



Aalto University
School of Engineering

MEC-E1070

Selection of Engineering Materials

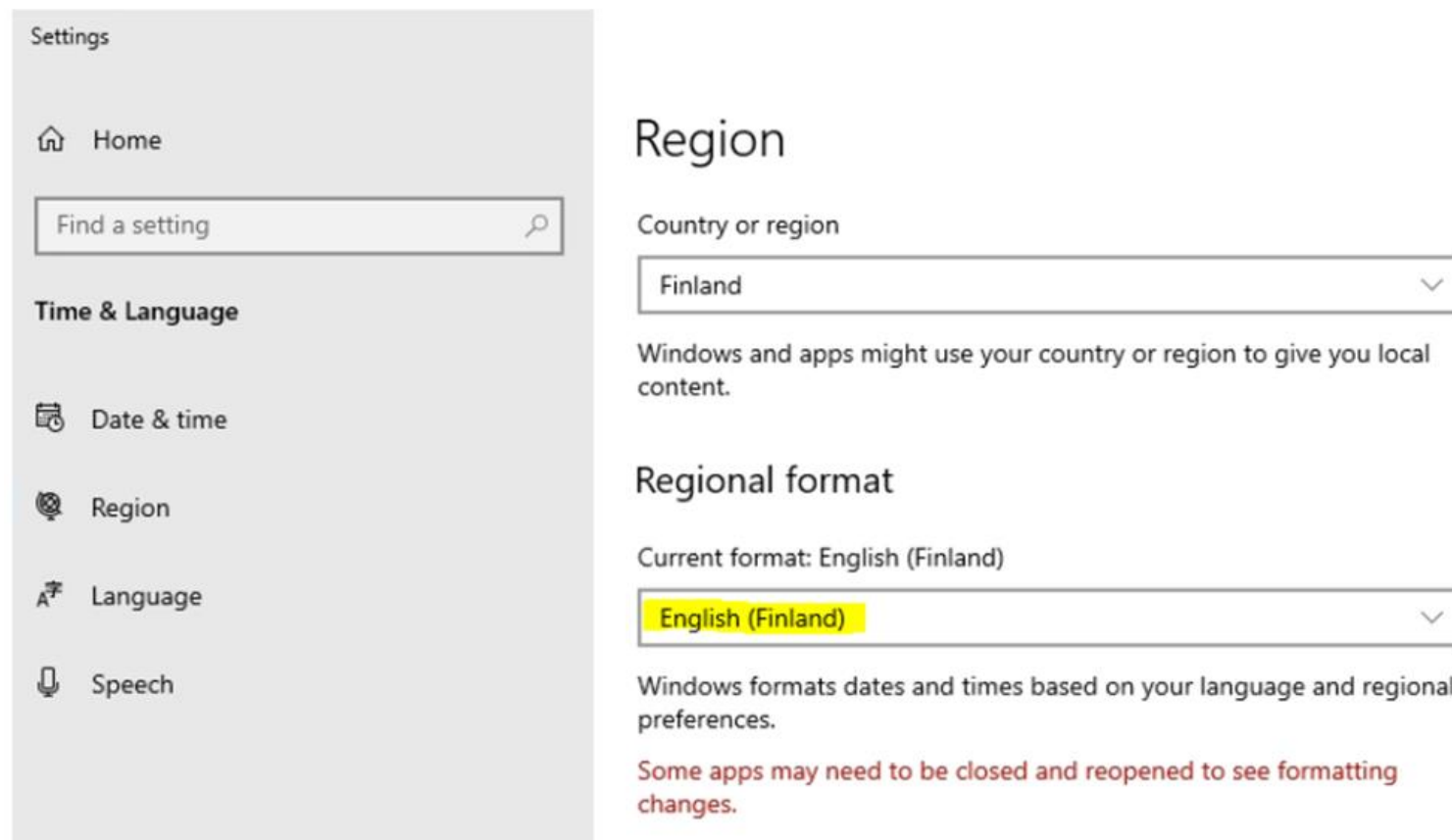
Prof. Junhe Lian, Prof. Sven Bossuyt
course assistant Zinan Li

Notes

Fix Eco Audit Crashes (Remote connection)

This software is picky about the Regional format setting in Windows. Unfortunately at least on our VDI workstations the default format is not working with the Eco Audit feature, and may need to be changed by the user on each session. This is how to do it:

1. Click the Windows Start-menu on the lower left corner of desktop.
2. Search for "region" by typing it, then choose "Region Settings".
3. Regional format might be Recommended [English (United States)]
change it to for example:
English (Finland)



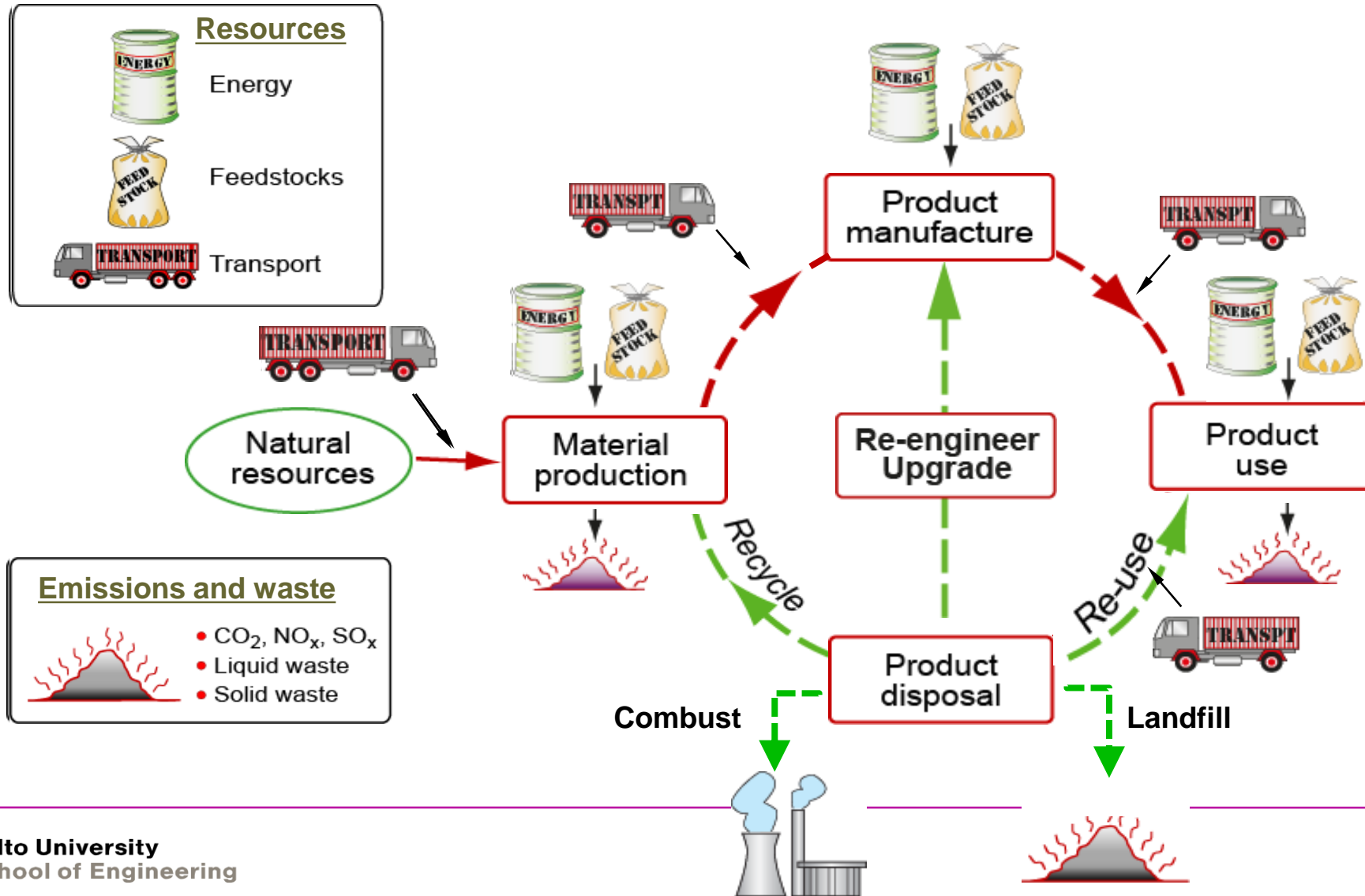
4. Restart EduPack and Eco Audit should work. Remember, you may need to do this again on your next session.

