Aalto University
School of Engineering

MEC-E1070 Selection of Engineering Materials

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Learning objectives for this Lecture

Knowledge and Understanding

Understanding **eco-informed design** and **material selection & processes**

Skills and Abilities

Ability to use Material Indices in eco-selection and connect processes with materials

Values and Attitudes

Appreciation of the possibilities to reduce environmental impact by design

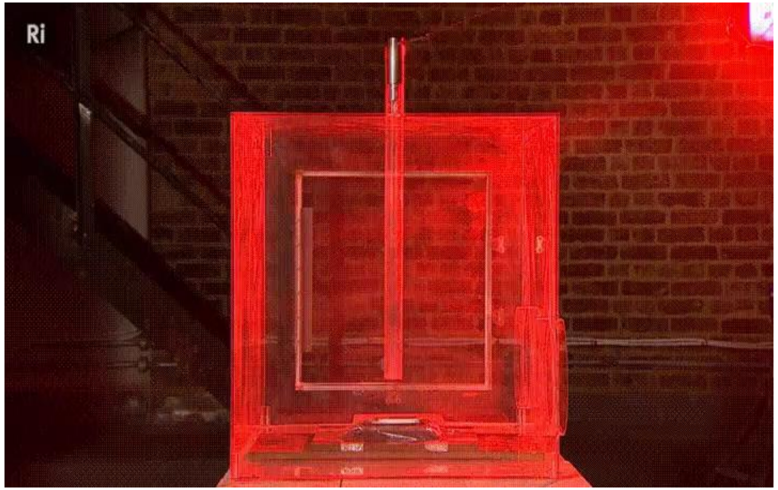
Resources

- Text: *“**Materials: engineering, science, processing and design**”* 4th edition by M.F. Ashby, H.R. Shercliff and D. Cebon, Butterworth Heinemann, Oxford, 2011, Chapters 13-15.
- Text: “**Materials and the Environment**”, 2nd Edition by M.F. Ashby, Butterworth-Heinemann, Oxford 2012, UK. Chapters 9-10

Outline of Lecture

An electric-powered Tesla car burns after a crash on the Swiss A2 motorway on Monte Ceneri near Bellinzona, Switzerland, May 10. | REUTERS

- Eco-informed selection – the strategy
- Case study: drink containers
- Processes



Lithium-ion battery fracture to explosion.

