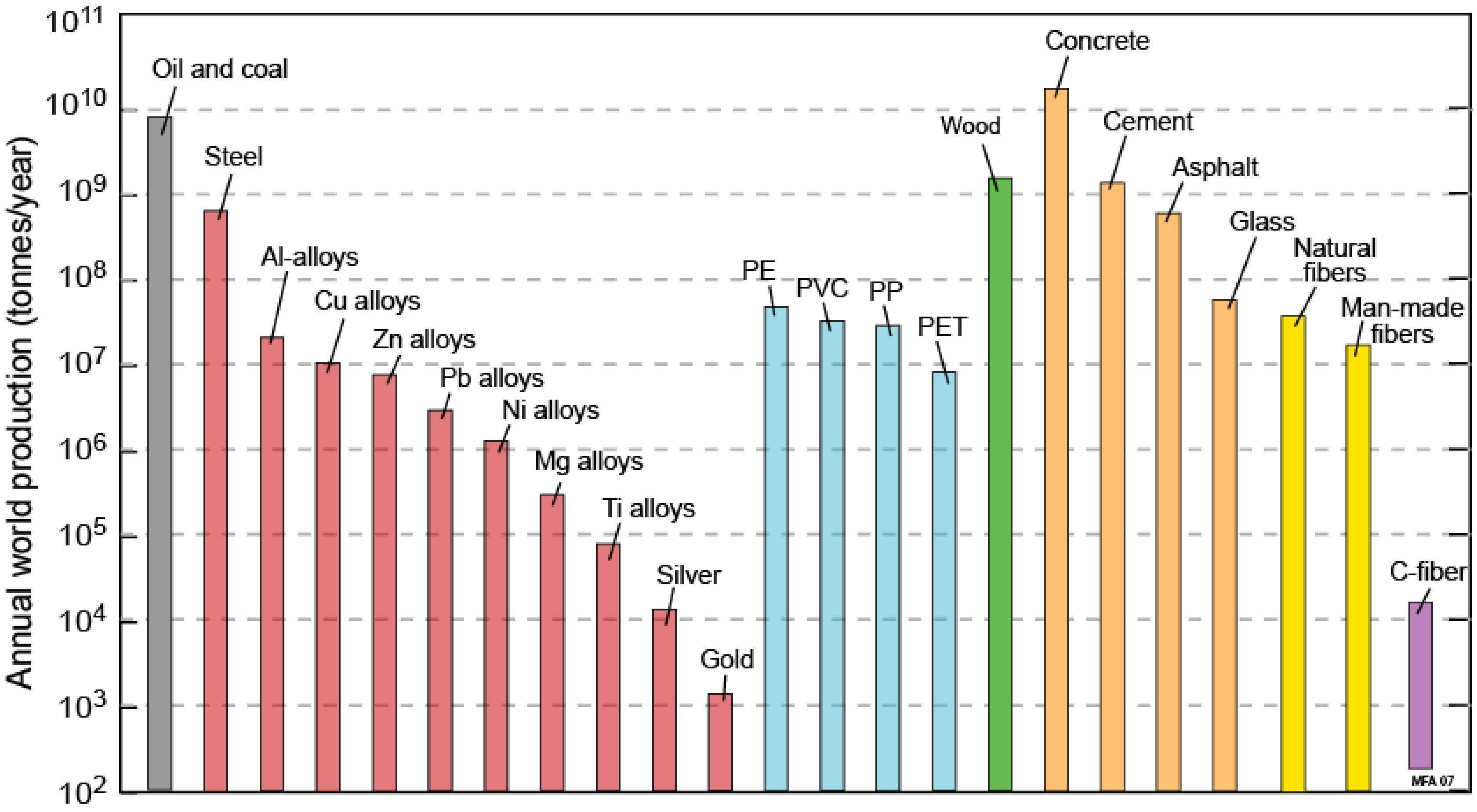
eco-selecão: escolha de material

baseado em metodologia do Prof. Ashby, Univ. de Cambridge, Inglaterra.
Aula concebida pelo prof. Cesar Azevedo, PMT.

outline

- Material consumption and the material life-cycle assessment (LCA)
- LCA, problems and solutions
- Analysis of products
- Strategy for materials selection

material production

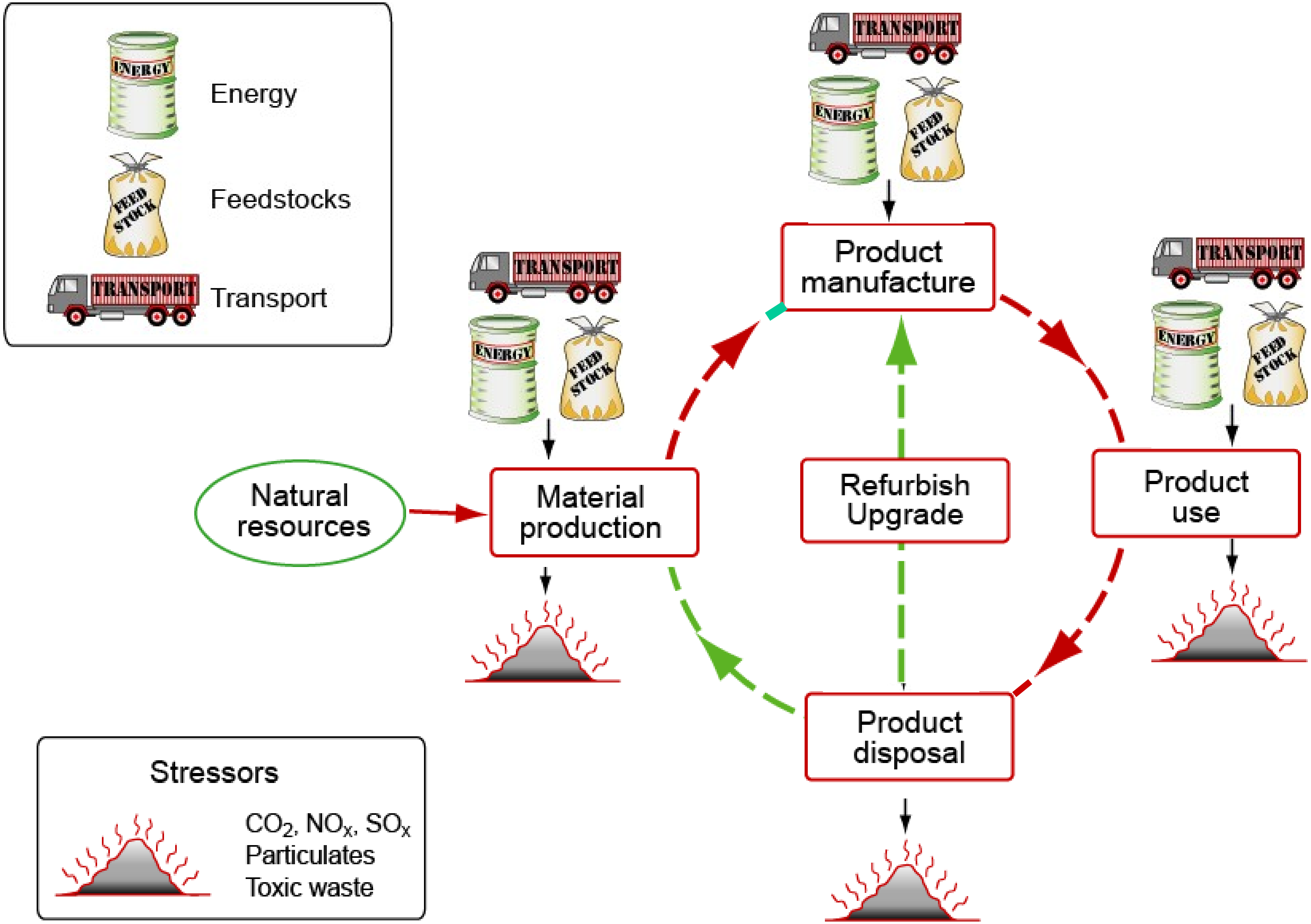


Natural fibers: cotton, silk, wool, jute

Man-made fibers: polyester, nylon, acrylic, cellulosics

(1995)

the product life-cycle



Energy

Feedstocks

Transport

Natural resources

Material production

Product manufacture

Refurbish Upgrade

Product use

Product disposal

Stressors

CO_2, NO_x, SO_x
Particulates
Toxic waste

life cycle assessment (LCA)