Material and process selection



- Eco-informed selection
- Eco Audits and the Audit tool
- Demo: soft drink containers

The product life-cycle



Eco-informed design

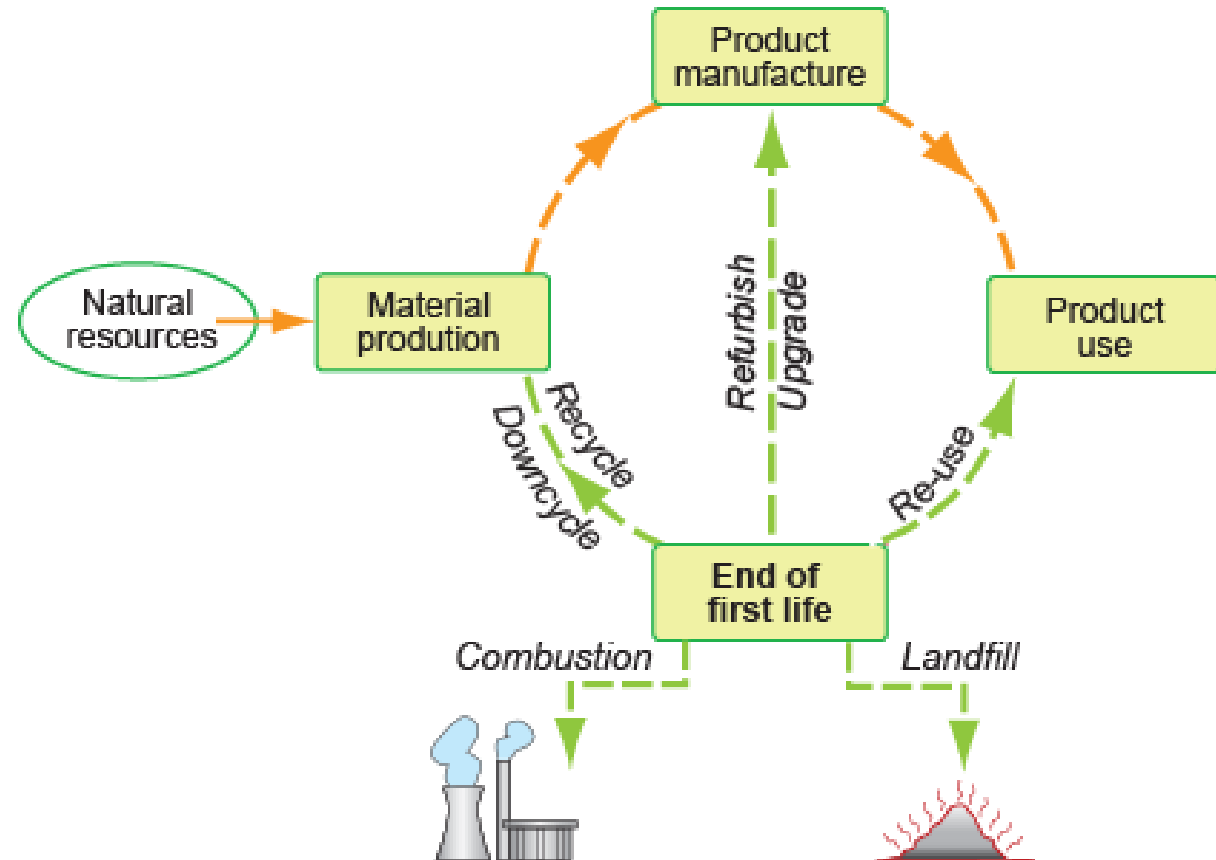
Eco-informed design

- 80% of eco-impact tied in at design stage
- Build-in eco criteria at the design stage