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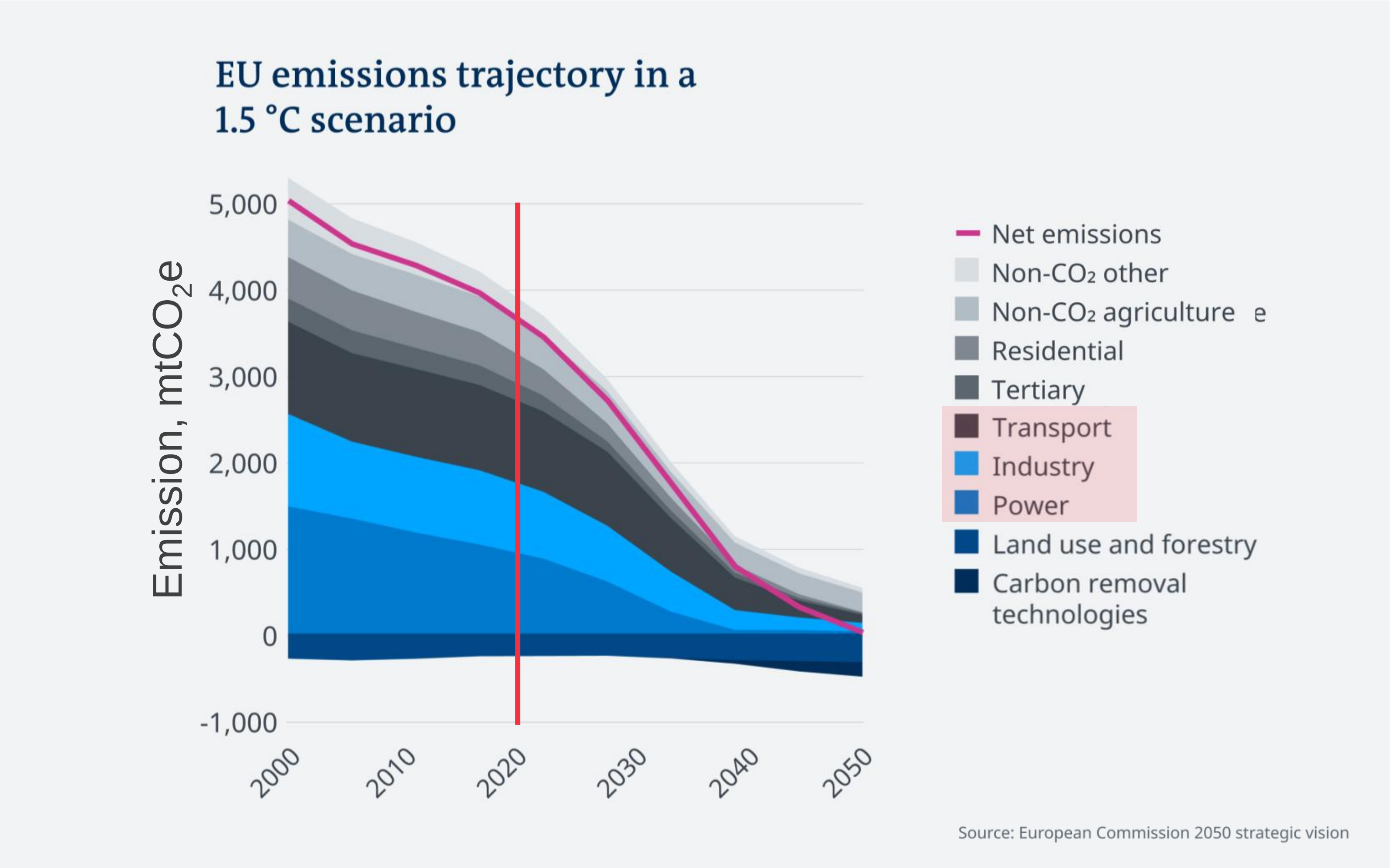
