for low-impact transport.

Actions

- Reduce the mass transported, material-efficient design helps here.
- Rethink the transport mode.
- Reduce the distance of transport.
- Reduce the speed.

Conflicts

- The motive for off-shore manufacture, incurring the need for long haul transport, is that the lower labor costs more than off-set the greater transport costs. Use the Eco Audit tool to explore the impact of different transport modes and distances.

Improvement Strategies:
4. Use phase

Static mode - mechanical devices:

Aim

- Design for energy use.

Actions

- Select material with the lowest value of the appropriate index (e.g. mass, friction).

Conflicts

- The material choice that minimizes mass may not minimize embodied energy or cost. Use trade-off methods to resolve the conflict.

Improvement Strategies:
4. Use phase

Static mode – heating and cooling systems:

Aim

- Design for minimum thermal loss.

Actions

- Select material with the lowest value of the appropriate index (e.g. insulation).

Conflicts

- The material choice that minimizes mass may not minimize embodied energy or cost. Use trade-off methods to resolve the conflict.

Improvement Strategies:
4. Use phase

Mobile mode – transportation:

Aim

- Design for minimum mass.

Actions

- Select material with the largest value of the appropriate index (e.g. strength), to reduce mass.
- Lean design: use as little material as possible.

Conflicts

- The material choice that minimizes mass may not minimize embodied energy or cost. Use trade-off methods to resolve the conflict.

Improvement Strategies:
5. Disposal and end of life phases

There are six options for disposal of products at the end of their first life:

1) Landfill: The first, landfill, is the least attractive.
2) Combust for energy recovery: Combustion recovers some of the embodied energy of the materials of the product, but the recovery-efficiency is low, the economics are unattractive and proposals to build combustion plants are often opposed.
3) Downcycle & 4) Recycle: Recycling is the best way to extract value from waste and return materials to the supply-stream, but materials are often downcycled.
5) Re-condition or re-engineer: Re-conditioning or re- engineering restores used products or recoverable components to as-new condition, but establishing a market and maintaining a supply chain of recondition products is not easy.
6) Reuse as is: Reuse sounds the most attractive option. This requires a market place where seller and buyer can meet and negotiate, and an acceptance of used products rather than new.
7) None: Applicable to very few materials/components

Improvement Strategies:
5. Disposal and end of life phases

Aim

- Increase end-of-life potential, design for recycling.

Actions

- Select material that have high recycle ratio (the 'Recycle fraction in current supply', listed on the material datasheets).
- Minimize the number of different materials in the product.
- Avoid combining materials that are incompatible if recycled together.
- Identify materials used in components, using recycle marks or color coding, preferably with grades, filler type and content.
- Design for ease of disassembly: snap fits, fasteners, releasable adhesives.

Conflicts

- The material choice that best suits end-of-life may not minimize the use energy. Use trade-off methods to resolve the conflict.

