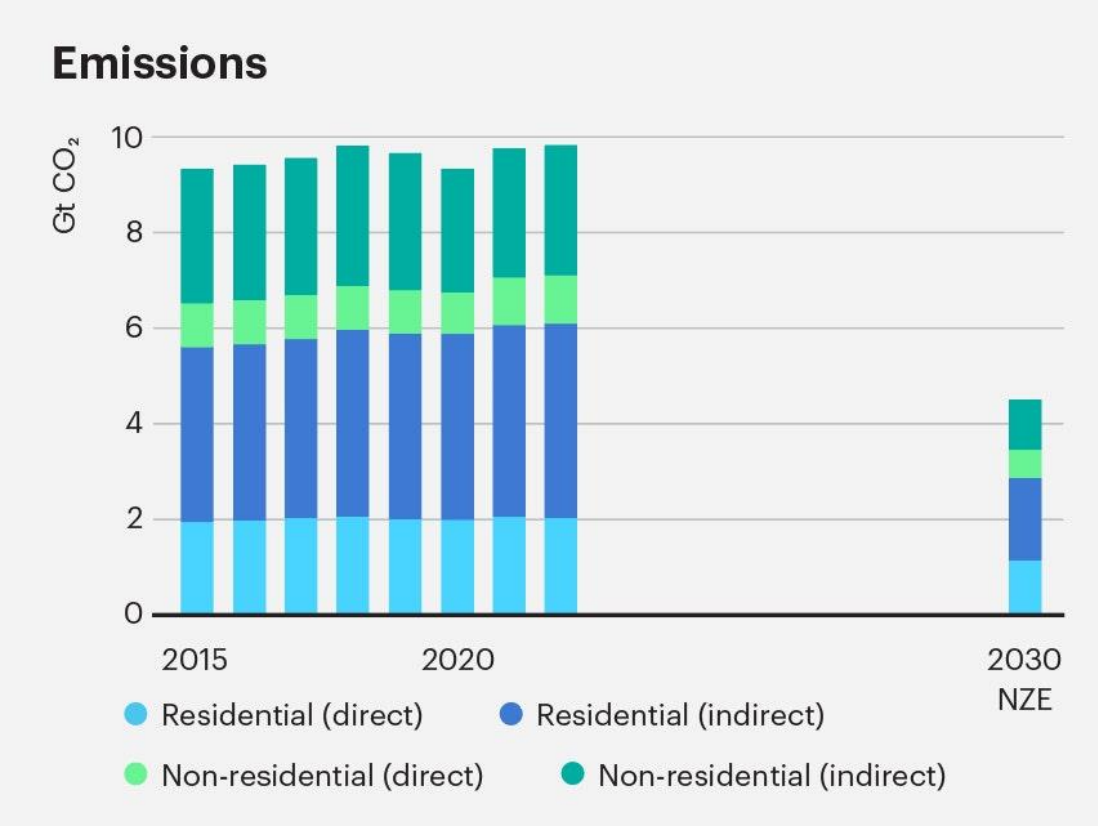
Energia e **Sustentabilidade:** duas faces da mesma moeda?

Energia e sustentabilidade

Emissões de CO_2 – contribuição dos edifícios e do setor da construção

The buildings sector is not on track for net zero by mid-century, with emissions growing at an average of 1% per year since 2015. Global growth in floor area is more than offsetting the increased efficiency and decarbonisation efforts A major shift is required to decarbonise the sector while also ensuring it delivers resilience for communities.

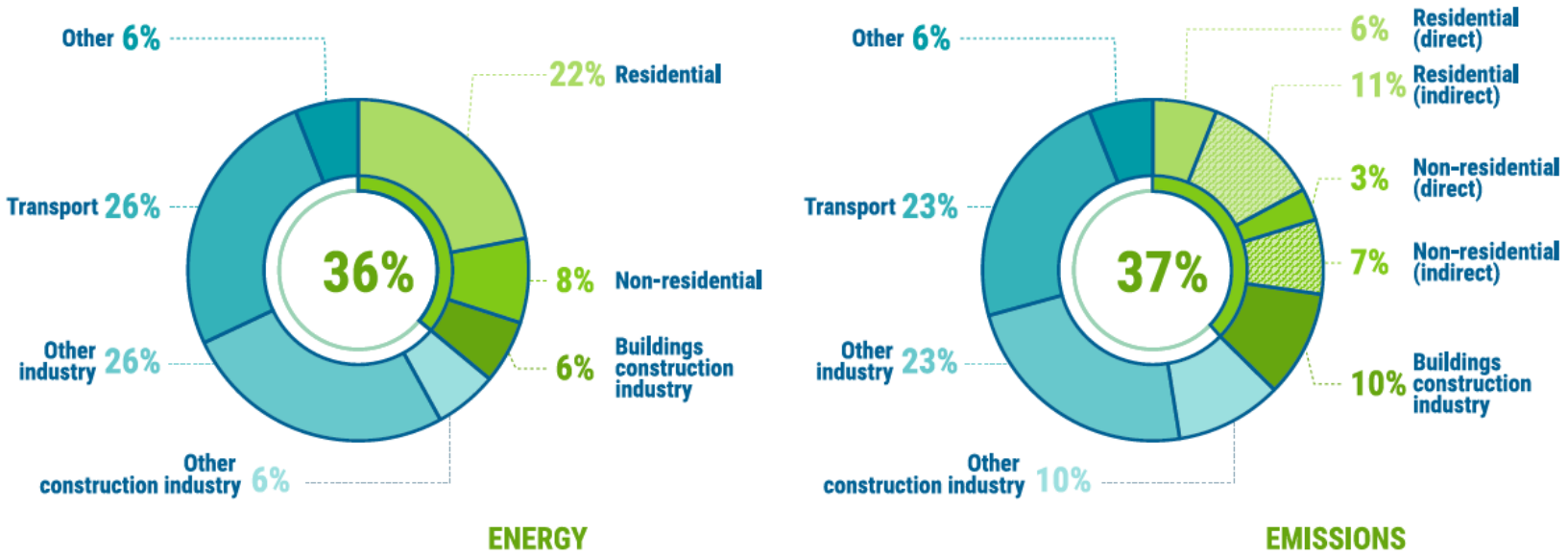


Fonte: IEA (https://www.iea.org/reports/breakthrough-agenda-report-2023/buildings)

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.

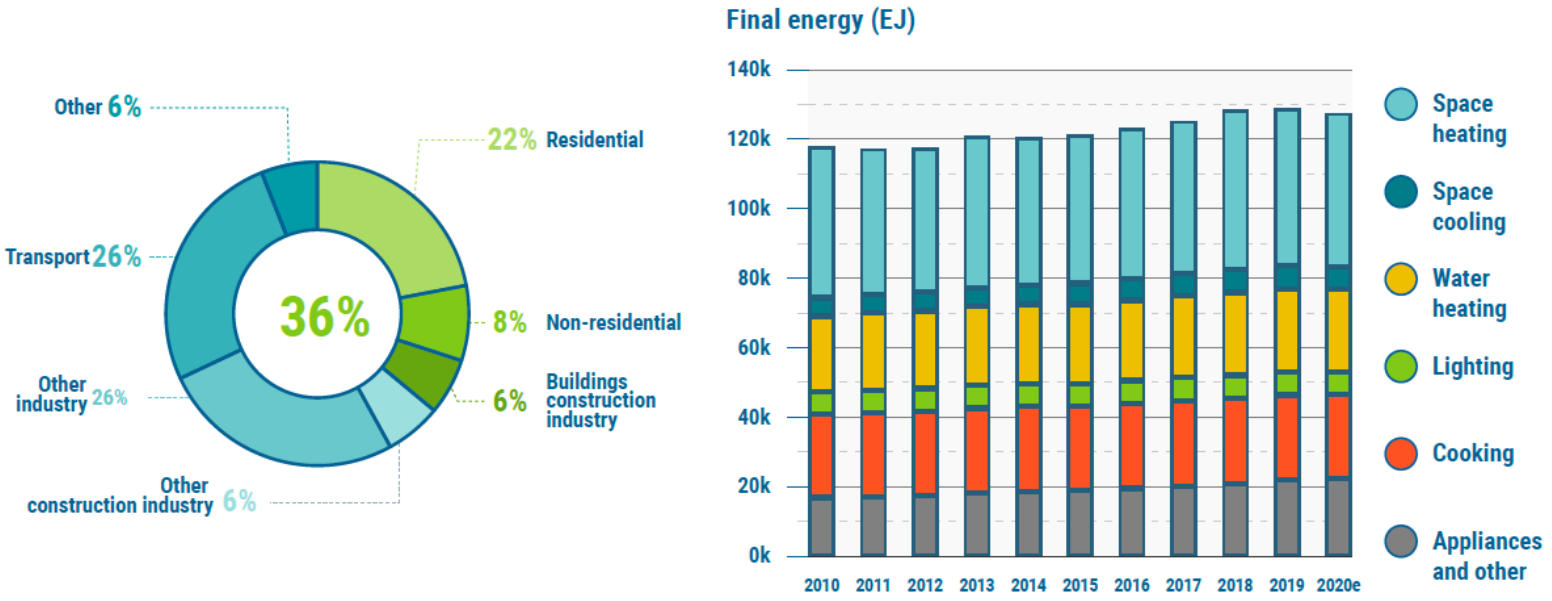
Source: IEA 2021a. All rights reserved. Adapted from "Tracking Clean Energy Progress"

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.

