Materiais e Desenvolvimento Sustentável

Auditoria ecológica

42295

2024/2025

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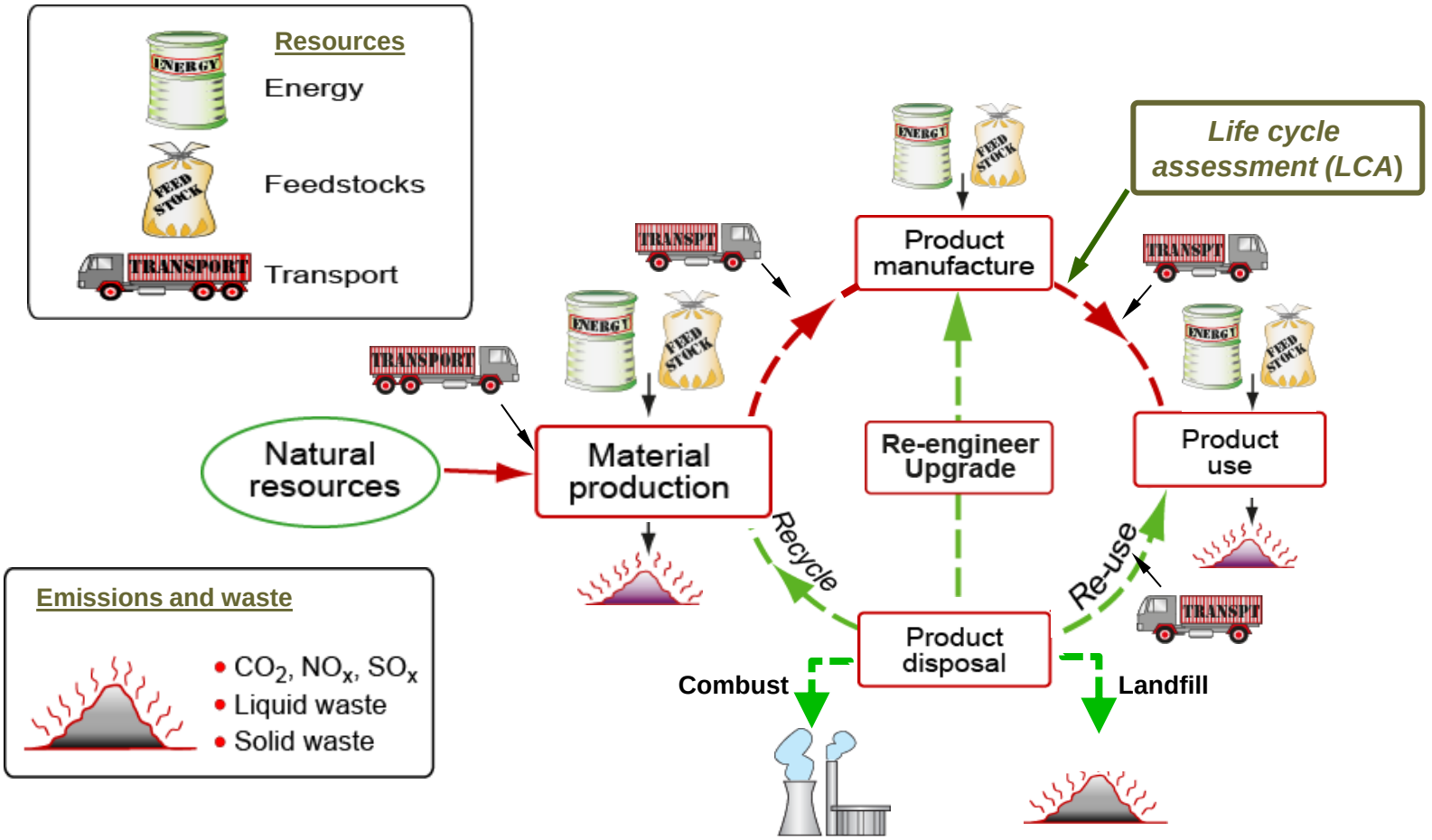
Ciclo de vida do produto



Fonte: Granta Design and Mike Ashby, 2020.

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Life cycle assessement (LCA)

ISO 14040 – Sistema de gestão ambiental

***Resultados* típicos de um LCA**

Latas de alumínio, por 1000 units

Consumo de recursos	• *Bauxite*	*59*	*kg*
	• *Oil fuels*	*148*	*MJ*
	• *Electricity*	*1572*	*MJ*
	• *Energy in feedstock*	*512*	*MJ*
	• *Water use*	*1149*	*kg*
Inventário das emissões	• *Emissions: CO_2*	*211*	*kg*
	• *Emissions: CO*	*0.2*	*kg*
	• *Emissions: NO_x*	*1.1*	*kg*
	• *Emissions: SO_x*	*1.8*	*kg*
	• *Particulates*	*2.47*	*kg*
Avaliação de impacto	• *Ozone depletion potential*	*0.2×10^{-9}*	
	• *Global warming potential*	*1.1×10^{-9}*	
	• *Acidification potential*	*0.8×10^{-9}*	
	• *Human toxicity potential*	*0.3×10^{-9}*	

Qual a situação de cada *"eco-indicador"* ?

- Uma análise do LCA de um produto/material é um processo que requere grande **detalhe** e **experiência**, sendo um **processo moroso** e como tal **caro.**

Consensual: o LCA é ***inviável*** como ferramenta de design de rotina.

Alternativa???

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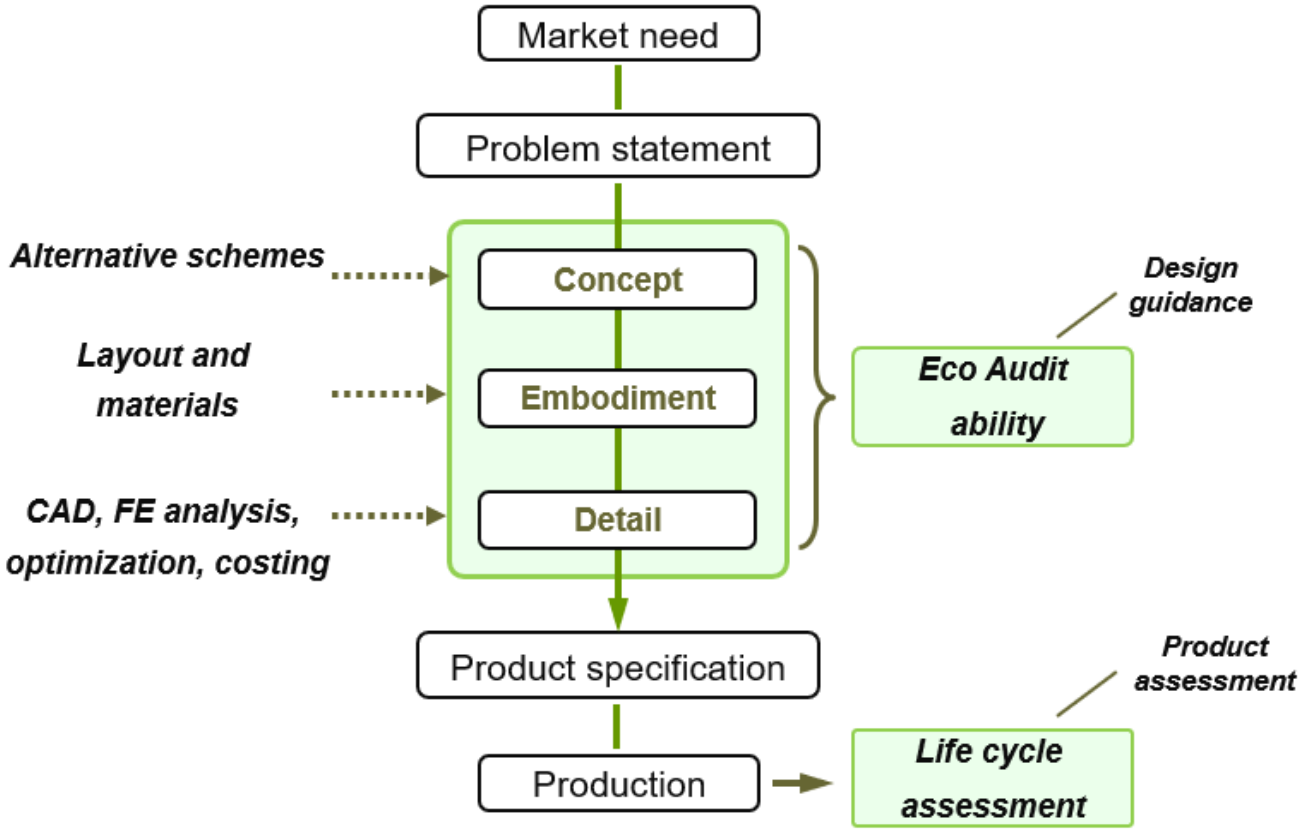
Design vs análise do produto



Fonte: Granta Design and Mike Ashby, 2020.

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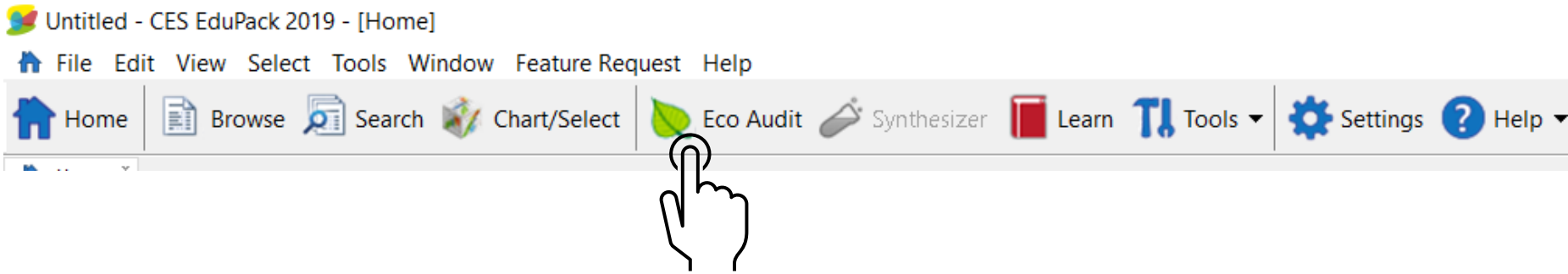
Desenvolvimento de estratégias para orientar a conceção

Necessidade:

Eco auditoria que combina o custo aceitável com precisão suficiente, para ajudar na tomada de decisões

Ferramenta Eco Audit (CES EduPack)



Alternativa rápida, mas menos rigorosa do que um LCA!