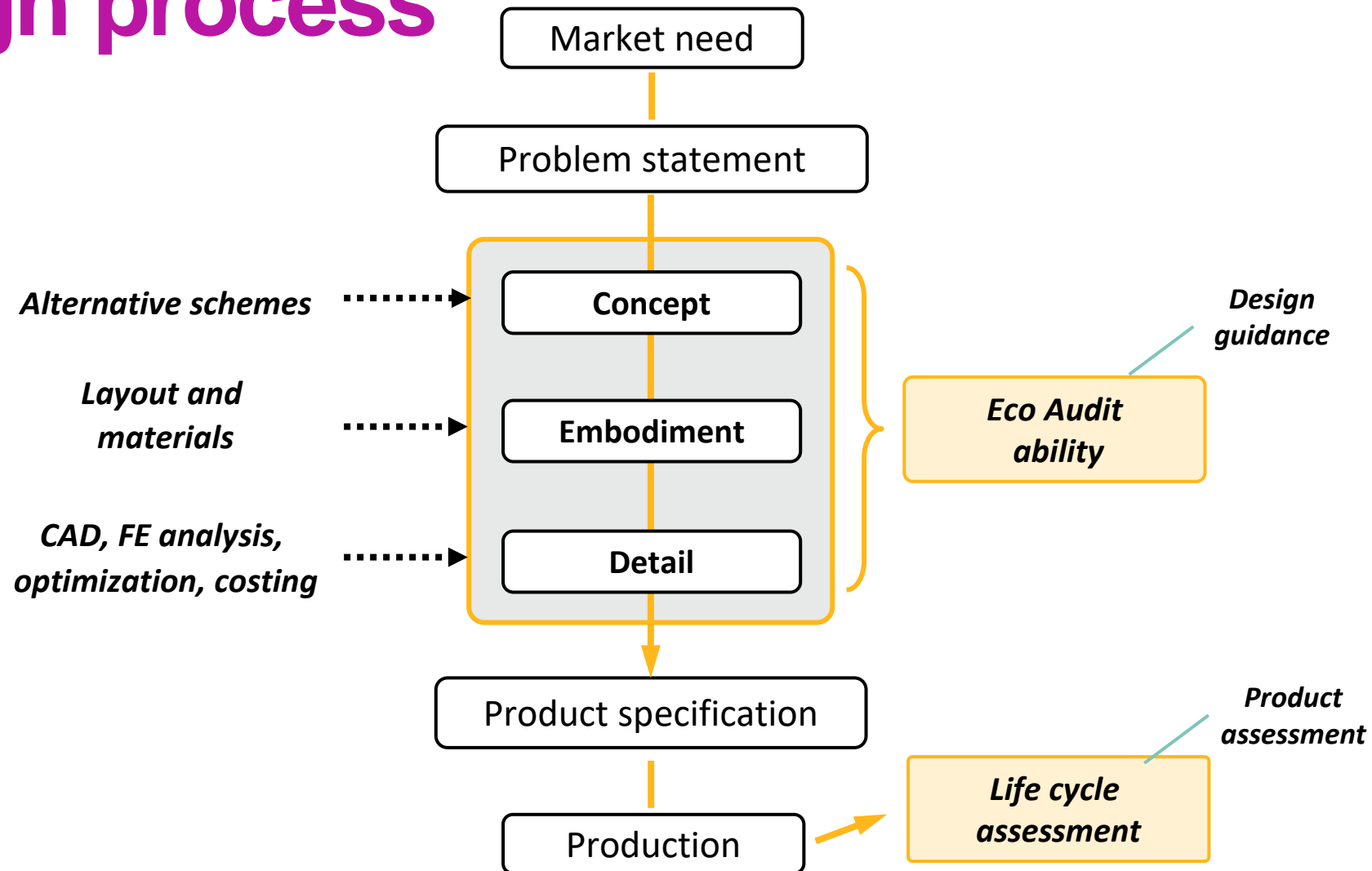
The drivers for eco-design

- Focus on carbon footprint by governments
- Legislation (Carbon taxes, **EuP**, **REACH**)
- Incentives (Subsidies, concessions)
- Urge for “responsible” manufacture
- Doing more with less = \$\$\$