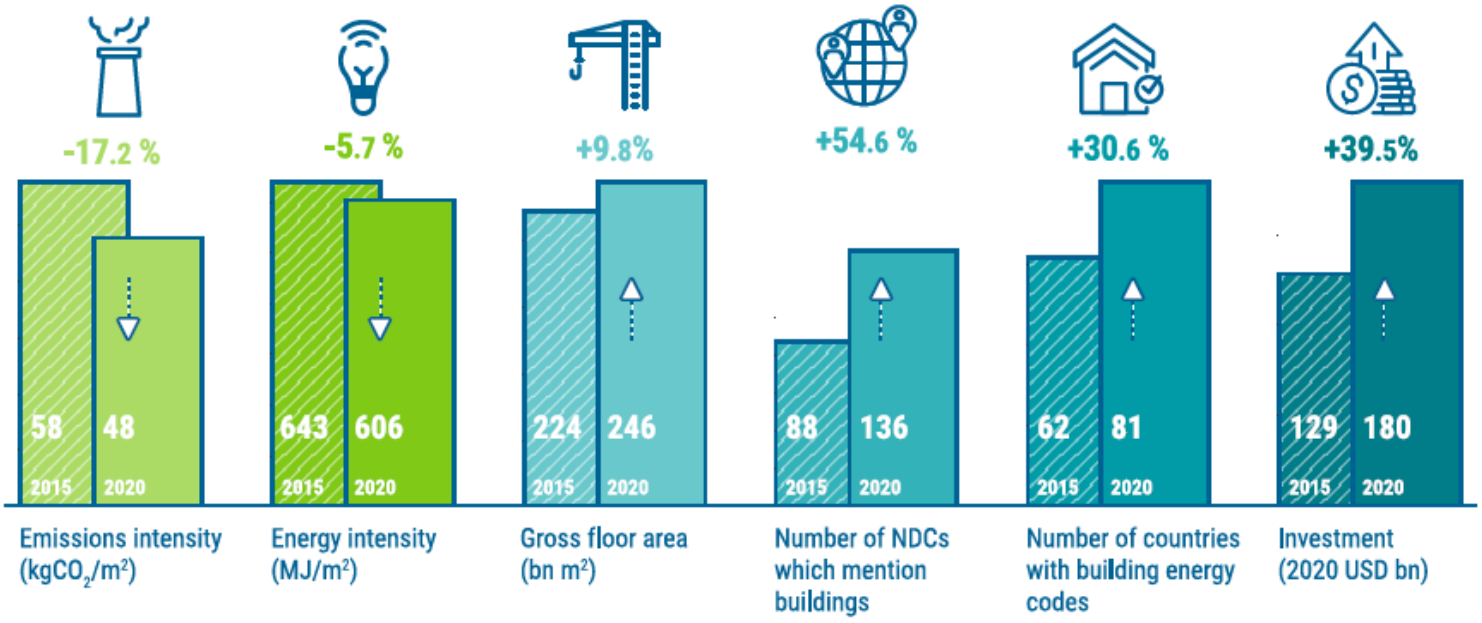
Source: IEA 2021a. All rights reserved. Adapted from "Tracking Clean Energy Progress"

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 – alterações entre 2015 e 2020

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



Sources: UNFCCC 2021; Buildings-GSR 2021; IEA 2021a. All rights reserved.

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

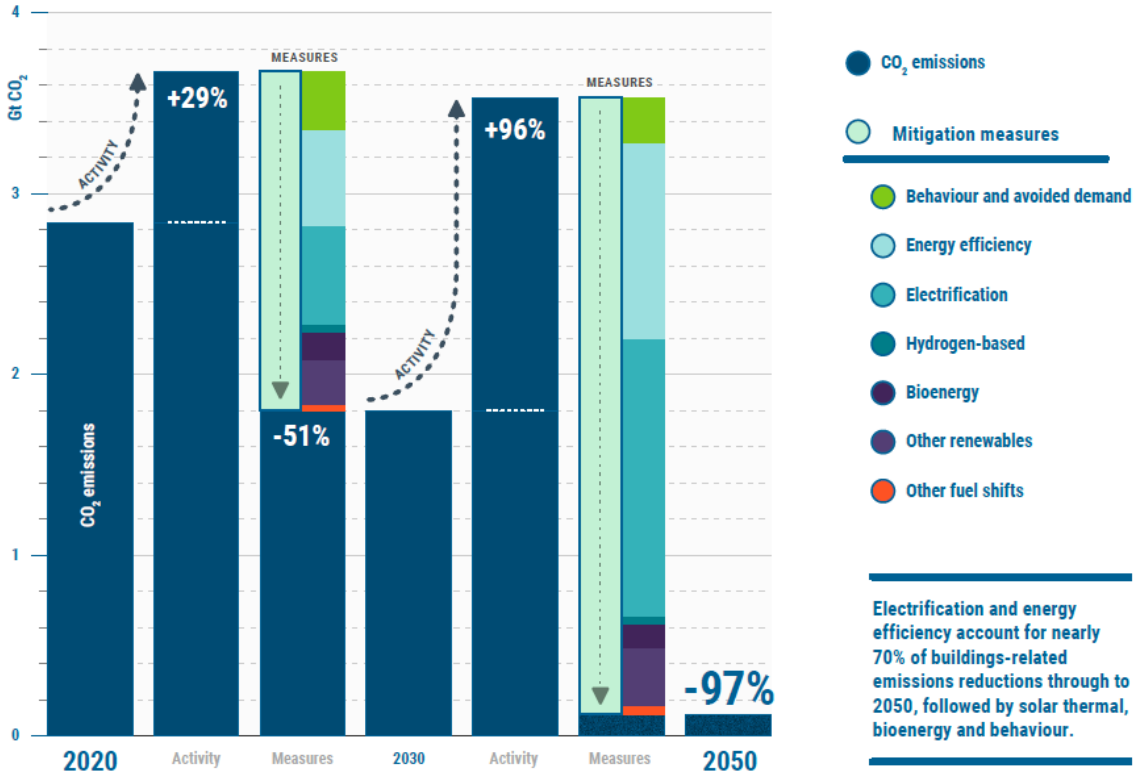
Fonte: United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.