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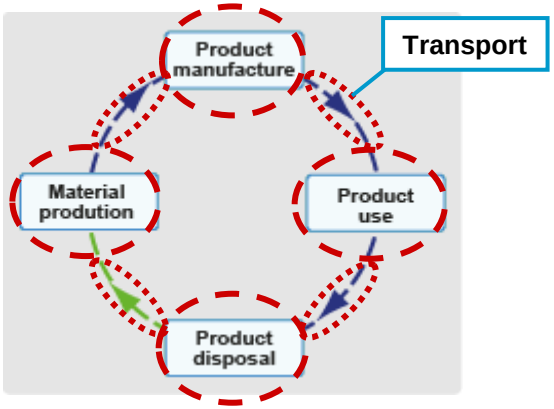
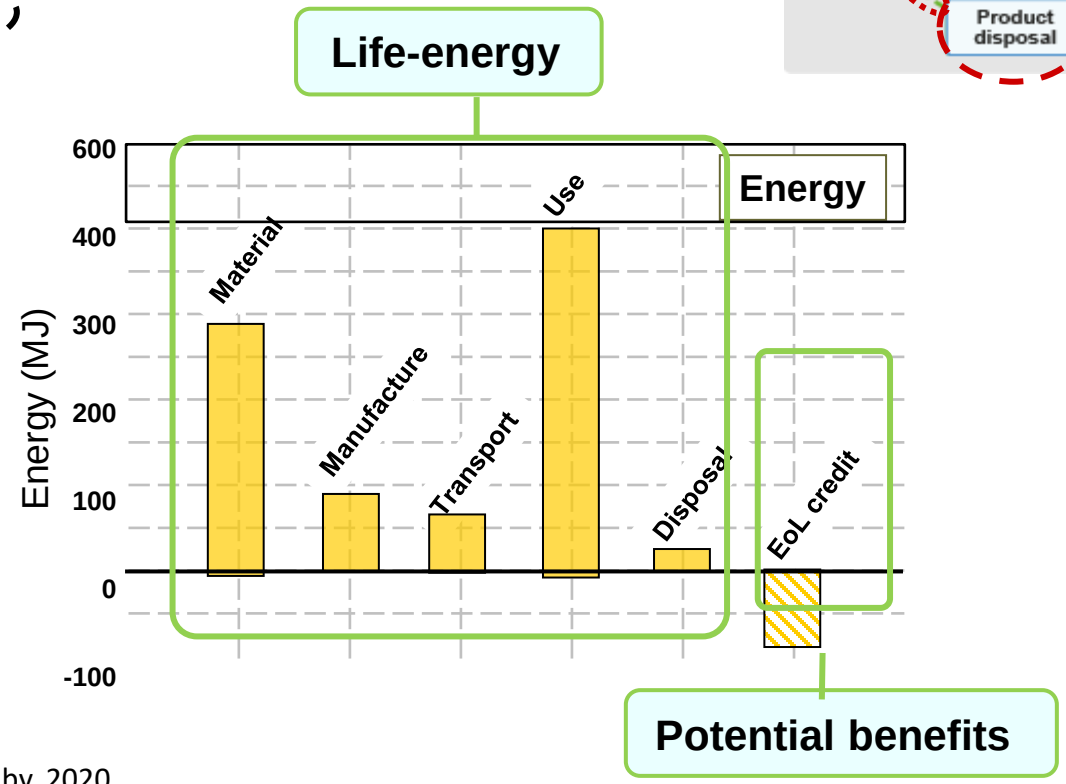
Ferramenta Eco Audit (CES EduPack)

Opção para guiar um processo de decisão

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





Distinguir as diferentes fases da vida de um produto

Fonte: Granta Design and Mike Ashby, 2020.

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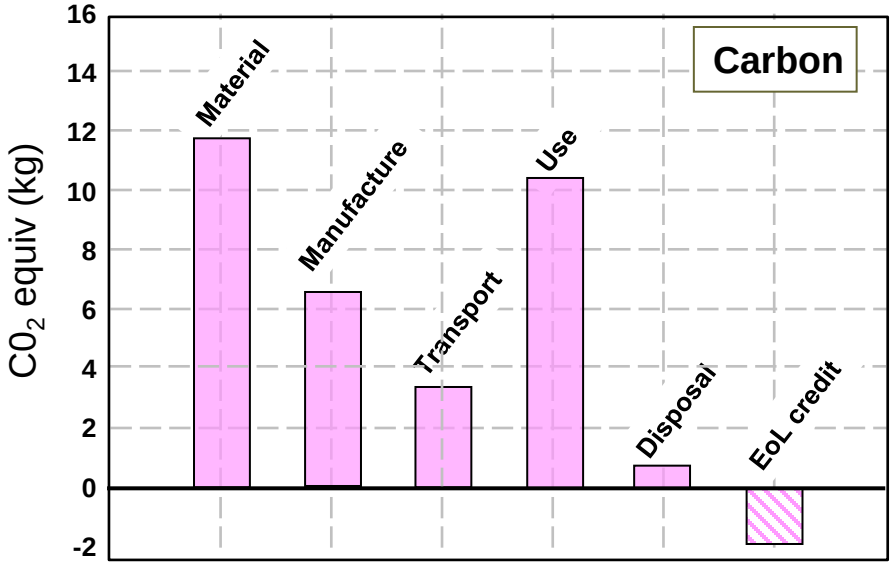
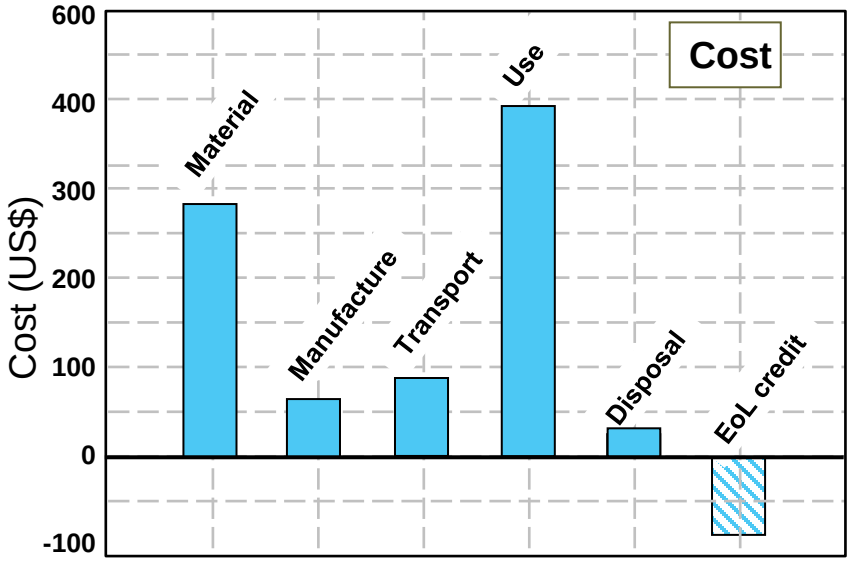
Ferramenta Eco Audit (CES EduPack)

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





Fonte: Granta Design and Mike Ashby, 2020.

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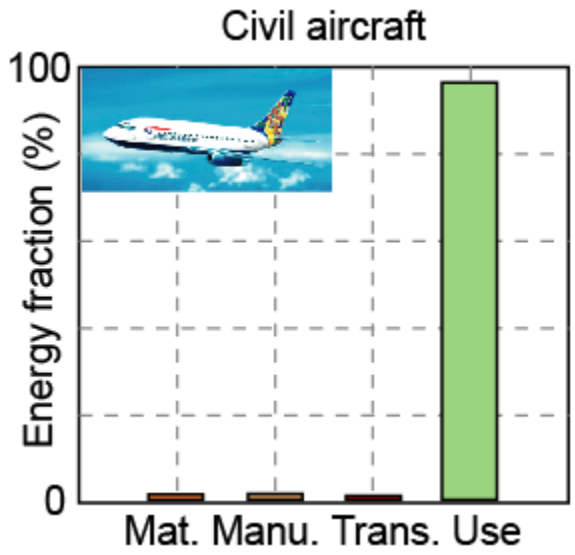
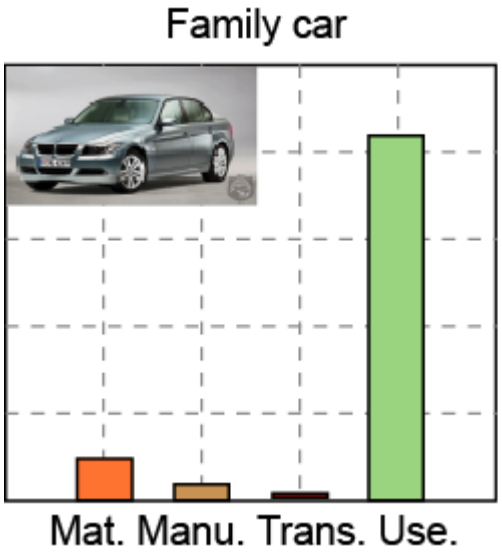
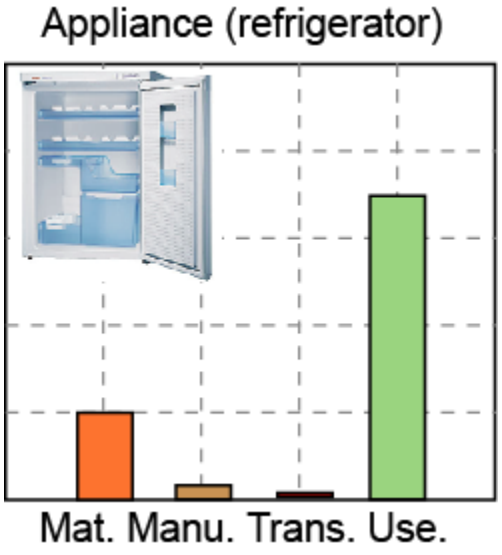
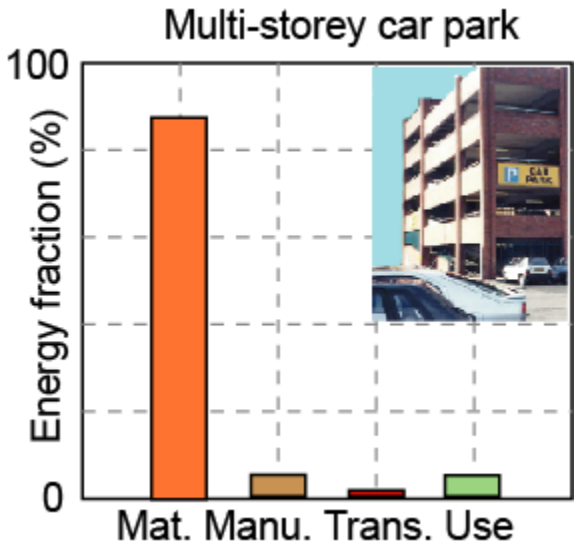
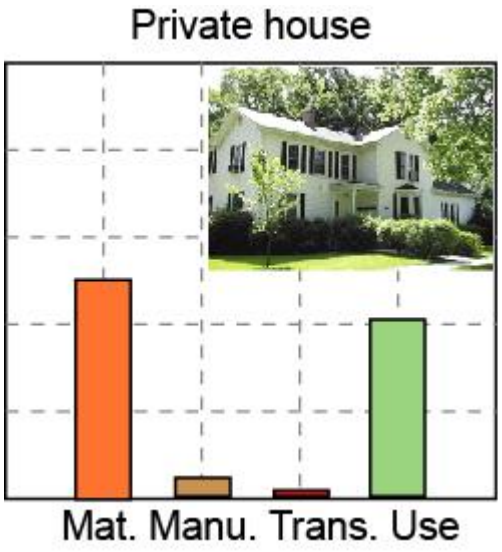
Grande panorama: consumo de energia dos produtos