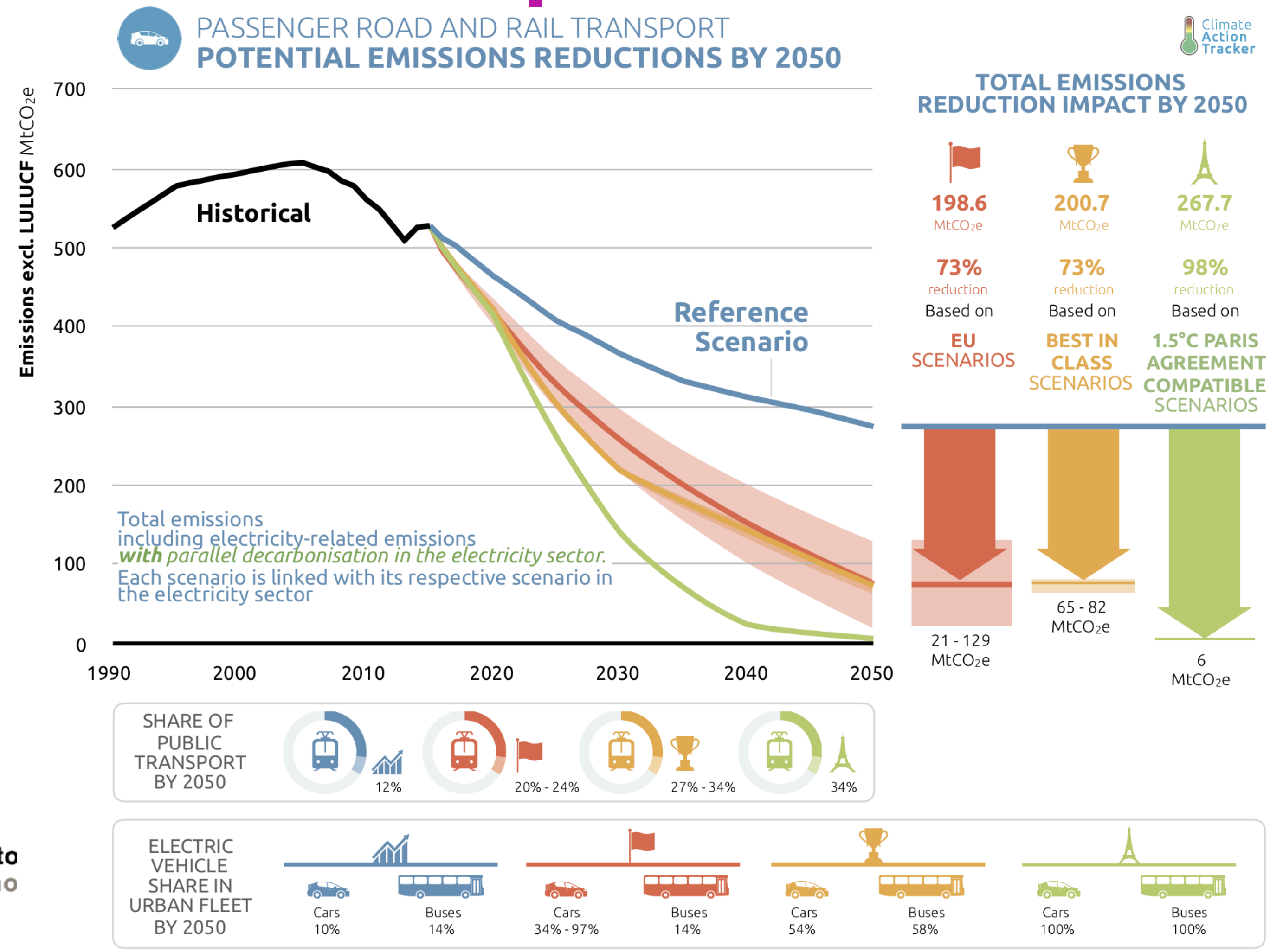
EU strategic vision: Net-zero by 2050