Energia e sustentabilidade

Estratégias de mitigação

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

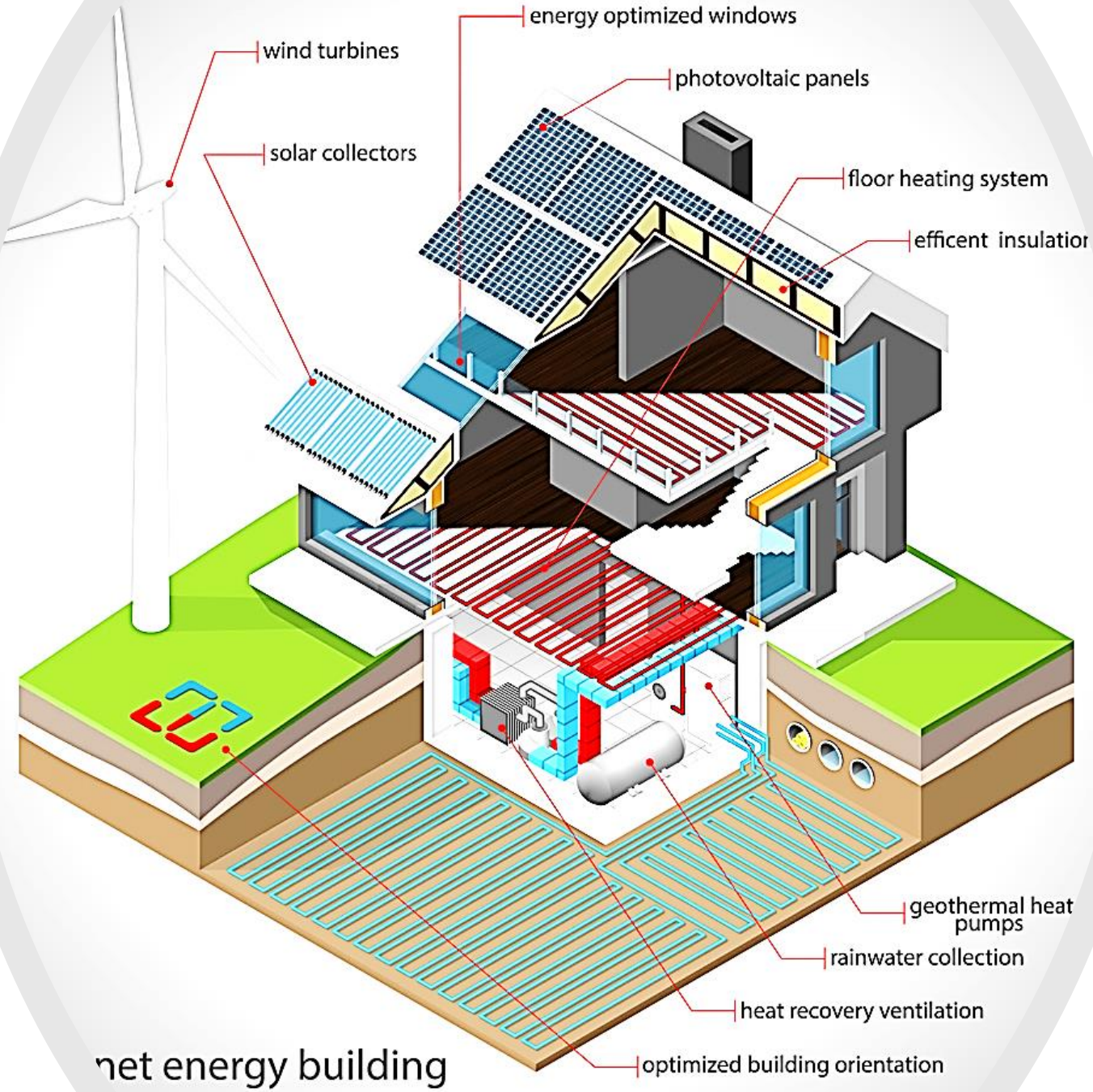
Electrification and energy efficiency account for nearly 70% of buildings-related emissions reductions through to 2050, followed by solar thermal, bioenergy and behaviour



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.



net energy building

Energia e sustentabilidade

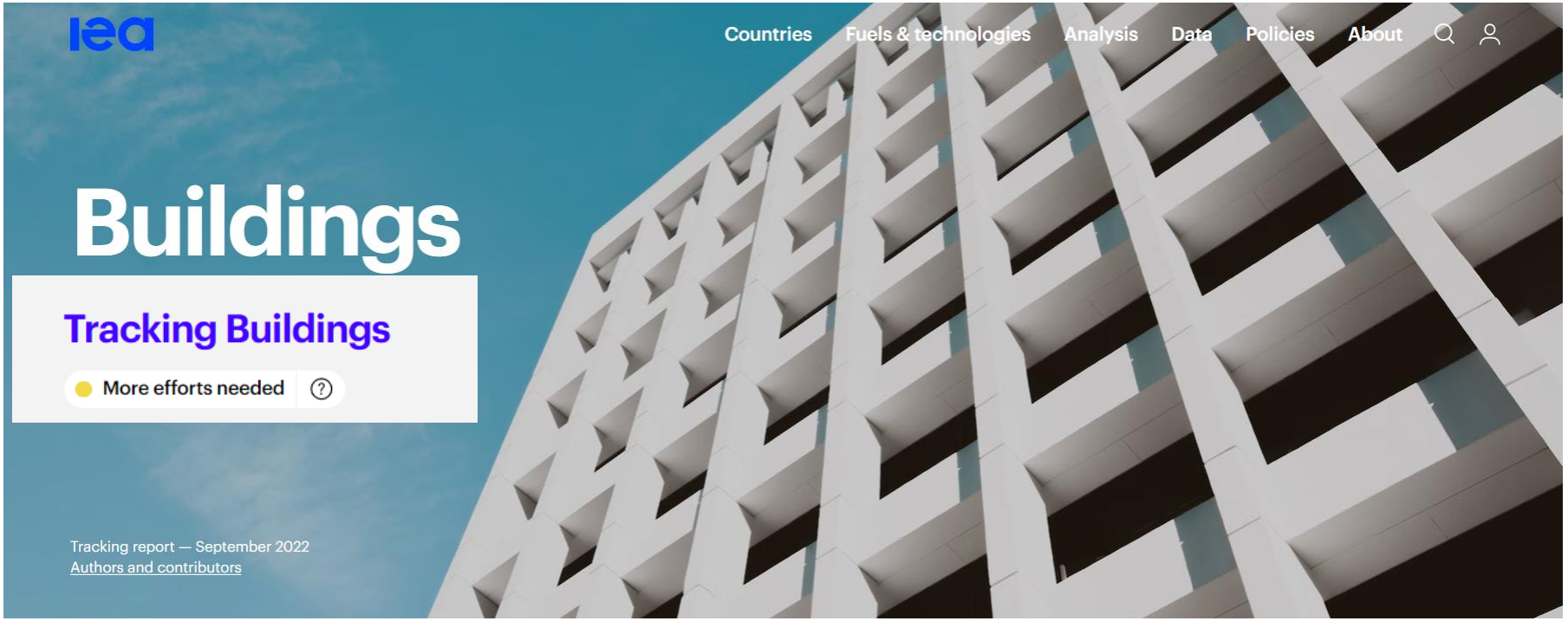
Edifícios – *nearly zero-energy buildings*

	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

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

Buildings

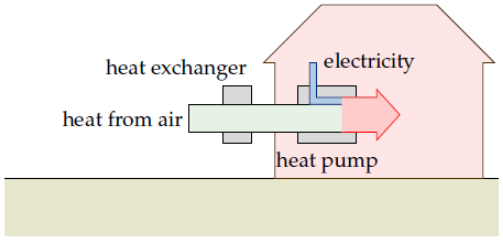


Fonte: IEA (https://www.iea.org/energy-system/buildings)

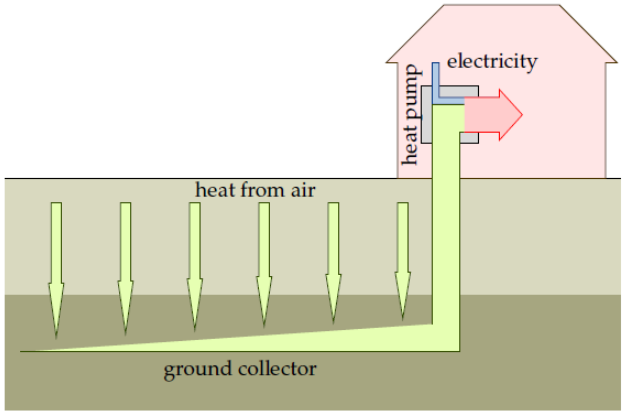
Energia e sustentabilidade

Edifícios – Bombas de calor

Tecnologia eficiente e sustentável!