The materials life-cycle

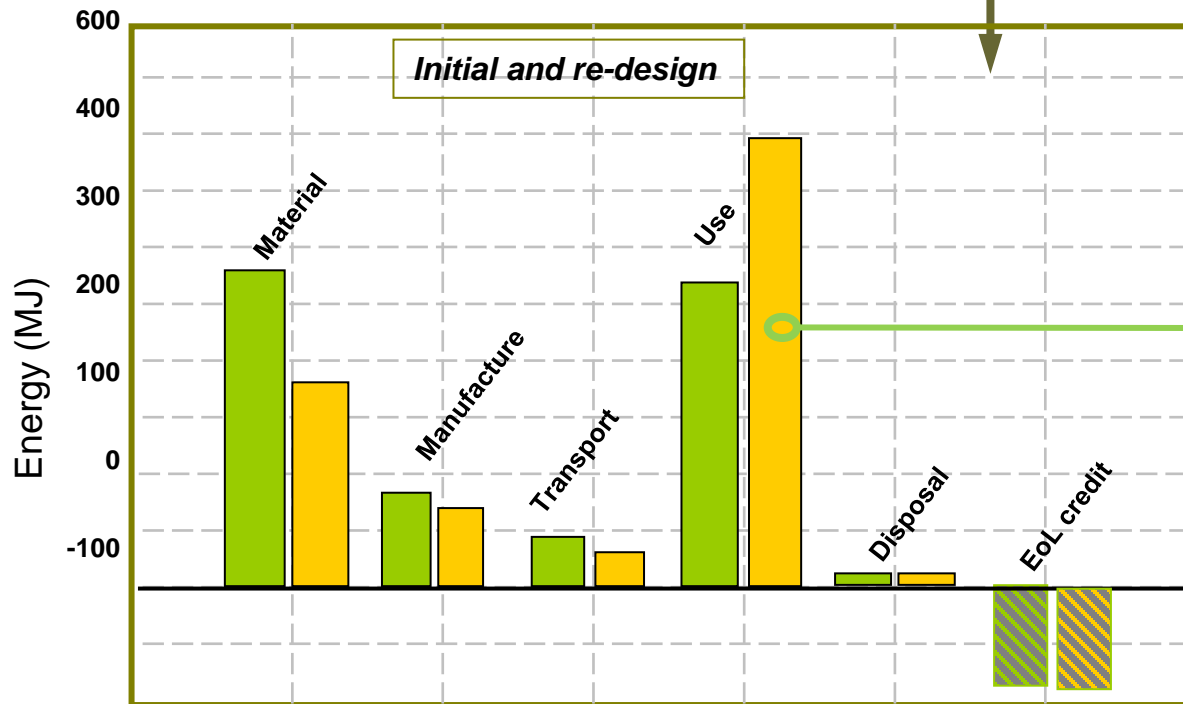


Design process



Eco-informed selection

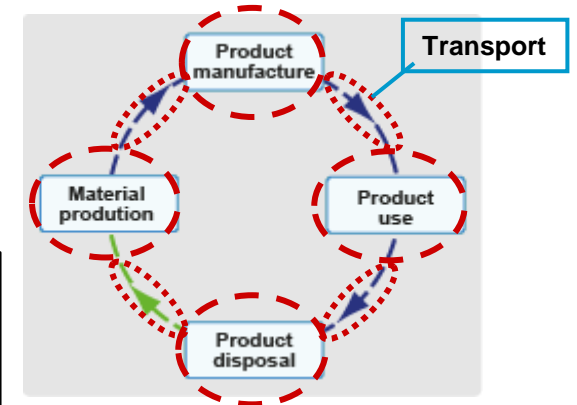
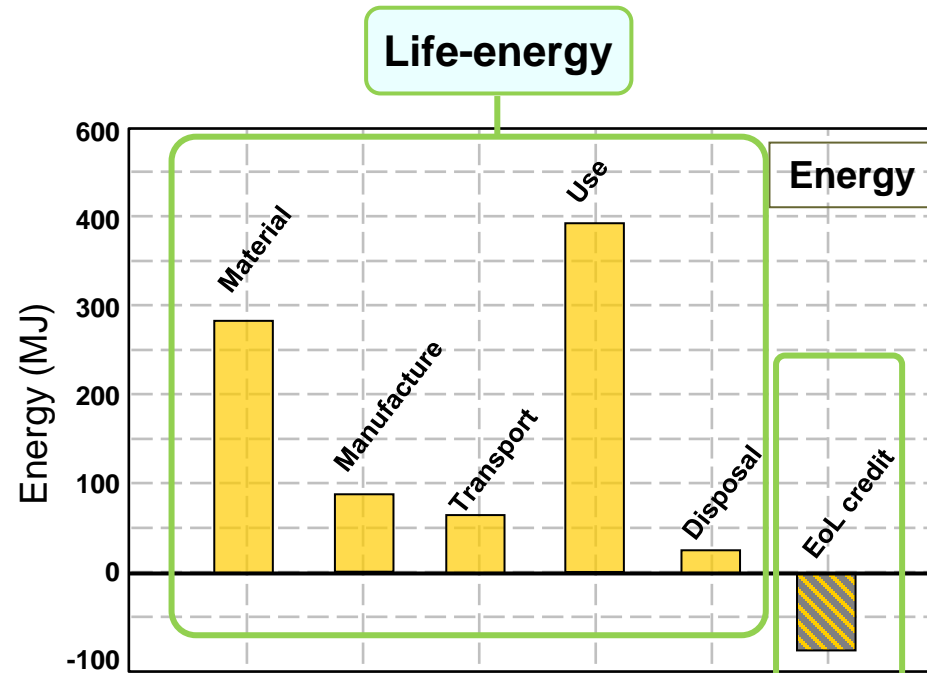
The steps



- With "what if's", make assumptions
- Can be better? A systematic analysis
- Click on bar for advice
- Use Eco Audit or other tools to identify design objective
- Apply the selection methodology

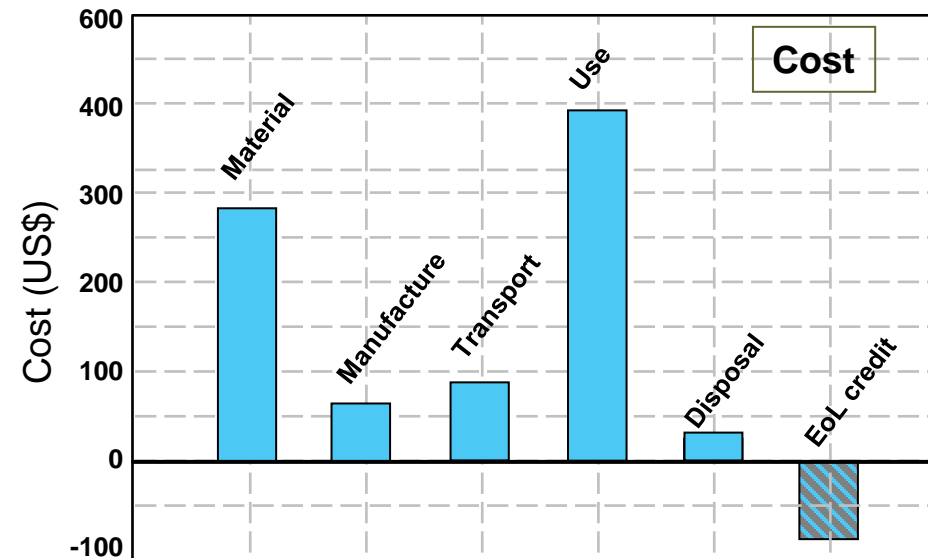
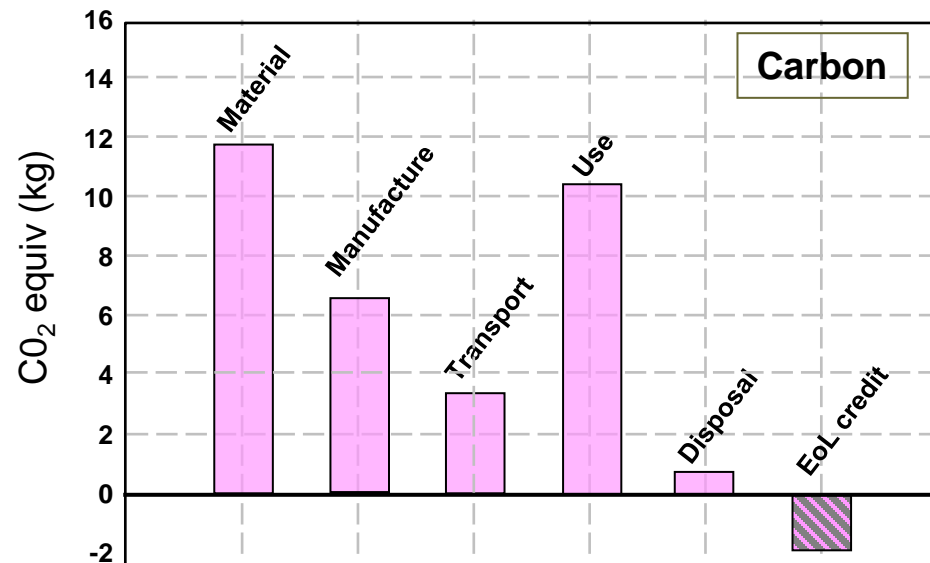
Eco Audit for design

- 1 resource – *energy* (oil equivalent)
- 1 emission – CO_2 equivalent
- Distinguish life-phases
- Audit: Energy