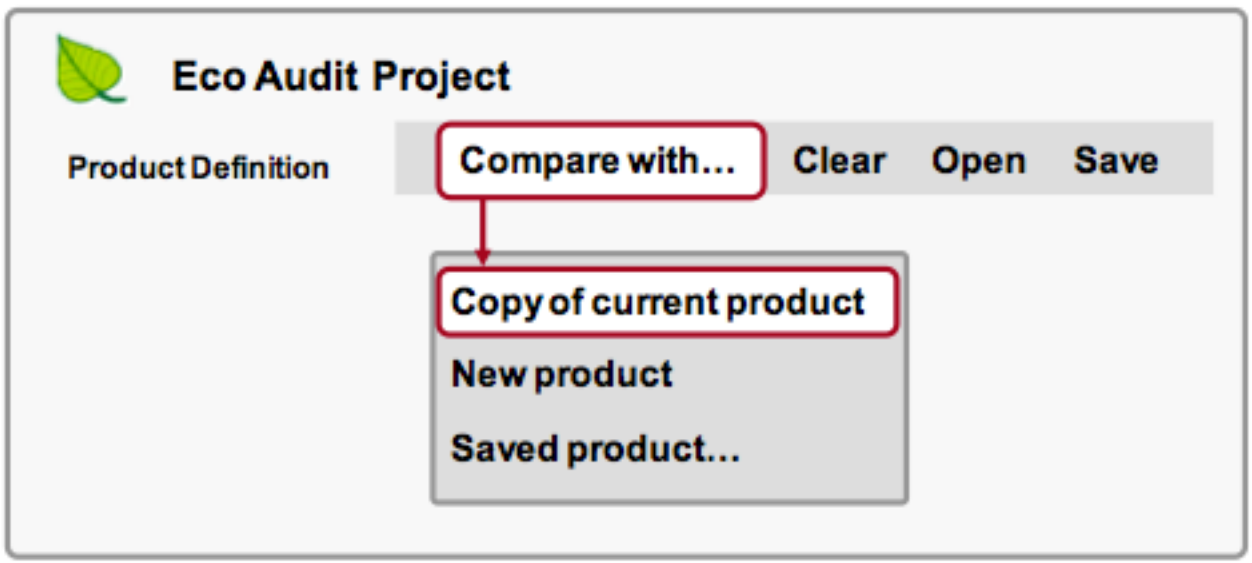
Exercise 2:
Comparing eco-audits

Using EduPack Level 2
with eco and durability properties

Exercise 2:
COMPARE Eco Audits, 1/2

Compare eco audits:

- In Product Definition page, click “Compare with”, then select Copy of current product.
- In the copy, change product name to ‘PET Bottle (Recycled)’



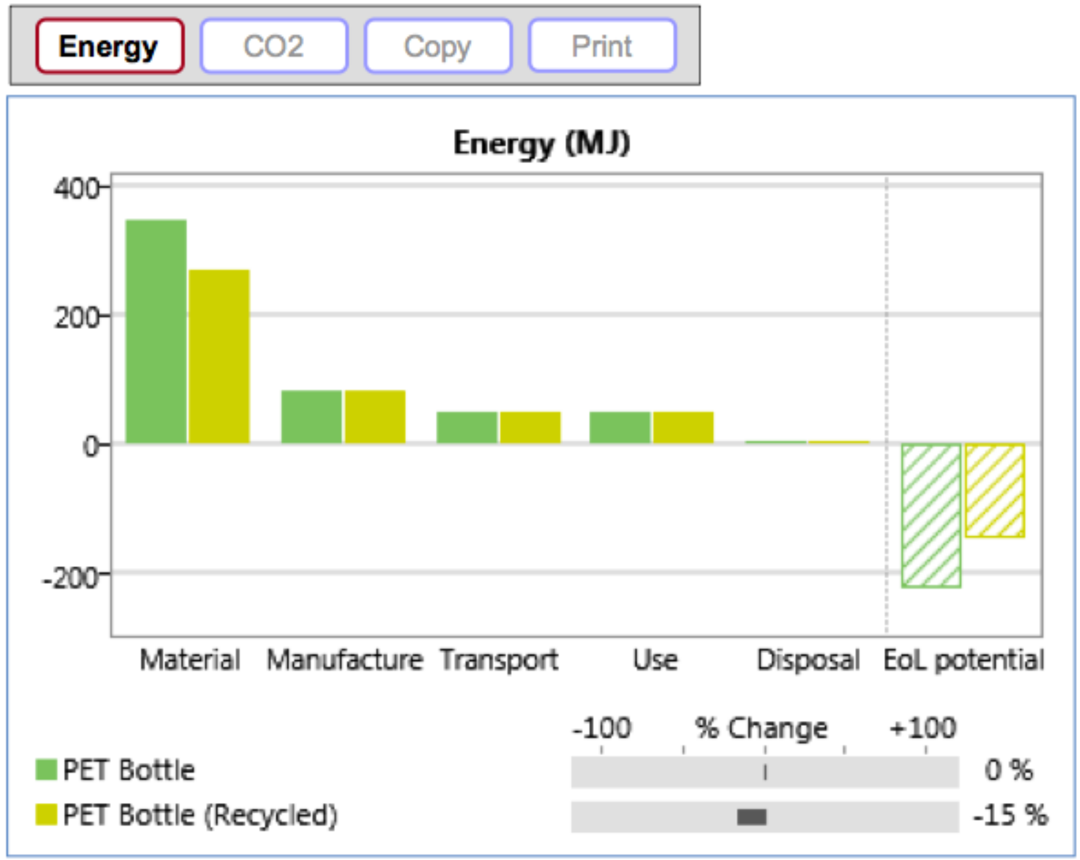
Exercise 2:
COMPARE Eco Audits, 2/2

Recycled PET:

- – Change the RECYCLED CONTENT to 35% Note the first life energy (not including the 'EoL potential') is reduced by 12%

Copying graphs:

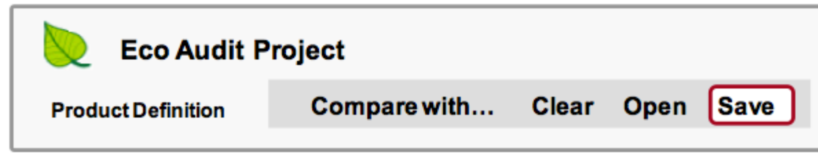
- – Click COPY to copy the chart and PASTE it into a document



Exercise 3:
Saving & exporting

Saving Eco Audit Product Definition:

– Eco audit projects are not part of a selection project, and need to be saved separately

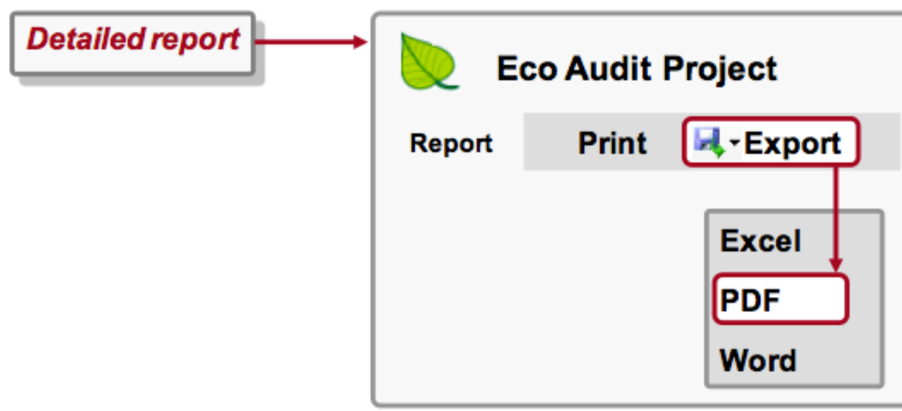


– SAVE the product definition (give it a filename and directory location; Eco Audit product files have the extension ".prd")

Saving/Exporting Eco Audit Report:

– GENERATE the eco audit report

– EXPORT the eco audit report as a PDF (Note: You will require Microsoft Excel or a PDF reader such as Adobe Reader to view the exported eco audit report)



Project work progress

Working with your project ideas:

Steps so far:

1. Describe the prime objective in your project idea, eg. product assessment/comparison/redesign
2. Define system boundaries for the assessment
3. Review stakeholders and both production system and product components
4. Perform fact-finding on stakeholders and components (Materials & Manufacturing; Environment; Society; Economics; Regulation; Design)

Begin to perform assessment in Edupack:

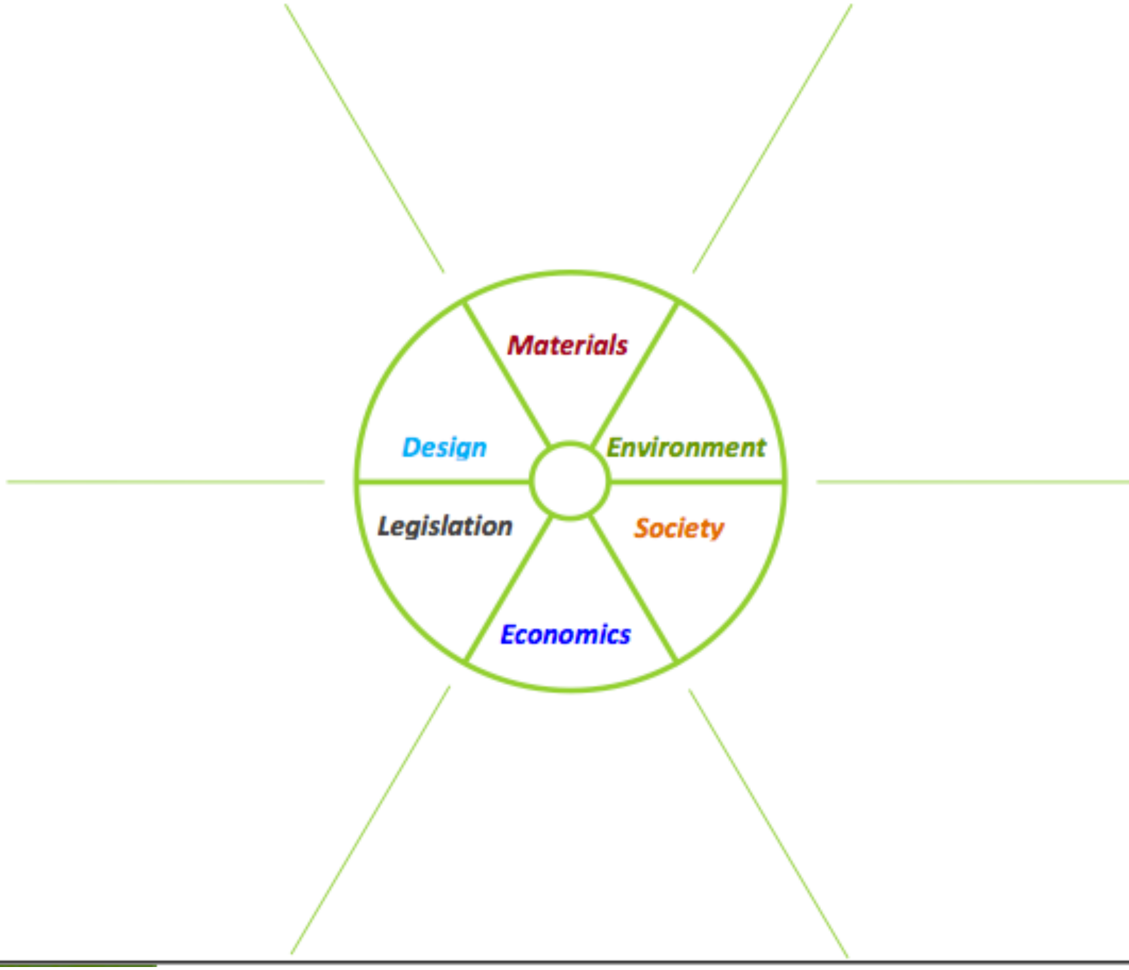
5. Perform impact assessment/comparison with Edupack and Eco-audit tool
6. Reflect on results, communicate in report

META matrix:

Impact category	Material production	Manufac-turing	Use-phase	End-life	Transport
M-Materials					
E-Energy					
T-Toxicity					
A-Socio-cultural					

