Energia e **Sustentabilidade:** duas faces da mesma moeda?

Energia e sustentabilidade

Emissões de gases com efeito de estufa

vs

necessidades das sociedades

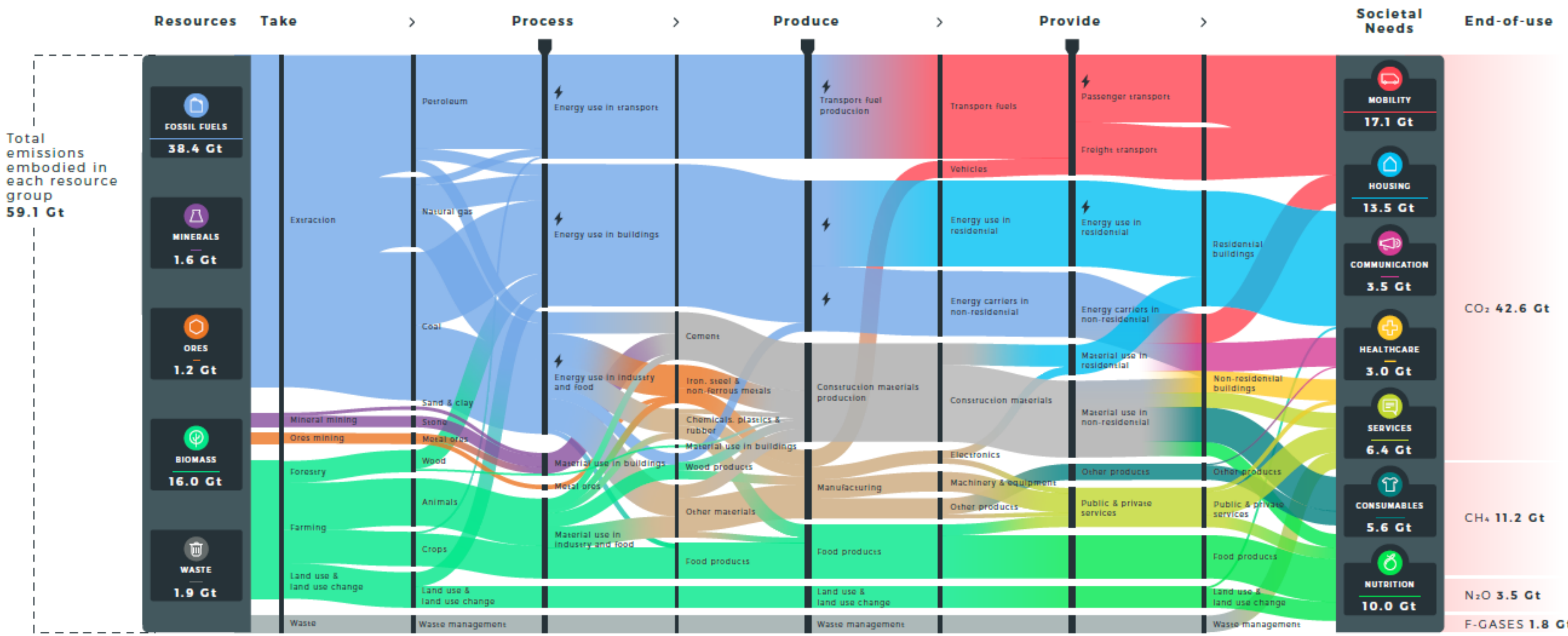
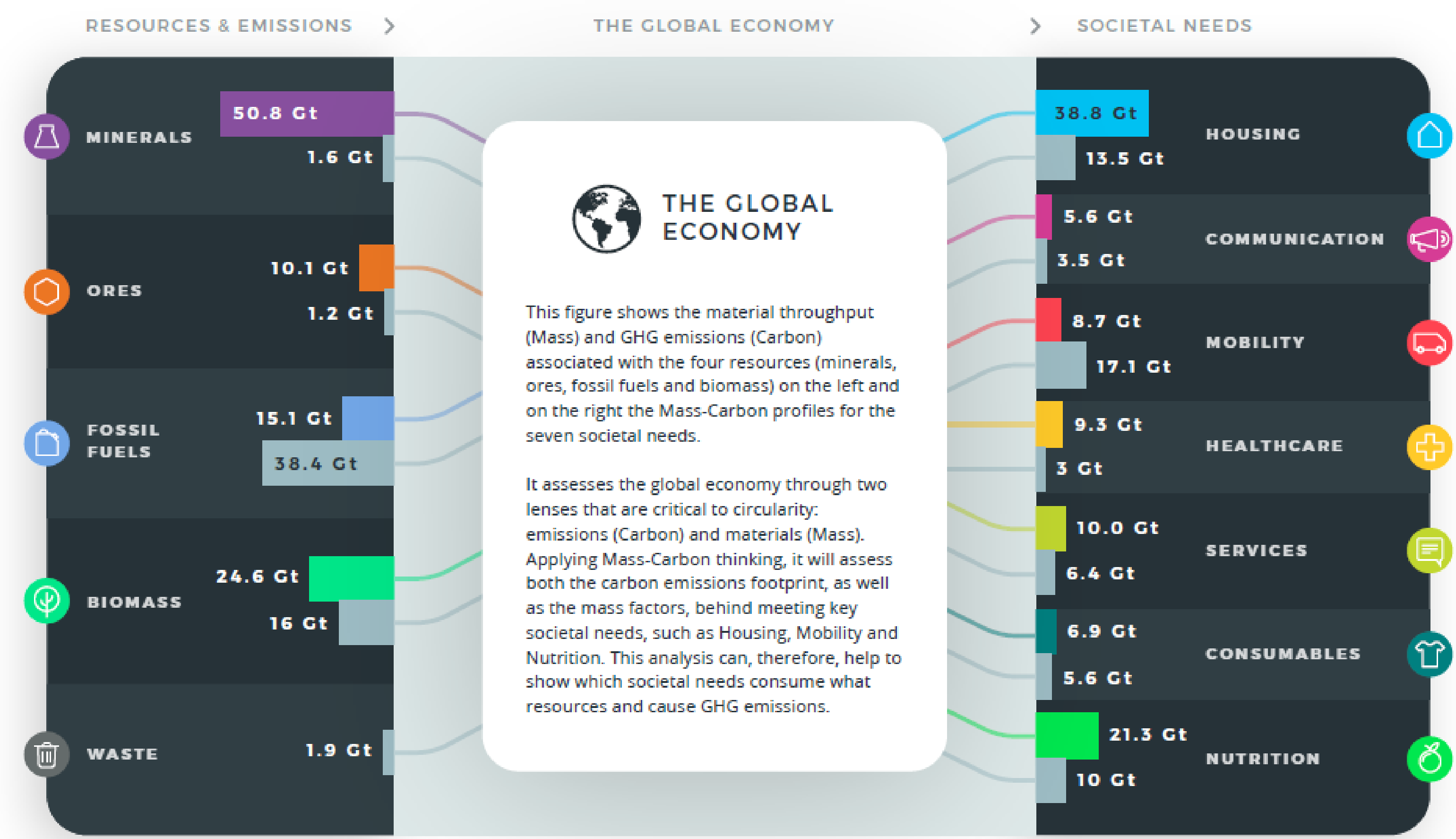


Figure One X-ray of global greenhouse gas emissions behind meeting key societal needs and wants in billion tonnes (Gt).

Energia e sustentabilidade

Global resource and emissions footprint



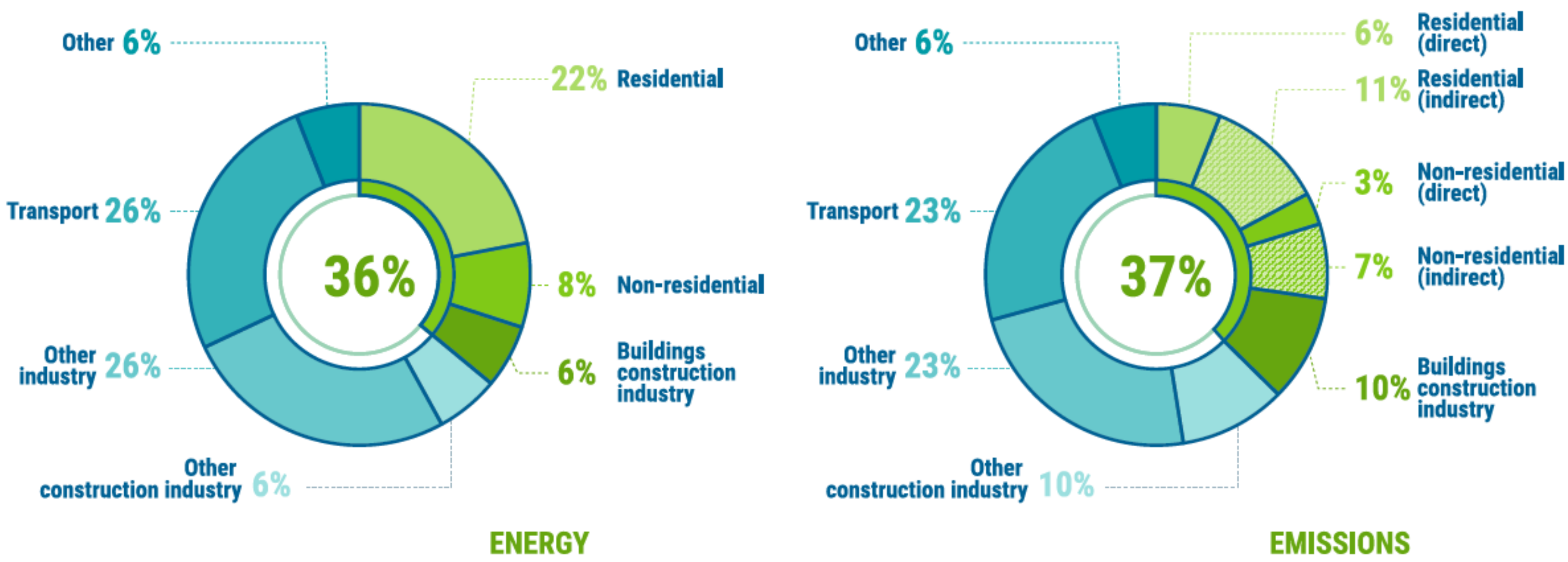
EMISSIONS CO_2eq

Figure Two The global resource and emissions footprint behind meeting key societal needs, side by side. Units in billion tonnes (Gt).

Energia e sustentabilidade

Consumo de energia e emissões de CO_2 –
contribuição dos edifícios e do setor da construção

Figure 2. Buildings and construction's share of global final energy and energy-related CO_2 emissions, 2020



Note: "Buildings construction industry" is the portion (estimated) of overall industry devoted to manufacturing building construction materials such as steel, cement and glass. Indirect emissions are emissions from power generation for electricity and commercial heat.

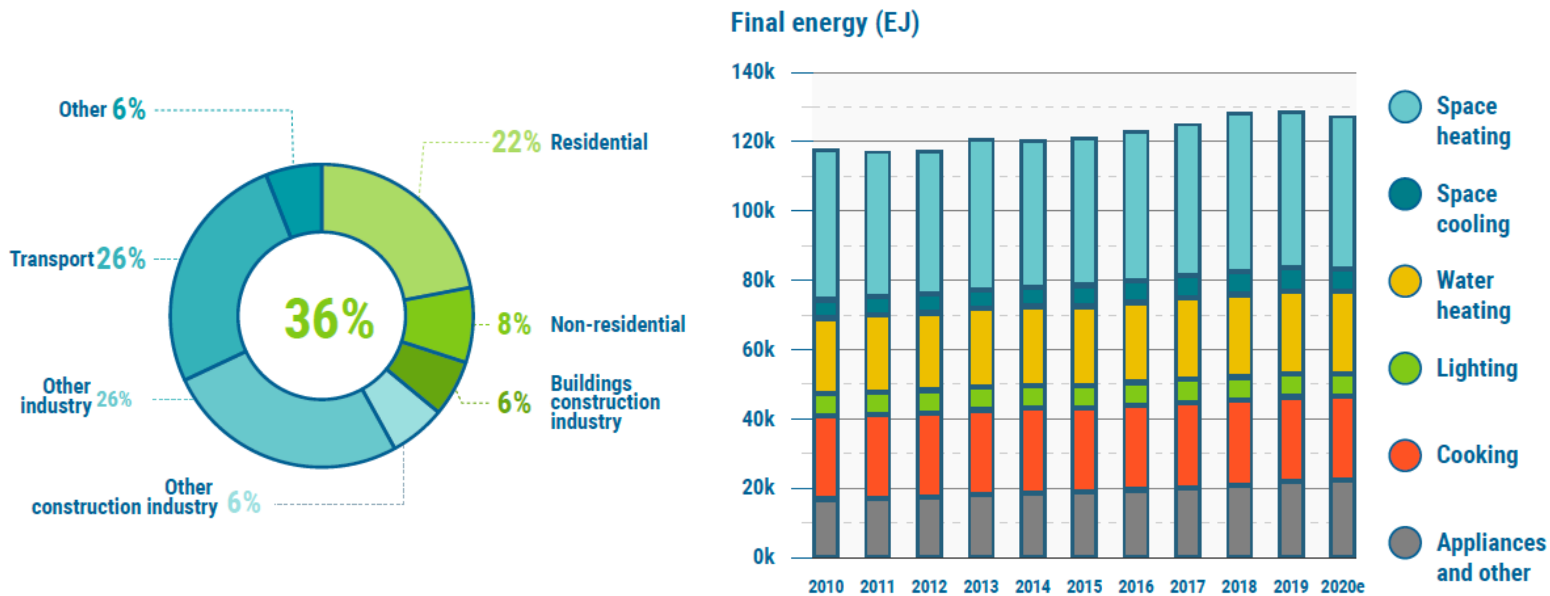
Source: IEA 2021a. All rights reserved. Adapted from "Tracking Clean Energy Progress"

Fonte: United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.