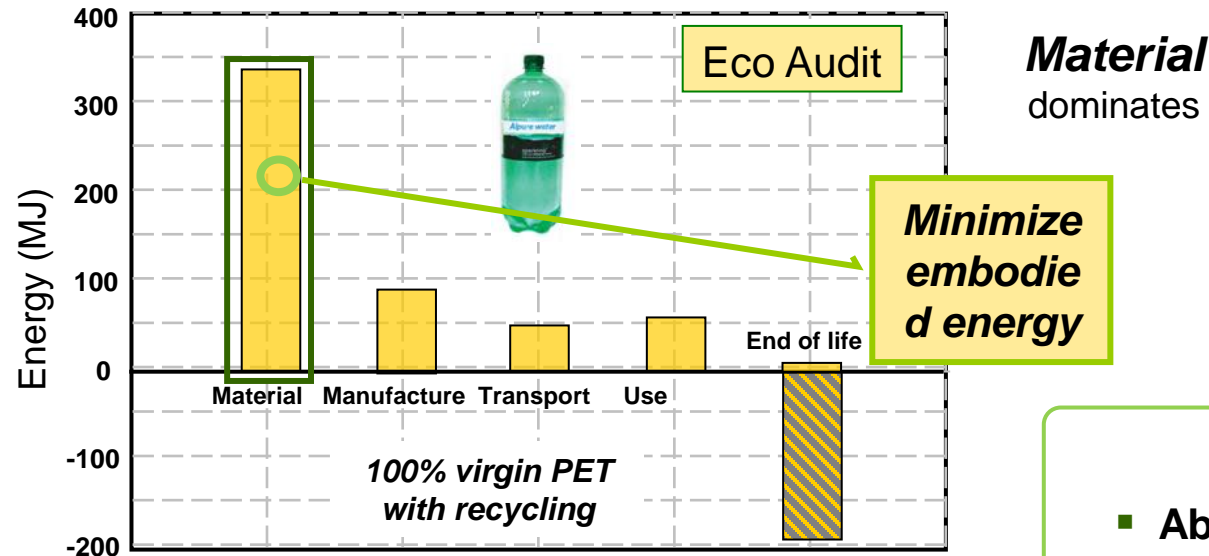


Eco Audit for design

- 1 resource – *energy* (oil equivalent)
- 1 emission – CO_2 equivalent
- Distinguish life-phases
- Audit: Energy or Cost



Eco-selection for a soft drink bottle



Design brief

Improve green credentials of bottle



Translation

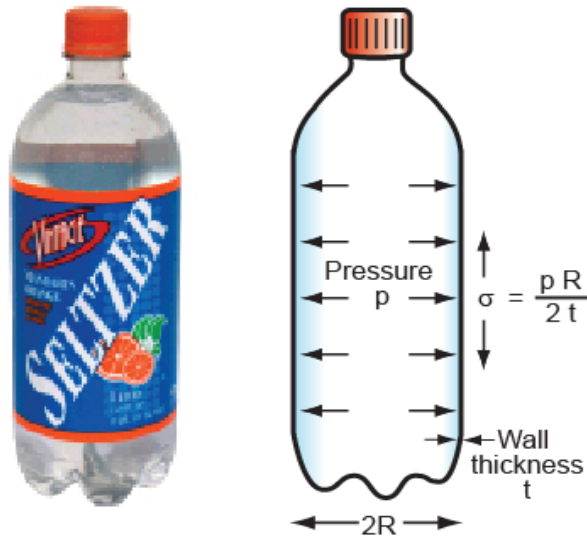
Constraints

- Able to be molded
- Transparent / translucent
- Able to contain pressure

Objectives

- Minimize embodied energy of bottle
- Minimize material cost of bottle

Modelling the bottle



R = Bottle radius
 t = Thickness of bottle wall
 p = Internal pressure
 σ_y = Yield strength of material
 ρ = Density of material
 H_m = Embodied energy of material/kg
 E = Embodied energy/m² of wall
 C_m = Material cost per kg

Cylindrical pressure vessel

- Circumferential stress $\sigma = \frac{pR}{t} < \sigma_y$
- Embodied energy per unit area of wall

$$E = t H_m \rho = pR \frac{H_m \rho}{\sigma_y}$$

Embodied energy / kg of material
- Find material with lowest energy, seek largest