Actions in transport sector



Source: Scaling up climate action in the European Union

Eco-informed design

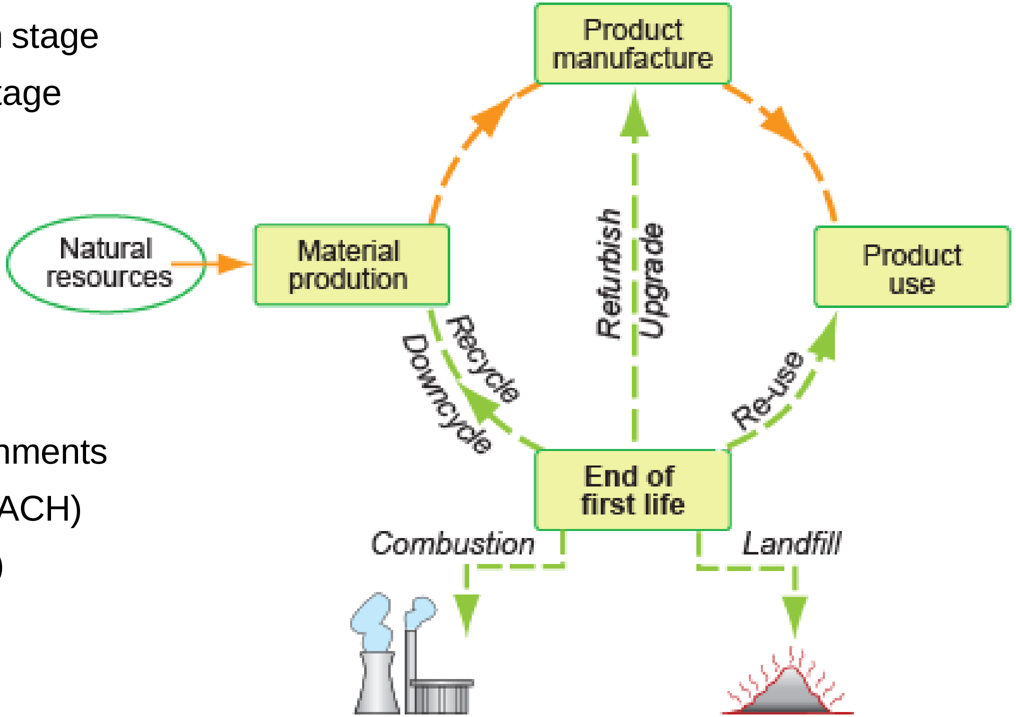
Eco-informed design

- 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 = $$$

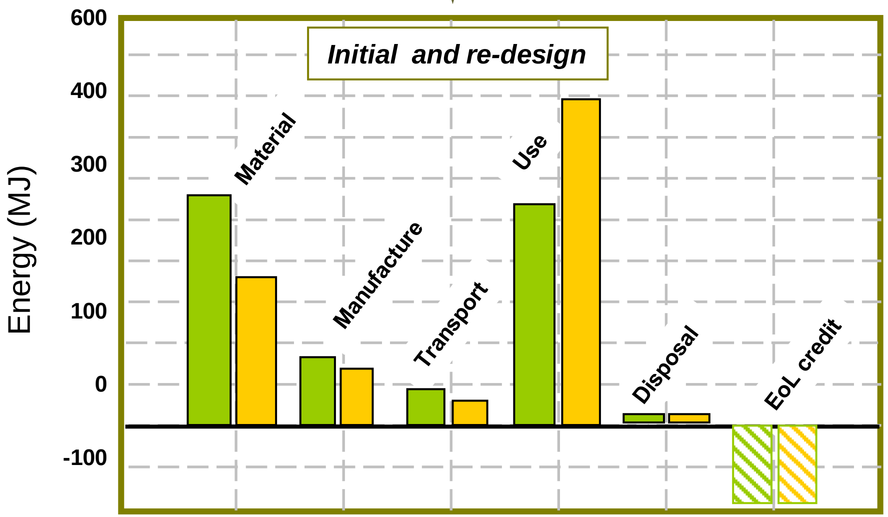
The materials life-cycle



Eco-informed selection: the strategy

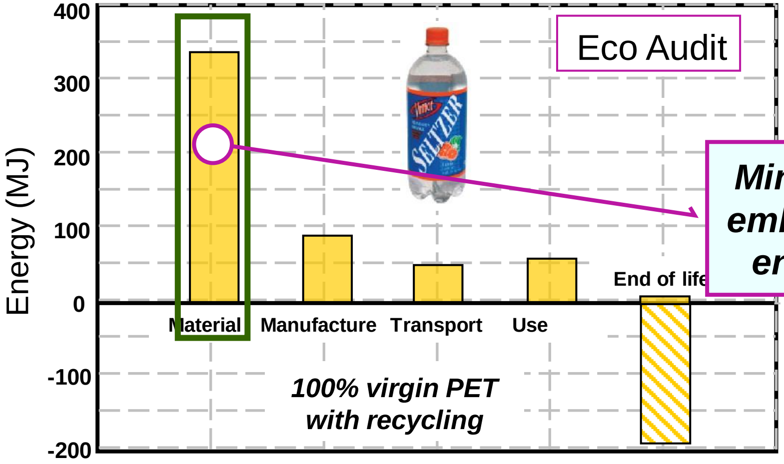
The steps

Fast Eco Audit → Analyse results, identify priorities → Explore options with "What if…"s → Select new Materials and/or Processes → Recommend actions & assess potential savings



- **When we did "what if's" we were guessing**
- **Can we do better? Be systematic?**
- **Apply the selection methodology**

Eco-selection for a fizzy drink bottle



Material dominates

Minimize embodied energy

Translation

Design brief

Improve green credentials of bottle

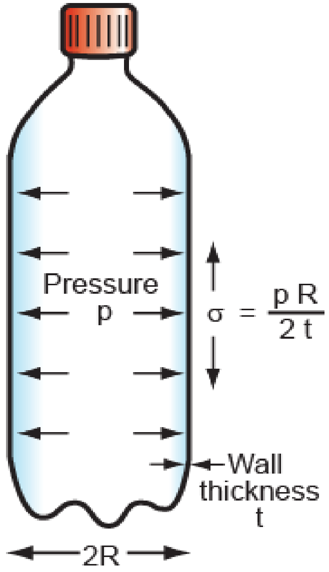
Constraints

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

Objectives

- **Minimize embodied energy 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/m^2 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