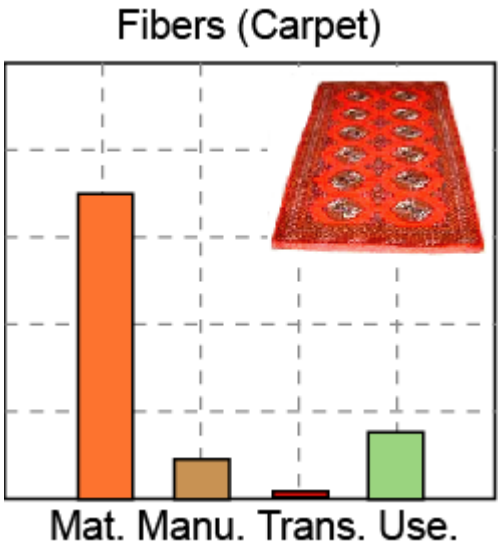












Auditoria ecológica

Extração do material

Representação dos eco dados: energia incorporada

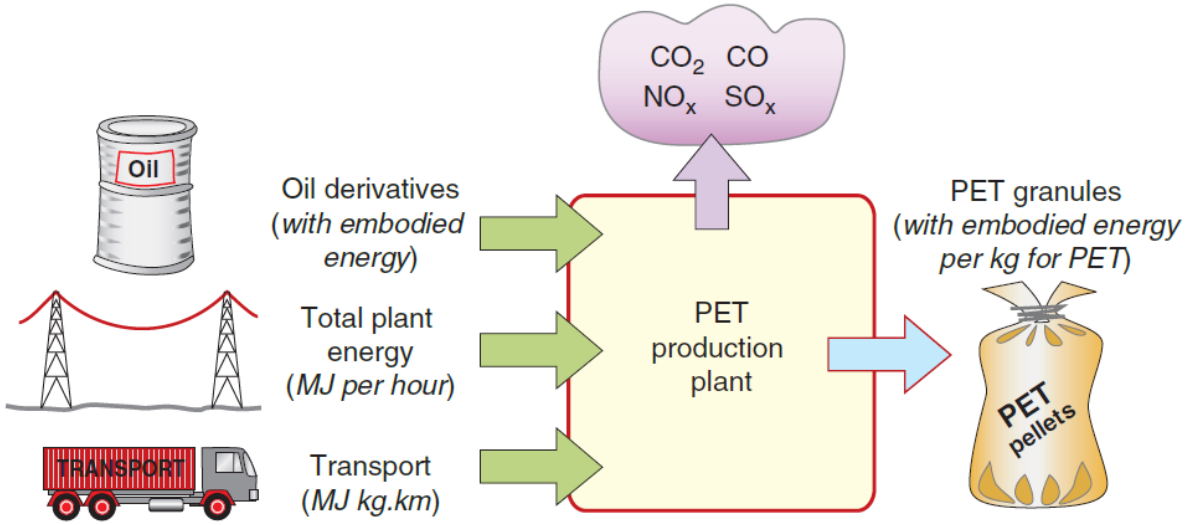


FIGURE 6.1 *The idea of embodied energy. Energy, in various forms, enters or is required by the plant. Its output is a material. The energy per kg of usable material is the embodied energy of the material.*

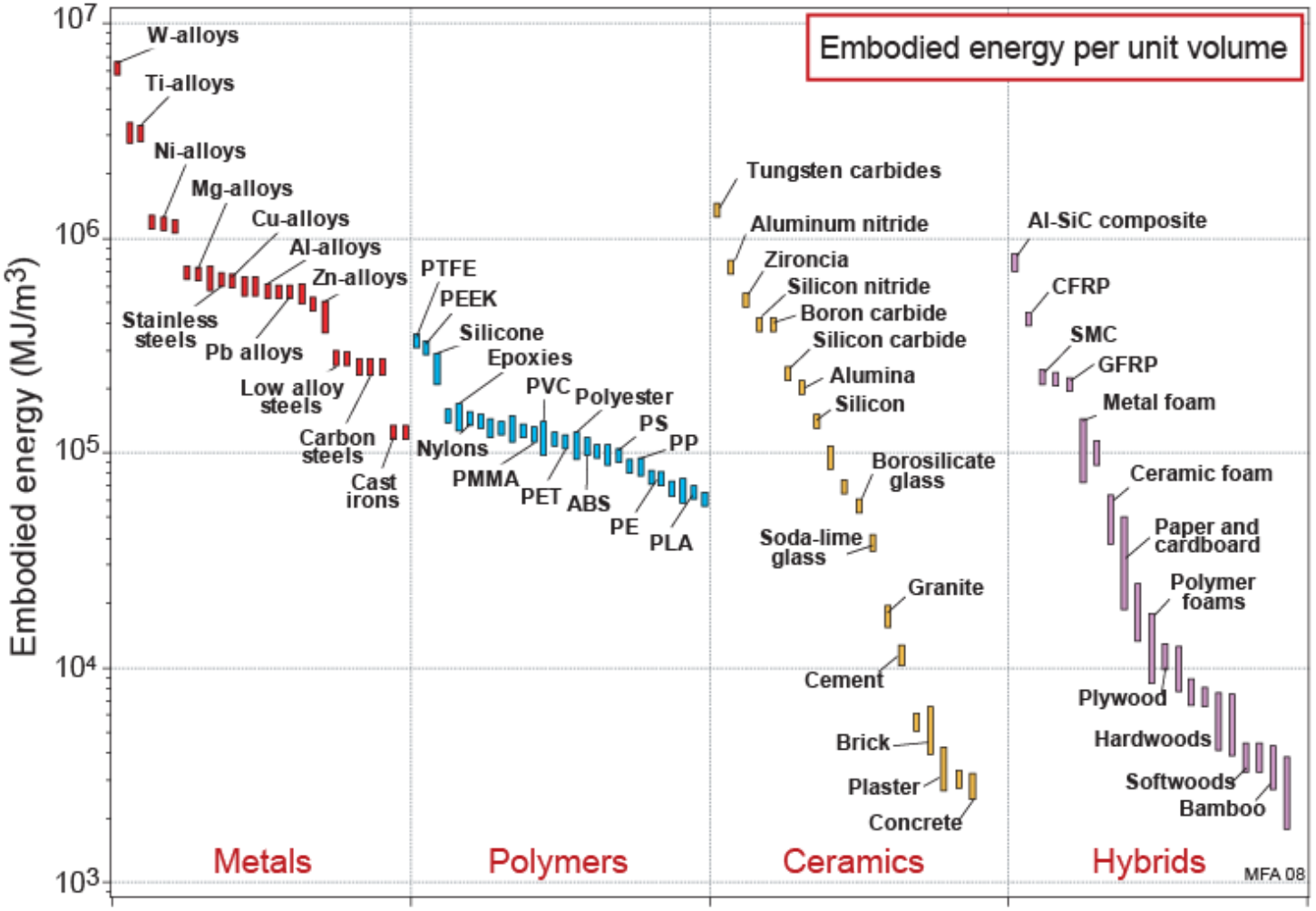
$$Energia\ incorporada = \frac{\sum energias\ que\ entram\ na\ fábrica\ por\ hora}{massa\ grânulos\ de\ PET\ produzidos\ por\ hora}$$

Energia incorporada primária (primary *embodied energy*) – soma das energias necessárias para produzir um bem ou serviço **(expressa em MJ/kg)**

Auditoria ecológica

Extração do material

Representação dos eco dados: energia incorporada

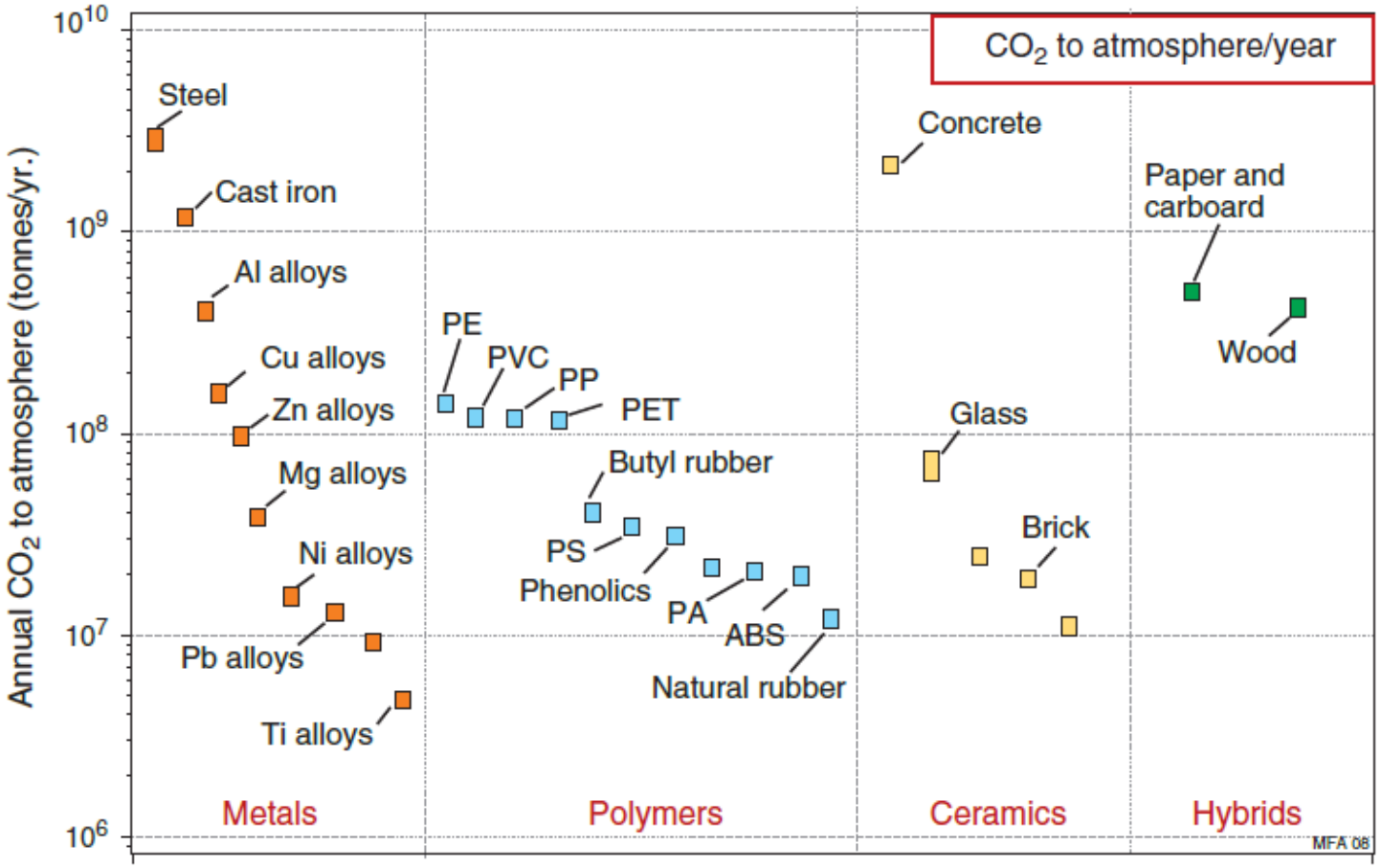


Fonte: "Materials and the environemnt: Eco-informed materials choice", Mike Ashby, 2009.