Typical LCA output:

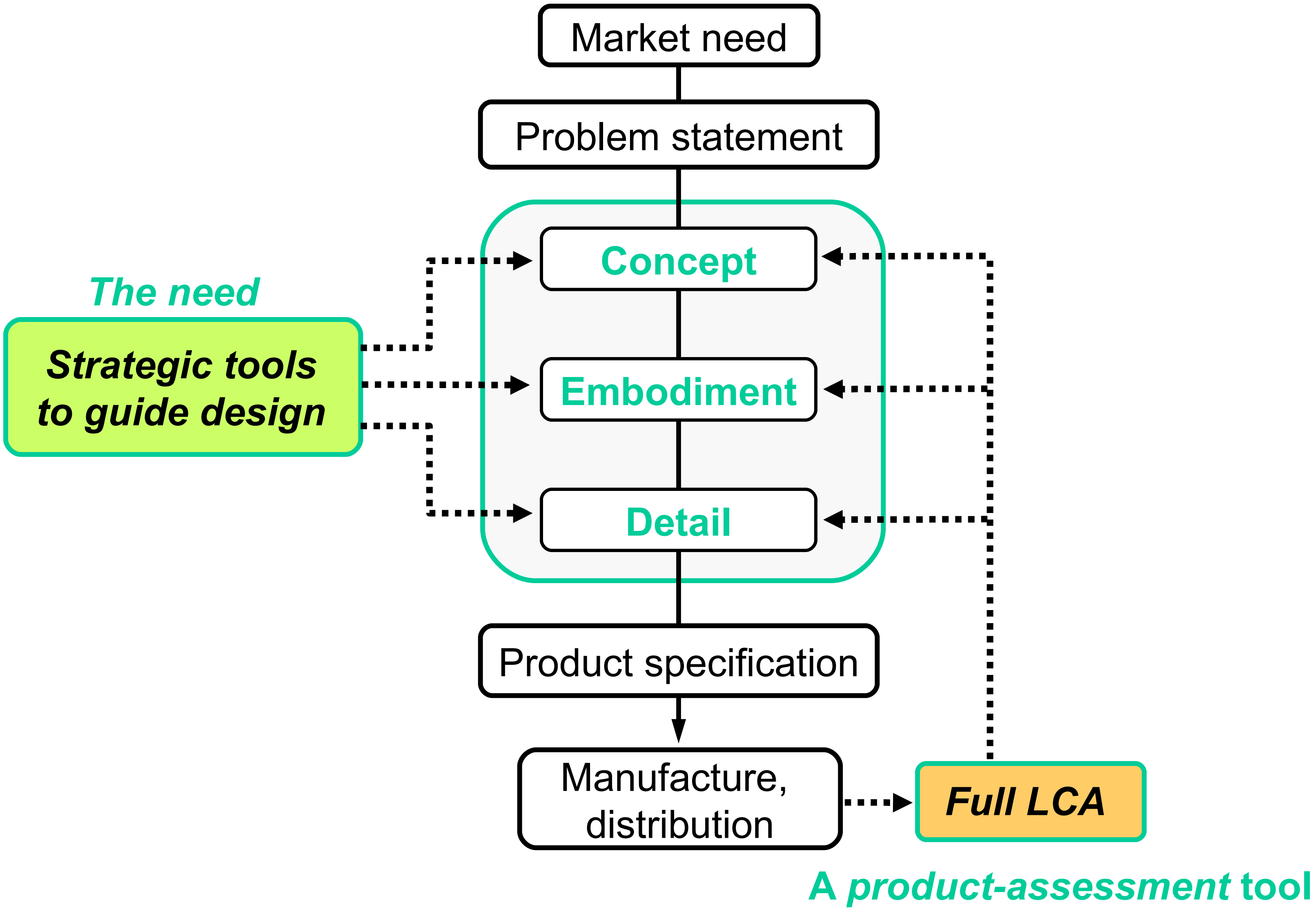
Environmental "stressors"

- Resource consumption
- Energy consumption over life
- Water consumption
- Emission of CO_2, NO_x, SO_x etc
- Particulates
- Toxic residues
- Acidification..Ozone depletion..

Roll up into an *Eco-indicator* ?

- Full LCA *time consuming, expensive*, and requires great *detail* – and even then is subject to uncertainty
- What is a designer supposed to do with these numbers?
- LCA is a *product assessment tool*, not a design tool

LCA in the context of eco-design



Market need

Problem statement

Concept

Embodiment

Detail

Product specification

Manufacture, distribution

The need

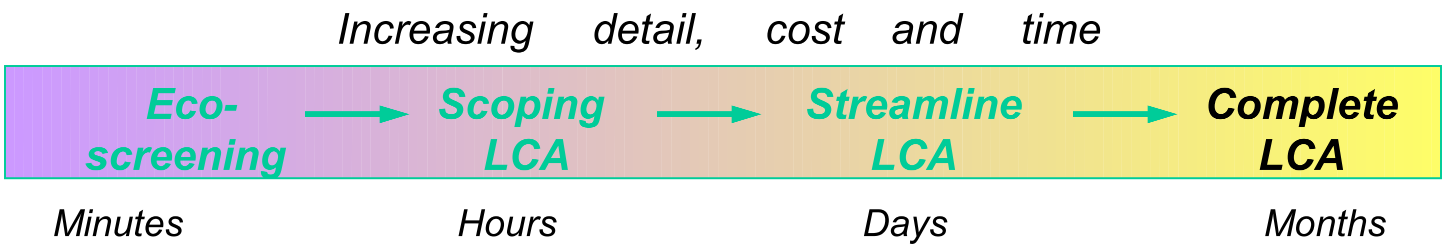
Strategic tools to guide design

Full LCA

A *product-assessment* tool

strategies for guiding eco-design

- **Step 1:** Seek method that combines acceptable cost burden with adequate accuracy to guide decision making – a *design tool*



Increasing detail, cost and time

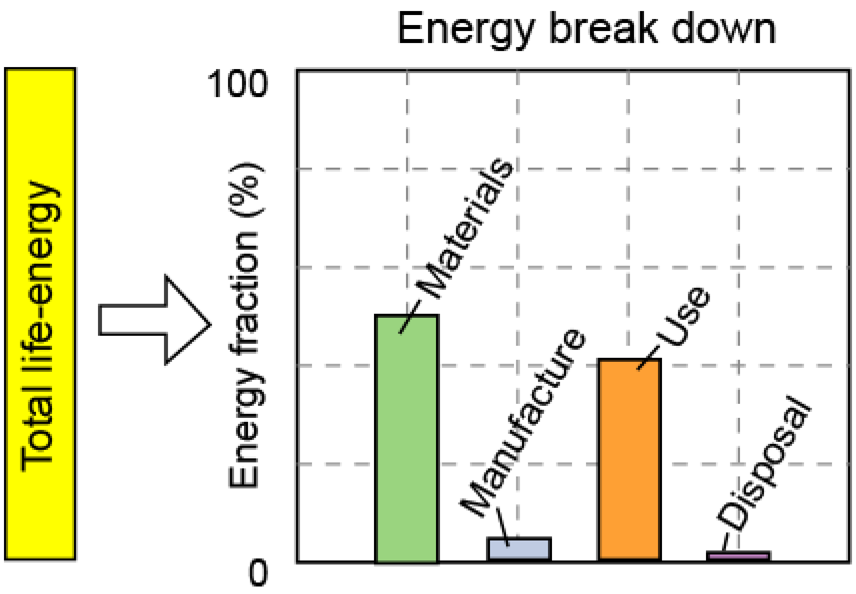
Eco-screening → ***Scoping LCA*** → ***Streamline LCA*** → ***Complete LCA***

Minutes *Hours* *Days* *Months*

- **Step 2:** Seek single measure of stress

  – energy or CO_2

- **Step 3:** Separate life-phases



strategies for guiding eco-design

- **Why energy or CO_2?**
  - **Kyoto Protocol (1997): international agreement to reduce greenhouse gasses**
  - **EU directives such as the EuP directive (2006)**
  - **Practicality:** CO_2 and Energy are related and understood by the public

- ***Cars: use-energy and CO_2 cited***

Appliances: use-energy cited

Official fuel economy figures:

Combined: 6 – 11 litre / 100km

CO_2 emissions: 158 – 276 g / km

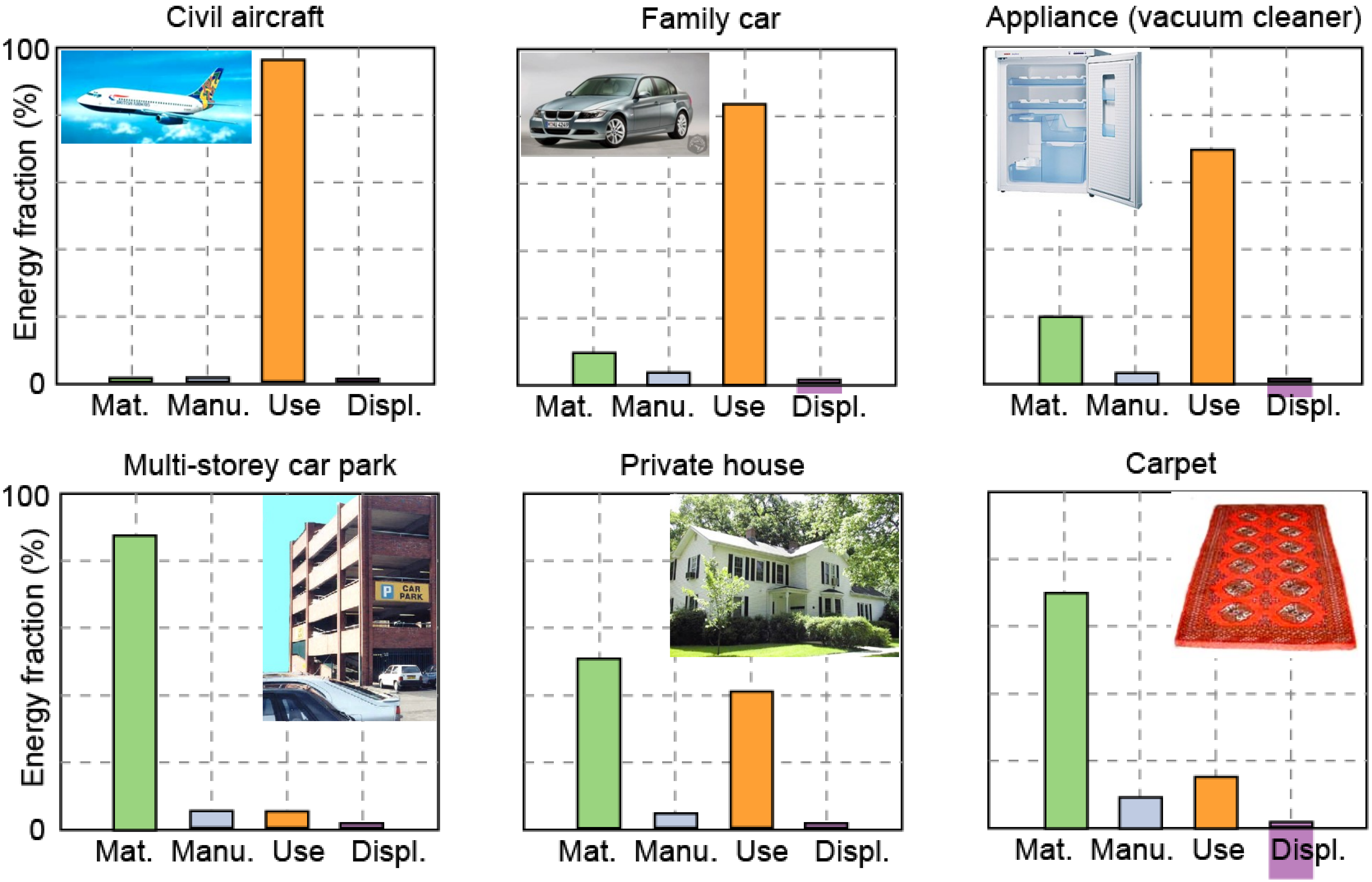
Efficiency rating: A

Volume 0.3 m^3

330 kWhr / year

energy consumption of products

Which phase dominates? Approximate breakdown (Bey, 2000., Allwood, 2006):



what is embodied energy of a material?

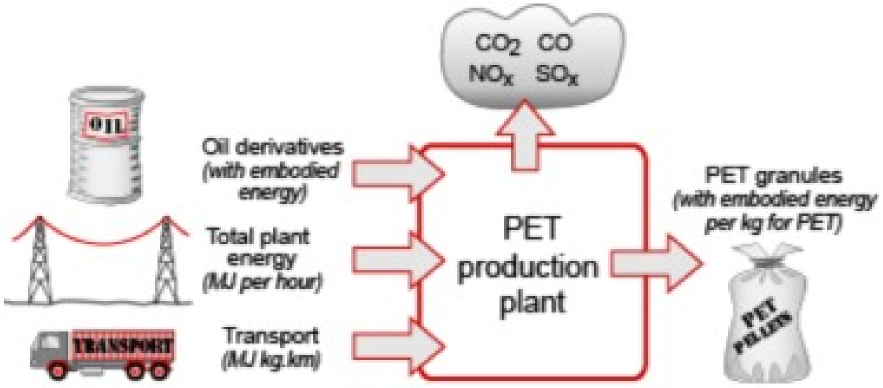


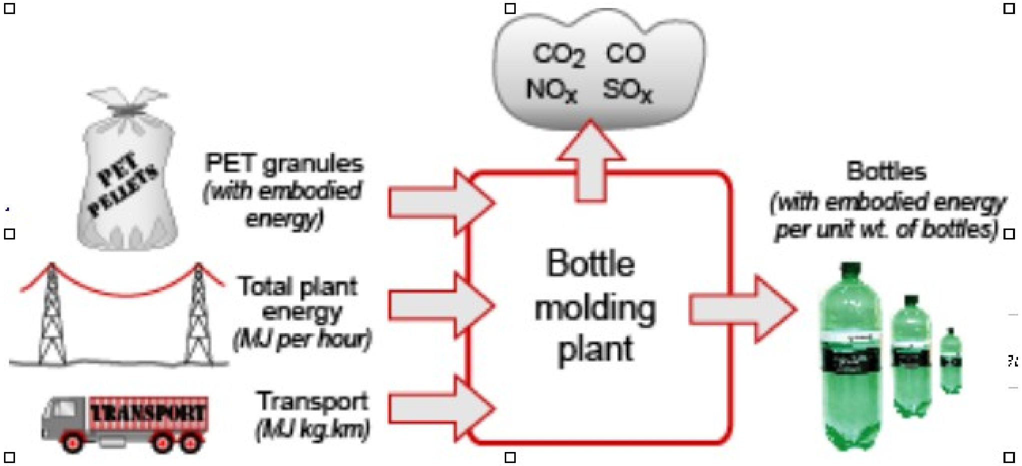
Figure 1. Input/output diagram for the production of PET granules.

definition and measurement. is the energy other than that from bio-fuels that is committed in making a unit weight of material from its ores and feedstock.

The *embodied energy* per unit weight (here, of the PET) is:

$$(H_e)_{PET} = \frac{\sum \textit{Energy entering plant per year}}{\textit{Mass of PET granules shipped per year}}$$

what is the embodied energy of a product?