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

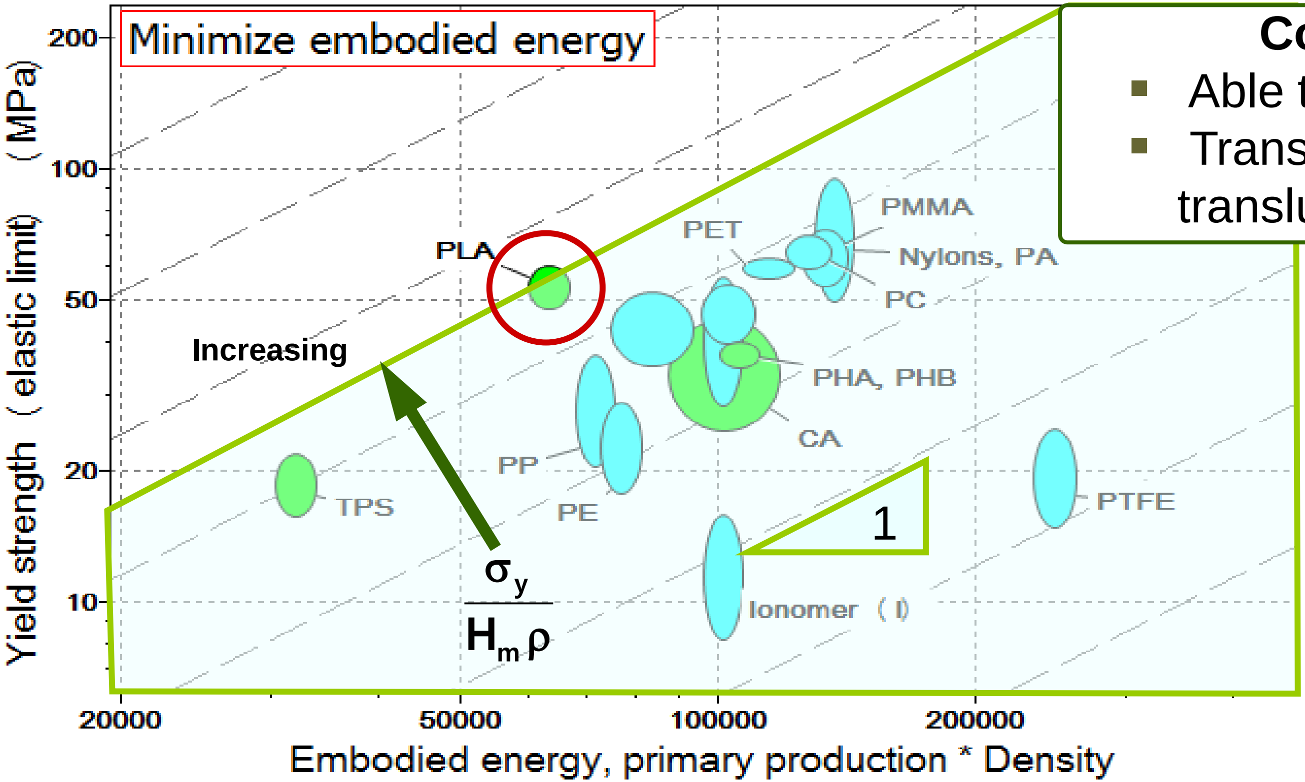
Embodied energy / kg of material

- Find material with lowest energy, seek largest

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

Selection to minimize embodied energy

First apply constraints, then use index to optimize choice



Constraints

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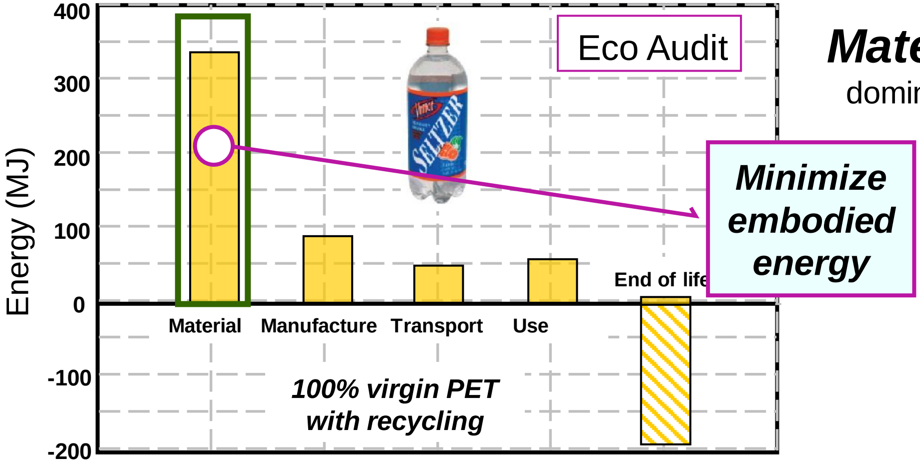
- Transparent / translucent