Energia e sustentabilidade

Edifícios – como se utiliza a energia?

Figure 13. Global share of buildings and construction final energy (left) and by end use (right), 2020



Notes: "Buildings construction industry" is the portion (estimated) of overall industry devoted to manufacturing building construction materials such as steel, cement and glass. Buildings construction industry related energy use not shown in Panel B.

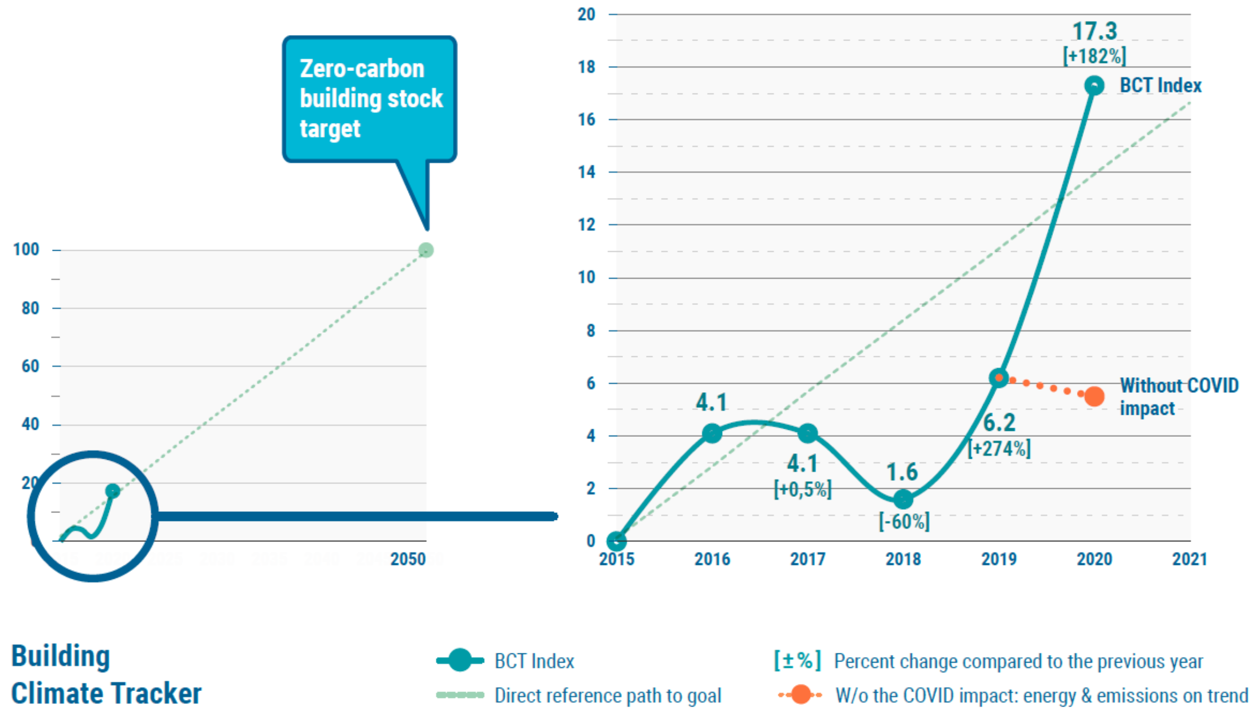
Source: IEA 2021a. All rights reserved. Adapted from "Tracking Clean Energy Progress"

Fonte: United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.

Energia e sustentabilidade

Edifícios – onde estamos no caminho para os *nearly zero-energy buildings*

Figure 6. Direct reference path to a zero-carbon building stock target in 2050 (left); zooming into the period between 2015 and 2020, comparing the observed Global Buildings Climate Tracker to the reference path (right)

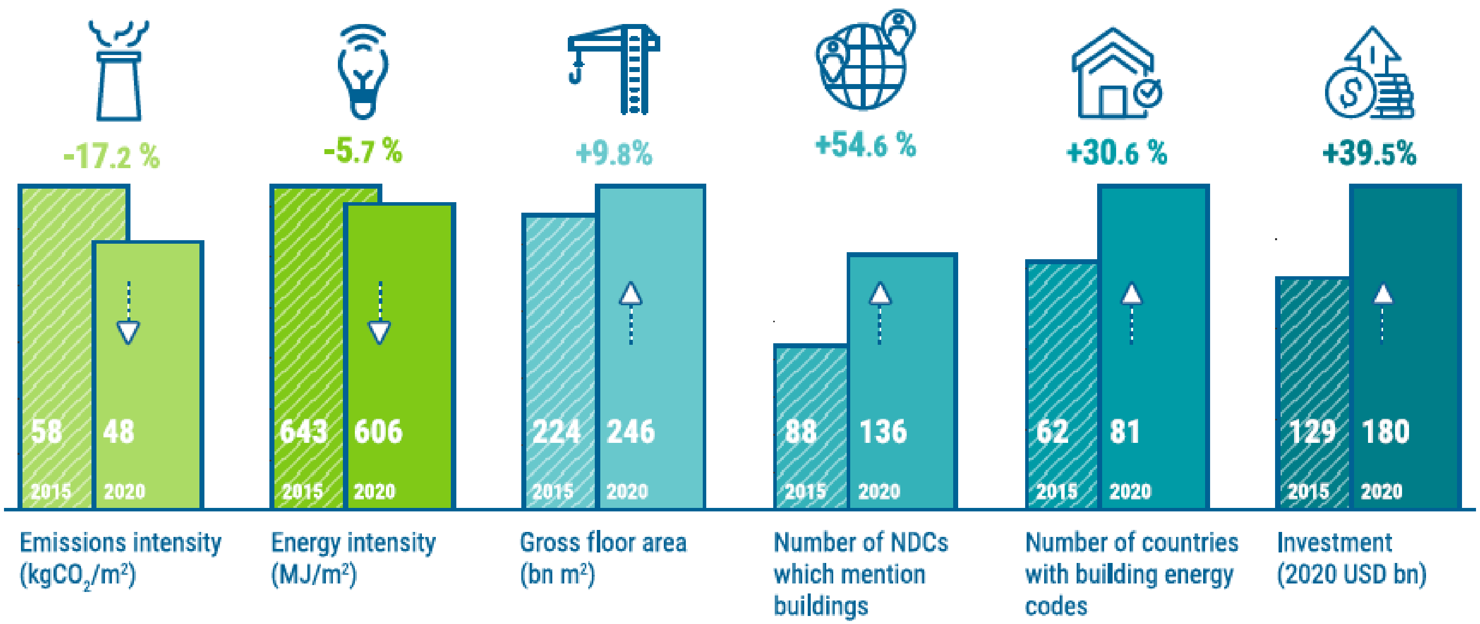


Fonte: United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.

Energia e sustentabilidade

Edifícios – alterações entre 2015 e 2020

Figure 1 - Key changes in buildings sector between 2015 and 2020



Sources: UNFCCC 2021; Buildings-GSR 2021; IEA 2021a.

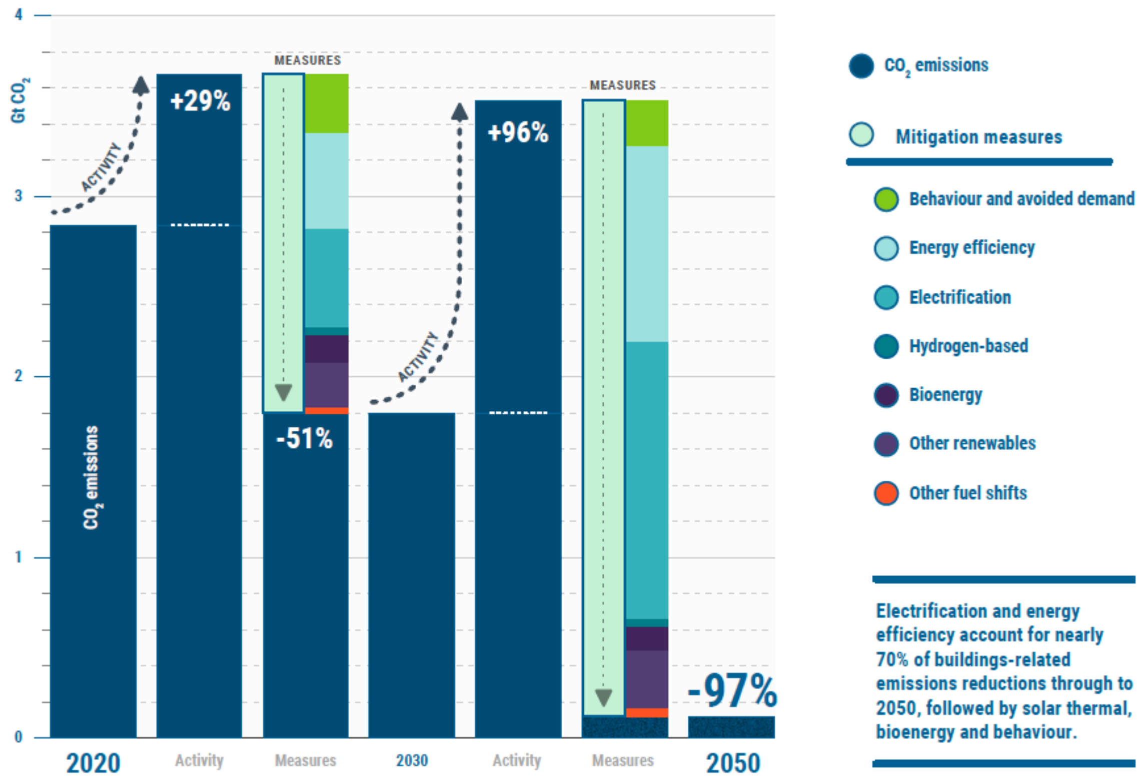
Notes: Emissions intensity is total buildings construction and operations emissions over total floor area, energy intensity is total building operational energy over

Fonte: United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.

Estratégias de mitigação

Figure 16. Global direct CO_2 emission reductions by mitigation in building in the net zero energy scenario 2050

Electrification and energy efficiency account for nearly 70% of buildings-related emissions reductions through to 2050, followed by solar thermal, bioenergy and behaviour



Notes: Activity = change in energy service demand related to rising population, increased floor area and income per capita. Behaviour = change in energy service demand from user decisions, e.g. changing heating temperatures. Avoided demand = change in energy service demand from technology developments, e.g. digitalisation.