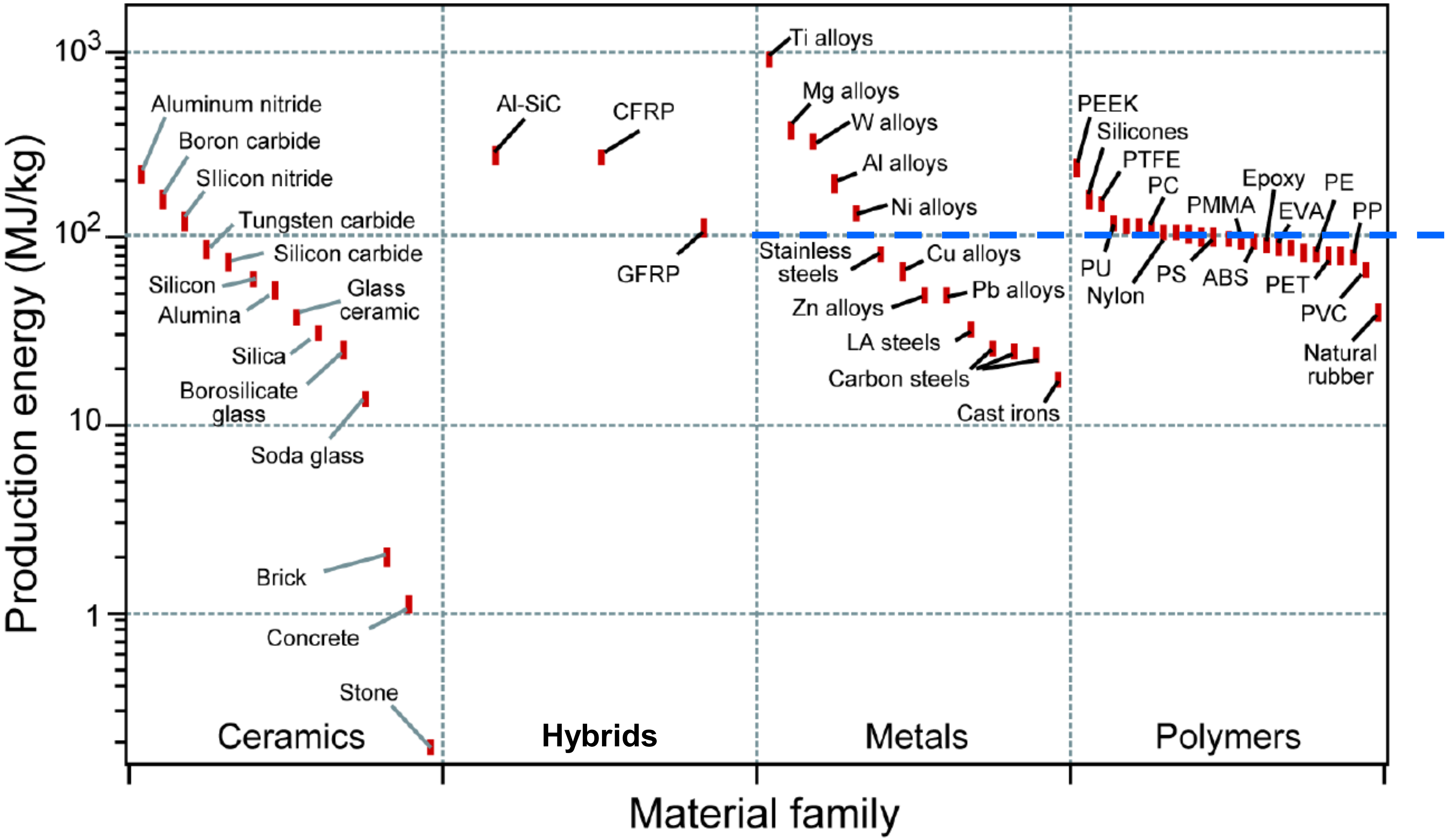


Materials are one input to a manufacturing plant. The energy and material flows are sketched as an input/output diagram in Figure 1.Granules and materials for finishing and packaging have an embodied energy. These are transported to the plant, consuming energy to do so, which in turn consumes energy to run and maintain the process equipment, provide heating, lighting, and other services. The total of these is the input energy to the plant. This, divided by the weight of usable bottles shipped is the *embodied energy* of the product:

$$\left(H_p\right)_{PET\ bottles} = \frac{\sum Energy\ \ entering\ \ plant\ \ per\ \ year}{Mass\ \ of\ \ PET\ \ bottles\ \ shipped\ \ per\ \ year}$$

production energy of materials per kg

CES Edu Level 2 DB



production energy of materials per m^3

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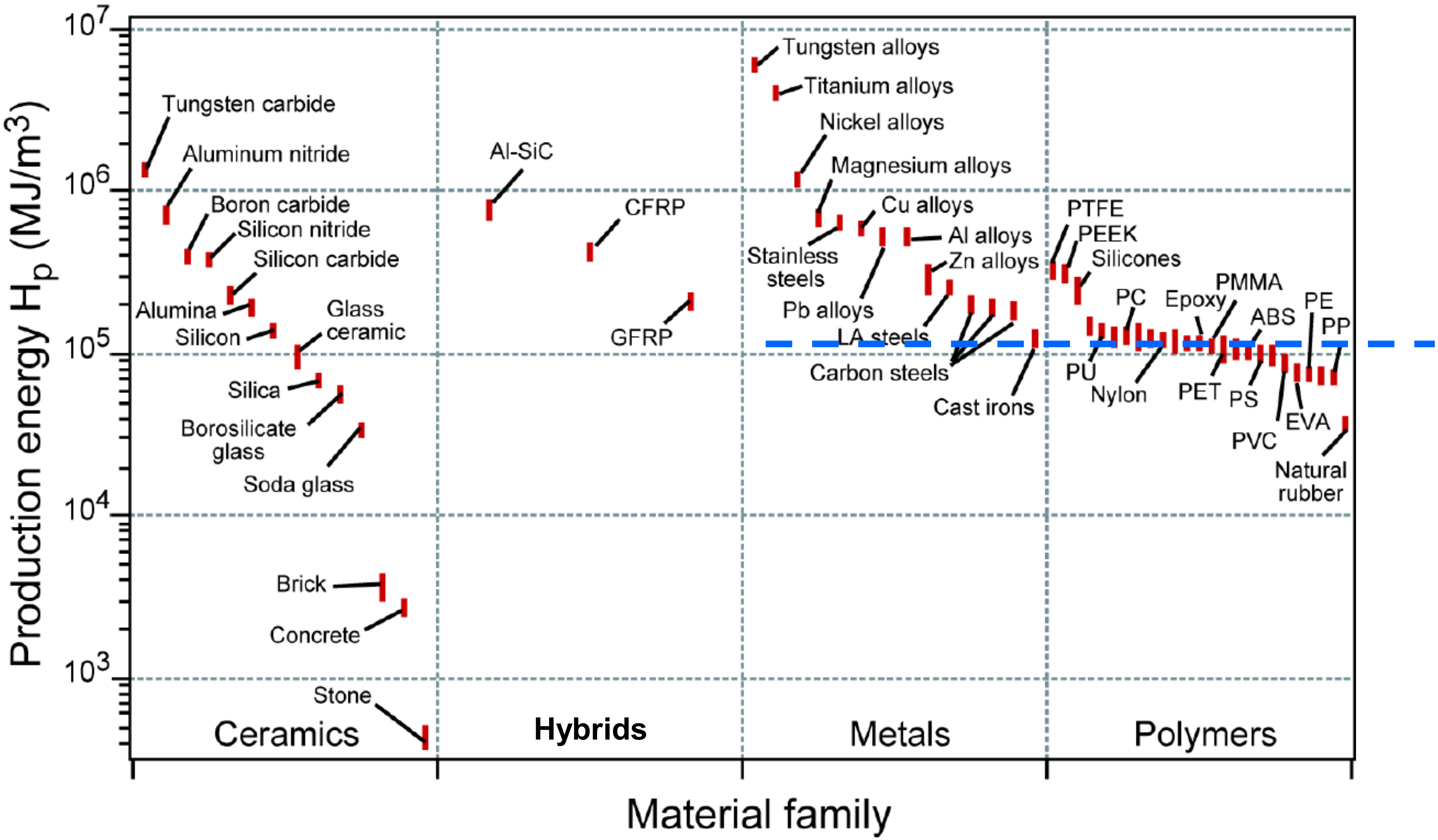