Eco informação no CES EduPack

Extração do material

Representação dos eco dados: Libertação de CO_2 para a atmosfera por ano

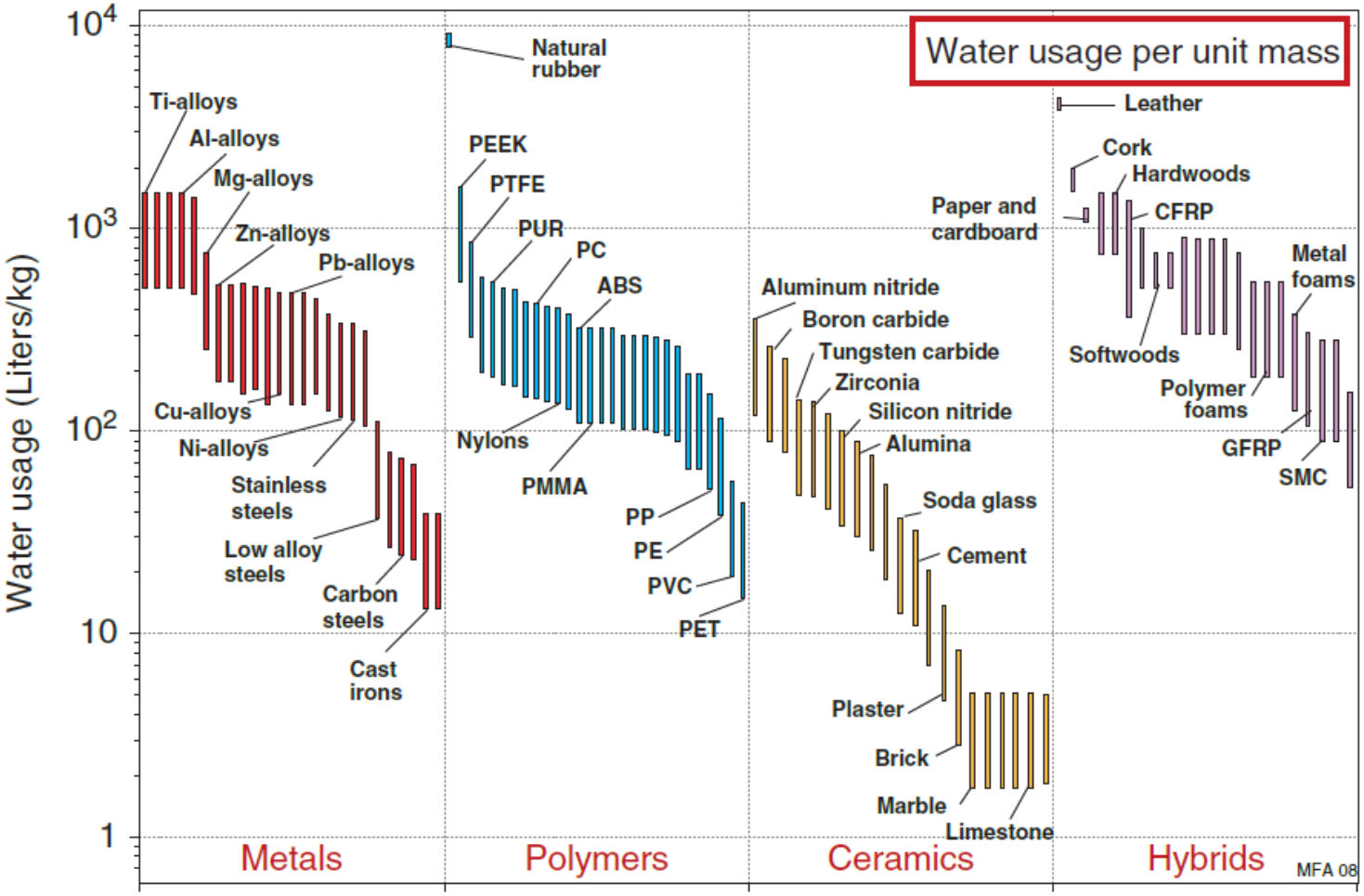


Fonte: "Materials and the environemnt: Eco-informed materials choice", Mike Ashby, 2009.

Eco informação no CES EduPack

Extração do material

Representação dos eco dados: quantidade de água utilizada por unidade de massa

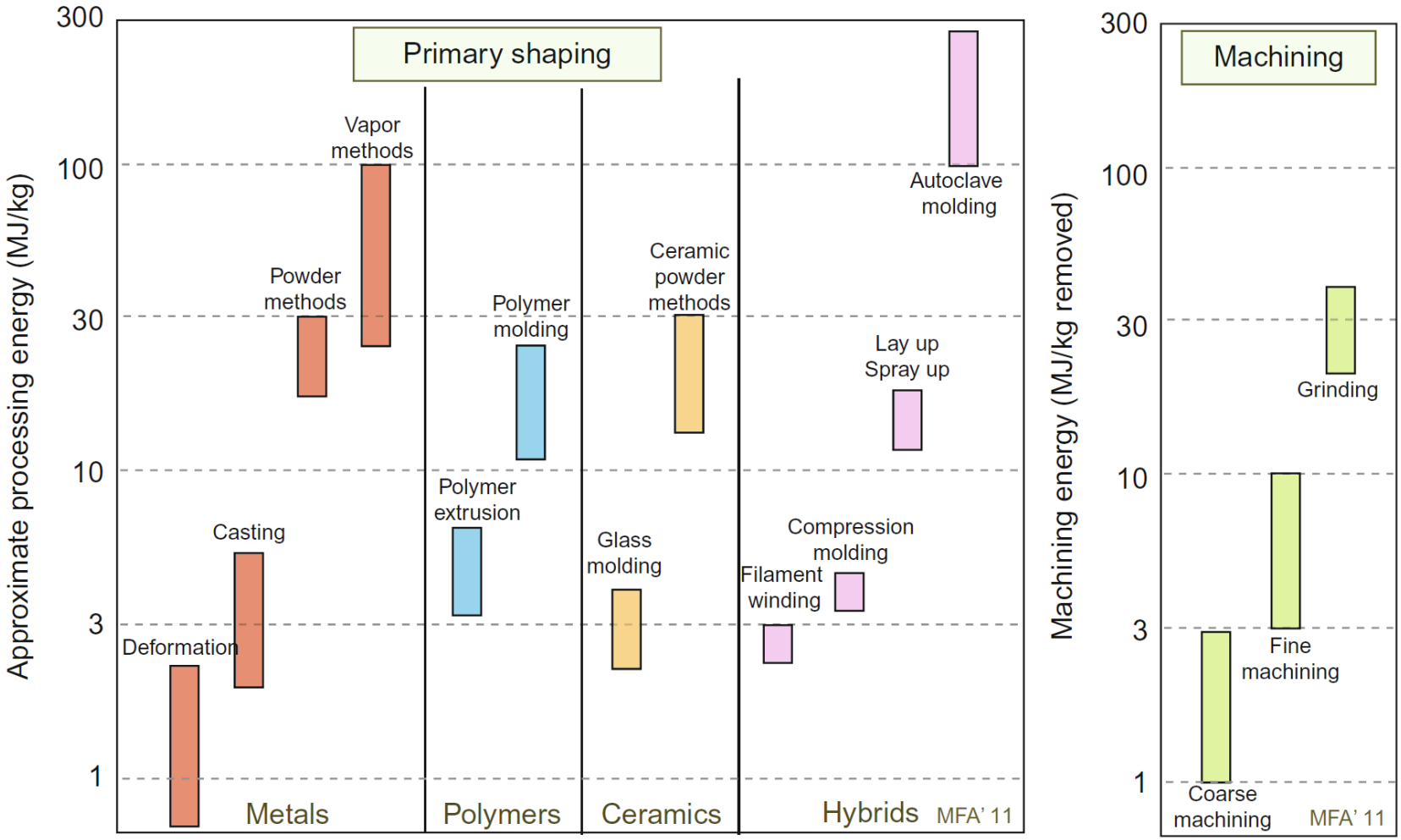


Fonte: "Materials and the environemnt: Eco-informed materials choice", Mike Ashby, 2009.

Eco informação no CES EduPack

Fabrico do produto

Energia associada ao processamento do produto



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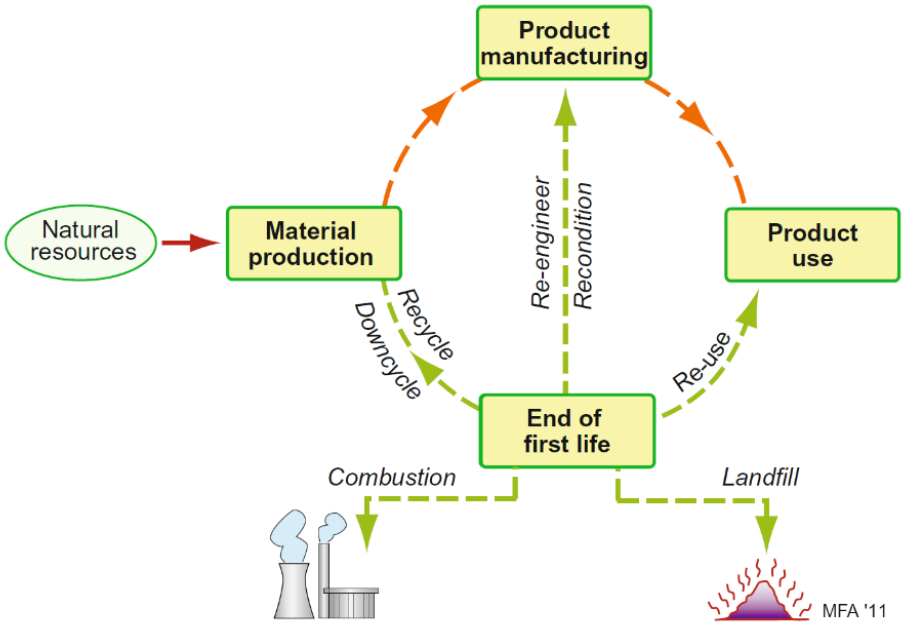
destino no final do ciclo de vida útil

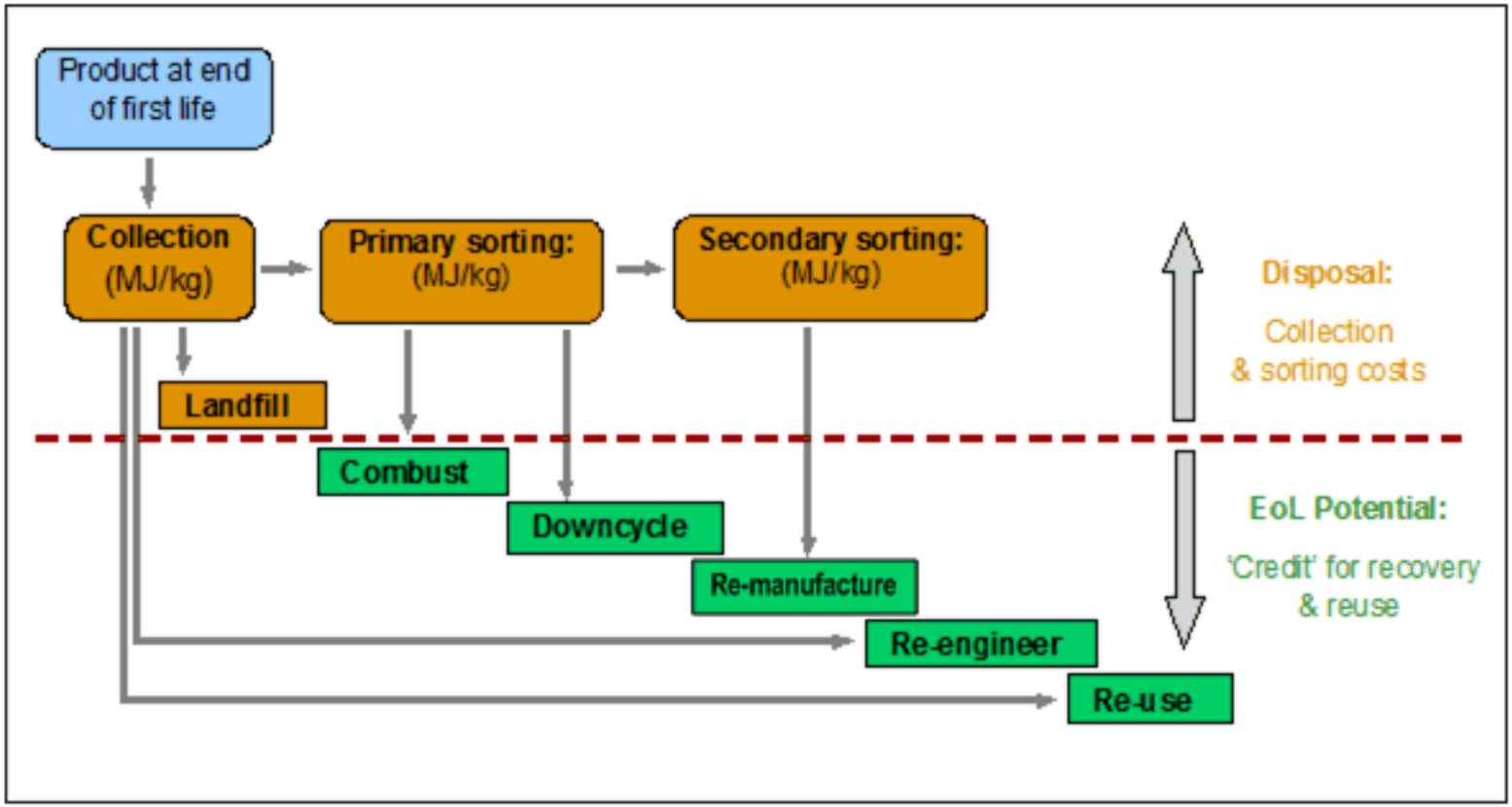


Opção de fim de vida	Descrição	Impacto ambiental
Re-use	Prolongamento da vida do produto por reutilização	Menor
Re-engineer	Utilização do material num novo produto	
Recycle	Reprocessamento do material e sua reutilização na cadeia de produção	
Downcycle	Reprocessamento com perda de qualidade do material e sua reutilização na cadeia de produção	
Combustion	Recuperação do conteúdo calorífico do material	
Landfill	Eliminação do material em aterro	Maior