1. Prime Objective and Scale:

3. Fact - finding



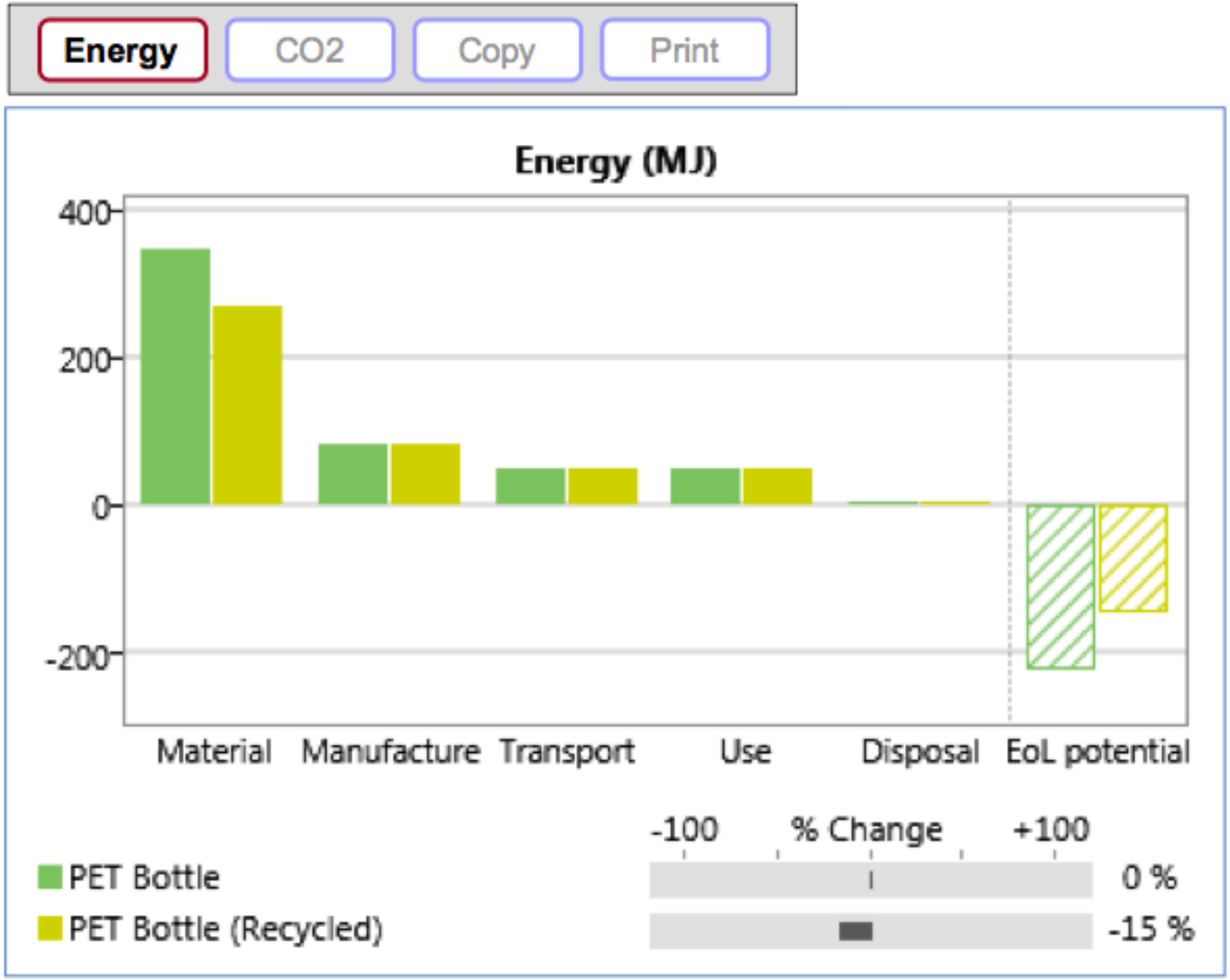
2. Stakeholders

Project work: Status reports

- Did you have time to do fact-finding on project idea?
- What have you learned regarding your initial idea?
- Where are you focusing?
- What are you assessing in greater detail?
- What difficulties/challenges exist?

Project work: Next steps…

- Start to build up your design concept, and study it through comparisons of material use and changes during other life phases…
- Create competing scenarios (eg. Material use; Logistics chain etc.)
- Assess the differences and their implications on different impacts
- Reflect all the way back to your initial idea, ideas of potential improvement, and changes with different capitals of sustainability (natural, human & financial)
- Be prepared to present your progress on next, final session…


Energy
CO2
Copy
Print
Energy (MJ)
400
200
0
-200
Material
Manufacture
Transport
Use
Disposal
EoL potential
-100
% Change
+100
PET Bottle
0 %
PET Bottle (Recycled)
-15 %

THANK YOU…
Continues on Thursday 26.1.