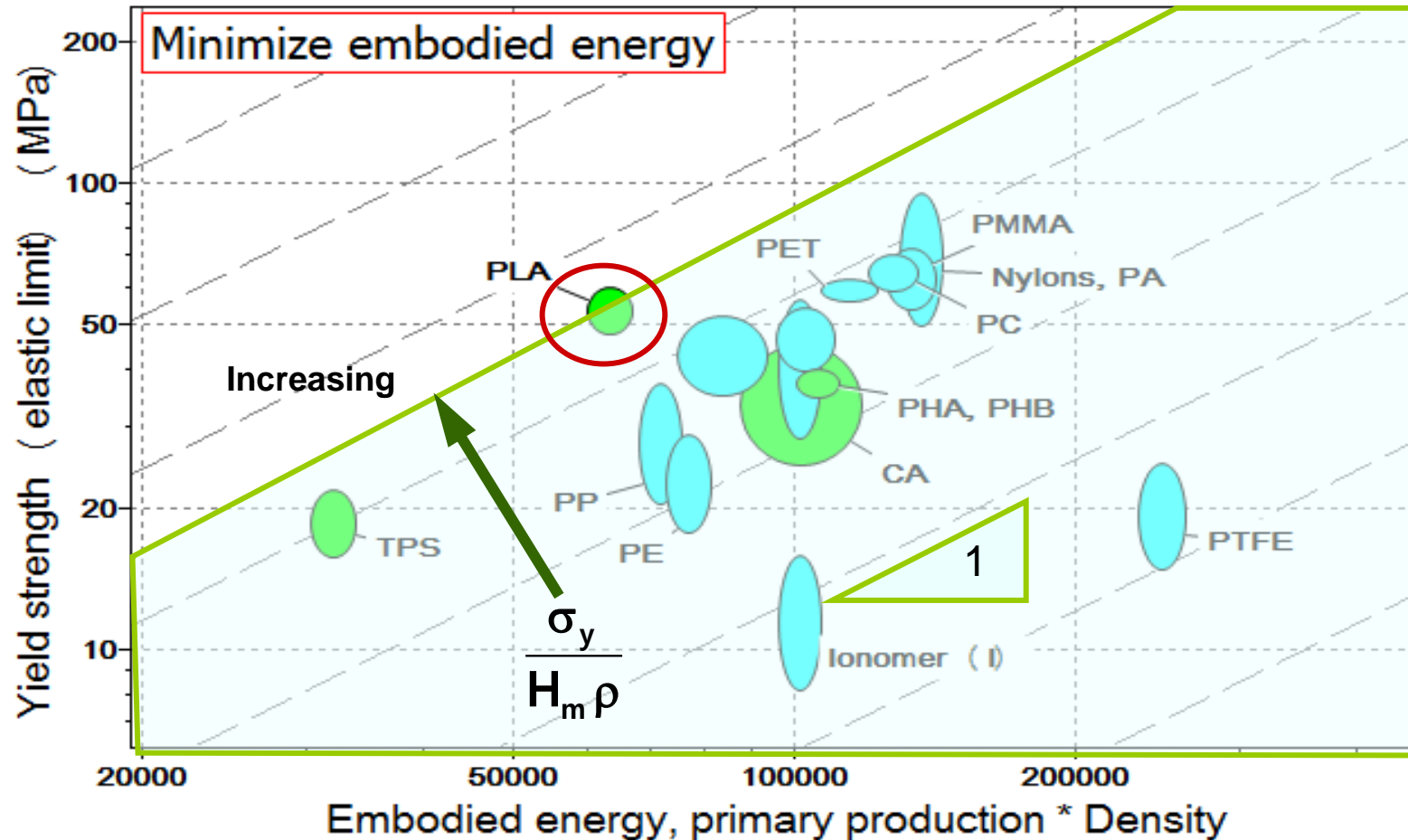
$$\frac{\sigma_y}{H_m \rho}$$

- Find material with lowest cost, seek largest

$$\frac{\sigma_y}{C_m \rho}$$

Price / kg of material

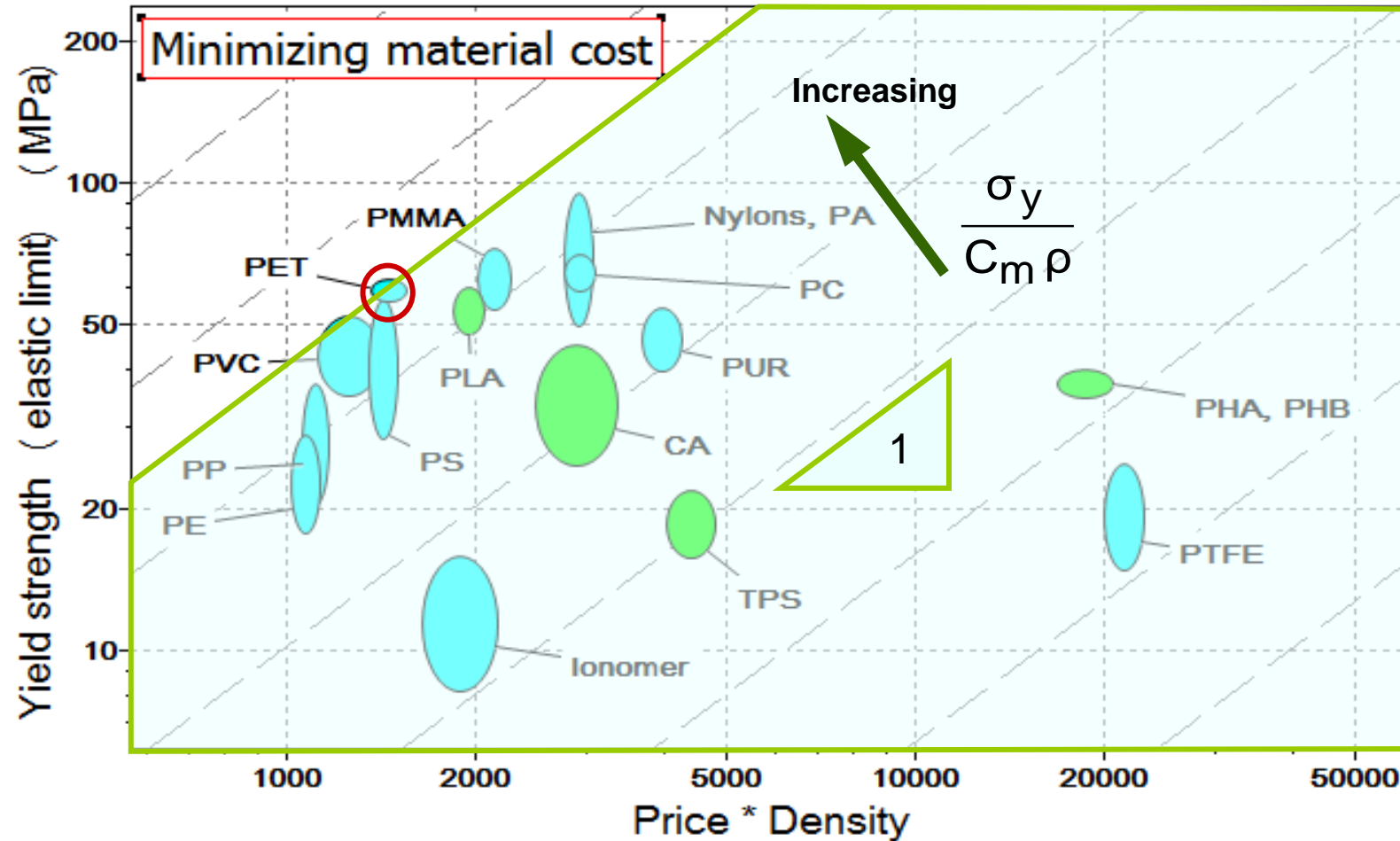
Selection to minimize embodied energy



- Constraints**
- Can be molded
 - Transparent / translucent

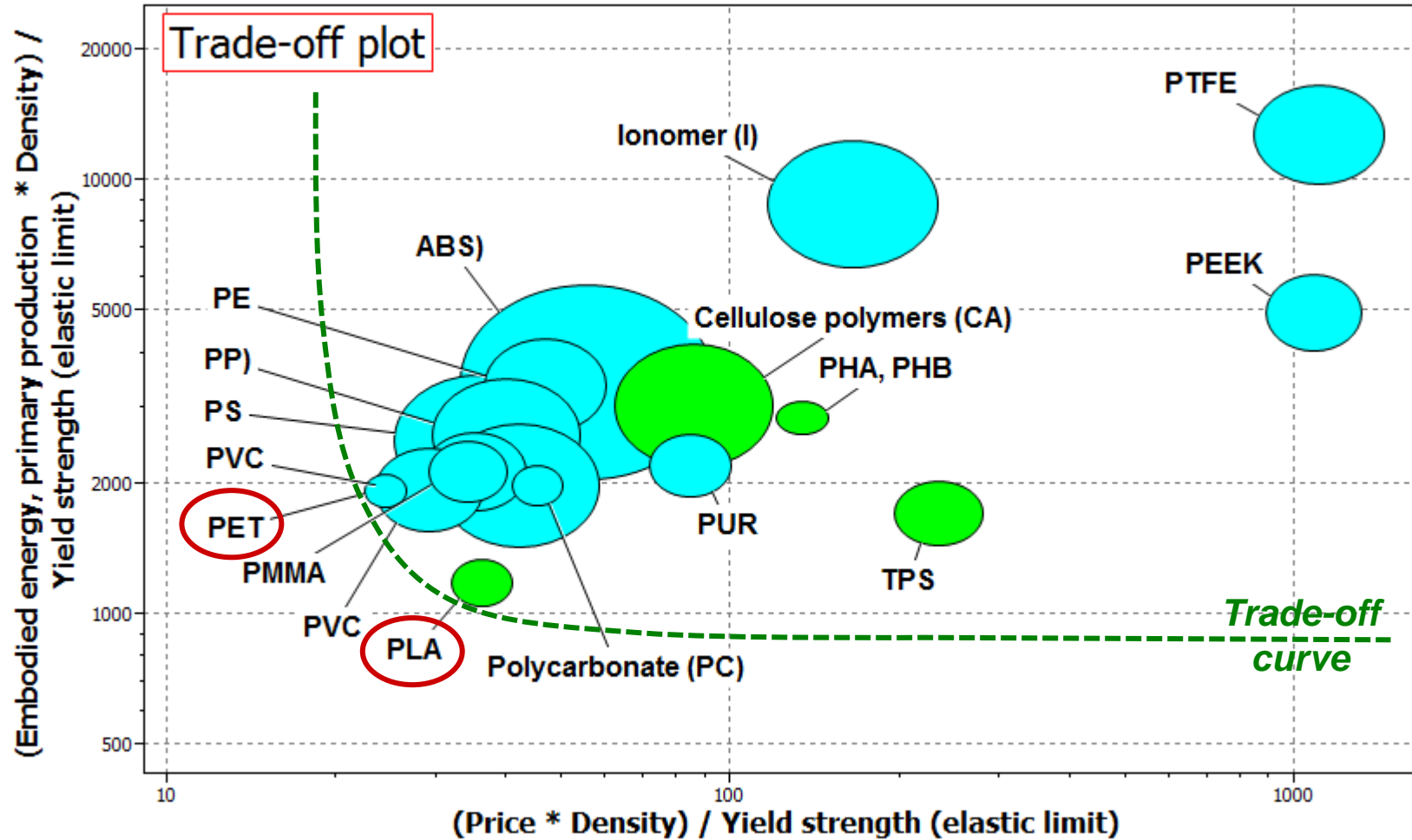
Bio-polymers are colored green

Selection to minimize cost



Trade-off plot

Minimizing both embodied energy and cost



Bio-polymers
are colored
green

Exchange
constant : not
established

Eco-property records

GE :Untitled - GRANTA EduPack 2020 - [MaterialUniverse\Polymers and elastomers\Polymers\Thermoplastics]

File Edit View Select Tools Window Feature Request Help

Home Browse Search Chart/Select Solver Eco Audit Synthesizer Learn Tools Settings Help

Browse Database: Level 2 Change... Table: MaterialUniverse Subset: All materials

MaterialUniverse

- Ceramics and glasses
- Hybrids: composites, foams, natural materials
- Metals and alloys
- Polymers and elastomers
 - Elastomers
 - Polymers
 - Thermoplastics
 - Acrylonitrile butadiene styrene (ABS)
 - Cellulose polymers (CA)
 - Ionomer (I)