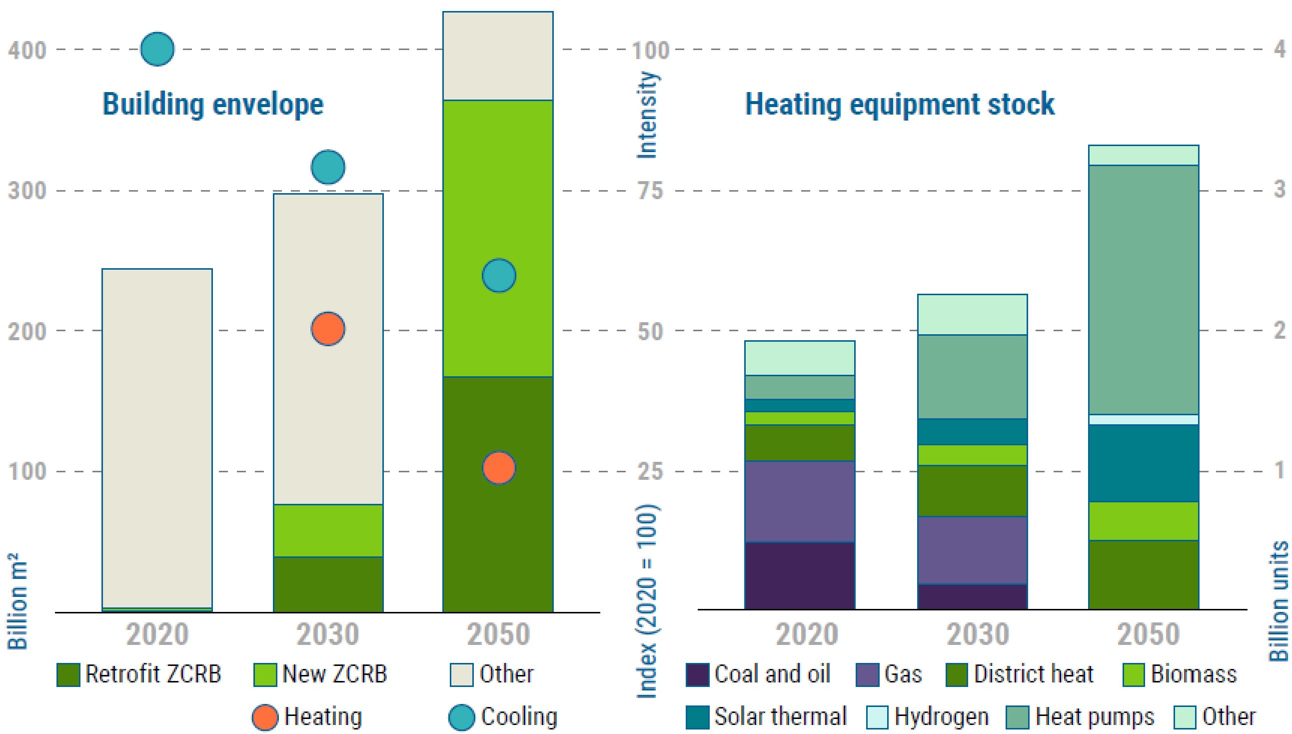
Sources: IEA 2021c. All rights reserved.

Fonte: United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.

Energia e sustentabilidade

Estratégias de mitigação

Figure 17. Final energy consumption by fuel and end-use in buildings in the net zero energy scenario 2050



By 2050, over 85% of buildings are zero-carbon-ready, reducing average useful heating intensity by 75%, with heat pumps meeting over half of heating needs

Note: ZCRB -= zero-carbon-ready buildings

Sources: IEA 2021c.

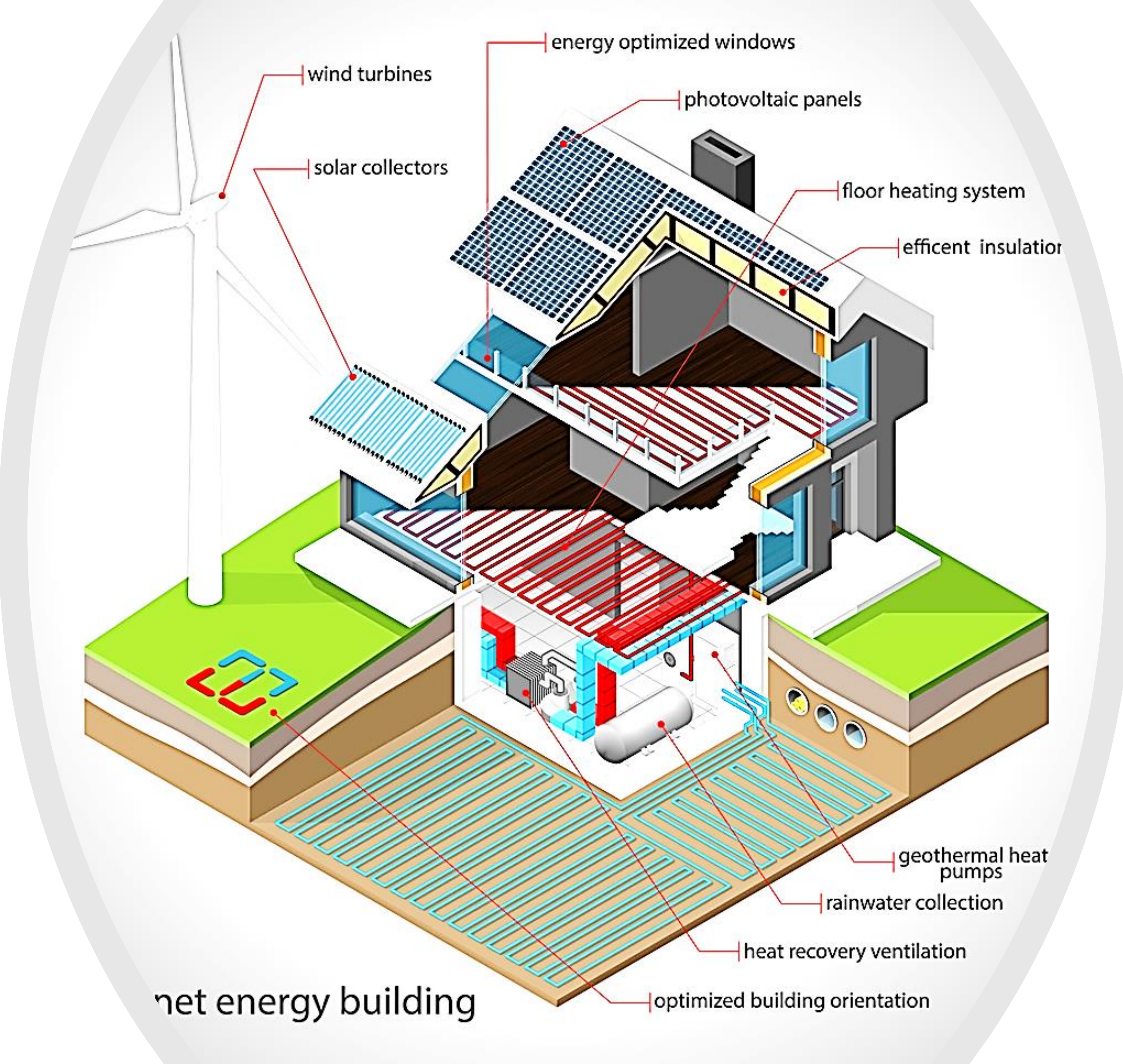
Fonte: United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.

Energia e sustentabilidade

Edifícios – ***nearly zero-energy buildings***

To set the global building sector on a pathway to net zero emissions by 2050, the IEA outlines a series of milestones that can serve as indicators to assess how on-track the buildings sector is and the scale of the transformation required (see figure 17). The indicators include: a near-term energy intensity improvement pathway; increasing the share of building stock that is zero carbon ready from less than 1 per cent today to 20 per cent by 2030 and almost 100 per cent by 2050; drastically increasing the stock of heat pumps and solar thermal systems, plus LEDs accounting for 100 per cent lighting by 2030; increasing appliance efficiency to consume 25 per cent less by 2030 and 40 per cent less by 2050; significantly growing solar PV generation; and finally, all new buildings need to be zero-carbon-ready by 2030.

Fonte: United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.


energy optimized windows
wind turbines
photovoltaic panels
solar collectors
floor heating system
efficent insulatior
geothermal heat pumps
rainwater collection
heat recovery ventilation
optimized building orientation
net energy building

Energia e sustentabilidade

Edifícios – *nearly zero-energy buildings*

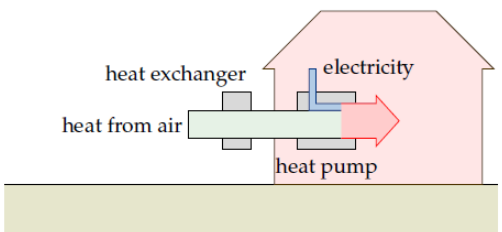
	2020	2030	2050
Energy intensity	Improve by 6% per year 2020-2030	Improve by 4% per year 2030-2040	Improve by 3% per year 2040-2050
Share of existing buildings net-zero ready	<1%	20%	>85%
Avoided demand in homes from behaviour	-	12%	14%
Stock of heat pumps	180 million	600 million	1 800 million
Dwellings with solar thermal	250 million	400 million	1 200 million
Appliances unit consumption (realtive to 2020)	-	-25%	-40%
Distributed PV generation	320 TWh	2 200 TWh	7 500 TWh

*'ources: IEA 2021c. *

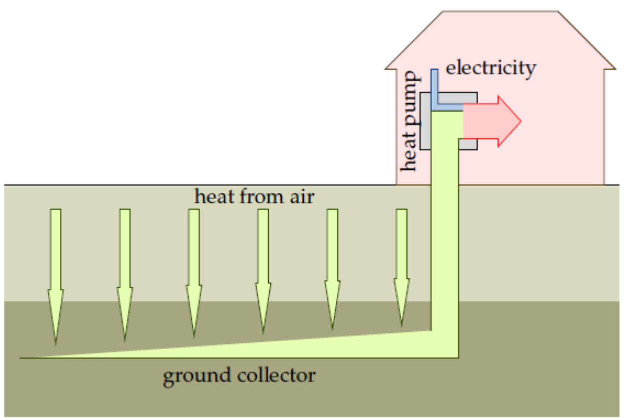
Fonte: United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.

Edifícios – Bombas de calor

Tecnologia eficiente e sustentável!