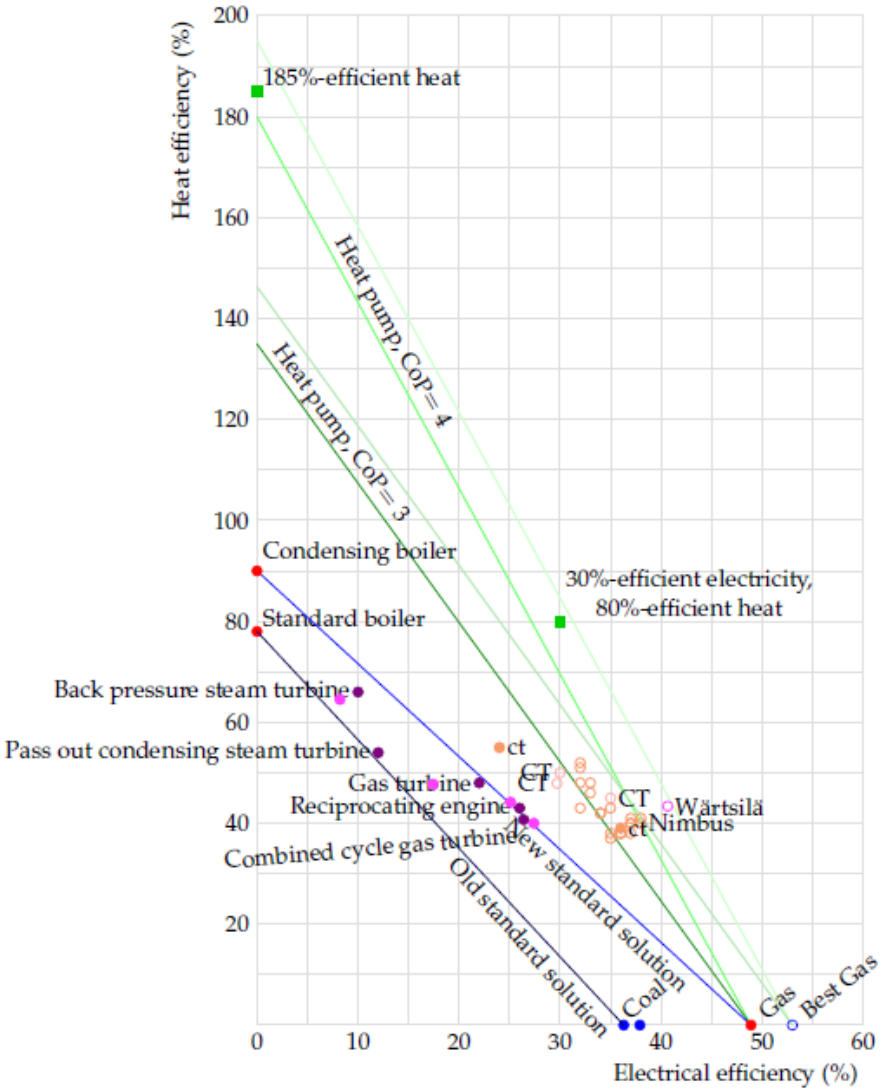
air-source heat pump



ground-source heat pump

Energia e sustentabilidade

Edifícios – Bombas de calor



Energia e sustentabilidade

Edifícios – Bombas de calor

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

Caldeira a gás

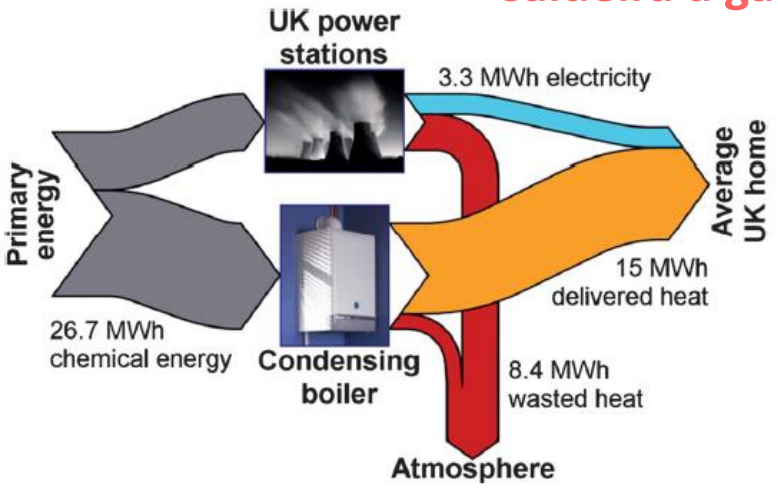
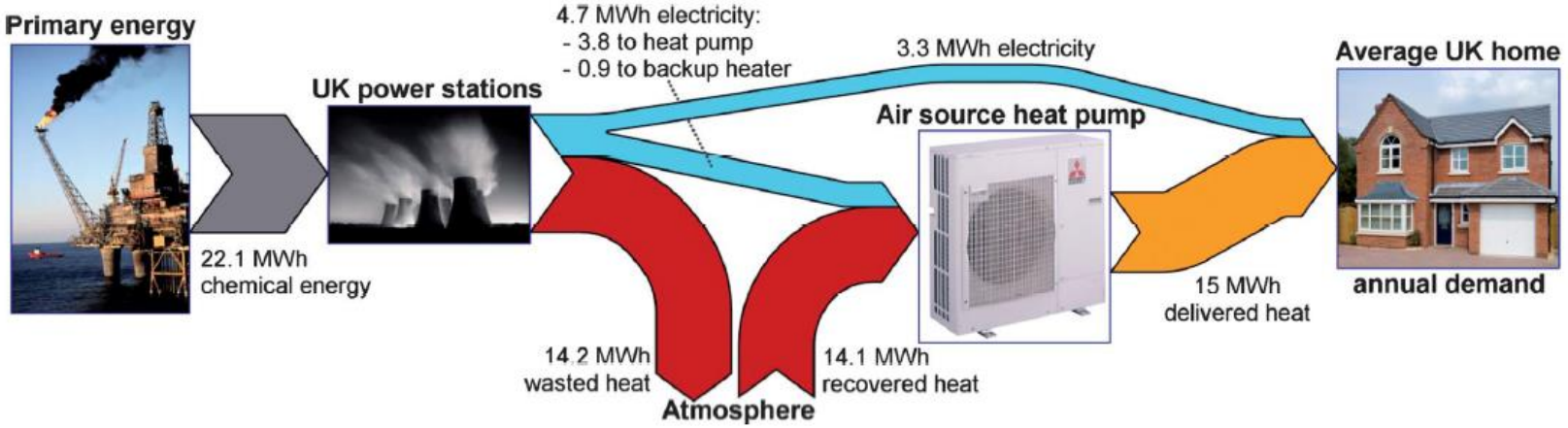


Fig. 2 A Sankey diagram depicting the provision of energy to the same house using a high efficiency condensing gas boiler.

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.

Energia e sustentabilidade

Edifícios – autoprodução de energia

Energia solar térmica

Solar Thermal Panels

OR

Solar PV Panels

Energia solar fotovoltaica

Energia e sustentabilidade

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 m^2 of expensive (20%-efficient) solar panels and cover all south-facing roofs. These will deliver

5 kWh per day per person.

Materiais de isolamento

Energia e sustentabilidade

Edifícios – materiais de isolamento

Sector da construção

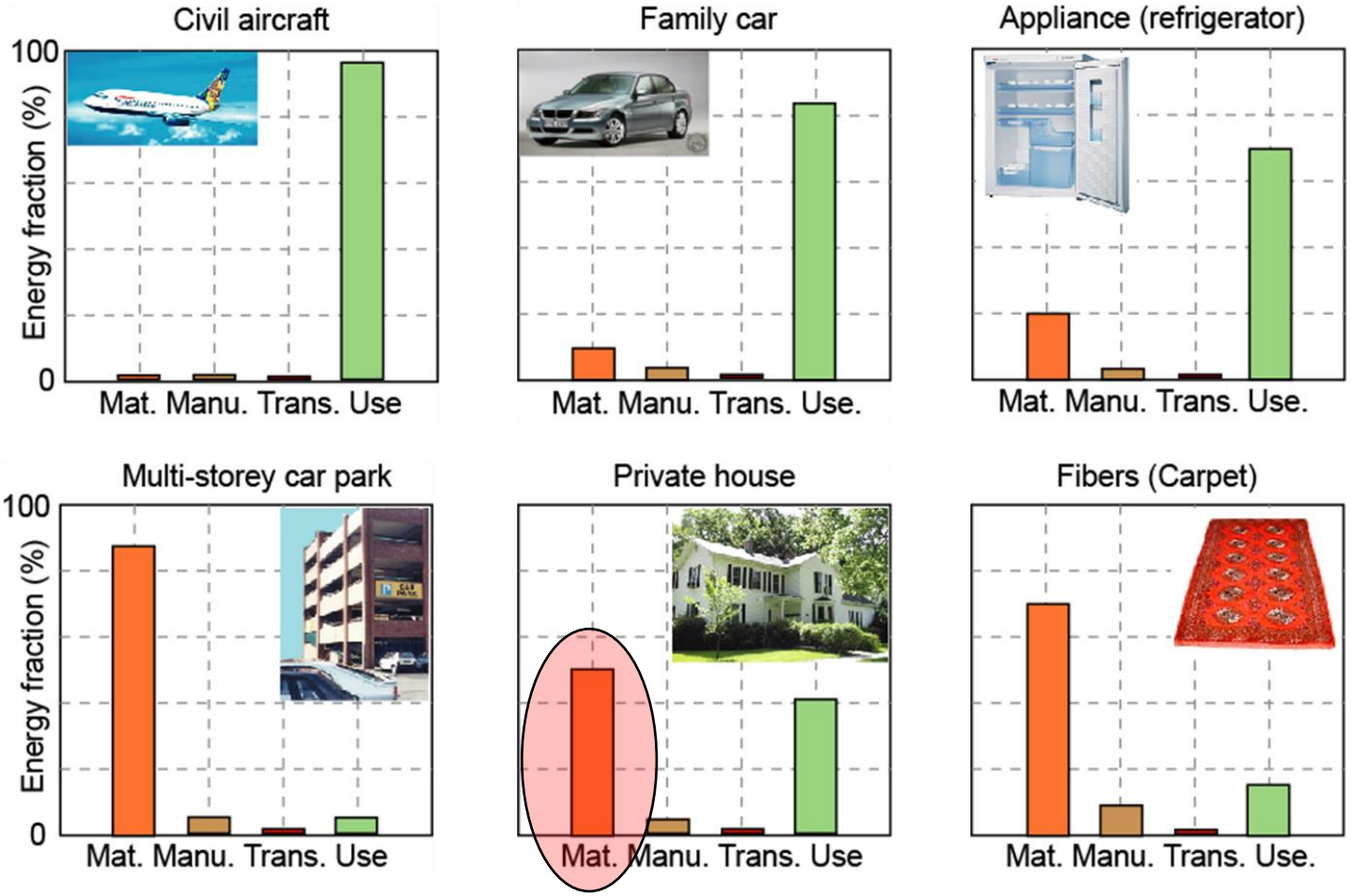
Table 1: **Properties of insulation materials**

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

Energia e sustentabilidade

Edifícios – utilização de materiais de construção alternativos?