Resistência por energy per m^3

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Viga resistente e ecológica

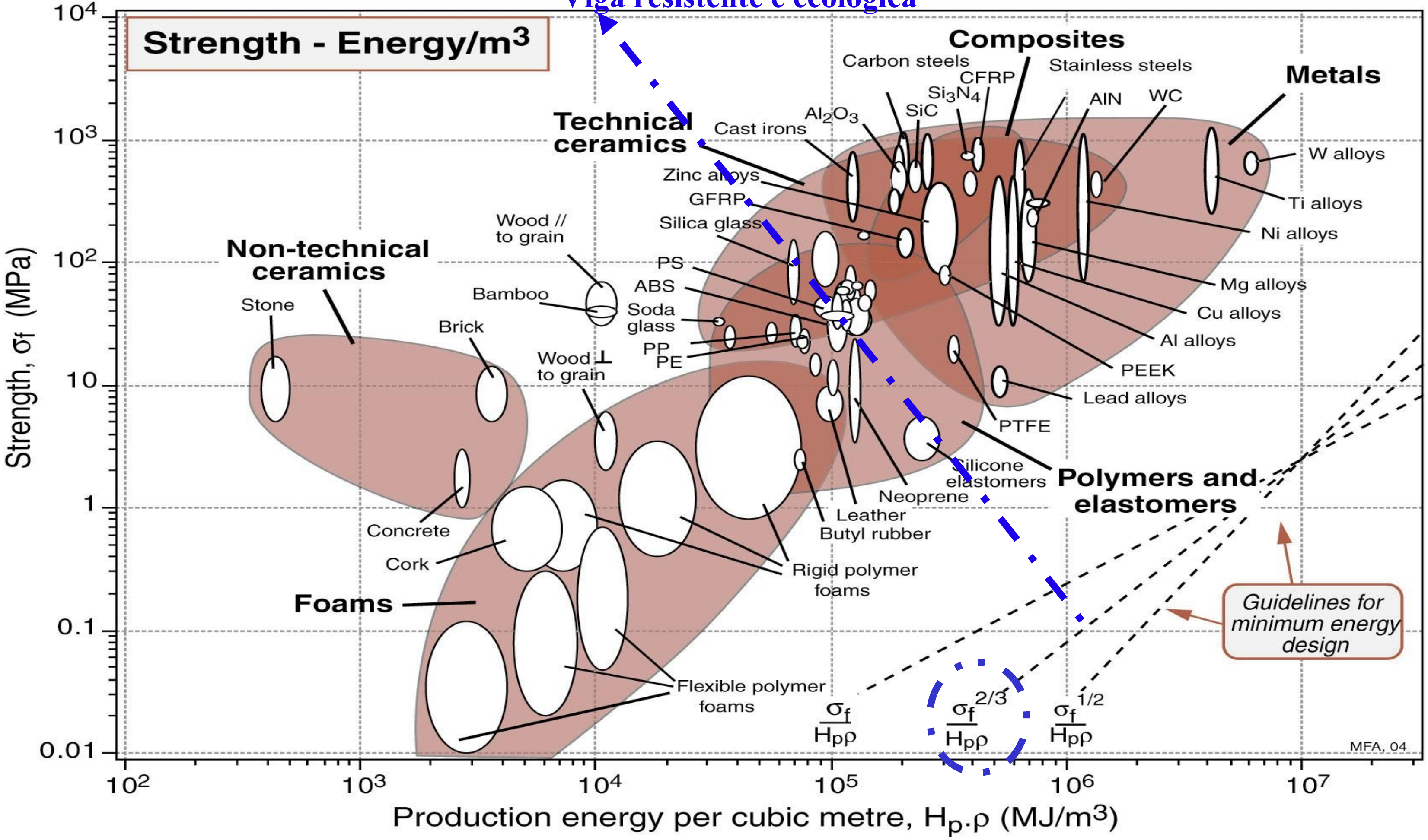


Figure 16.9 A selection chart for strength with minimum production energy. It is used in the same way as Figure 4.4.

strategies

- **What should strategic tools do?**
- **Example: drink containers**

Glass

PE

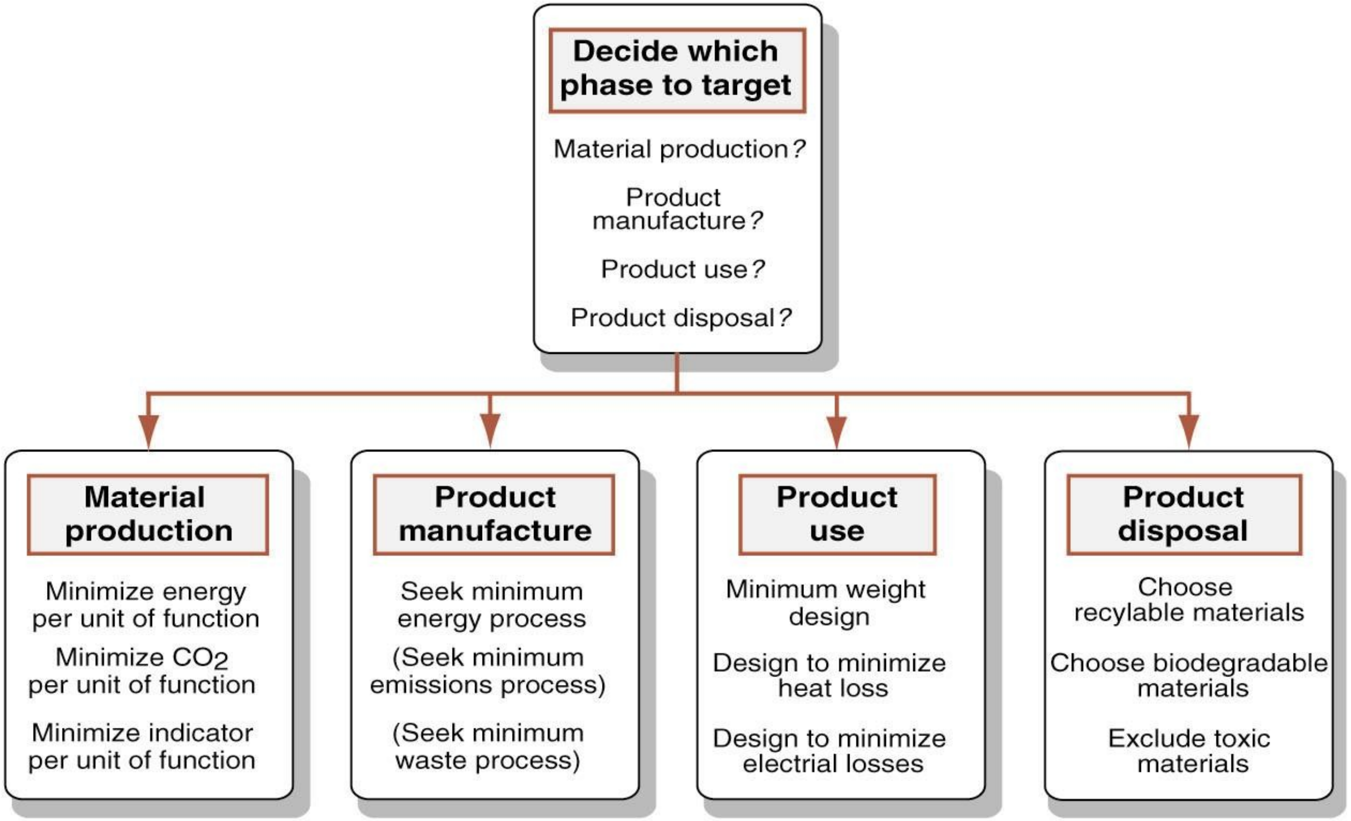
PET

Aluminum

Steel

- Aims:
  - to assess energy or CO_2 burden quickly and cheaply
  - to explore alternatives

strategies



Decide which phase to target

Material production?

Product manufacture?

Product use?

Product disposal?

Material production

Minimize energy per unit of function

Minimize CO_2 per unit of function

Minimize indicator per unit of function

Product manufacture

Seek minimum energy process

(Seek minimum emissions process)

(Seek minimum waste process)

Product use

Minimum weight design

Design to minimize heat loss

Design to minimize electrial losses

Product disposal

Choose recylable materials

Choose biodegradable materials

Exclude toxic materials

Figure 16.5 Rational design for the environment starts with an analysis of the phase of life to be targeted. This decision then guides the method of selection to minimize the impact of the phase on the environment.