Bio-polymers are colored green

PLA meets the constraints at lowest embodied energy

Eco-selection for a fizzy drink bottle



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Design brief

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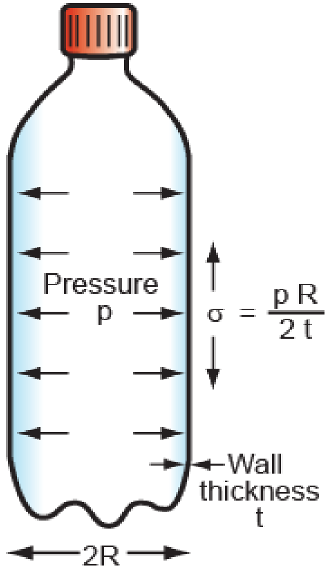
- **Minimize embodied energy of bottle**

Minimize material cost of bottle

Modelling the bottle



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Embodied energy / kg of material

- Find material with lowest energy, seek largest

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

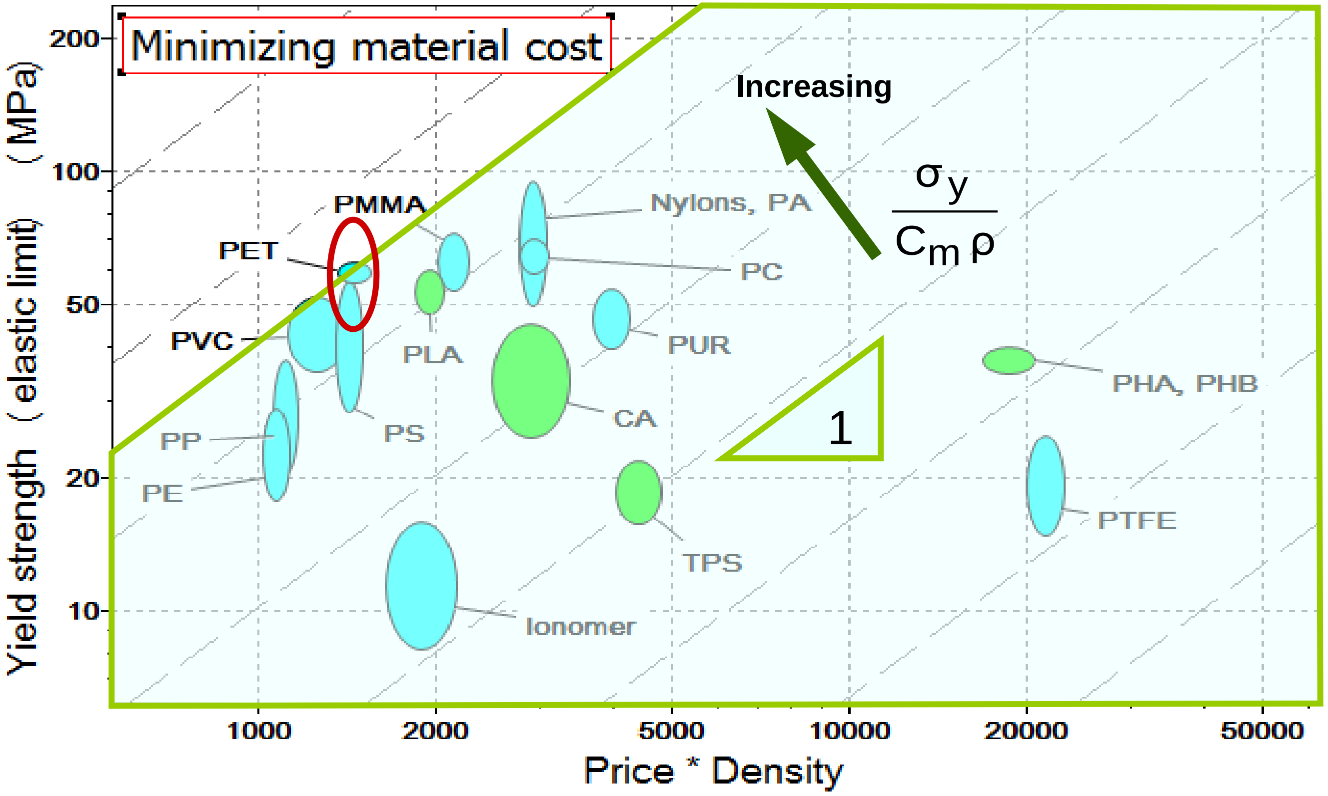
- Find material with lowest cost, seek largest