Consumo de energia de produtos



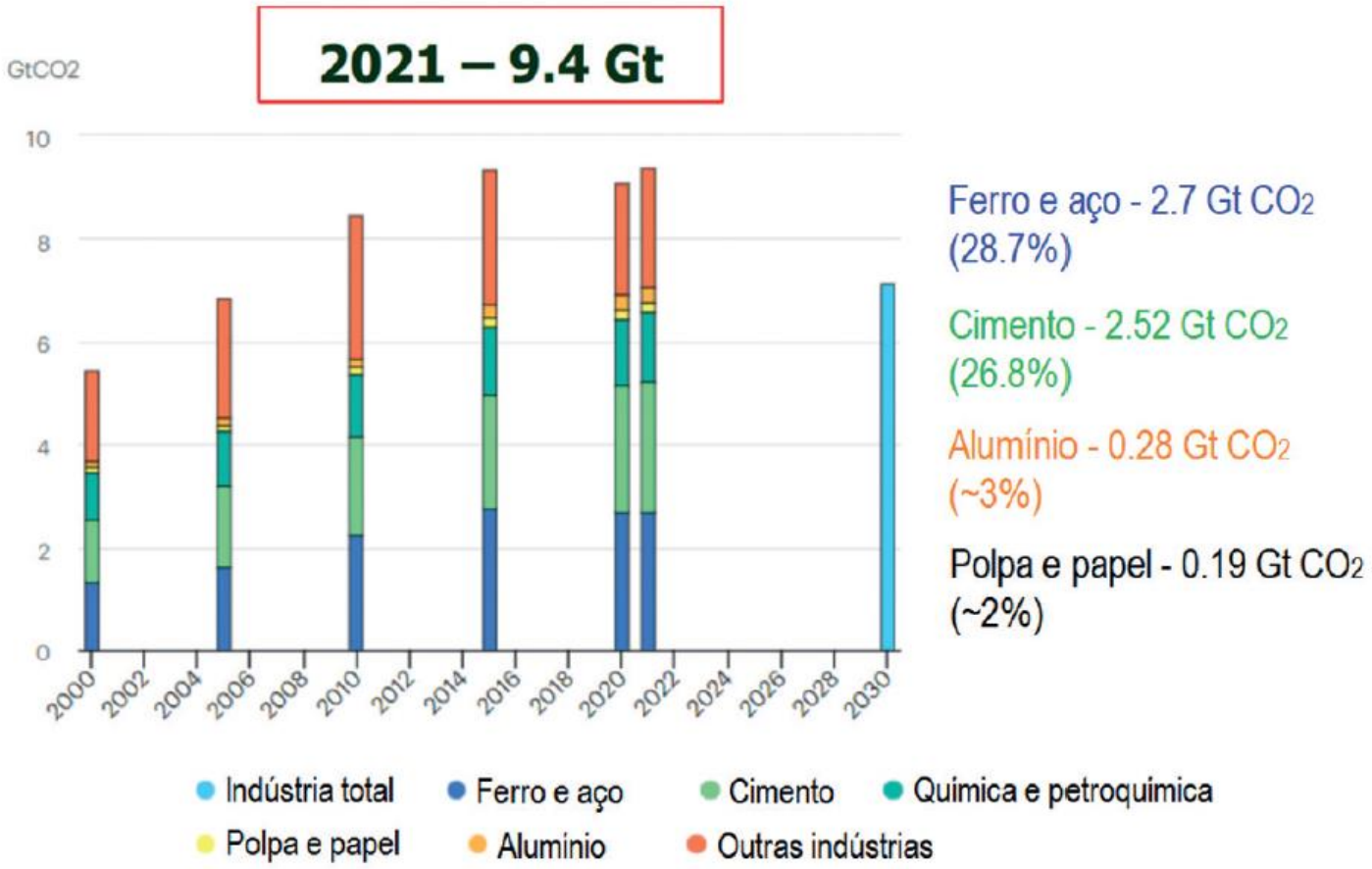
Energia e sustentabilidade

Cement

https://www.iea.org/reports/cement

Energia e sustentabilidade

Evolução das emissões carbónicas de algumas indústrias, com previsão para 2030



Source: "Materiais e Sustentabilidade", João Labrincha, Rui Novais, Dachamir Hotza, Engebook 2024.
ISBN: 978-989-9177-48-2

Construção sustentável

A importância da Construção (Sustentável)

Segundo o Conselho Internacional da Construção, os princípios que enformam o conceito de construção sustentável, são:

- redução do consumo de recursos;
- reutilização de recursos;
- utilização de recursos recicláveis;
- proteção da natureza;
- eliminação do uso de componentes tóxicos;
- uso de analises de ciclo de vida ambientais e económicos;
- melhoria da qualidade e minimização da degradação.

Source: "Materiais e Sustentabilidade", João Labrincha, Rui Novais, Dachamir Hotza, Engebook 2024.
ISBN: 978-989-9177-48-2

Construção sustentável

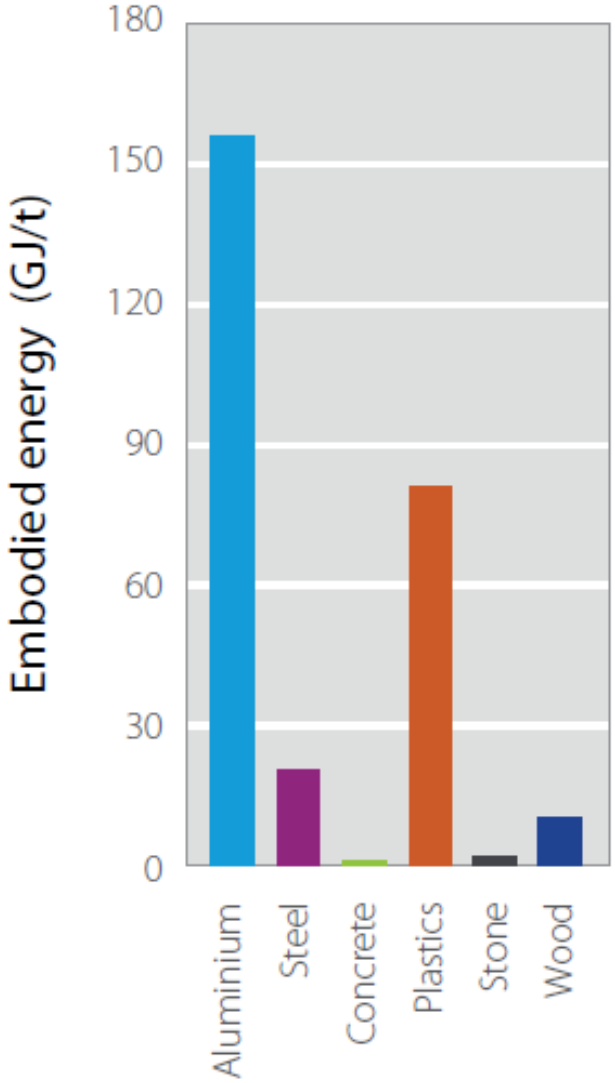
Estimativa da percentagem mássica de diferentes materiais de uso comum