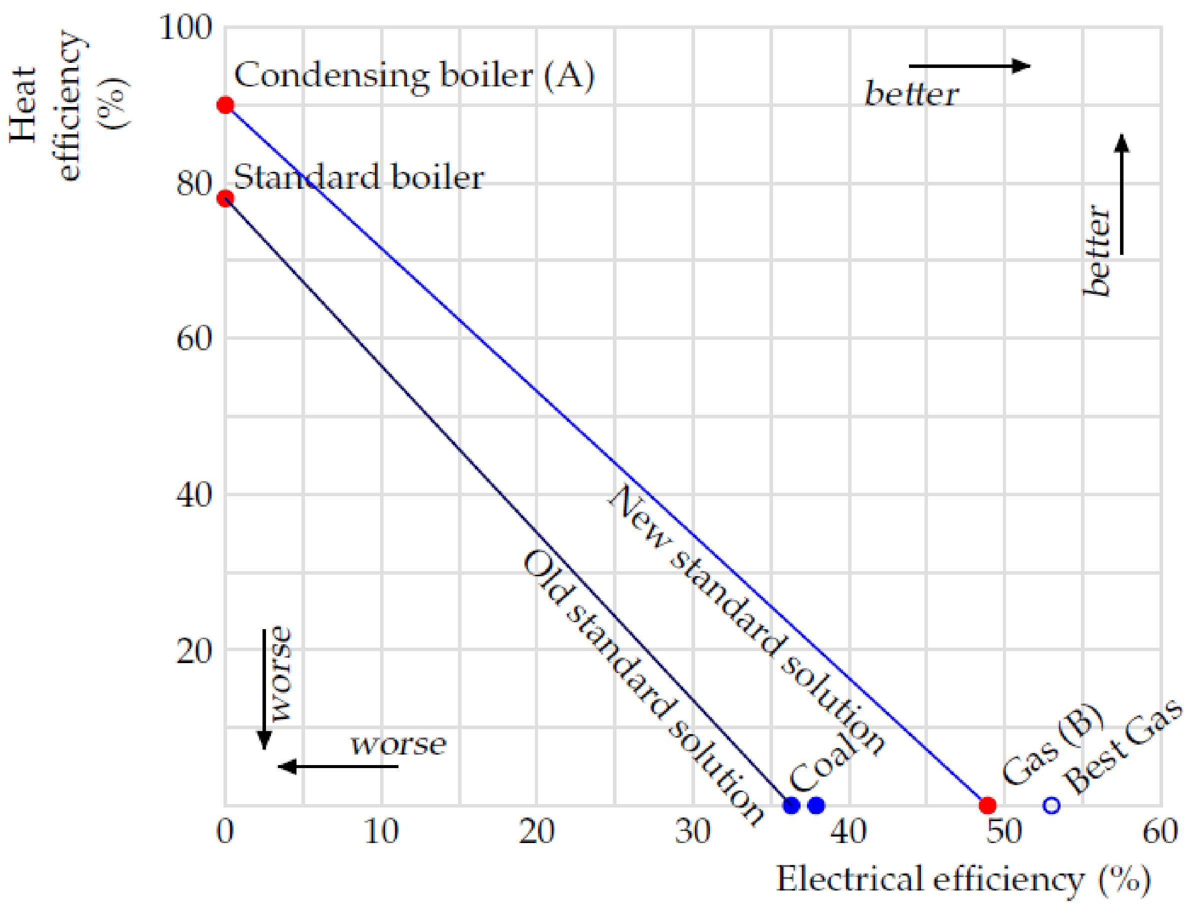


air-source heat pump

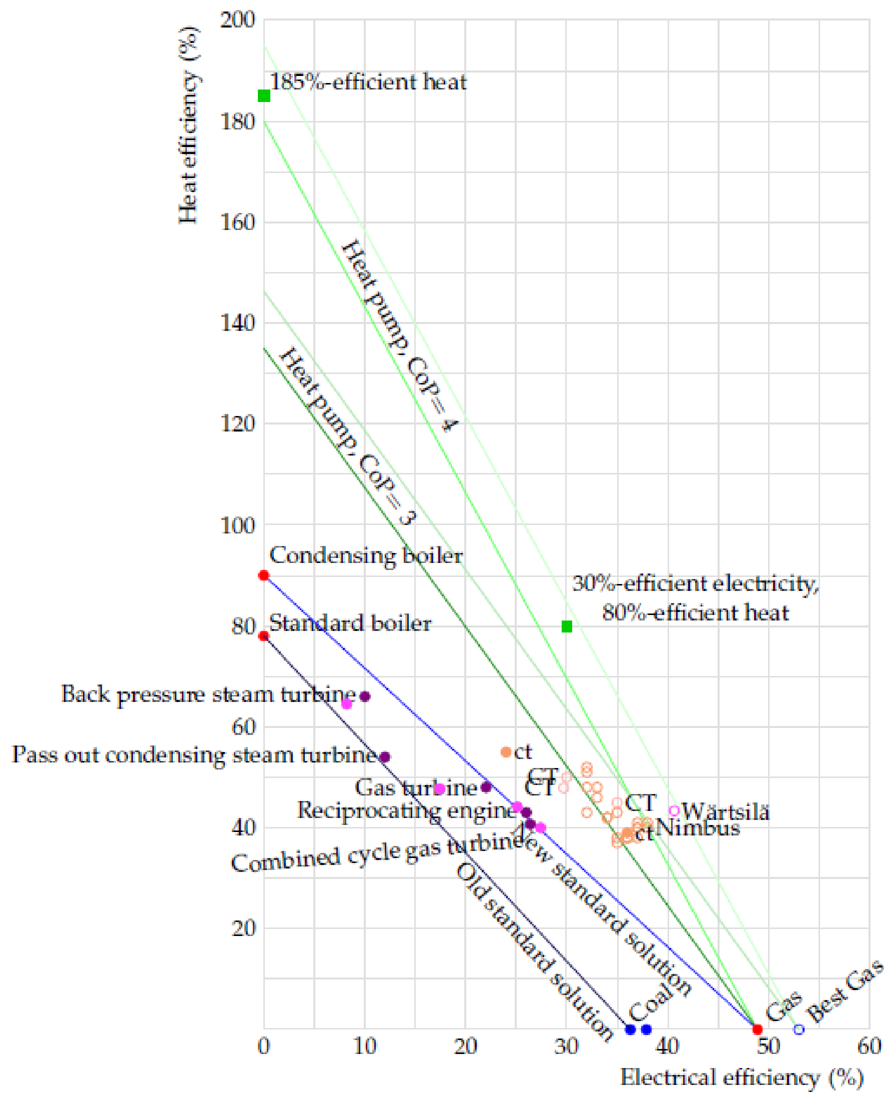


ground-source heat pump

Edifícios – Bombas de calor



Edifícios – Bombas de calor



Edifícios – Bombas de calor

Cenário:

Aquecimento de uma casa típica no Reino Unido durante 1 ano.

Caldeira a gás

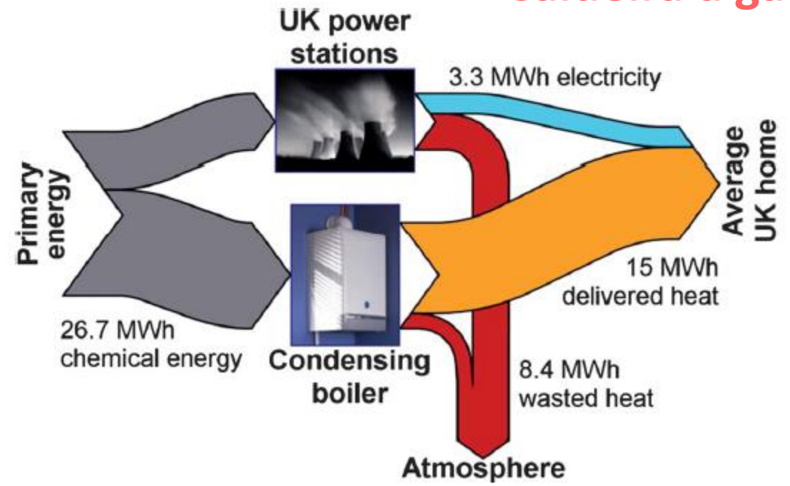
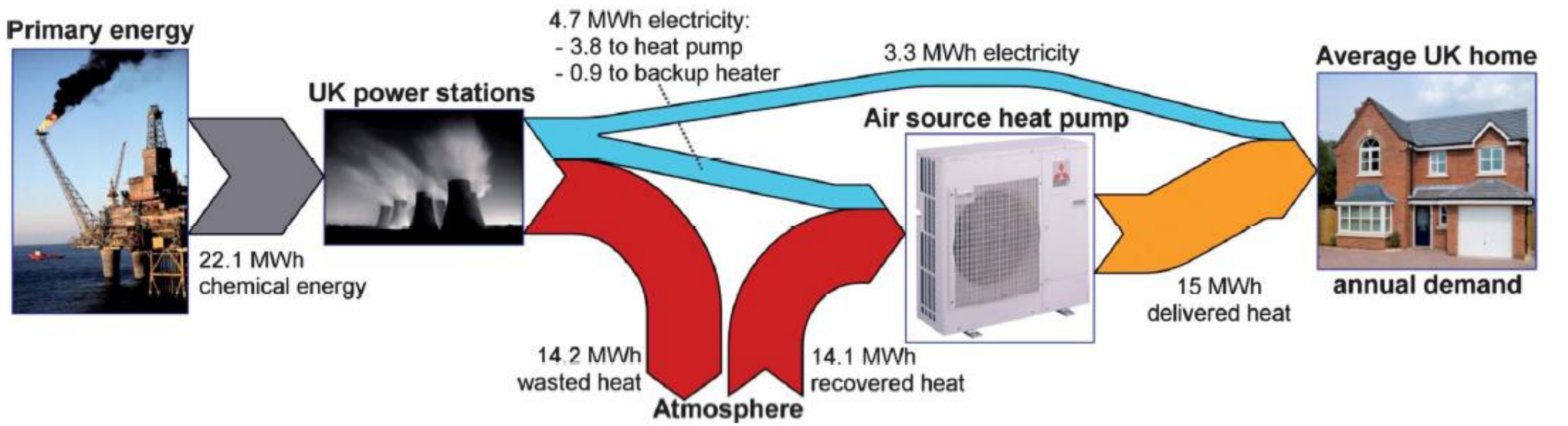


Fig. 2 A Sankey diagram depicting the provision of energy to the same house using a high efficiency condensing gas boiler.

Bomba de calor



Fonte: I. Staffell, D. Brett, N. Brandon, and A. Hawkes, "A review of domestic heat pumps," Energy Environ. Sci., vol. 5, no. 11, pp. 9291–9306, 2012.

Edifícios – Bombas de calor

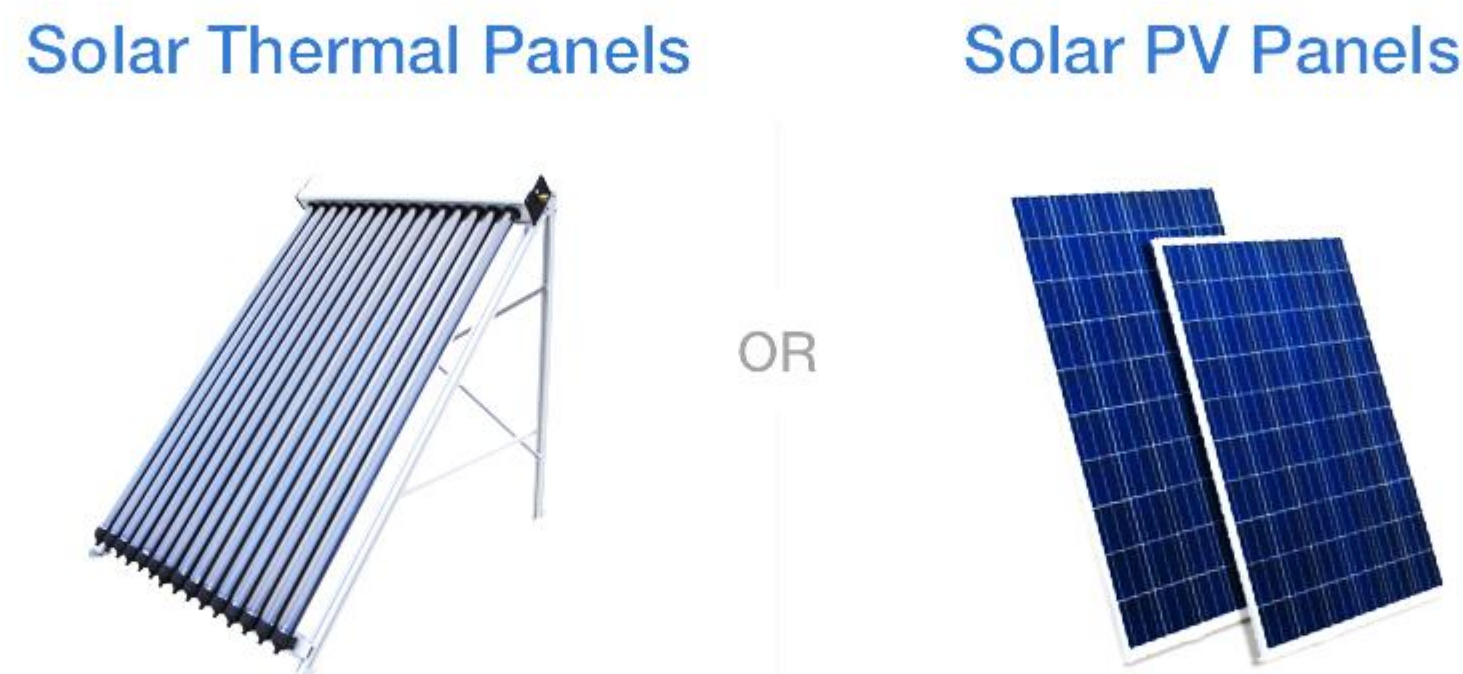
The inner and outer bits of an air-source heat pump that has a coefficient of performance of 4.

One of these Fujitsu units can deliver 3.6 kW of heating when using just 0.845 kW of electricity. It can also run in reverse, delivering 2.6 kW of cooling when using 0.655 kW of electricity.

Energia e sustentabilidade

Edifícios – autoprodução de energia

Energia solar térmica



Energia solar fotovoltaica

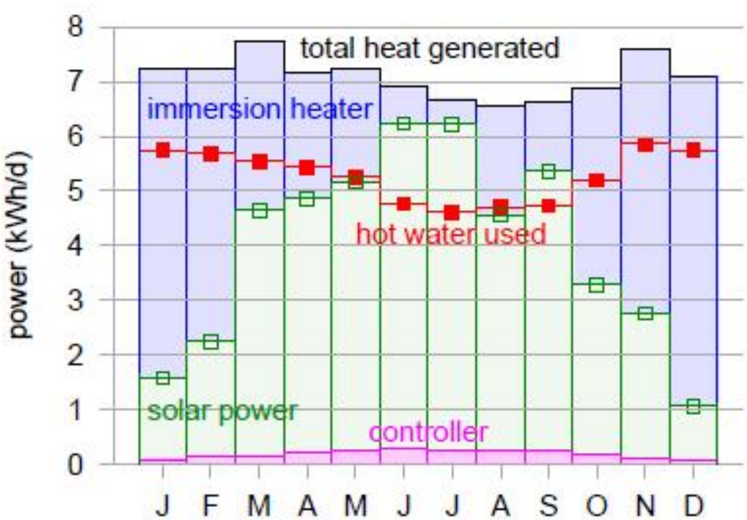
Energia e sustentabilidade

Edifícios – autoprodução de energia

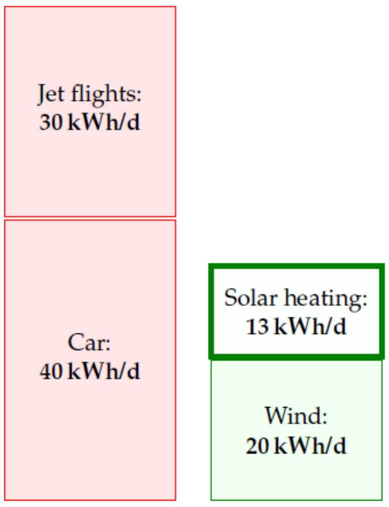
Energia solar térmica

Cenário:

Instalar 10 m^2 de painéis no telhado com eficiência de 50%.