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

Price / kg of material

Selection to minimize cost

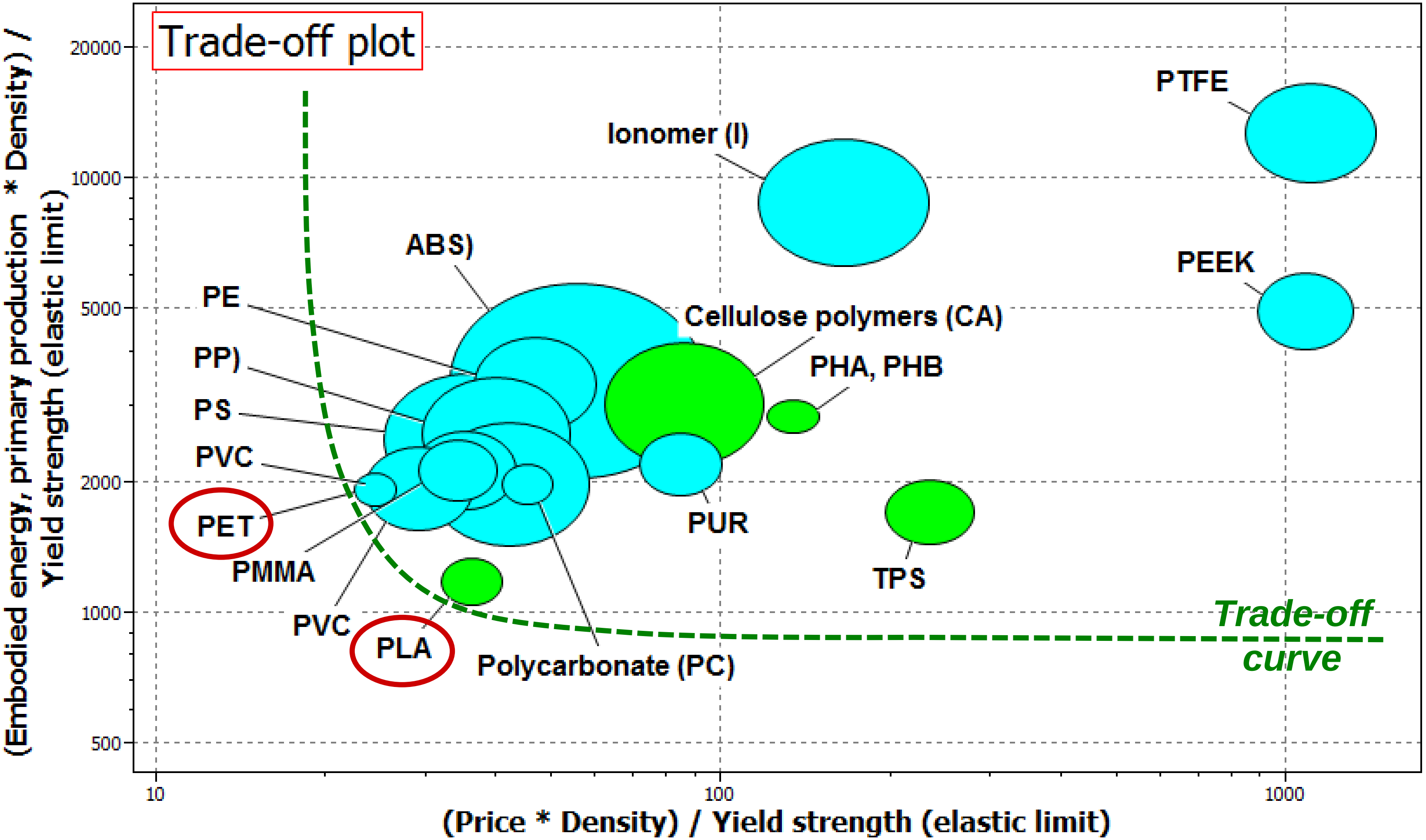
Can’t ignore cost



Bio-polymers are colored green

PET meets the constraints at lowest cost