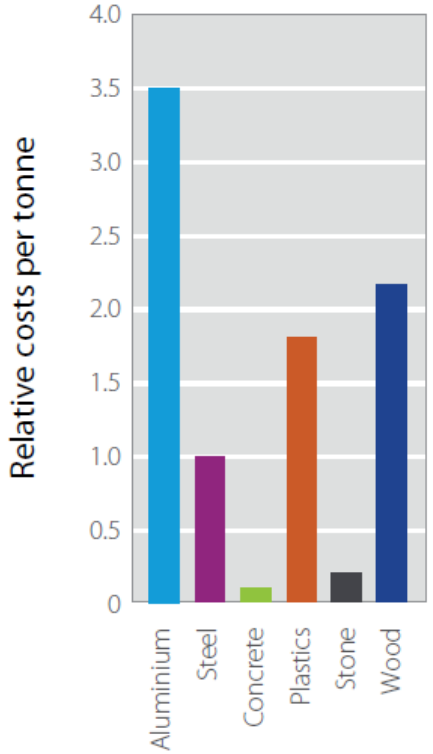
Materiais	Percentagem (%)
Betão	40,6
Aço	34,3
Cimento	6,88
Madeira	2,47
Materiais de alvenaria	1,60
Cal	1,16
Areias e britas	0,06

Source: "Materiais e Sustentabilidade", João Labrincha, Rui Novais, Dachamir Hotza, Engebook 2024. ISBN: 978-989-9177-48-2

Construção sustentável

Comparação entre diferentes materiais

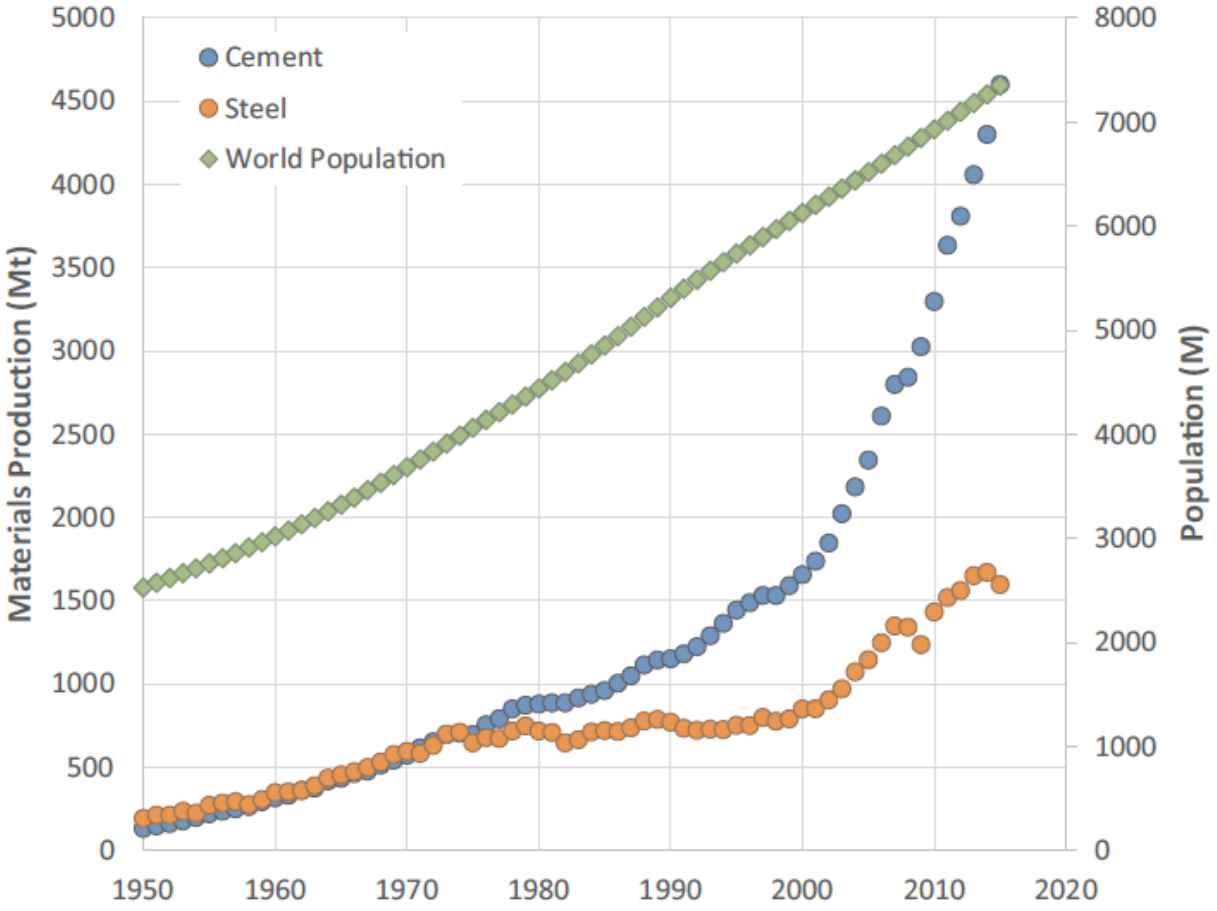




Material	Global annual production (Mt)	Energy intensity (GJ/t)	Carbon intensity (tCO_2/t)
Cement	2,800	5	1
Steel	1,400	35	3
Plastic	230	80	3
Paper	390	20	1
Aluminium	70	170	10

Construção sustentável

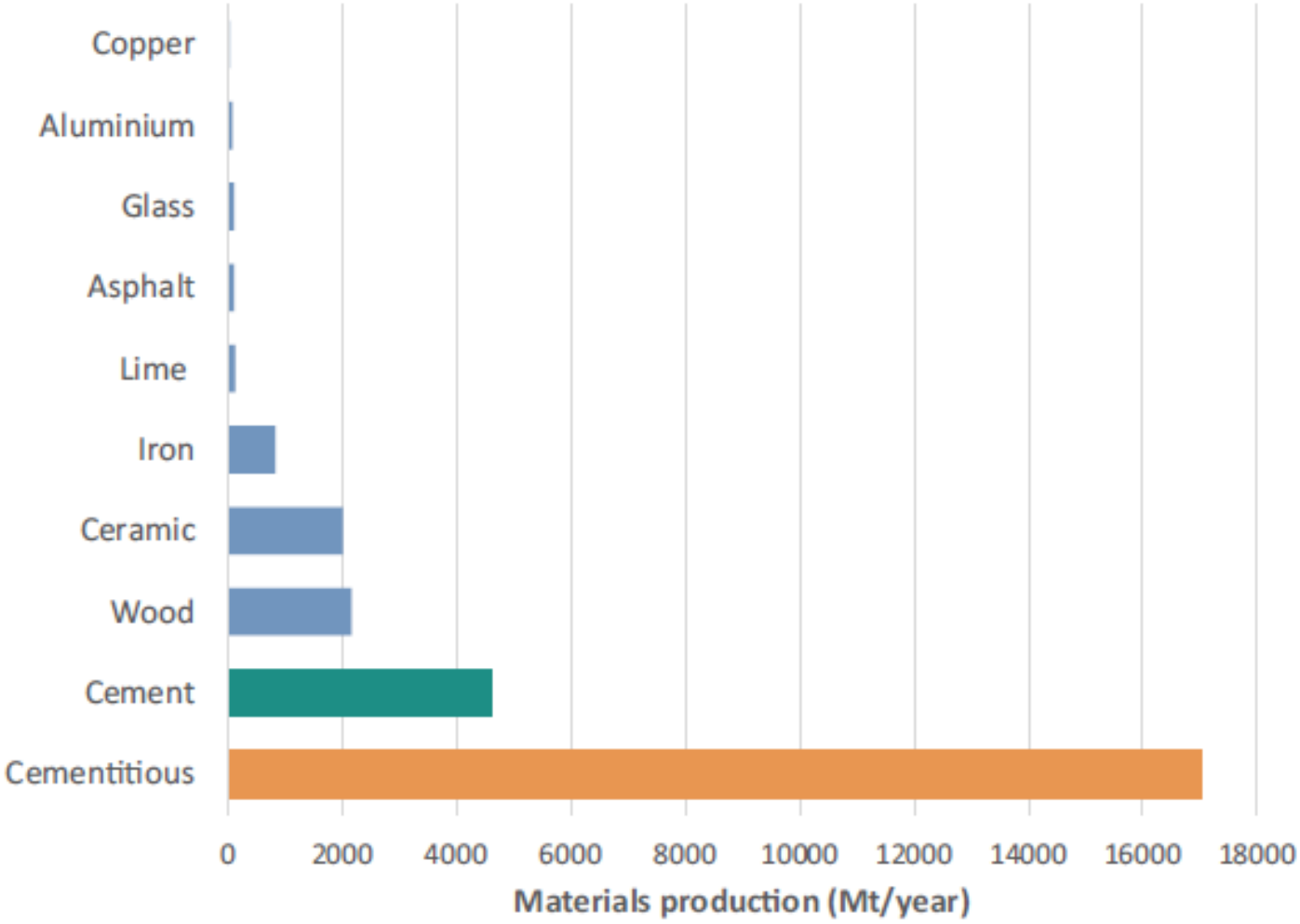
Comparison of cement and steel production with population