50% x 10 m^2 x 110 W/m^2 = 13 kWh/d/pessoa



Edifícios – autoprodução de energia

Energia solar fotovoltaica

Cenário:

Instalar 10 m^2 de painéis no telhado com eficiência de 20%.

Photovoltaic (PV) panels convert sunlight into electricity. Typical solar panels have an efficiency of about 10%; expensive ones perform at 20%. (Fundamental physical laws limit the efficiency of photovoltaic systems to at best 60% with perfect concentrating mirrors or lenses, and 45% without concentration. A mass-produced device with efficiency greater than 30% would be quite remarkable.) The average power delivered by south-facing 20%-efficient photovoltaic panels in Britain would be

$$20\% \times 110\,\mathrm{W/m^2} = 22\,\mathrm{W/m^2}.$$

Figure 6.5 shows data to back up this number. Let's give every person $10\,\mathrm{m^2}$ of expensive (20%-efficient) solar panels and cover all south-facing roofs. These will deliver

$$5\,\mathrm{kWh\ per\ day\ per\ person.}$$

Materiais de isolamento

Edifícios – materiais de isolamento

Sector da construção

Table 1: **Properties of insulation materials**

Material	Typical thermal conductivity (W/m/K)	Commonly available formats
Natural materials		
Wood fibre	0.038–0.050	Boards, semi-rigid boards and batts
Paper (cellulose)	0.035–0.040	Loose batts, semi-rigid batts
Hemp	0.038–0.040	Semi-rigid slabs, batts
Wool	0.038–0.040	Semi-rigid boards, rolls
Flax	0.038–0.040	Semi-rigid boards, rolls
Cork	0.038–0.070	Boards, granulated
Synthetic materials		
Mineral fibre	0.032–0.044	Boards, semi-rigid boards, rolls
Glass fibre	0.038–0.041	Boards, semi-rigid boards, rolls
Extruded polystyrene (XPS)	0.033–0.035	Boards
Expanded polystyrene (EPS)	0.037–0.038	Boards
Polyurethane (PUR)/polyisocyanorate (PIR)	0.023–0.026	Boards

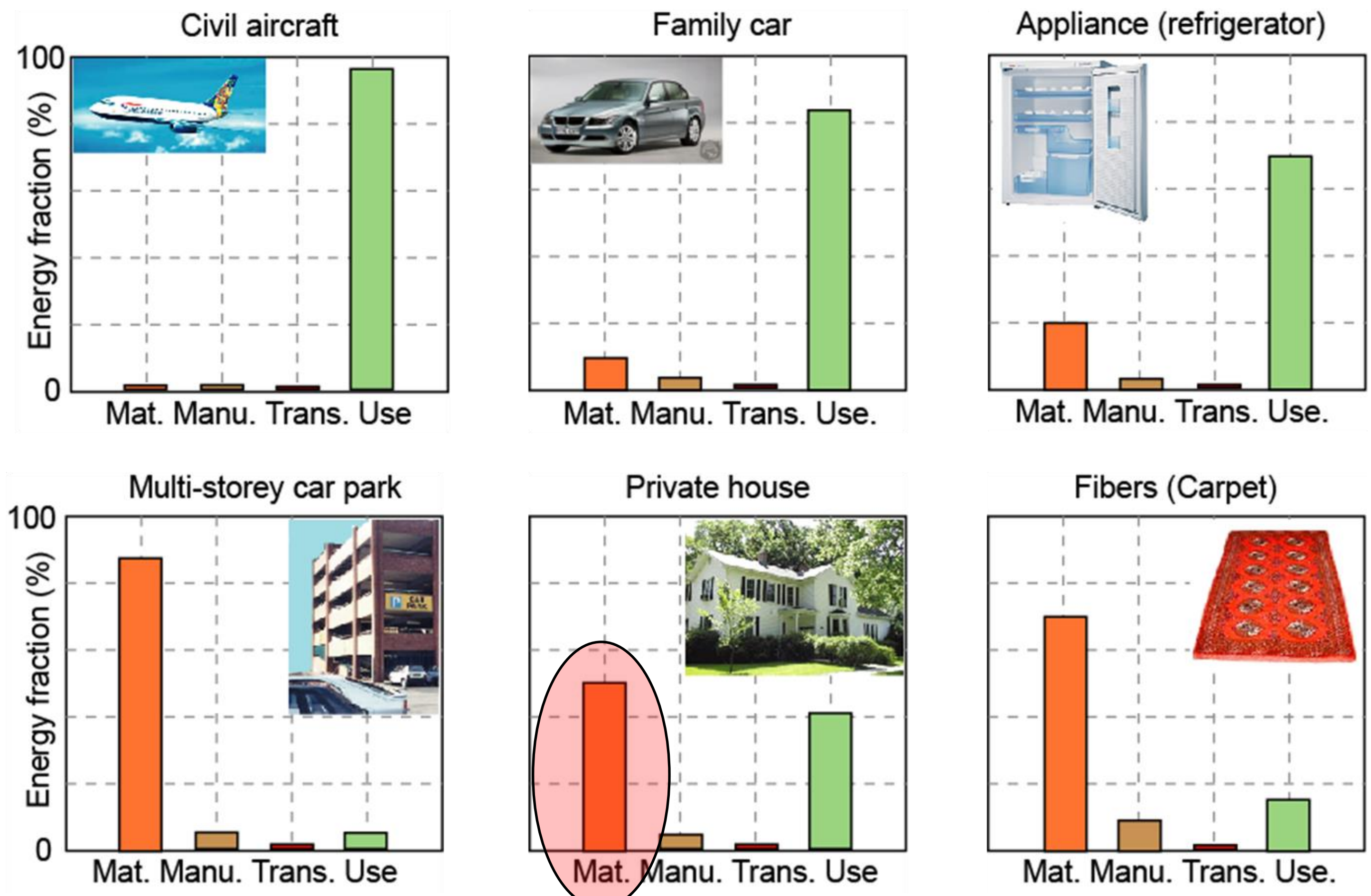
Edifícios – estratégias a implementar vs poupanças energéticas

Major action	possible saving
Eliminate draughts.	5 kWh/d
Double glazing.	10 kWh/d
Improve wall, roof, and floor insulation.	10 kWh/d
Solar hot water panels.	8 kWh/d
Photovoltaic panels.	5 kWh/d
Knock down old building and replace by new.	35 kWh/d
Replace fossil-fuel heating by ground-source or air-source heat pumps.	10 kWh/d

Energia e sustentabilidade

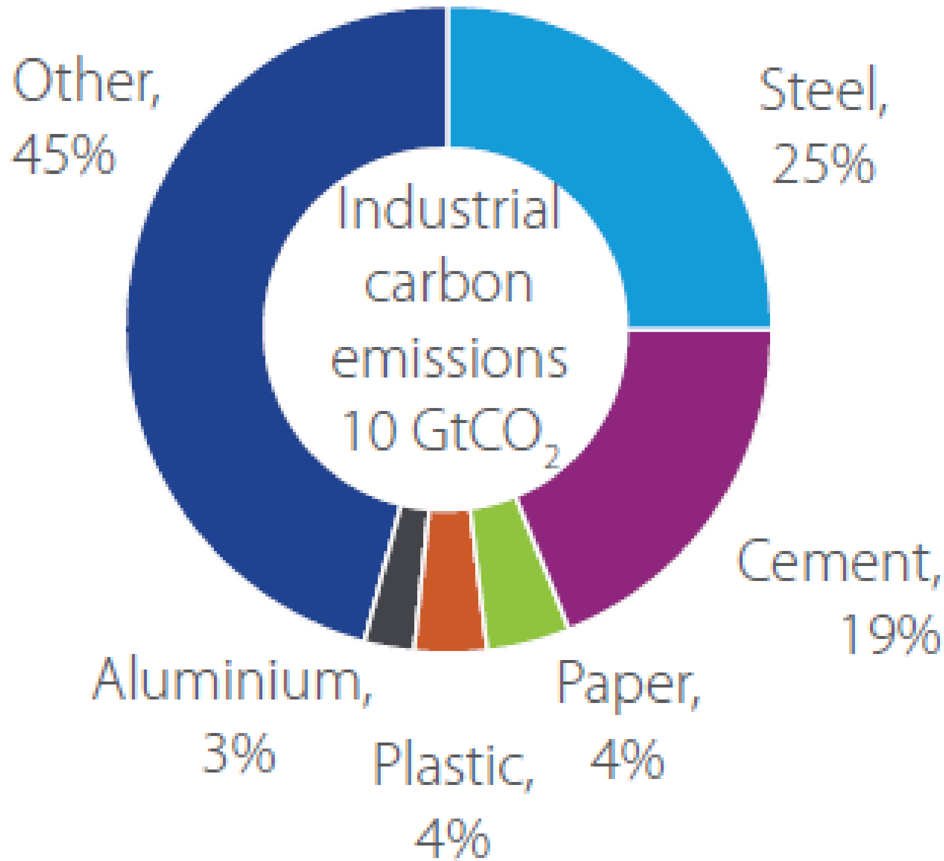
Edifícios – utilização de materiais de construção alternativos?

Consumo de energia de produtos



Energia e sustentabilidade

Fontes antropogénicas de CO_2 por material
(com identificação de 5 materiais chave)



Energia e sustentabilidade

A importância da **Construção (Sustentável)**

Em 1994, o Conselho Internacional da Construção-CIB, definiu o conceito de construção sustentável como *" a criação e manutenção responsáveis de um ambiente construído saudável, baseado na utilização eficiente de recursos e no projecto baseado em princípios ecológicos"* (Kibert, 2008).

Tabela 1.2: Os Princípios da Construção Sustentável (Kibert, 2008)

1	Redução do consumo de recursos
2	Reutilização de recursos
3	Utilização de recursos recicláveis
4	Protecção da natureza
5	Eliminação de tóxicos
6	Aplicação de analises de ciclo de vida em termos económicos
7	Ênfase na qualidade