 - Polyamides (Nylons, PA)
 - Polycarbonate (PC)
 - Polyetheretherketone (PEEK)
 - Polyethylene (PE)
 - Polyethylene terephthalate (PET)
 - Polyhydroxyalkanoates (PHA, PHB)
 - Poly lactide (PLA)
 - Polymethyl methacrylate (Acrylic, PMMA)
 - Polyoxymethylene (Acetal, POM)
 - Polypropylene (PP)
 - Polystyrene (PS)
 - Polytetrafluoroethylene (Teflon, PTFE)
 - Polyurethane (tpPUR)
 - Polyvinylchloride (tpPVC)
 - Starch-based thermoplastics (TPS)
 - Thermosets

Acrylonitrile butadiene styrene (ABS)

Datasheet view: All properties Show/Hide Find Similar

Geo-economic data for principal component

Annual world production, principal component	8.07e6	tonne/yr
Reserves, principal component	7.13e7 - 7.88e7	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	87.7 - 96.7	MJ/kg
CO2 footprint, primary production	3.27 - 3.61	kg/kg
Water usage	* 167 - 185	l/kg

Material processing: energy

Polymer extrusion energy	* 5.86 - 6.47	MJ/kg
Polymer molding energy	* 19.7 - 21.7	MJ/kg
Coarse machining energy (per unit wt removed)	* 1 - 1.11	MJ/kg
Fine machining energy (per unit wt removed)	* 5.76 - 6.37	MJ/kg
Grinding energy (per unit wt removed)	* 11 - 12.2	MJ/kg