Eco informação no CES EduPack

destino no final do ciclo de vida útil

Potencial de fim de vida (*end of life (EoL) potential*) – crédito por reciclar ou reutilizar o material



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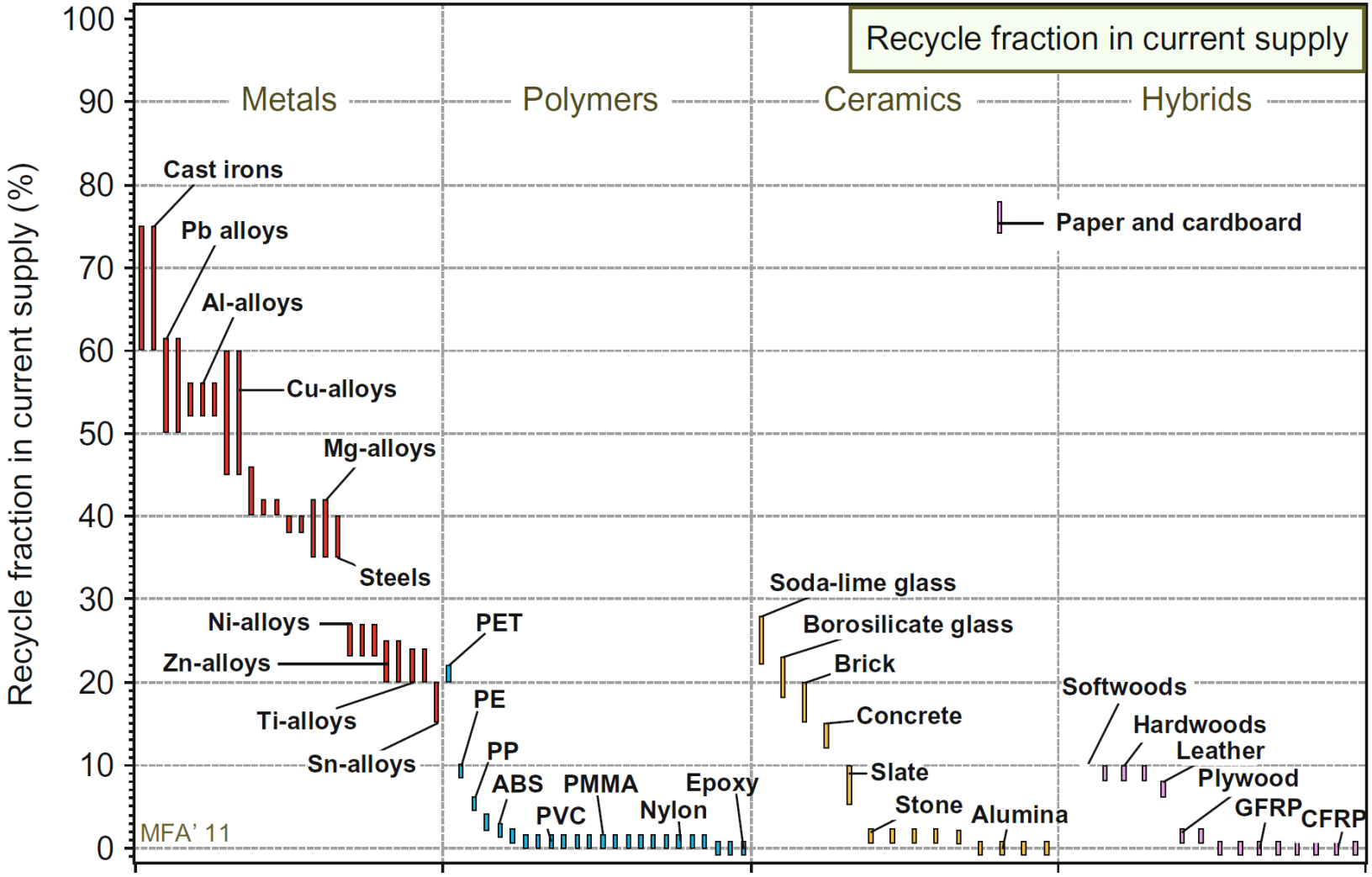
destino no final do ciclo de vida útil

Fração reciclada por material



Eco informação no CES EduPack

Science note

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Eco properties: recycling and disposal

End of life options. Materials have a life-cycle. They are extracted and refined, manufactured into products, used, and at end of first life, rejected as "waste". But what is waste to some markets is a resource to others, creating a number of alternative channels down which the materials continue to flow. Figure 1 introduces the options: commit to landfill, combust for heat recovery, recycle (or downcycle), re-engineer (refurbish or recondition) and reuse. They are not easy to quantify – the last two (re-engineer, re-use) in particular, depend on the nature of the relative cost of goods and labor and on standard of living. One – recycling – can be analyzed, at least approximately. The database contains data for the energy and carbon footprint of recycling and for the fraction of recycled material entering current supply.

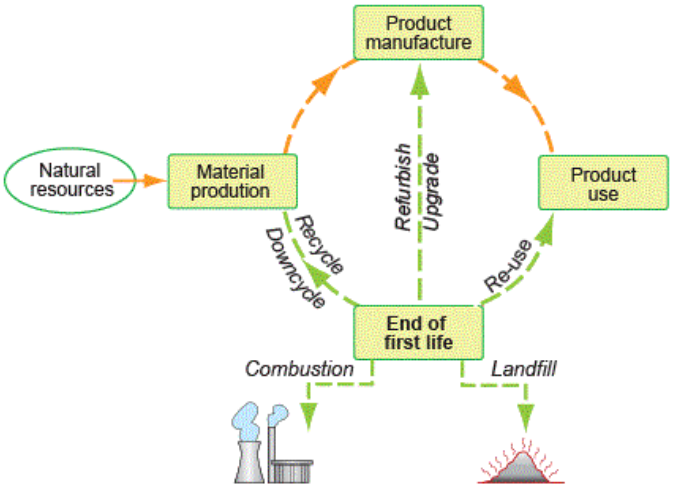

Figure 1. The material life-cycle with, superimposed, the end-of-life options.

Top

Recycling and downcycling. There are two sorts of *scrap*, by which we mean "material with recycle-potential". *In-house scrap* is the off-cuts, bits and ends left in a material

ProcessUniverse ...

Concluído NUM

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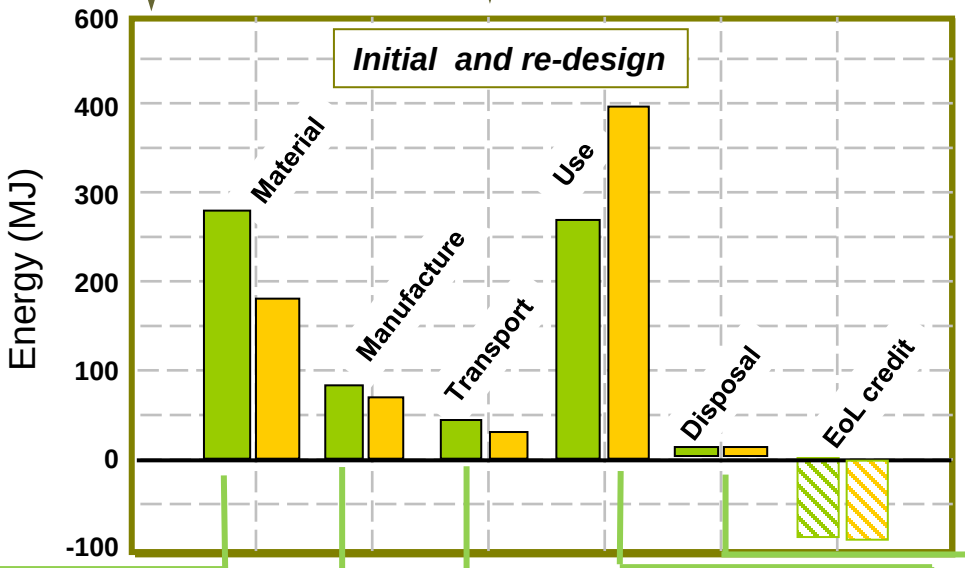
Estratégia para a seleção dos materiais

The steps

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



Duas ferramentas:

1) Eco Auditoria
2) Design

Material
Minimize:
- material in part
- embodied energy
- CO_2 / kg

Manufacture
Minimize:
- process energy
- CO_2/kg

Transport
Minimize:
- mass
- distance
- transport type

Use
Minimize:
- mass
- thermal loss
- electrical loss

End of Life
Select:
- recyclable materials
- non-toxic materials

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Ferramenta Eco Audit (CES EduPack)

User inputs

User interface

- *Bill of materials*
- *Manufacturing process*
- *Transport needs*
- *Duty cycle*
- *End of life choice*

2 kW electric kettle

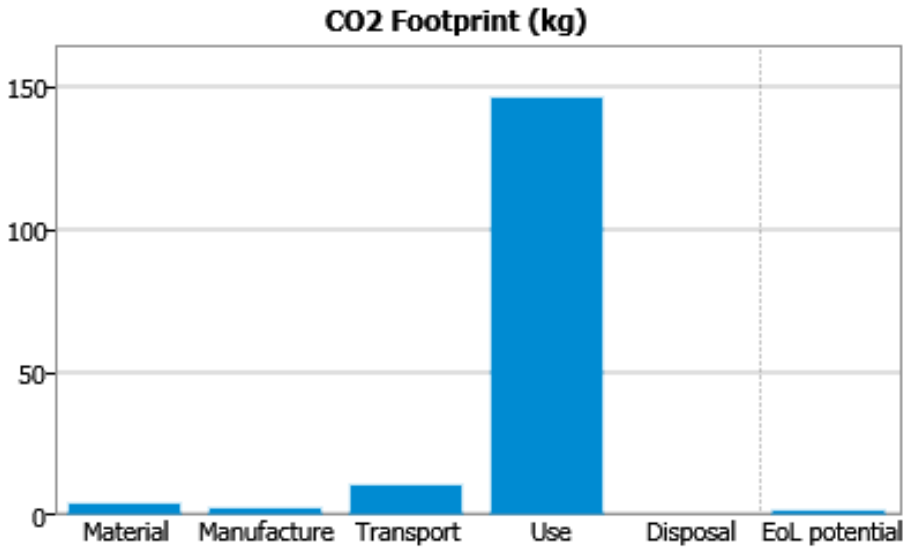
Eco Audit model

Database

Eco data

- *Embodied energies*
- *Process energies*
- *CO_2 footprints*
- *Unit transport energies*
- *Recycling / combustion*

Outputs:



Full report

- *Data*
- *Criticality*
- *Hazard*

Fonte: Granta Design and Mike Ashby, 2020.