Energia e sustentabilidade

Energia incorporada em materiais de construção

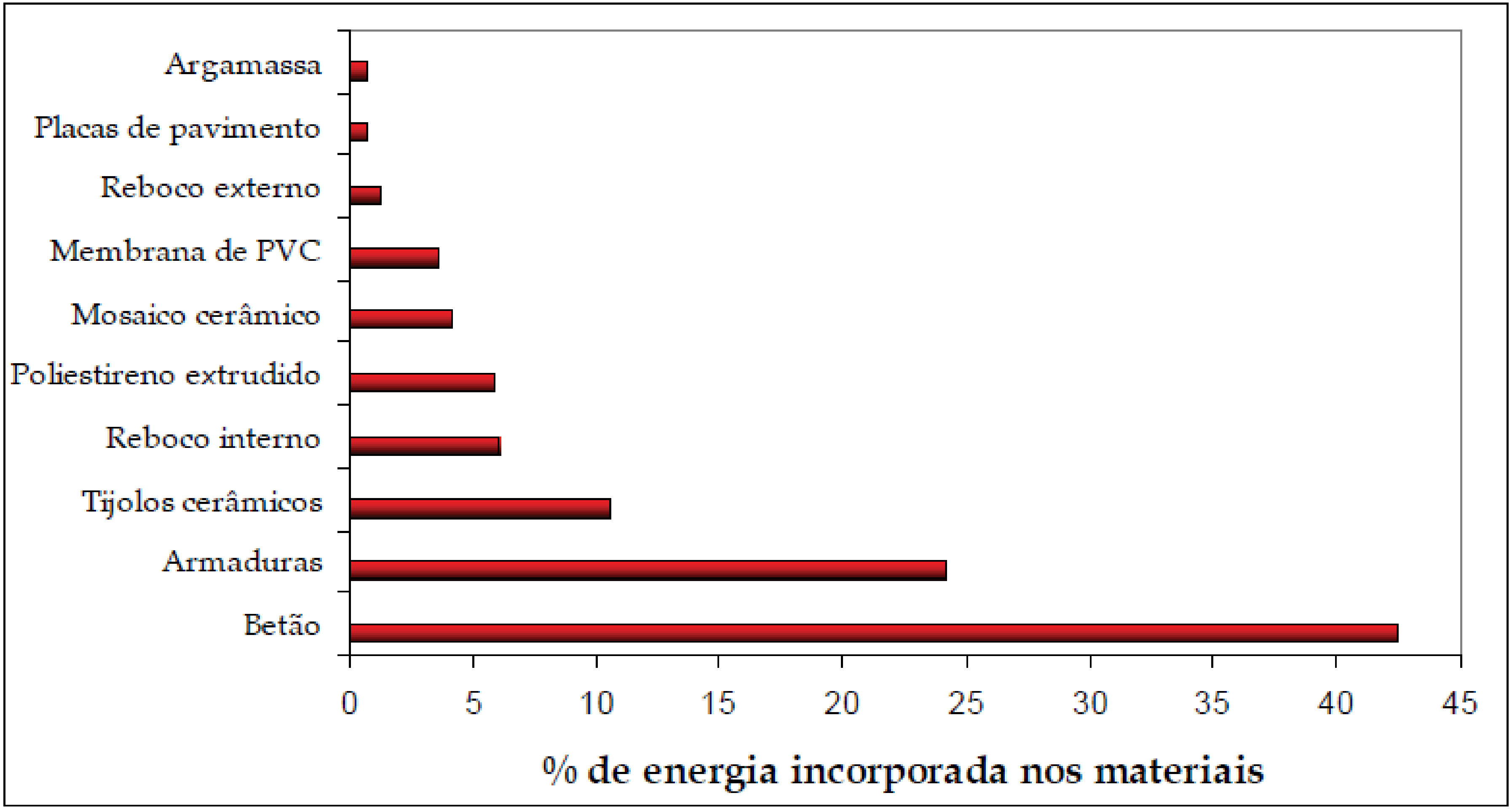
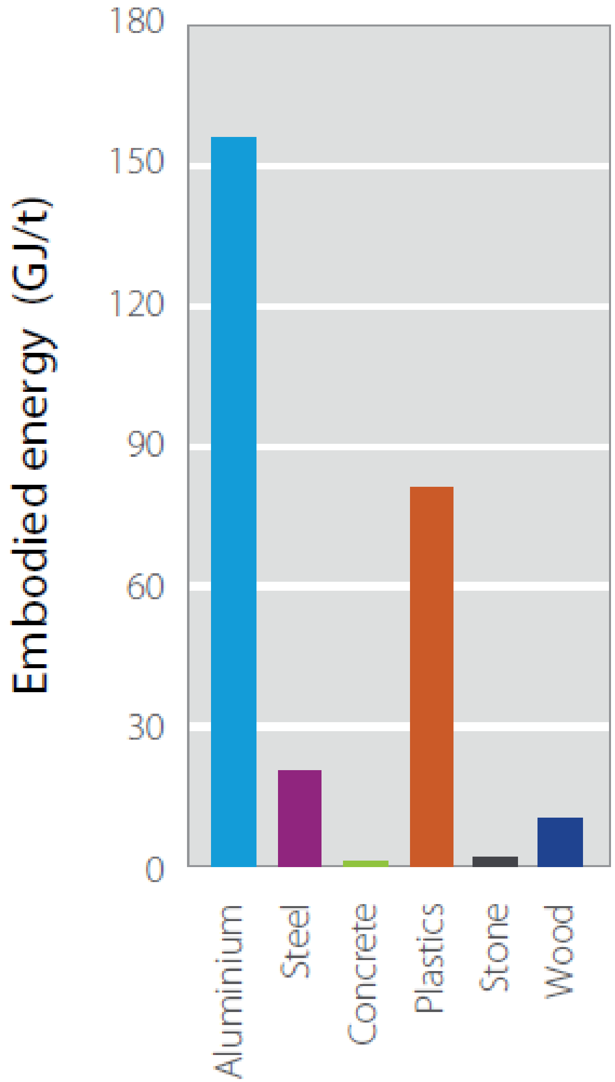
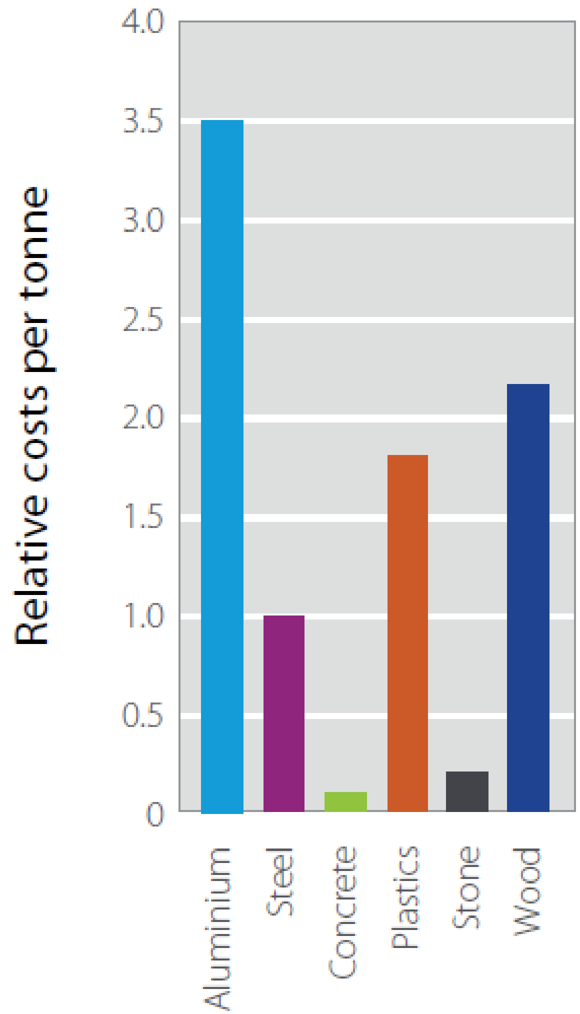


Figura 3.6: Contributo de diferentes materiais para a energia incorporada (Dimoudi & Tompa, 2008)

Energia e sustentabilidade

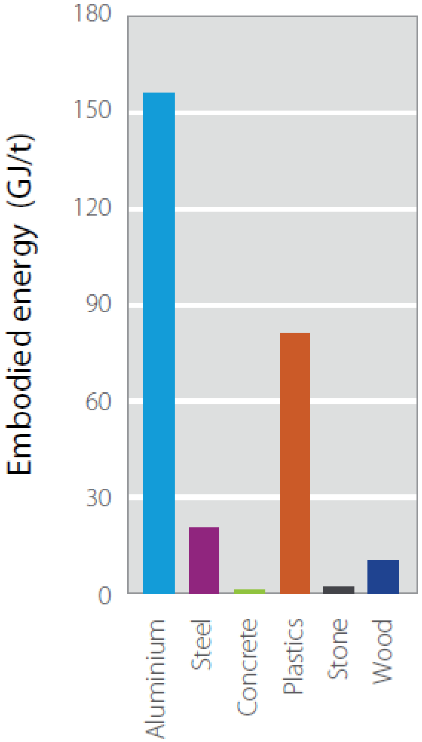
Comparação entre diferentes materiais





Energia e sustentabilidade

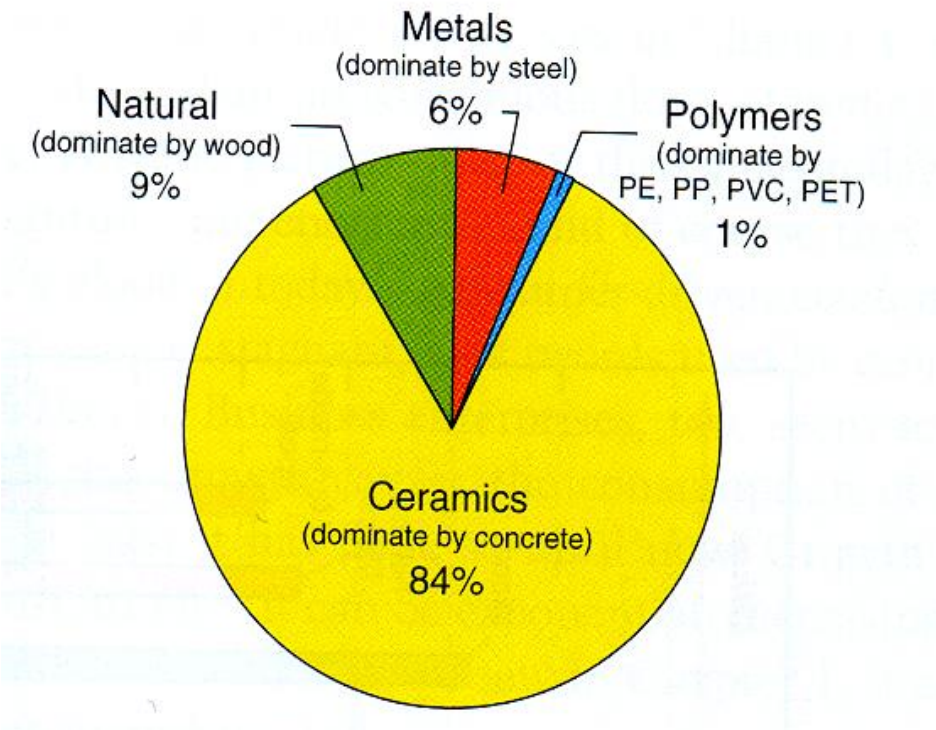
Comparação entre diferentes materiais



Material	Global annual production (Mt)	Energy intensity (GJ/t)	Carbon intensity ($t\,CO_2/t$)
Cement	2,800	5	1
Steel	1,400	35	3
Plastic	230	80	3
Paper	390	20	1
Aluminium	70	170	10

Energia e sustentabilidade

Cimento

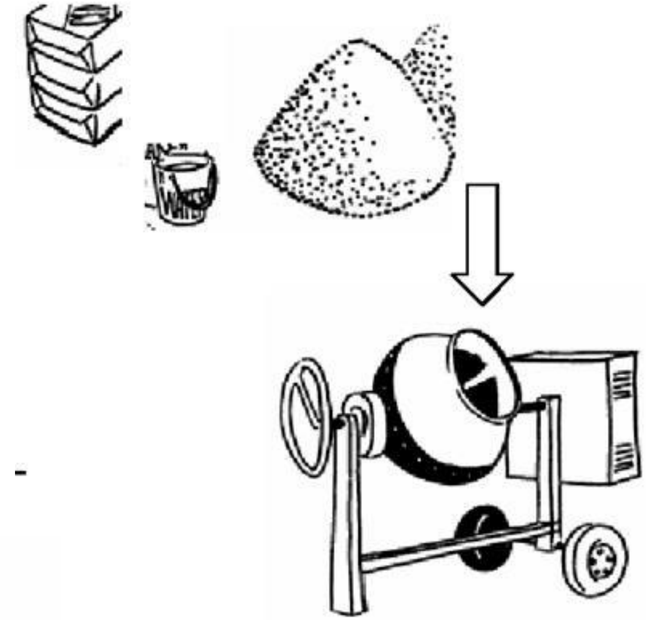


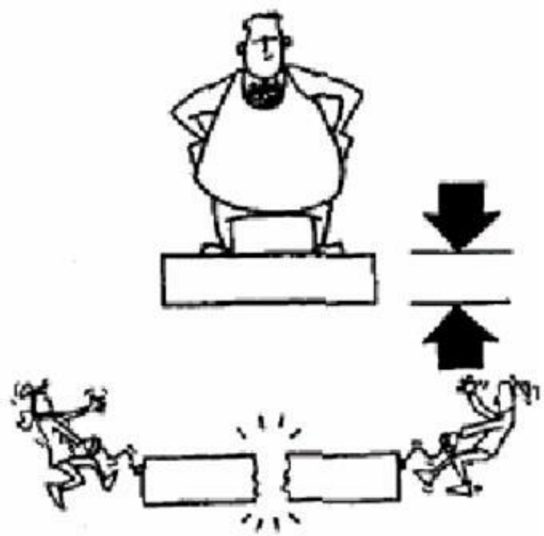
- Distribution of materials used annually per family (in tonnes).
- "Ceramics" are clearly dominant, basically due to concrete
- This perception is important when we want to have an idea of the scale of the environmental impact of a given material.

- The results show the extraordinary influence of concrete/cement production.

Produção de argamassas e betão

- **Constituents**
  - Cement/Binder
    + Aggregates (fine and coarse)
    + Water
    (+ Additives)
  - Typical ratios:
    c/a = 1:3
    w/c = 0,4





Energia e sustentabilidade

Agregados

- The aggregates are the minerals most consumed on Earth:
  - A flat consumes about 150 tons of aggregates, 1km road about 10,000 tons and 1 km of highway about 30,000 tons.
  - Globally the total consumption is approximately 20 Gt/year
  - The expected demand for this resource will grow at an annual rate of 4.7%.