Souce: Scrivener *et al., Advances in understanding hydration of Portland cement, Cement and Concrete Research 78 (2015) 38–56.*

Construção sustentável

Estimated consumption of common materials 2002–2005

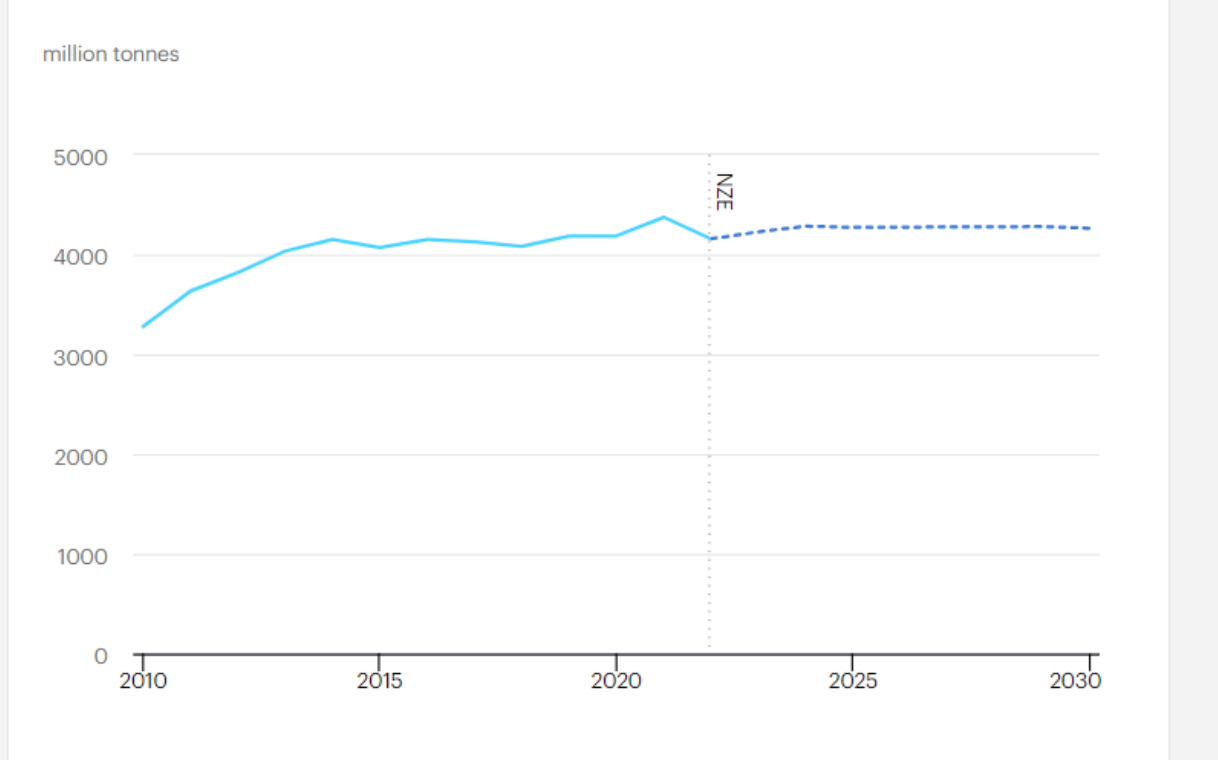


Souce: Scrivener *et al., Advances in understanding hydration of Portland cement, Cement and Concrete Research 78 (2015) 38–56.*

Construção sustentável

Global cement production in the Net Zero Scenario, 2010-2030

Cement production levels have stabilized in line with the NZE Scenario. Global cement production must stay relatively flat through to 2030 to align with the NZE Scenario. Material efficiency strategies, such as resource-efficient manufacturing, promoting material efficiency in construction by avoiding overdesign and maximising the lifetimes of buildings and infrastructure, are critical to reducing cement demand.

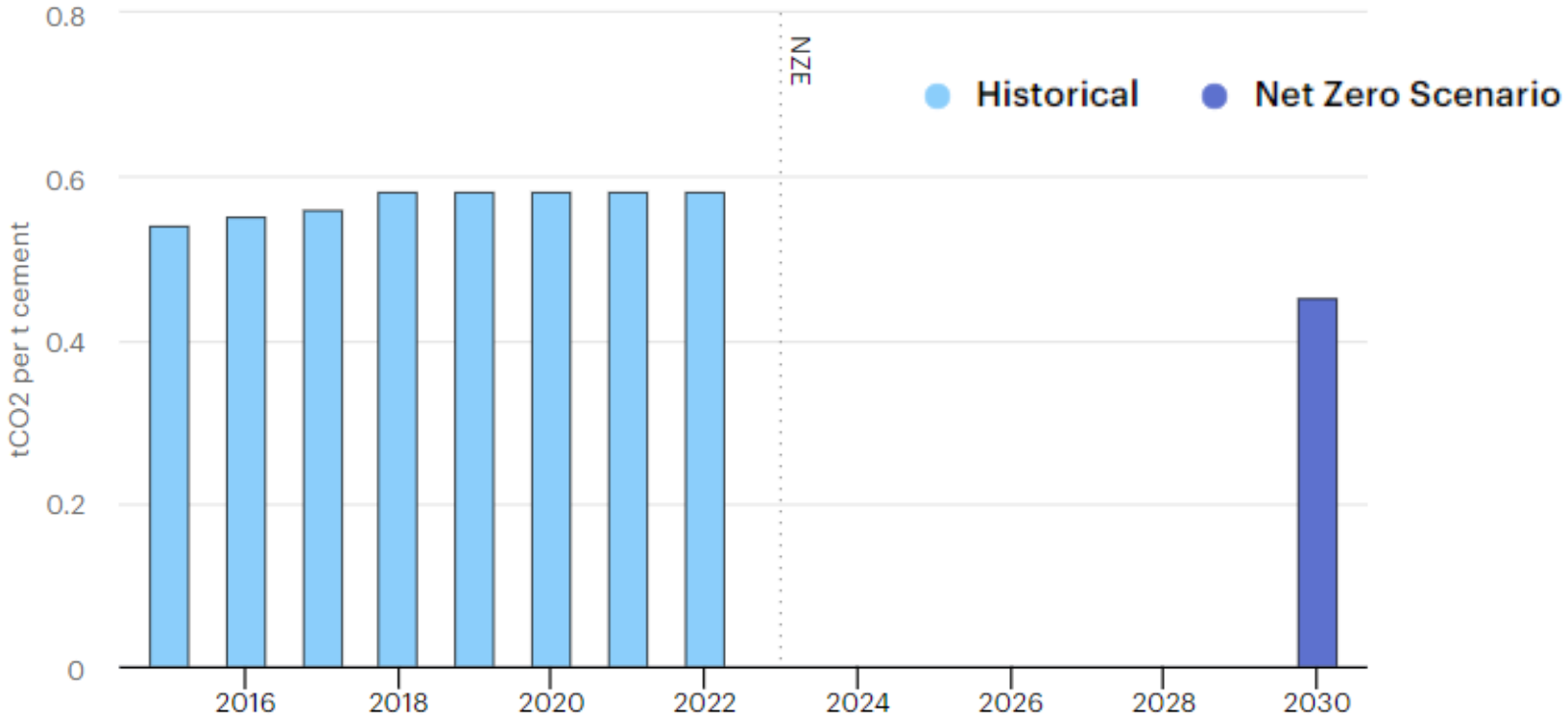


Source: International Energy Agency (IEA) (https://www.iea.org/energy-system/industry/cement#tracking)

Construção sustentável

Direct CO_2 emissions intensity of cement production

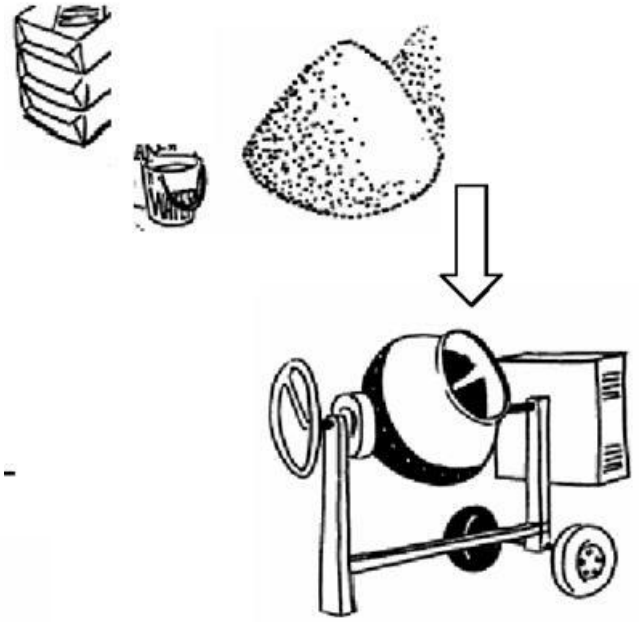
The direct CO_2 emissions intensity of cement production has been broadly flat over the last five years, and is estimated to have increased slightly (by 1%) in 2022. In contrast, annual CO_2 intensity declines of 4% through to 2030 are required for the sector to get on track with the Net Zero Emissions by 2050 (NZE) Scenario.