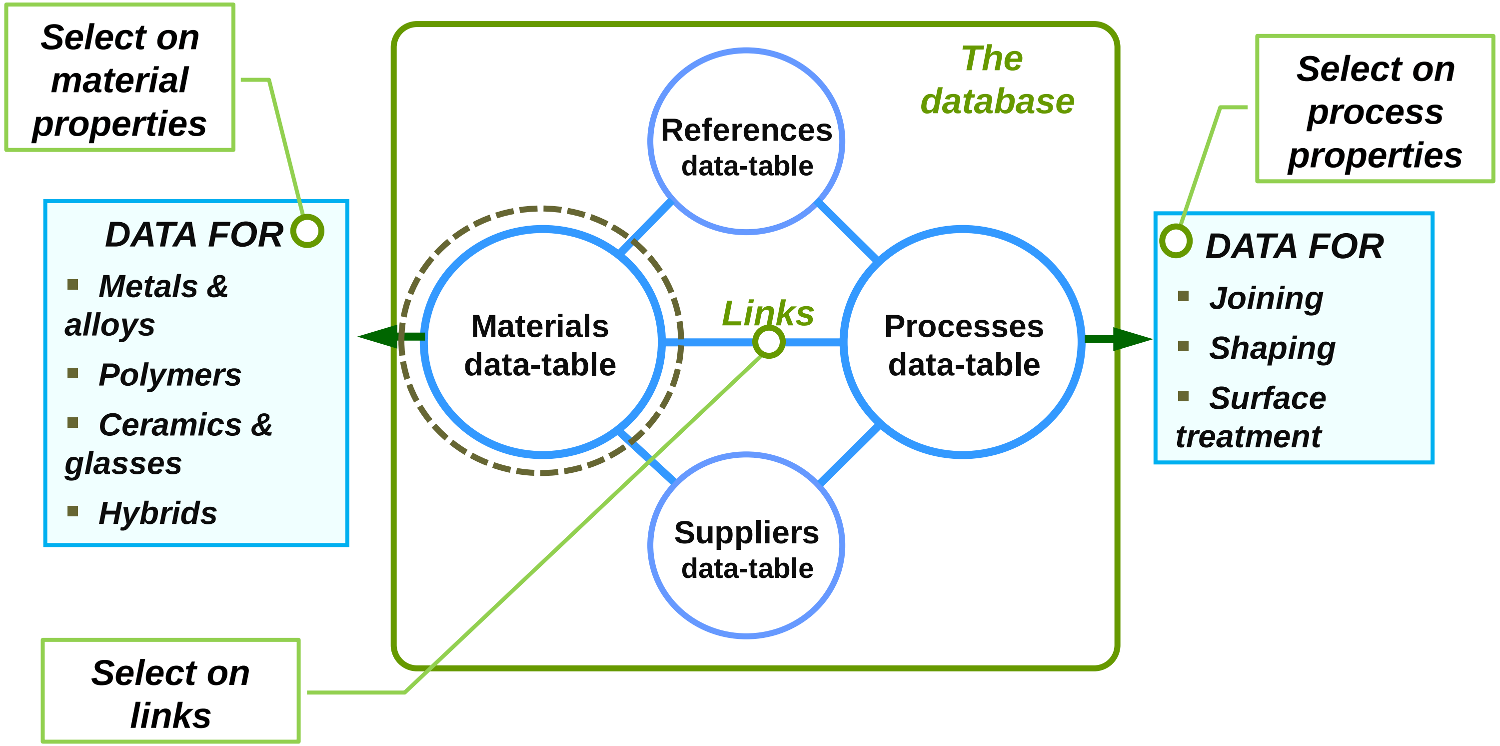
Trade-off plot



Bio-polymers are colored green

Exchange constant cost/energy not established

Organizing information



Organizing information: the PROCESS TREE