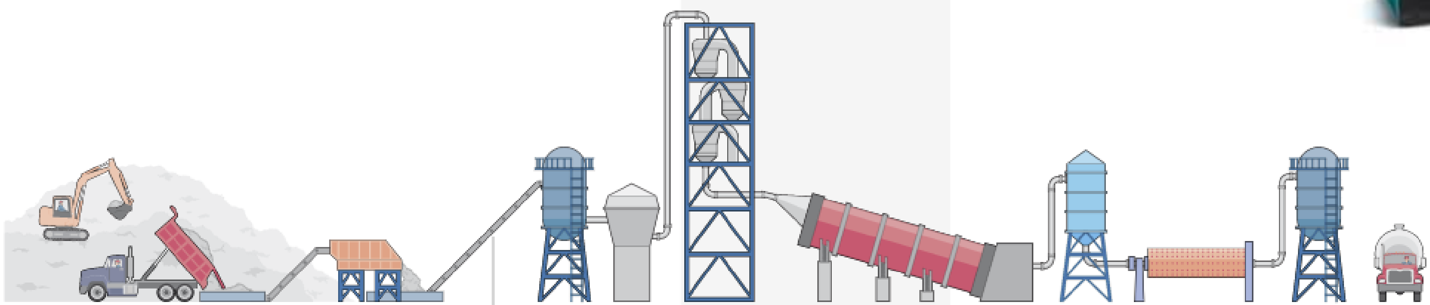
In Portugal the consumption of aggregates is around 80 million tons/year, however, given the incidence of transport costs in the overall cost of these materials (implying that for each ton the value doubles for each 50 km transportation), meaning that quarries tend to be distributed "almost like mushrooms" throughout the country.
The first impact is the biodiversity change/destruction !

Energia e sustentabilidade

Fabricação de cimento Portland

Cement manufacturing is a highly complex process.

Raw materials, energy, and resources | **Clinker and cement manufacturing**



	Quarry	Crusher	Transport[1]	Raw mill	Kiln and preheater/ precalcinator[2]	Cooler[3]	Cement mill	Logis-tics[4]	**Total**
Energy, mega-joule/ton	40	5	40	100	3,150	160	285	115	3,895
CO_2, kilogram/ton	3	1	7	17	479 Calcination process 319 Fossil fuels	28	49	22	925

[1] Assumed with 1kWh/t/100m.
[2] Assumed global average, data from the Global Cement and Concrete Association, Getting the Numbers Right 2017.
[3] Assumed reciprocating grate cooler with 5kWh/t clinker.
[4] Assumed lorry transportation for average 200km.

Fonte: https://www.mckinsey.com/industries/chemicals/our-insights/laying-the-foundation-for-zero-carbon-cement

Desafios na fabricação de cimento Portland

Estima-se que a produção de uma tonelada de cimento Portland comum (OPC) gera aproximadamente 800 Kg de CO_2. Para além da componente associada à queima de combustível (frequentemente carvão ou coque de petróleo), há que juntar a decomposição da calcite (que gera 0,54 ton de CO_2/ton. de cimento).

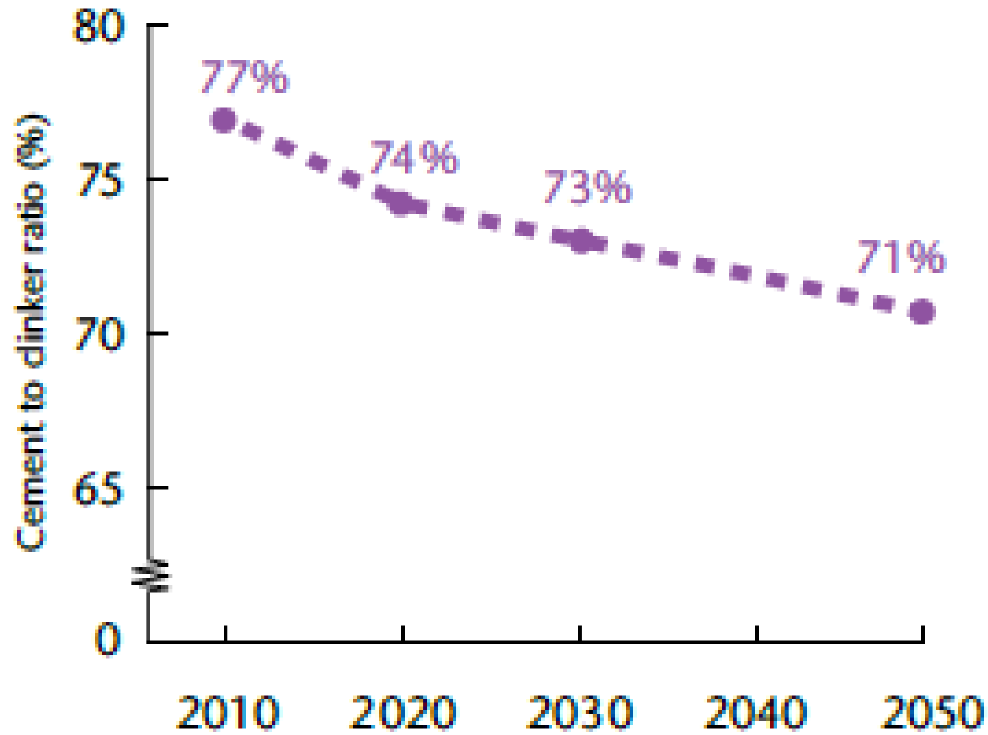
Por isso, a indústria responde por cerca de 7% do total de CO_2 antropogénico libertado globalmente e estima-se ser responsável em 4% do aquecimento global verificado.

Reduções nas emissões podem ser conseguidas através de:
(i) ***minimização do teor de clínquer no cimento e uso de materiais suplementares (resíduos ?)***;

Energia e sustentabilidade

(i) minimização do teor de clínquer no cimento e uso de materiais suplementares (resíduos ?);

- Escórias de alto forno
- Cinzas (centrais termoelétricas a carvão e de biomassa)
- Materiais vulcânicos
- Lama vermelha
- Resíduos de mineração
- etc ...



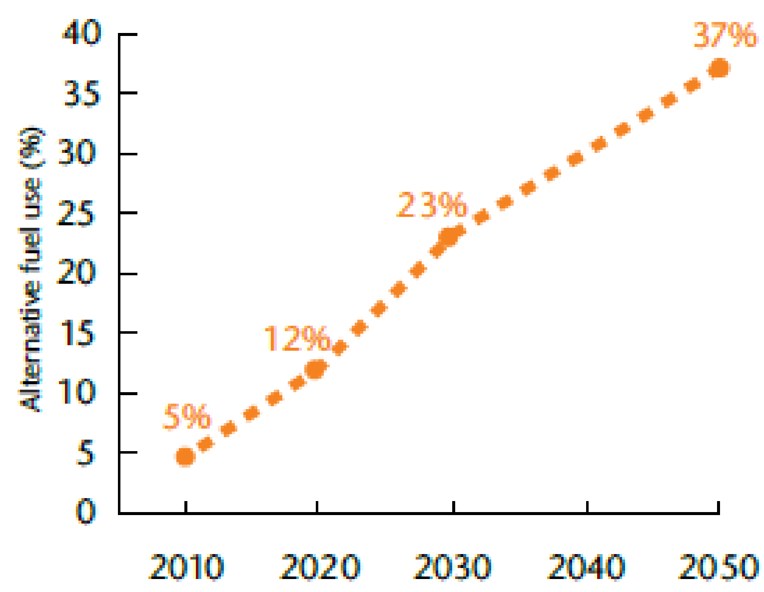
Energia e sustentabilidade

(ii) Uso de combustíveis derivados de resíduos – taxa de substituição térmica

O clínquer comum (Portland) é obtido a cerca de 1450 ^{o}C.
A substituição dos combustíveis fósseis não renováveis por combustíveis alternativos permite reduzir os custos com combustíveis, as emissões de CO_2, e, simultaneamente, prestar à sociedade um serviço seguro para que esta se desfaça dos resíduos que gera valorizando-os energeticamente.

- Os materiais usados são:

- Resíduos pré-tratados industriais e municipais
- Pneus
- Resíduos oleosos e solventes
- Plásticos, têxteis e resíduos de papel
- Biomassa
- Farinhas de origem animal
- Lodos de esgoto



Energia e sustentabilidade

(iii) *desenvolvimento de cimentos não calcários (ex. geopolímeros)*

- Os geopolímeros são polímeros inorgânicos formados pela reação entre uma solução alcalina e uma fonte de aluminossilicatos;

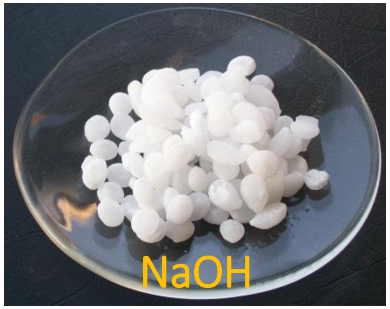
- O material endurecido apresenta uma estrutura 3D, com meso e microporos, semelhante aos zeólitos;

- Usa-se como cimento ou em aplicações especiais (adsorvente, retentor de metais – remediação ambiental).