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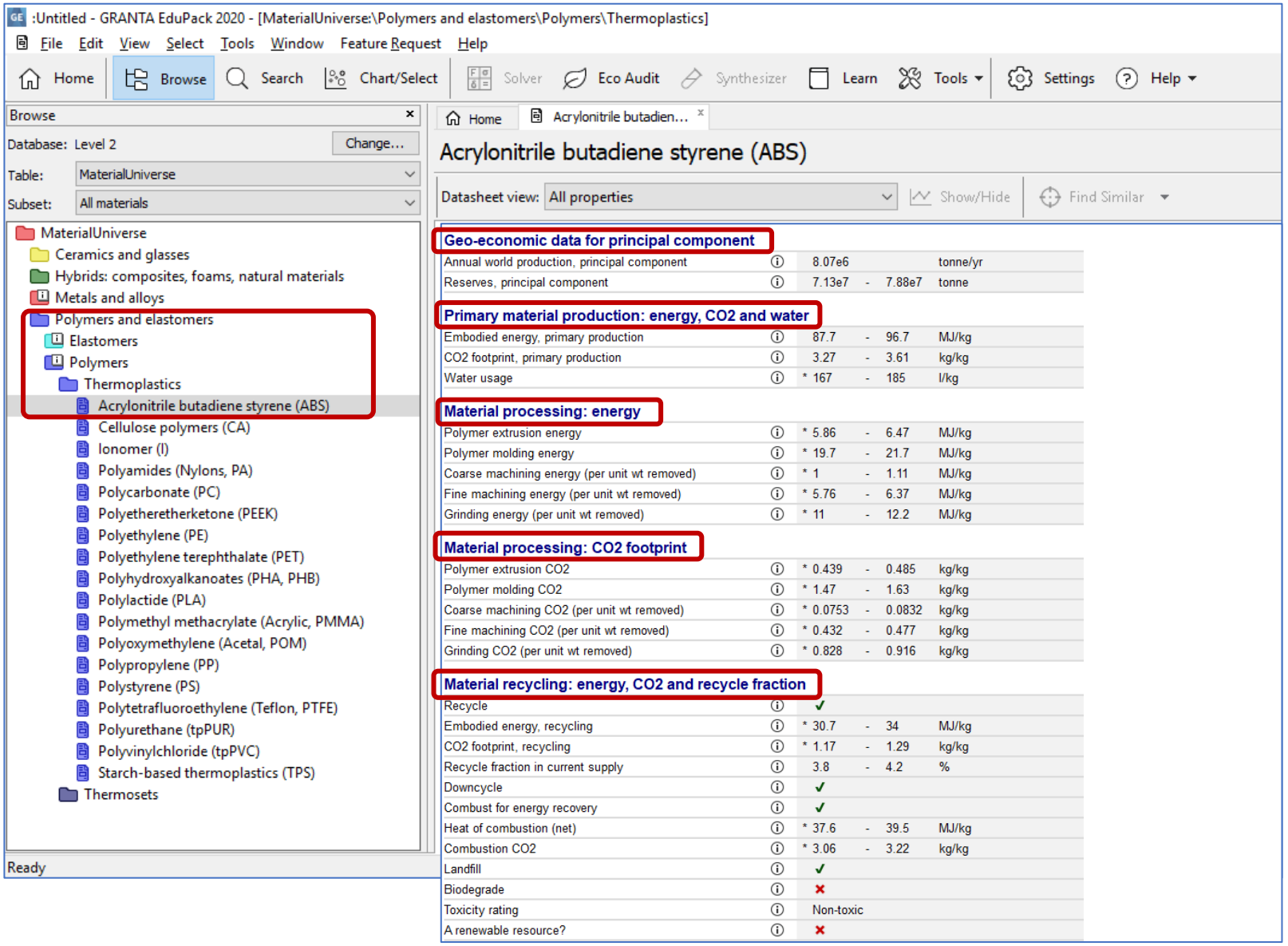
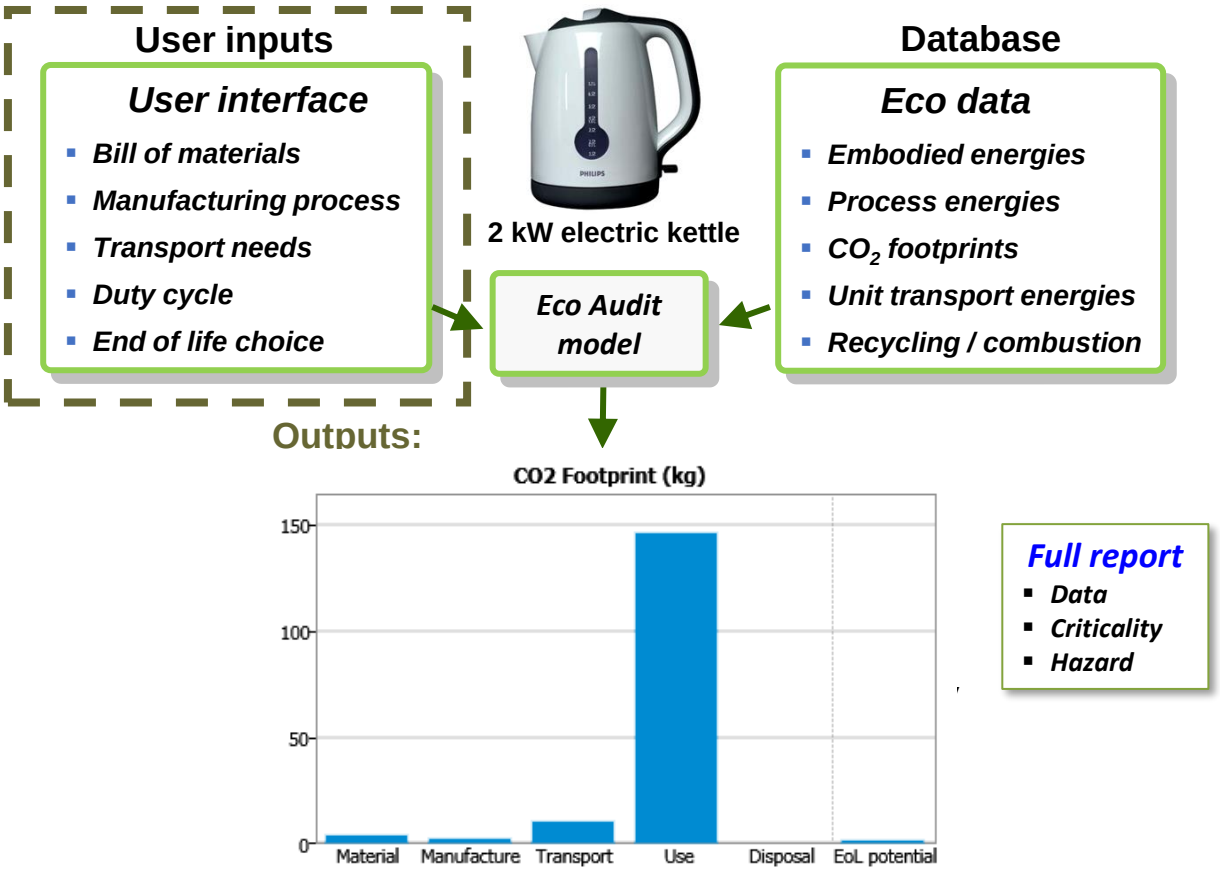
Eco dados no CES EduPack



Auditoria ecológica

Ferramenta Eco Audit (CES EduPack)



Fonte: Granta Design and Mike Ashby, 2020.

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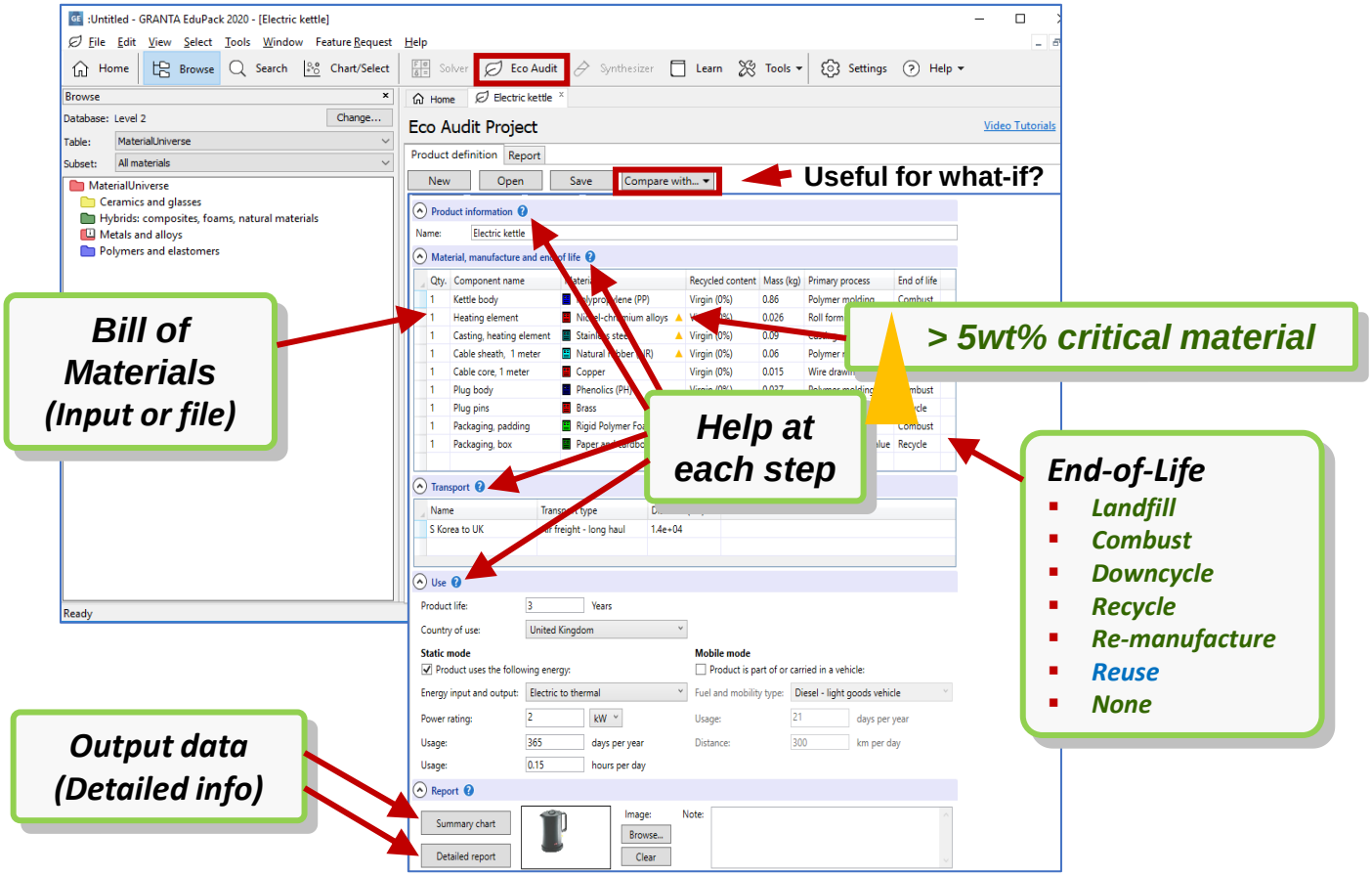
Ferramenta Eco Audit (CES EduPack)



Fonte: Granta Design and Mike Ashby, 2020.