eco-evaluation

PET bottle

- Separate the phases of life

1. Material production: the embodied energy

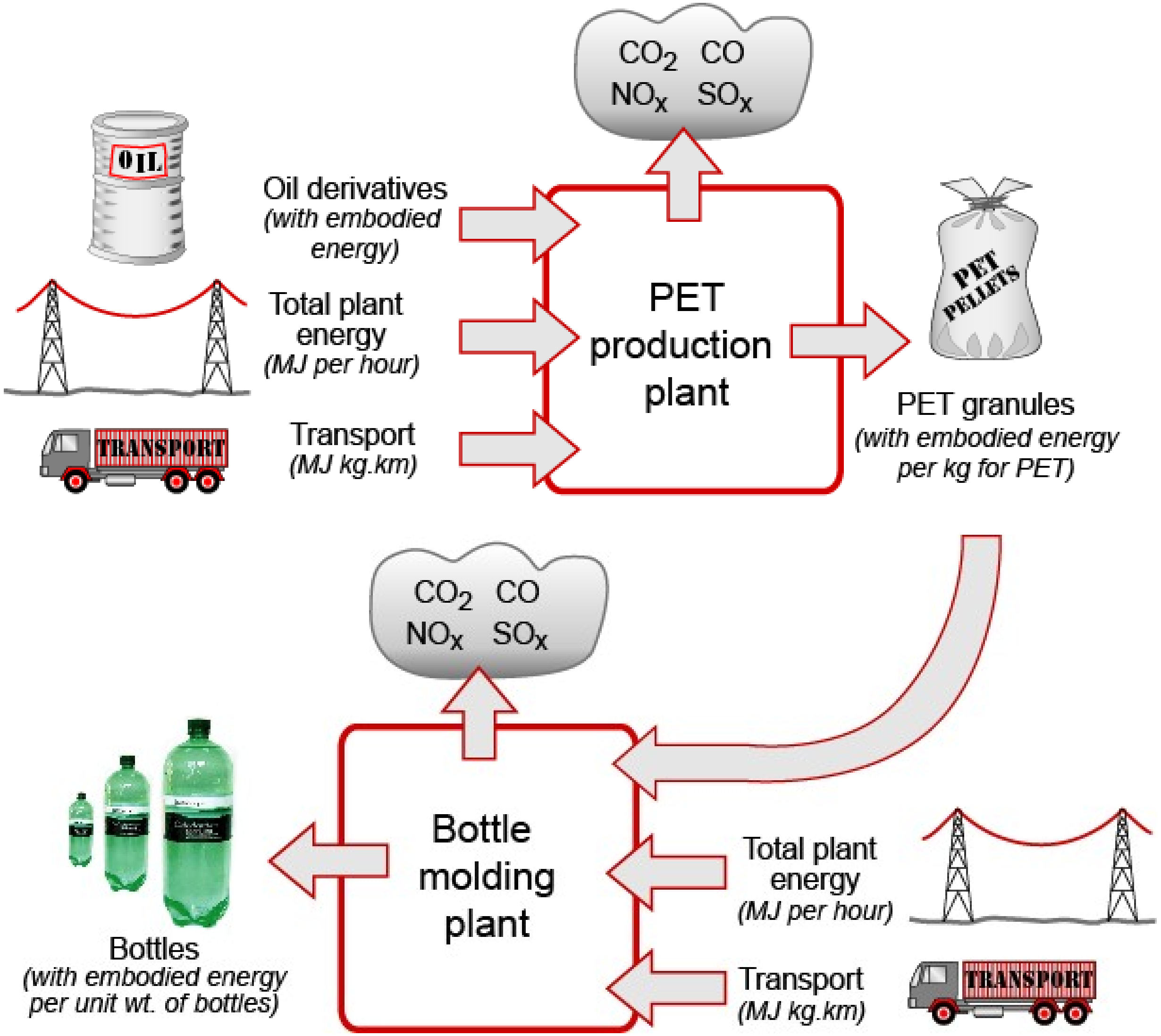
2. Bottle manufacture: the processing energy

3. Delivery and use: transport and refrigeration

4. Disposal: collection, recycling, energy recovery

- To assess, need both *local and generic data.*

embodied energy



CO_2 CO
NO_x SO_x

Oil derivatives
(with embodied energy)

Total plant energy
(MJ per hour)

Transport
(MJ kg.km)

PET production plant

PET granules
(with embodied energy per kg for PET)

CO_2 CO
NO_x SO_x

Bottle molding plant

Total plant energy
(MJ per hour)

Transport
(MJ kg.km)

Bottles
(with embodied energy per unit wt. of bottles)

Generic data

Material energy MJ / kg

- **Database of embodied energies for materials**

Process energy MJ / kg

- **Database of processing energies for materials**

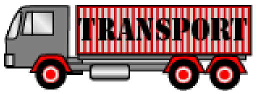
Transport, MJ / tonne.km

Sea freight	**0.11 – 0.15**
Barge (river)	**0.75 – 0.85**
Rail freight	**0.80 – 0.9**
Truck	**0.9 – 1.5**
Air freight	**8.3 – 15**

use energy and disposal

1. **Material production: the embodied energy**

2. **Bottle manufacture: the processing energy**



3. **Delivery and use: transport and refrigeration**

4. **Disposal: collection, recycling, energy recovery**

Generic data

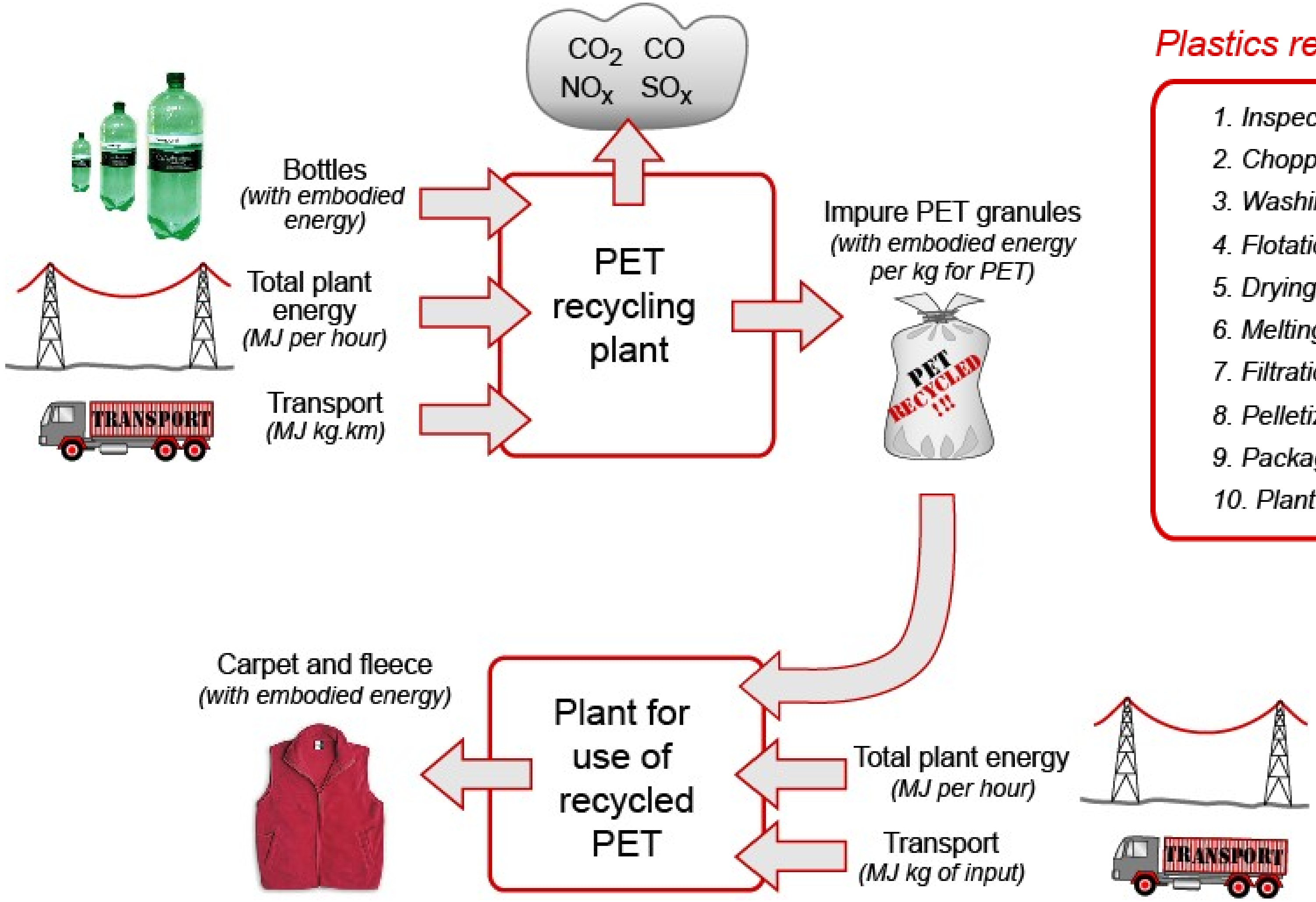
Transport, MJ / tonne.km

- **As before**

Refrigeration, MJ/m³.day

- **Refrigeration (4°C) 10.5**
- **Freezing (-5°C) 13.0**

disposal: recycling – the problems



CO_2 CO
NO_x SO_x

Bottles
(with embodied energy)