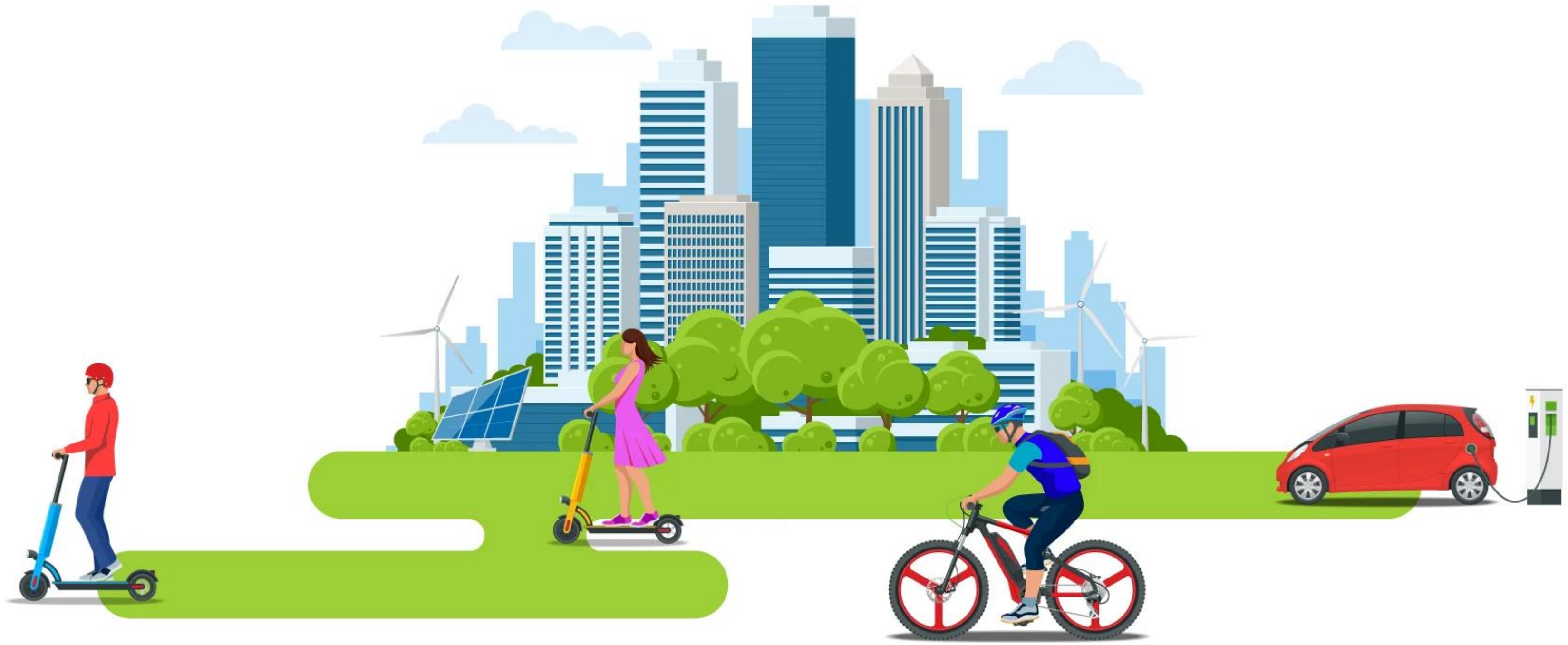
Ligante

- **Metacaulino**
- **Cinzas volantes**
- **Escórias de alto forno**

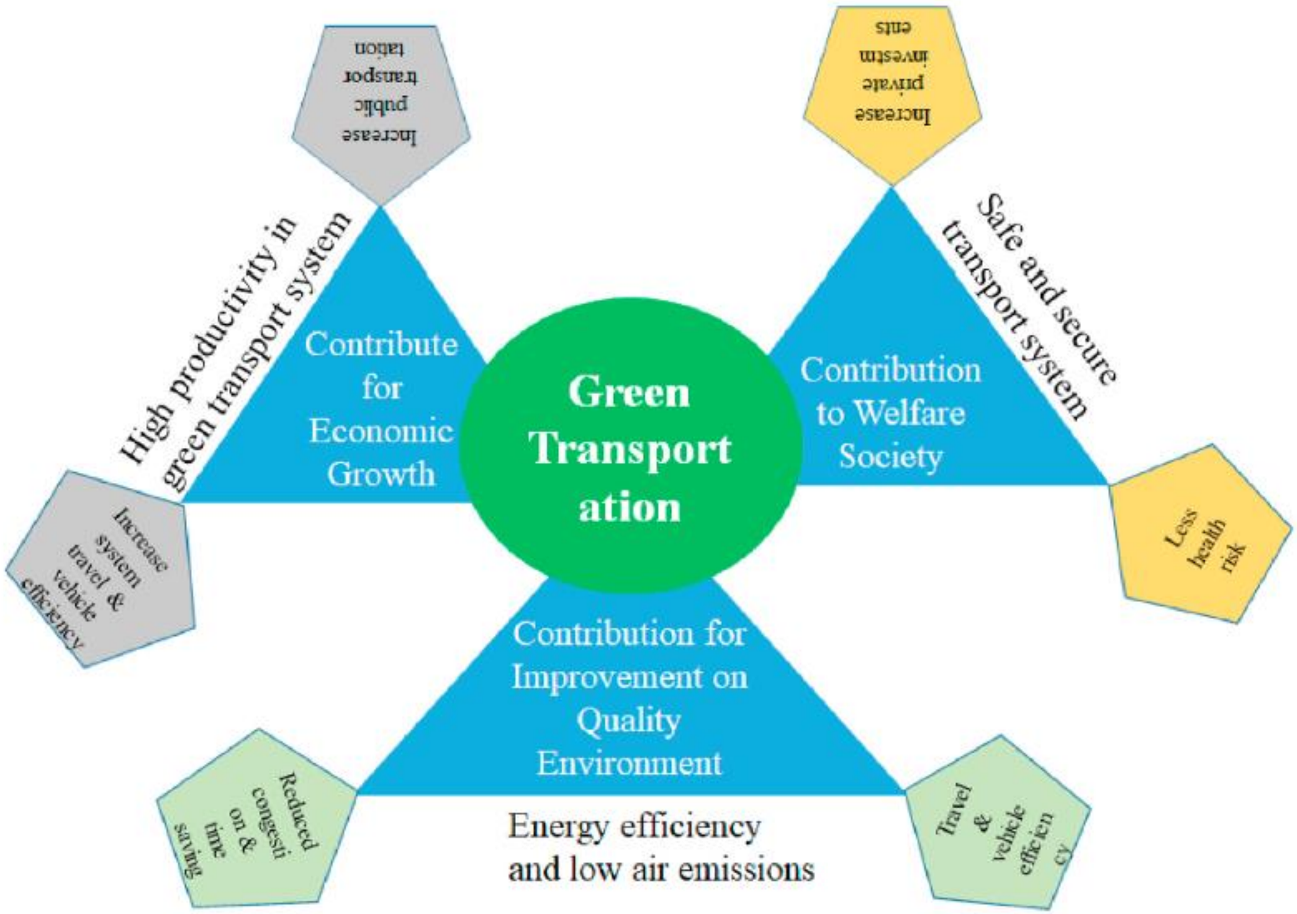
Ativadores alcalinos



Transportes – mobilidade sustentável

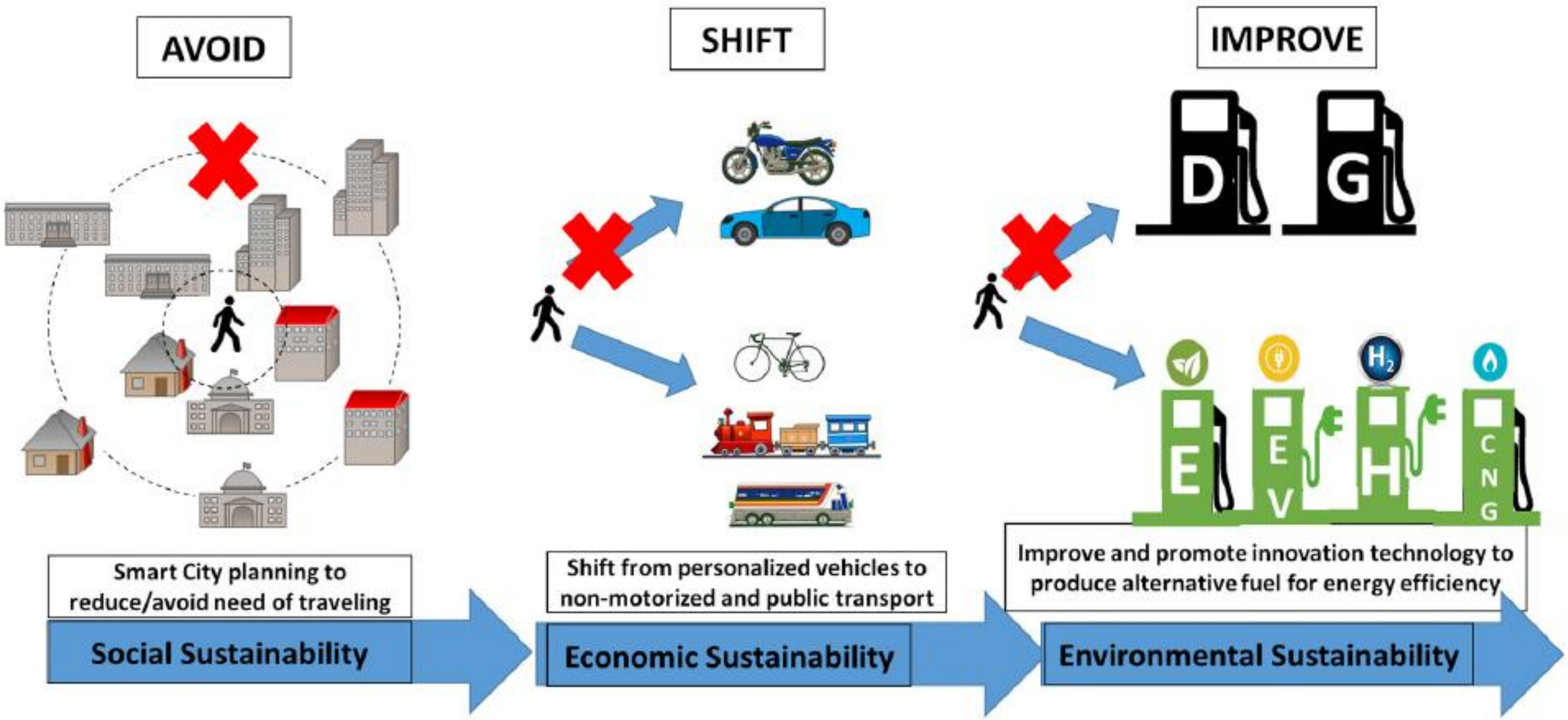


Parâmetros chave para atingir a sustentabilidade na mobilidade



Fonte: Shah *et al.*, **"**Green transportation for sustainability: Review of current barriers, strategies, and innovative technologies". Journal of Cleaner Production 326 (2021).

Estratégia “Avoid-Shift-Improve”



Fonte: Shah *et al.*, **“**Green transportation for sustainability: Review of current barriers, strategies, and innovative technologies”. Journal of Cleaner Production 326 (2021).

Transportes – consumo de energia

Figure 20.1. This chapter's starting point: an urban luxury tractor. The average UK car has a fuel consumption of 33 miles per gallon, which corresponds to an energy consumption of 80 kWh per 100 km. Can we do better?

Cenário ótimo:
Capacidade máxima de utilização.

3–9 kWh per 100 seat-km, if full

Two high-speed trains. The electric one uses 3 kWh per 100 seat-km; the diesel, 9 kWh.

7 kWh per 100 p-km, if full

21 kWh per 100 p-km, if full

Transportes – consumo de energia

Cenário realista:

Consumos de energia médios

32 kWh per 100 p-km

9 kWh per 100 p-km

	Energy consumption (kWh per 100 p-km)
Car	68
Bus	19
Rail	6
Air	51
Sea	57

Table 20.8. Overall transport efficiencies of transport modes in Japan (1999).

Figure 20.1. This chapter's starting point: an urban luxury tractor. The average UK car has a fuel consumption of 33 miles per gallon, which corresponds to an energy consumption of 80 kWh per 100 km. Can we do better?

Energia e sustentabilidade

Transportes – consumo de energia e emissão de CO_2

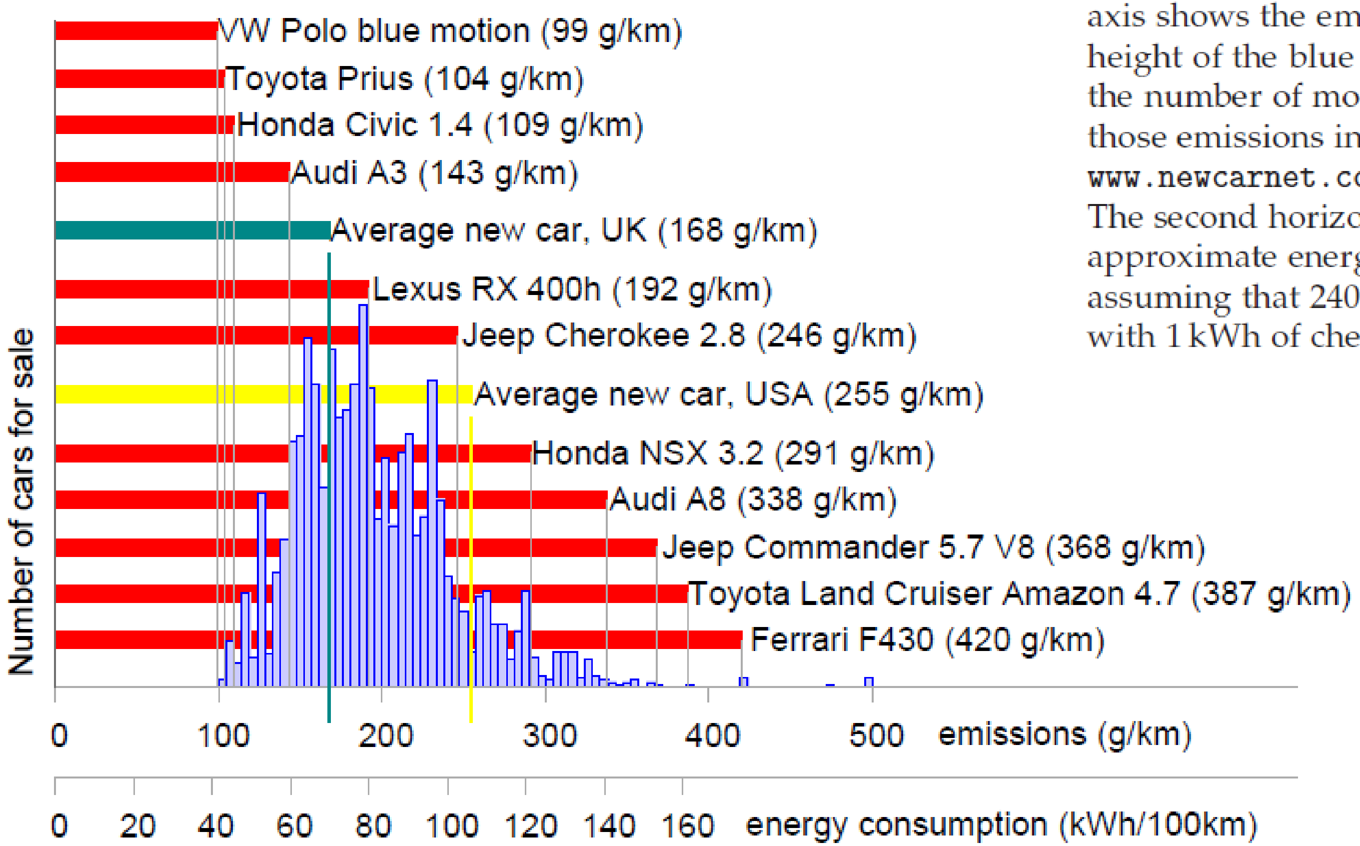


Figure 20.9. Carbon pollution, in grams CO_2 per km, of a selection of cars for sale in the UK. The horizontal axis shows the emission rate, and the height of the blue histogram indicates the number of models on sale with those emissions in 2006. Source: www.newcarnet.co.uk.
The second horizontal scale indicates approximate energy consumptions, assuming that 240 g CO_2 is associated with 1 kWh of chemical energy.

Energia e sustentabilidade

Transportes – consumo de energia vs velocidade