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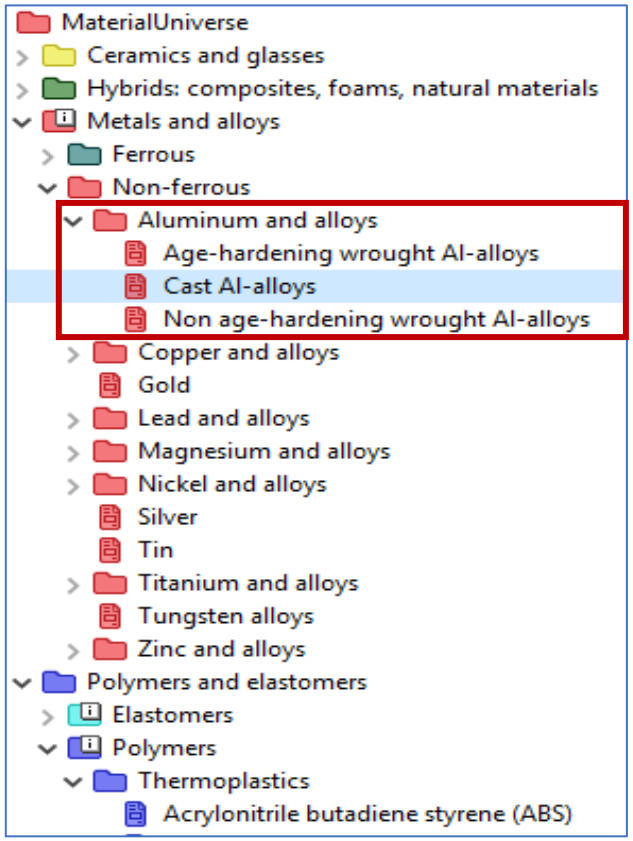
1º passo: materiais e energia do processo/ CO_2

Component name	Material	Process	Mass (kg)	End of life
Component 1	*Aluminum alloys*	*Casting*	*2.3*	*Recycle*



- **Casting**
- **Forging / rolling**
- **Extrusion**
- **Wire drawing**
- **Powder forming**
- **Vapor methods**

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

End of life options

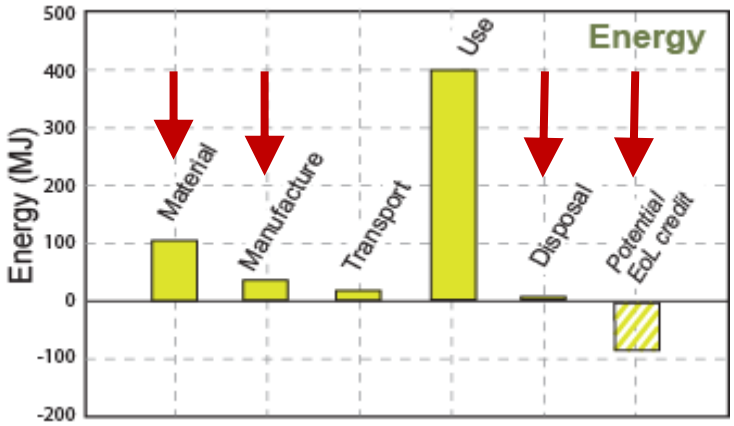
Fonte: Granta Design and Mike Ashby, 2020.

Auditoria ecológica

1º passo: materiais e energia do processo/ CO_2

Component name	Material	Process	Mass (kg)	End of life
Component 1	Aluminum alloys	Casting	2.3	Recycle
Component 2	Polypropylene	Polymer molding	1.85	Landfill
Component 3	Glass	Glass molding	3.7	Reuse

Total embodied energy	Total process energy	Total mass	Total end of life energy



Fonte: Granta Design and Mike Ashby, 2020.

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2º passo: transporte

Transport stage	Transport type	Distance (km)
Stage 1	*32 tonne truck*	*350*
Stage 2	*Coastal freight*	*12 000*

- Coastal freight
- River/canal freight
- Rail freight
- 55 tonne (8 axle) truck
- 40 tonne (6 axle) truck
- 32 tonne (4 axle) truck
- 26 tonne (3 axle) truck
- 14 tonne (2 axle) truck
- Light goods vehicle
- Air freight - long haul
- Air freight - short haul
- Helicopter

Transport energy

Transport CO_2

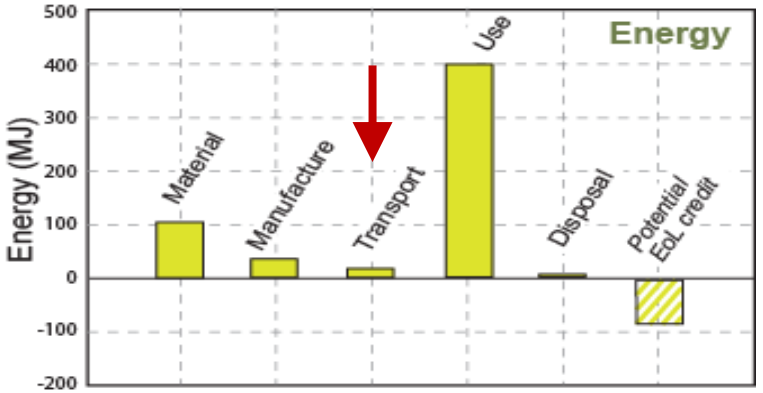

Table of transport types:
MJ / tonne.km
CO_2 / tonne.km

Fonte: Granta Design and Mike Ashby, 2020.

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3º passo: fase de utilização – Modo estático

Energy input and output — *Electric to mechanical*

Power rating — *1.2* *kW*

Usage — *365* days per year

Usage — *0.5* hours per day

Total energy or CO_2 for use

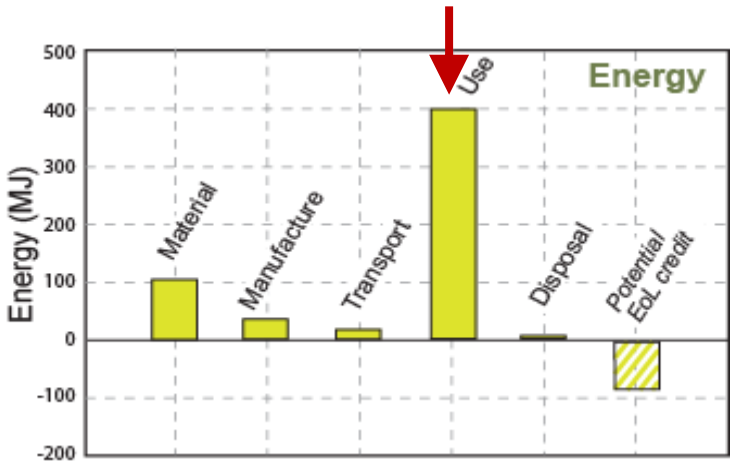
W
kW
MW
hp
ft.lb/sec
kCal/yr
BTU/yr

Energy input and output

- Electric to thermal
- Electric to mechanical (electric motors)
- Electric to chemical (lead acid battery)
- Electric to chemical (advanced battery)
- Electric to em radiation (incandescent lamp)
- Electric to em radiation (LED)

- Fossil fuel to thermal, enclosed system
- Fossil fuel to thermal, vented system
- Fossil fuel to electric
- Fossil fuel to mechanical, internal combustion
- Fossil fuel to mechanical, steam turbine
- Fossil fuel to mechanical, gas turbine

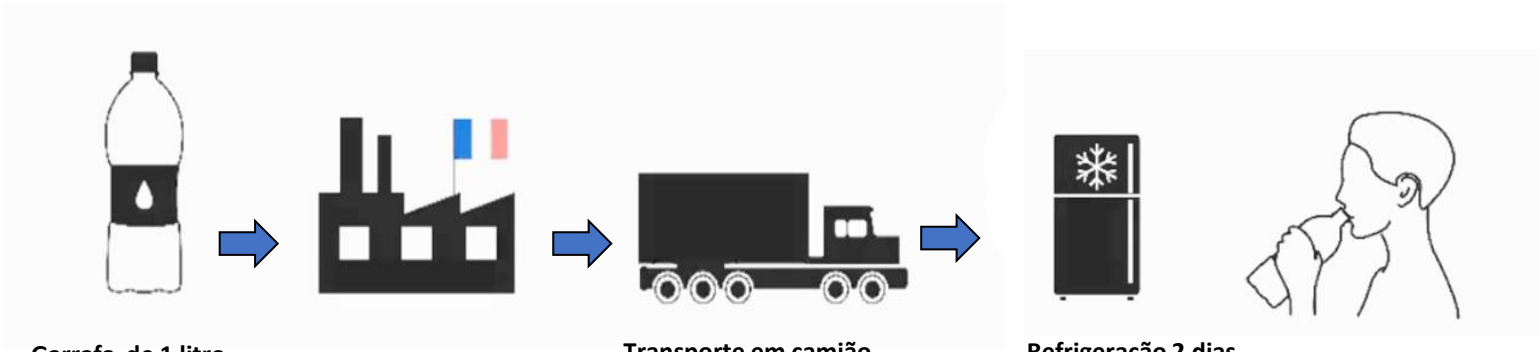
- Light to electric (solar cell)



Fonte: Granta Design and Mike Ashby, 2020.

Exemplo de uma Auditoria ecológica

100 unidades de água engarrafada



- Garrafa em PET de 1 litro, com tampa de PP
- Moldadas por sopro
- Fabricada em França, transportados 550 km para o Reino Unido
- Refrigerada durante dois dias, depois bebida

Exemplo de uma Auditoria ecológica

100 unidades de água engarrafada

Product name: *PET bottle*

New | Open | Save | Compare with...

Number	Name	Material	Process	Mass (kg)	End of life
100	Bottles	PET	Molding	0.04	Recycle
100	Caps	Polyprop	Molding	0.001	Landfill
100	Water			1.0	

Transport

Stage 1	14 tonne truck	550 km

Survey charts

Full report

Use - refrigeration

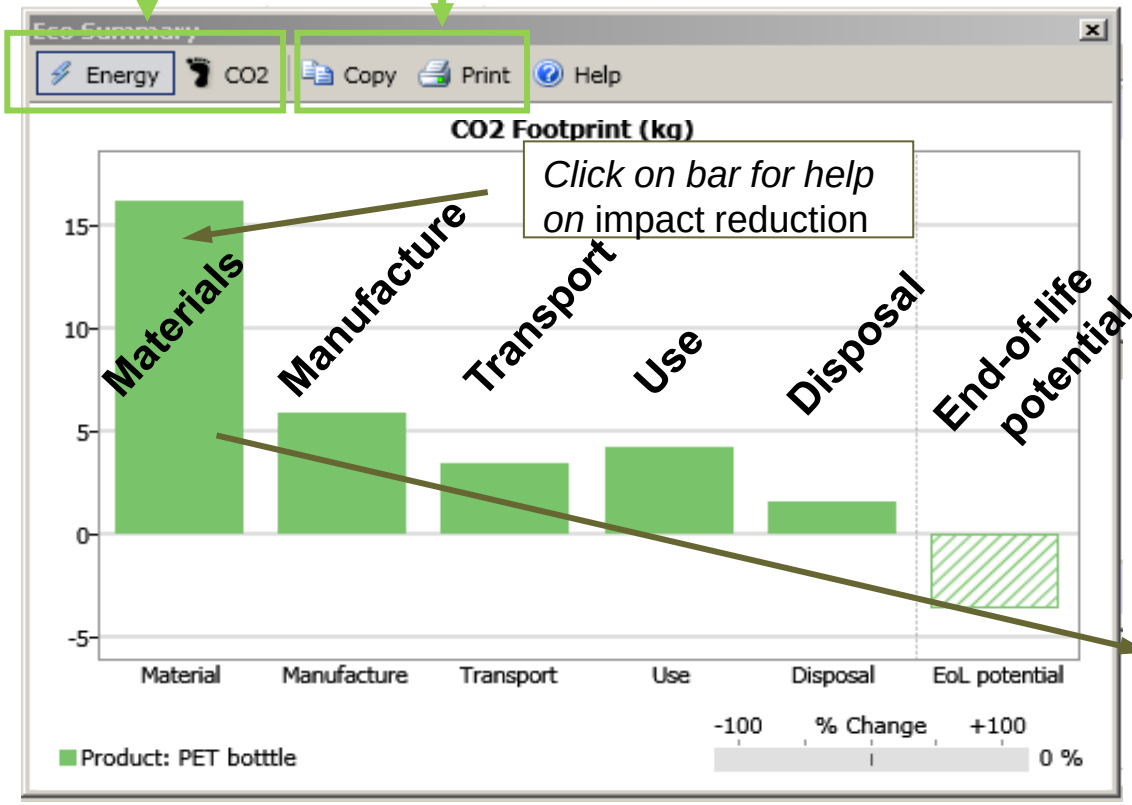
Electric to mechanical	0.12 kW	2 days	24 hrs/day

Fonte: Granta Design and Mike Ashby, 2020.