Material processing: CO2 footprint

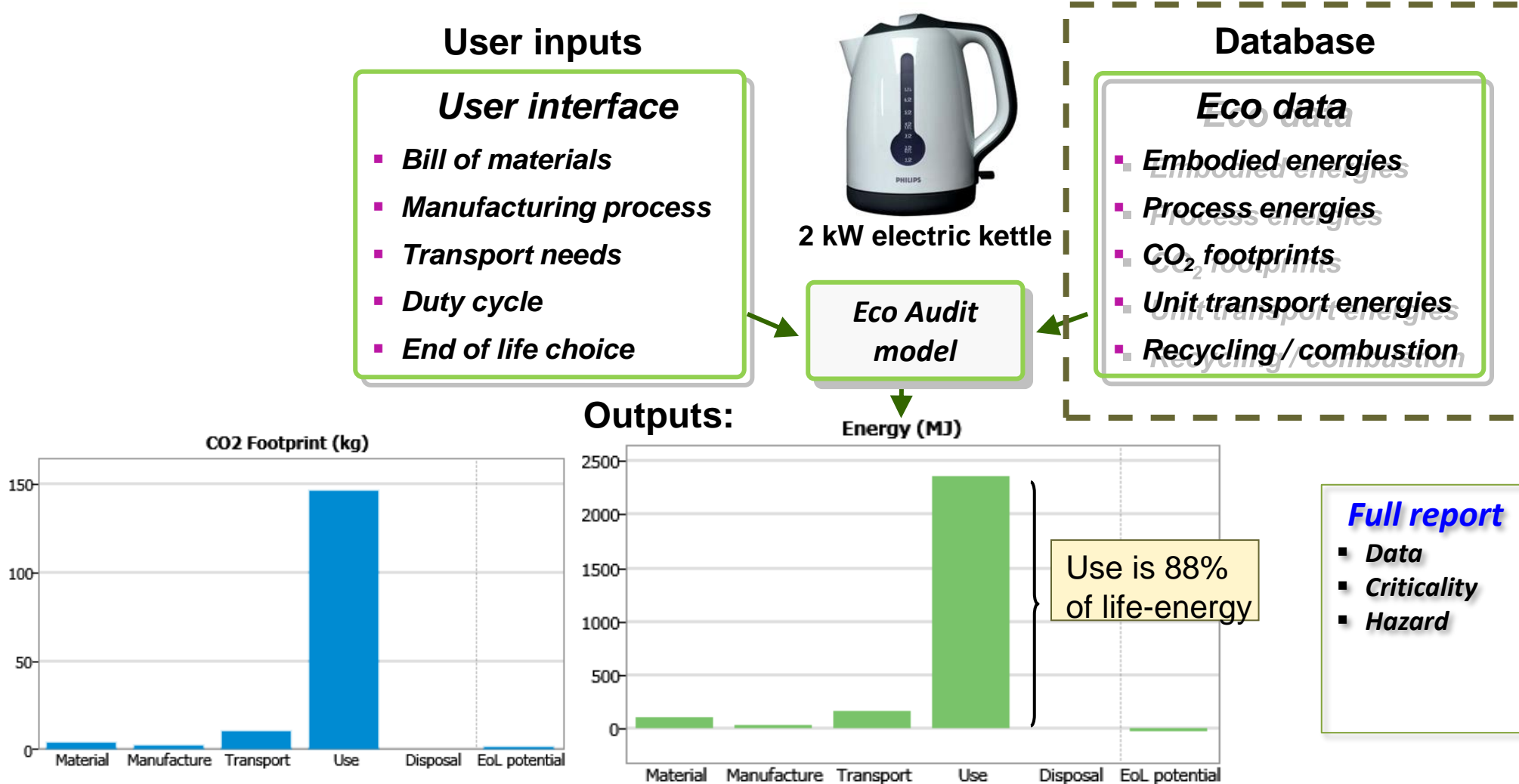
Polymer extrusion CO2	* 0.439 - 0.485	kg/kg
Polymer molding CO2	* 1.47 - 1.63	kg/kg
Coarse machining CO2 (per unit wt removed)	* 0.0753 - 0.0832	kg/kg
Fine machining CO2 (per unit wt removed)	* 0.432 - 0.477	kg/kg
Grinding CO2 (per unit wt removed)	* 0.828 - 0.916	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✓
Embodied energy, recycling	* 30.7 - 34 MJ/kg
CO2 footprint, recycling	* 1.17 - 1.29 kg/kg
Recycle fraction in current supply	3.8 - 4.2 %
Downcycle	✓
Combust for energy recovery	✓
Heat of combustion (net)	* 37.6 - 39.5 MJ/kg
Combustion CO2	* 3.06 - 3.22 kg/kg
Landfill	✓
Biodegrade	✗
Toxicity rating	Non-toxic
A renewable resource?	✗

Ready

The EduPack Eco Audit tool



The Eco Audit tool at Level 2

The screenshot shows the GRANTA EduPack 2020 Eco Audit tool interface. The main window is titled ':Untitled - GRANTA EduPack 2020 - [Electric kettle]'. The 'Eco Audit' tab is selected in the top menu. The 'Eco Audit Project' section shows 'Product definition' and 'Report' tabs. The 'Product information' section includes 'Name: Electric kettle'. The 'Material, manufacture and end of life' section displays a table of materials and their properties. The 'Transport' section shows 'S Korea to UK' with a distance of 1.4e+04 km. The 'Use' section includes 'Product life: 3 Years' and 'Country of use: United Kingdom'. The 'Static mode' section has 'Product uses the following energy:' checked, and 'Energy input and output: Electric to thermal'. The 'Mobile mode' section has 'Product is part of or carried in a vehicle:' unchecked. The 'End-of-Life' section lists options: Landfill, Combust, Downcycle, Recycle, Re-manufacture, Reuse, and None. The 'Summary chart' and 'Detailed report' buttons are at the bottom.

Bill of Materials (Input or file)

Help at each step

Useful for what-if?

Output data (Detailed info)

End-of-Life

- Landfill
- Combust
- Downcycle
- Recycle
- Re-manufacture
- Reuse
- None

> 5wt% critical material

Qty.	Component name	Material	Recycled content	Mass (kg)	Primary process	End of life
1	Kettle body	Polypropylene (PP)	Virgin (0%)	0.86	Polymer molding	Combust
1	Heating element	Nickel-chromium alloys	Virgin (0%)	0.026	Roll forming	Combust
1	Casting, heating element	Stainless steel	Virgin (0%)	0.09	Casting	Recycle
1	Cable sheath, 1 meter	Natural rubber (NR)	Virgin (0%)	0.06	Polymer molding	Combust
1	Cable core, 1 meter	Copper	Virgin (0%)	0.015	Wire drawing	Recycle
1	Plug body	Phenolics (PH)	Virgin (0%)	0.037	Polymer molding	Combust
1	Plug pins	Brass	Virgin (0%)	0.015	Roll forming	Recycle
1	Packaging, padding	Rigid Polymer Foam	Virgin (0%)	0.015	Polymer molding	Combust
1	Packaging, box	Paper and cardboard	Virgin (0%)	0.015	Polymer molding	Recycle

Task 5.1: Environment

Estimate the amount of energy in different polymers.

Which polymer embodies the least energy during its manufacture when a Young's modulus value of at least 0.8 GPa is required?

Solve the task with level 2 map.

Draw up a map with which you can compare different materials with regard to beam strength (in bending) versus CO₂-emissions.

Which material possesses the smallest carbon footprint compared to strength?

Also draw up this map for beam strength versus CO₂-emissions when recycled material is used.

Task 5.2: Processes

Essay in approximately 200-300 words with one or two illustrations

Summary

- Eco-informed material choice is part of the eco-design process
- An Eco Audit identifies the most damaging phase of life and identifies strategies for overcoming it
- Systematic strategies, using material indices, optimize material choice to minimize life energy, eco-impact.