Total plant energy
(MJ per hour)

Transport
(MJ kg.km)

PET recycling plant

Impure PET granules
(with embodied energy per kg for PET)

Carpet and fleece
(with embodied energy)

Plant for use of recycled PET

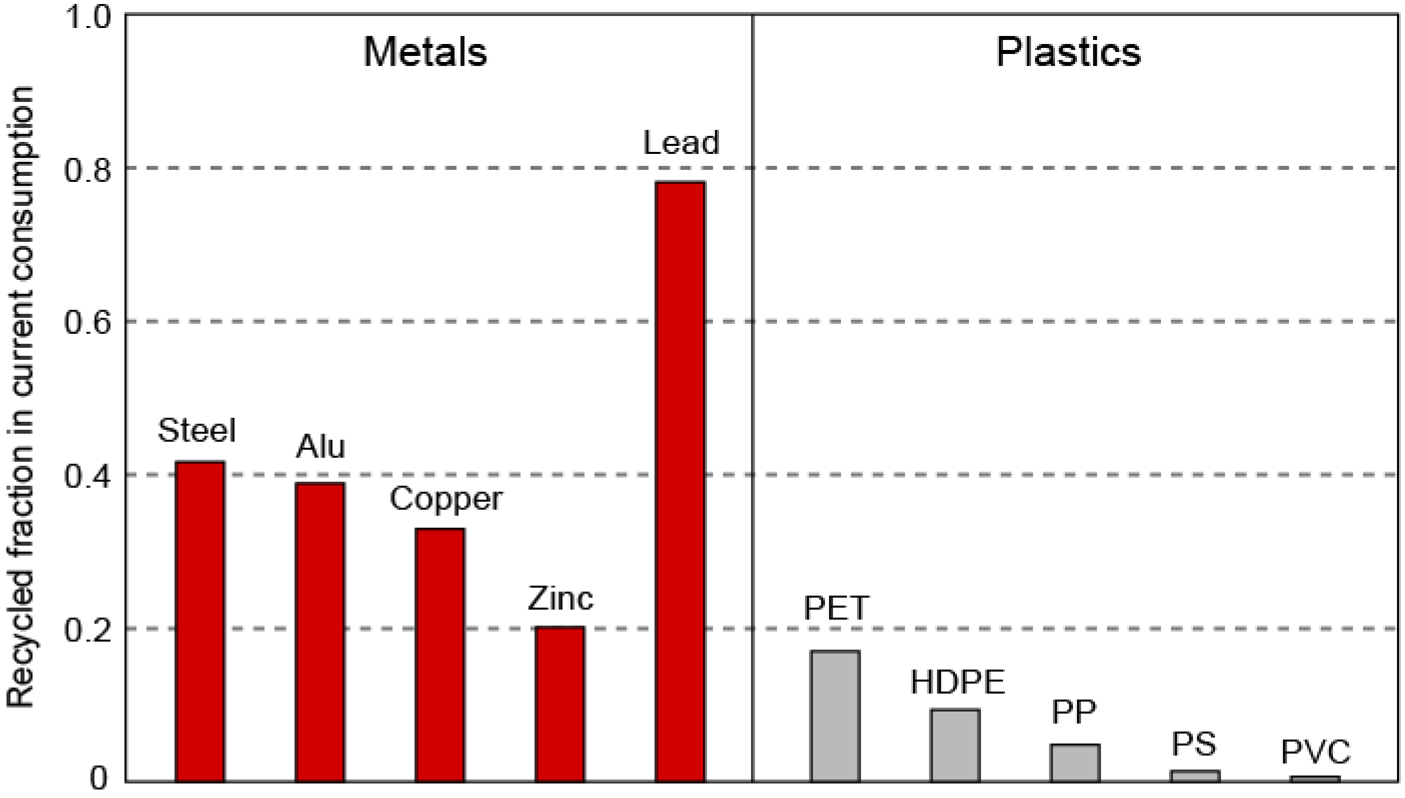
Total plant energy
(MJ per hour)

Transport
(MJ kg of input)

Plastics recycling plant

1. *Inspection*
2. *Chopping*
3. *Washing*
4. *Flotation-separation*
5. *Drying*
6. *Melting*
7. *Filtration*
8. *Pelletizing*
9. *Packaging*
10. *Plant heating, lighting*

recycle fractions for commodity materials



drink container: the evaluation tool

INPUTS by user

Materials

PET body	38 g
PP cap	5 g

Manufacture

PET body moulded	38 g
PP cap moulded	5 g

Use

Refrigeration	5 days
Transport	200 km

Disposal

Recycling ?	Yes
Transport	15,000 km

RETRIEVE from database

Material energy MJ / kg

Embodied energy, PET	85
Energy to blow mould	11

Transport, MJ / tonne.km

Sea freight	0.11
Truck	1.3

Refrigeration, MJ / m^3.day

Refrigeration (4°C)	10.5
Freezing (-5°C)	13.0

Record for PET

Polyethylene terephthalate (PET)

- **General Properties**
- Density 939- 960kg/m^3
- Price 1.3 - 1.45 US $/kg
- **Mechanical Properties**
- Young's Modulus 0.6 - 0.9 GPa
- Elastic Limit 17.9 - 29 MPa
- Tensile Strength 20 - 45 MPa
- Elongation 200- 800%
- Hardness - Vickers 5.4 - 8.7 HV
- Fracture Toughness 1.4 - 1.7 MPa.m$^{1/2}$
- **Thermal Properties**
- Max Service Temp 100- 120C
- Thermal Expansion 126- 198$10^{-6}$/K
- Specific Heat 1810 - 1880 J/kg.K
- Thermal Conductivity 0.4 - 0.44 W/m.K
- **Electrical Properties**
- Resistivity 3 x 10^{22}- 3 x 10^{24} μΩ.cm
- Dielectric constant 2.2 - 2.4