Exemplo de uma Auditoria ecológica

Toggle between **energy** *and* **carbon footprint**

Copy *or* print the chart



Which phase has the largest impact?

Materials!

Reducing Material-phase impact

Aim

Minimize embodied energy or CO_2 footprint / unit of function.

Actions

Select material with lowest embodied energy and CO_2 footprint per unit of function.

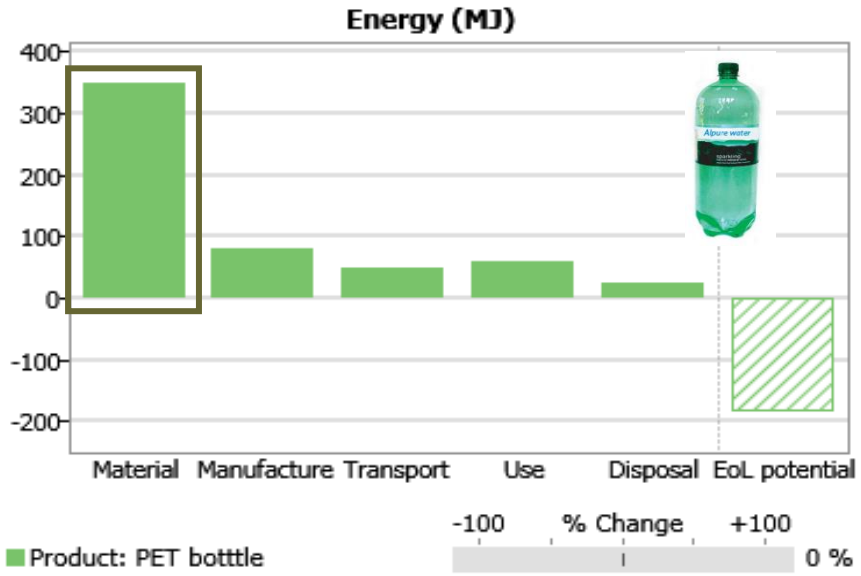
Use as large a 'recycled content' in the material as possible.

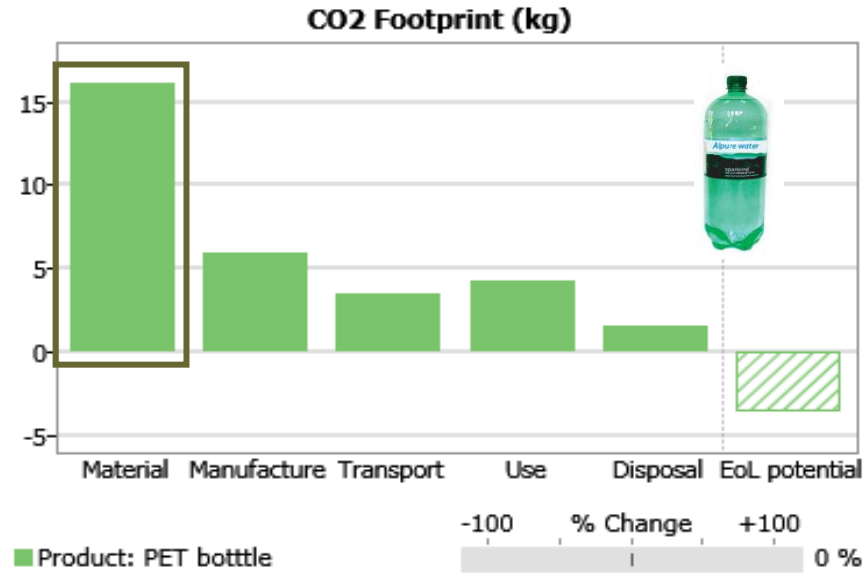
Use as little material as possible while retaining enough redundancy for safety.

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.

Exemplo de uma Auditoria ecológica





The audit reveals the most energy and carbon intensive steps…

PET

Fonte: Granta Design and Mike Ashby, 2020.

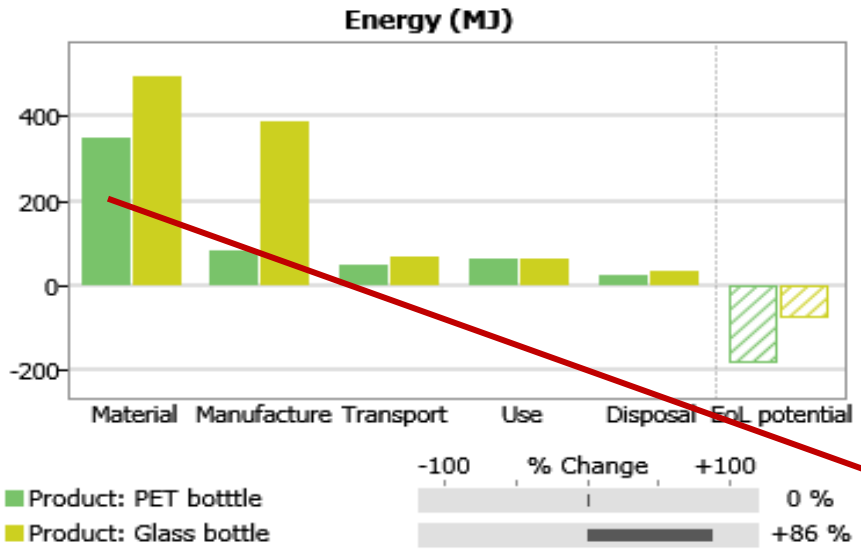
Exemplo de uma Auditoria ecológica

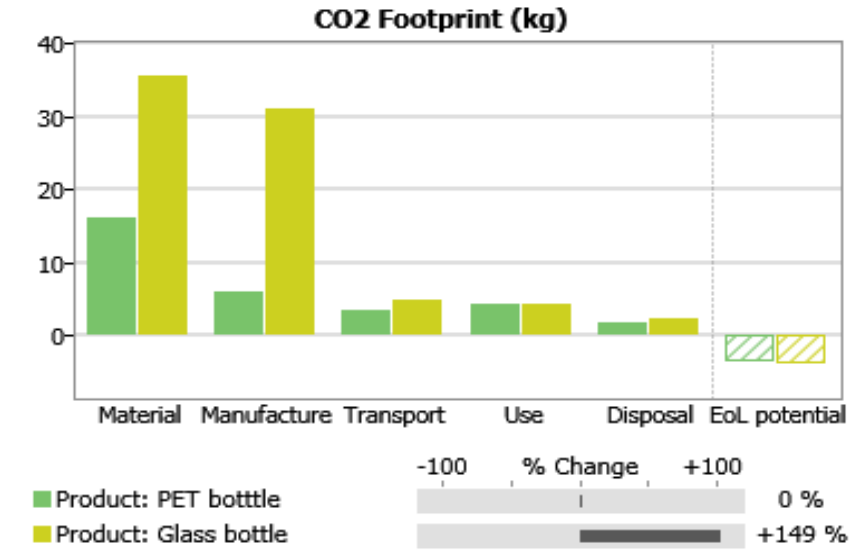
Esta ferramenta permite também **testar alternativas/hipóteses**, tais como a utilização de outros materiais, estratégias de fim de ciclo de vida diferentes, etc.

Será que as garrafas de vidro seriam uma melhor alternativa à utilização de garrafas à base de PET?

PET ***Glass ?***

Exemplo de uma Auditoria ecológica





The fast comparison allows design decisions on-the-fly

Reducing impact

Actions

- **Use as large a 'recycled content' in the material as possible.**

What if…….
100% recycled PET?

Fonte: Granta Design and Mike Ashby, 2020.

Exemplo de uma Auditoria ecológica

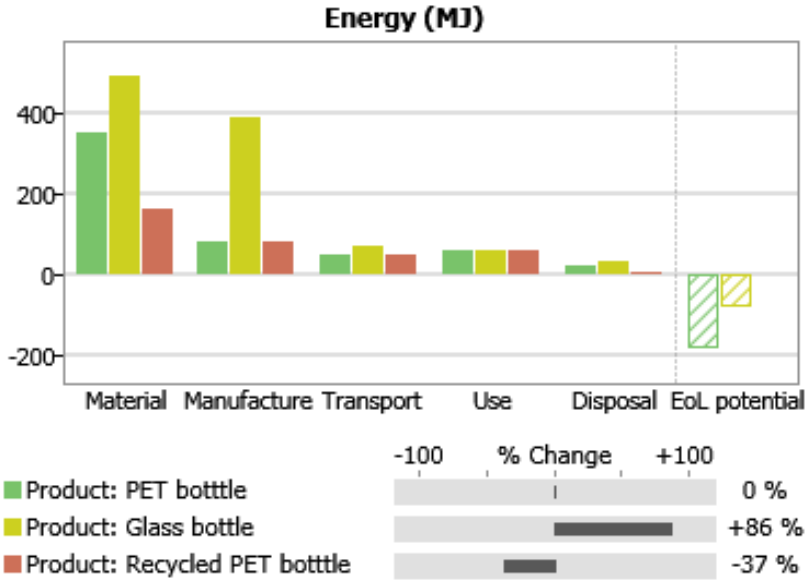
Click
Compare with….
Copy of current content

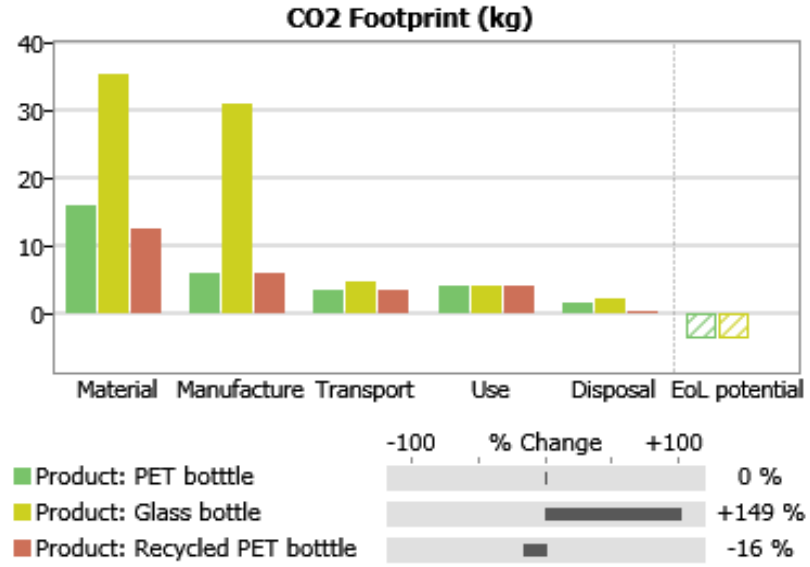
Set* Recycle content *to 100%

Virgin PET

Glass

Recycled PET





Can explore:

- **Material choice**
- **Recycle content**
- **Transport mode**
- **Transport distance**
- **Use pattern**
- **Electric energy mix**
- **End of life choice**

Fonte: Granta Design and Mike Ashby, 2020.