Source: International Energy Agency (IEA) (https://www.iea.org/energy-system/industry/cement#tracking)

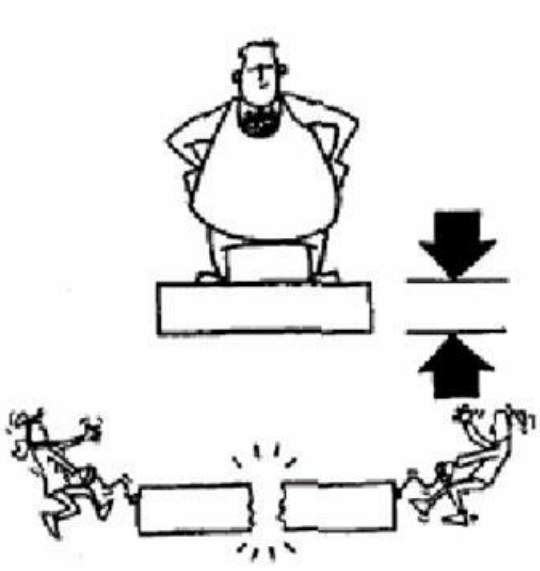
Construção sustentável

Produção de argamassas e betão



- **Constituents**
  - Cement/Binder
    + Aggregates (fine and coarse)
    + Water
    (+ Additives)

  - Typical ratios:
    c/a = 1:3
    w/c = 0,4



Construção sustentável

Agregados

- The aggregates are the minerals most consumed on Earth:
  - A flat consumes about 150 tons of aggregates, 1 km 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%.

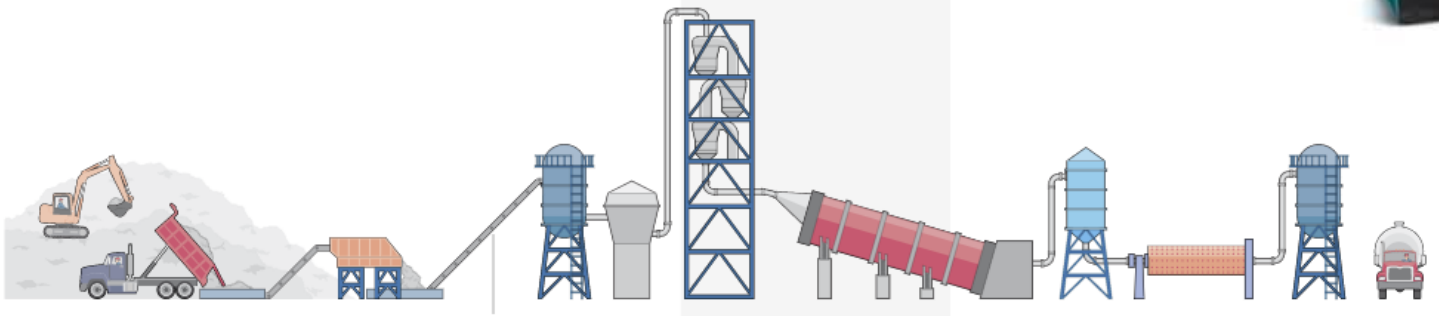
In Portugal the consumption of aggregates is around 80 million tons/year, however, given the incidence of transport costs in the overall cost of these materials (implying that for each ton the value doubles for each 50 km transportation), meaning that quarries tend to be distributed "almost like mushrooms"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

Construção sustentável

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

Construção sustentável

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?);

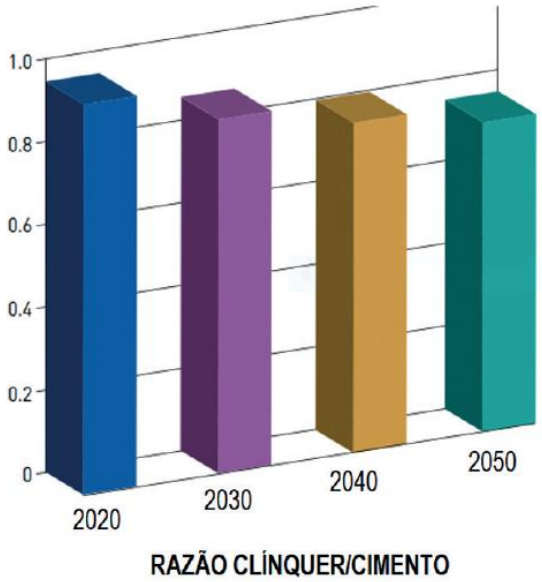
(ii) Uso de combustíveis derivados de resíduos – taxa de substituição térmica

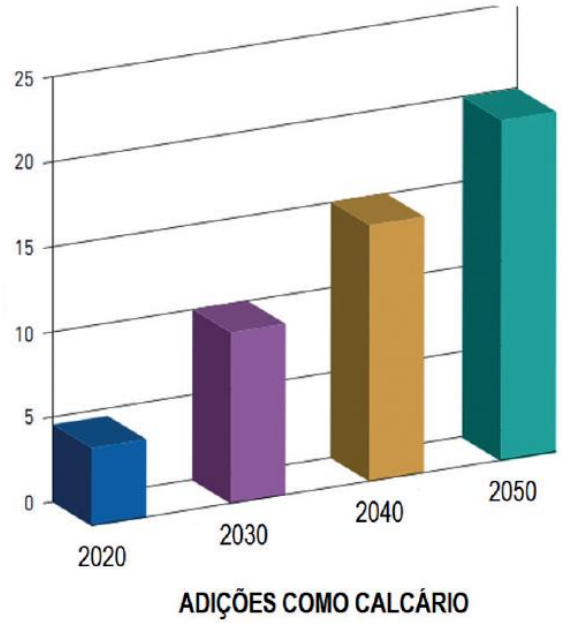
(iii) Desenvolvimento de cimentos não calcários (ex. geopolímeros)

Construção sustentável

(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 …





Source: "Materiais e Sustentabilidade", João Labrincha, Rui Novais, Dachamir Hotza, Engebook 2024.
ISBN: 978-989-9177-48-2

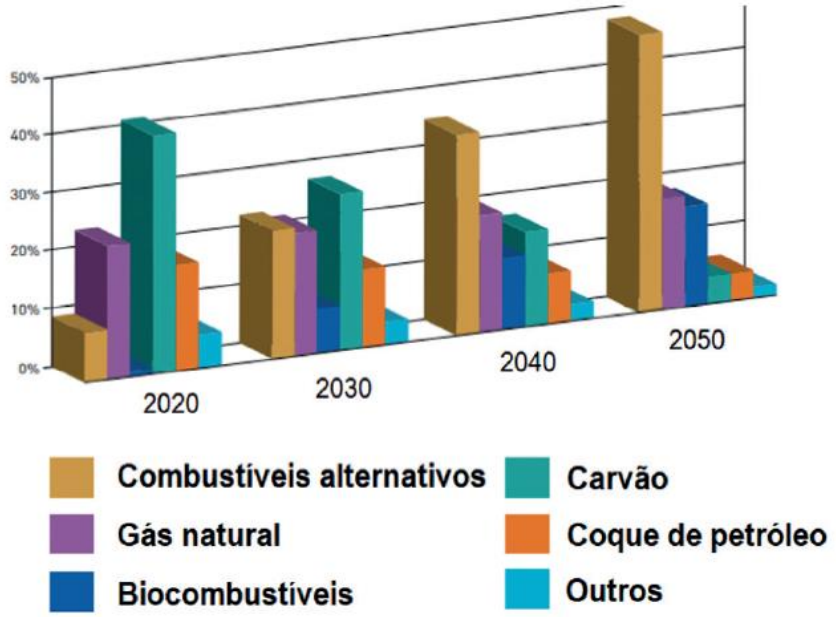
Construção sustentável

(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



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Construção sustentável

(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