Thermo-mechanical design

Eco-properties: production

Production energy: **77 - 85 MJ/kg**

Carbon dioxide: **1.9 - 2.2 kg/kg**

Recycle ? ☑ **yes**

Eco-properties: manufacture

Injection/blow moulding: **12 -15 MJ/kg**

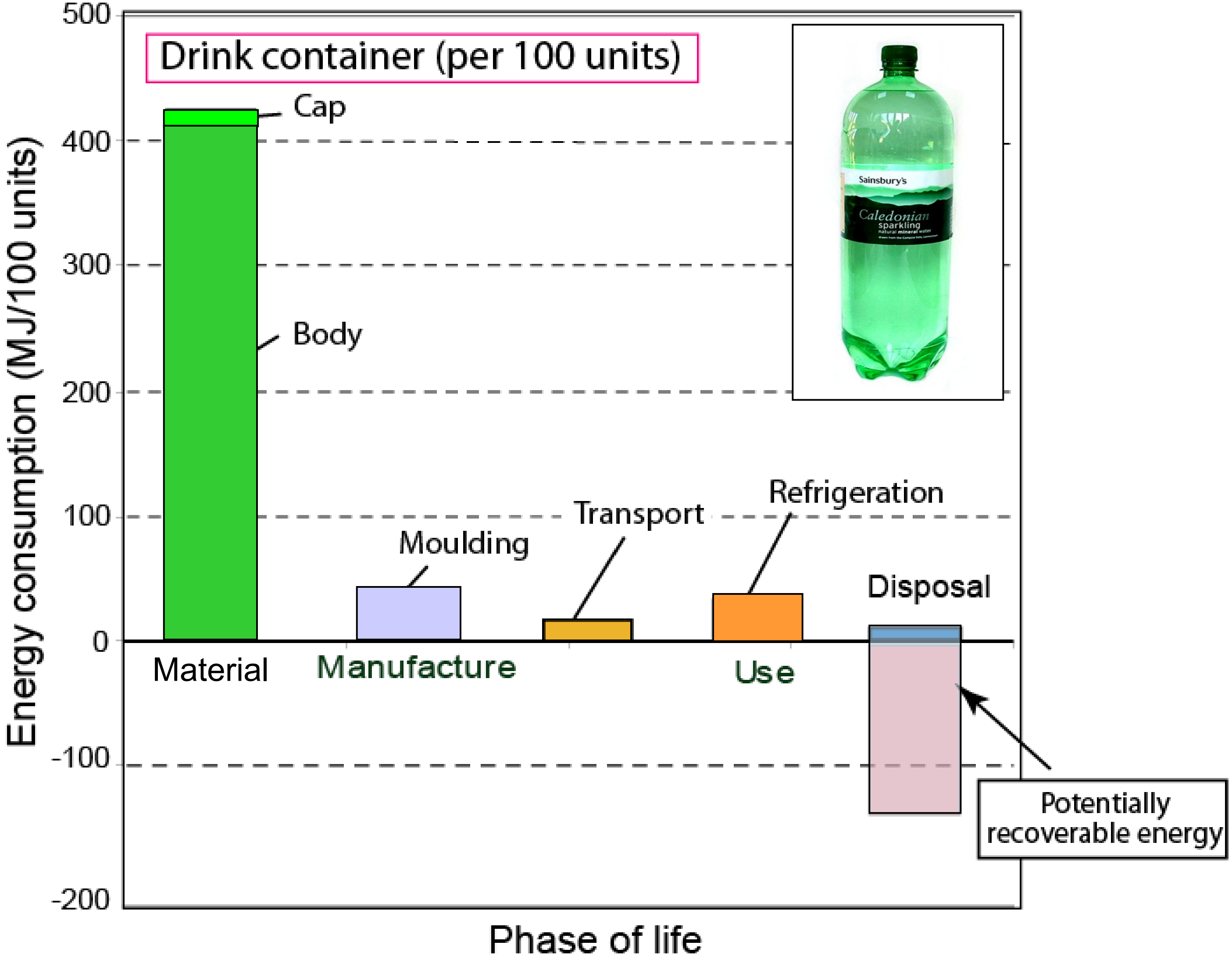
Polymer extrusion: **3 -5 MJ/kg**

Environmental notes.

PE is FDA compliant - it is so non-toxic that it can be embedded in the human body (heart valves, hip-joint cups, artificial artery).

Energy/CO_2 efficient design

energy breakdown for PET bottle



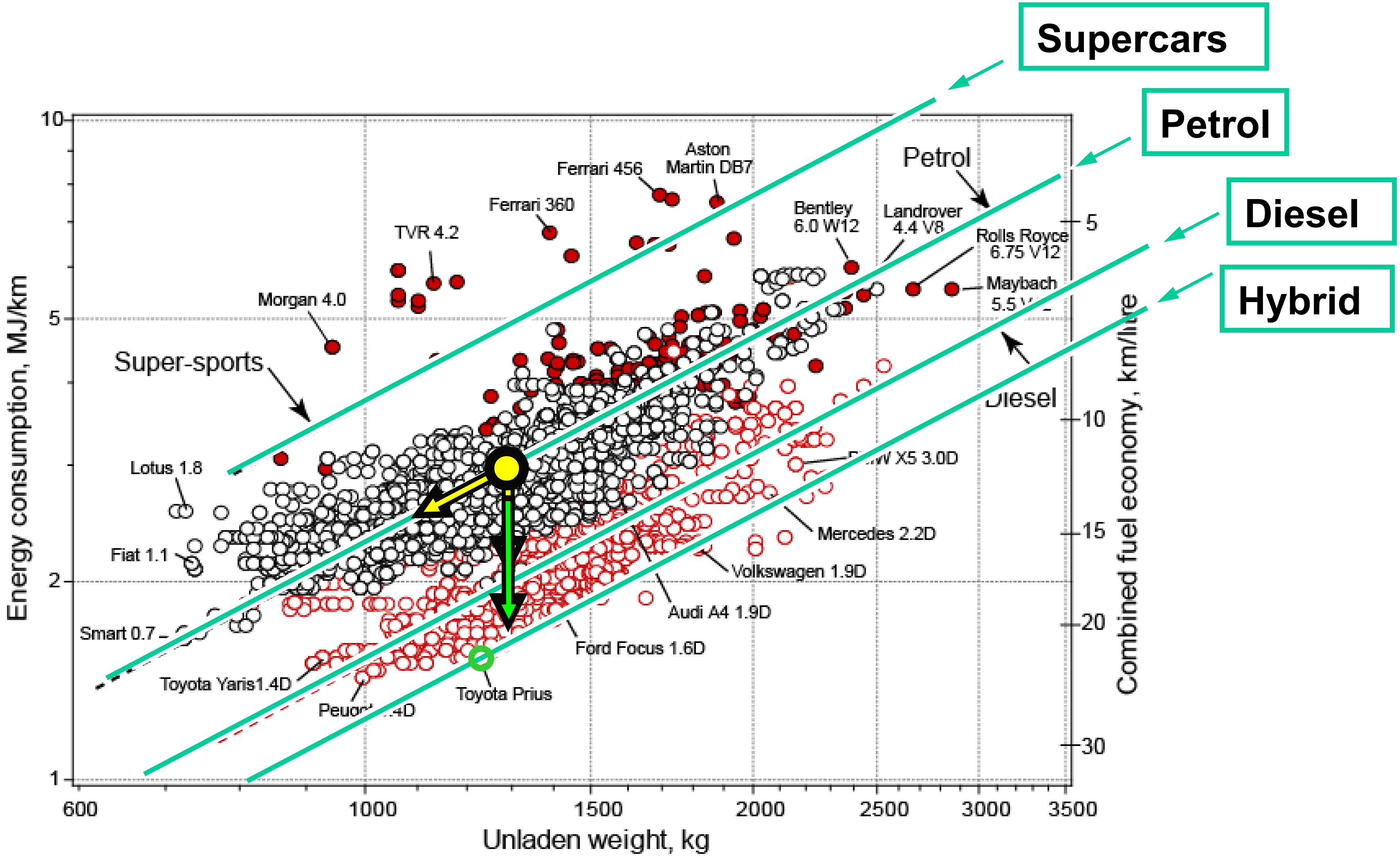
embodied energy per unit of function

Function: ***contain 1 litre of fluid***

	Glass	PE	PET	Aluminum	Steel	
Mass	325	38	25	**20**	45	**g**
Mass/litre	433	38	62	45	102	**g/litre**
Emb. energy	**14**	80	84	200	23	**MJ/kg**
Energy/litre	8.2	3.2	5.4	9.0	**2.4**	**MJ/litre**

- ***Steel*** **wins on material embodied energy**
- Processing?
- Recycling?
- Toxicity?

cars


Supercars
Petrol
Diesel
Hybrid
10
5
2
1
Energy consumption, MJ/km
600
1000
1500
2000
2500
3000
3500
Unladen weight, kg
5
10
15
20
30
Combined fuel economy, km/litre
Super-sports
Petrol
Diesel
Aston Martin DB7
Ferrari 456
Ferrari 360
TVR 4.2
Morgan 4.0
Bentley 6.0 W12
Landrover 4.4 V8
Rolls Royce 6.75 V12
Maybach 5.5 V12
Lotus 1.8
Fiat 1.1
Smart 0.7
Toyota Yaris1.4D
Peugeot 1.4D
Toyota Prius
Ford Focus 1.6D
Audi A4 1.9D
Volkswagen 1.9D
Mercedes 2.2D
BMW X5 3.0D

applying the strategy in eco-design

1. Analysis

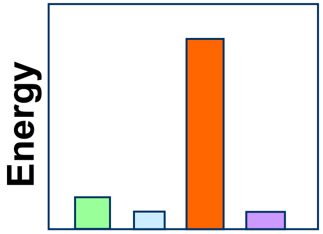
Assess energy use over life

Production

Manufacture

Use

Disposal



2. Strategy

Material

Minimize:

- **embodied energy**
- **CO_2 / kg**

Manufacture

Minimize:

- **process energy**
- **CO_2/kg**

Use

Minimize:

- **weight**
- **heat loss**
- **electrical loss**
- **system**

Disposal

Select:

- **recyclable**
- **non- toxic materials**

the main points

Scoping LCA gives quick, approximate “portrait” of energy / CO_2 burden of products. A practical tool for assessing eco-burden and guiding (re)-design.

Separate the life-phases

- Material
- Manufacture
- Use
- Disposal

Base material choice on **relative contributions to stress**

Consider system dependence

- Optimise within one concept
- Explore alternative concepts

- Base desse trabalho:
- Livros do professor Ashby, Inglaterra.