Energy Transitions Commission

Buildings decarbonisation workshop 6: Lighting and appliances

Wednesday 11th September, 2-3pm UKT

Agenda

2 – 2.30pm UK time – ETC presentation

- Context
- Lighting
- Appliances
- Actions to realise efficiency gains

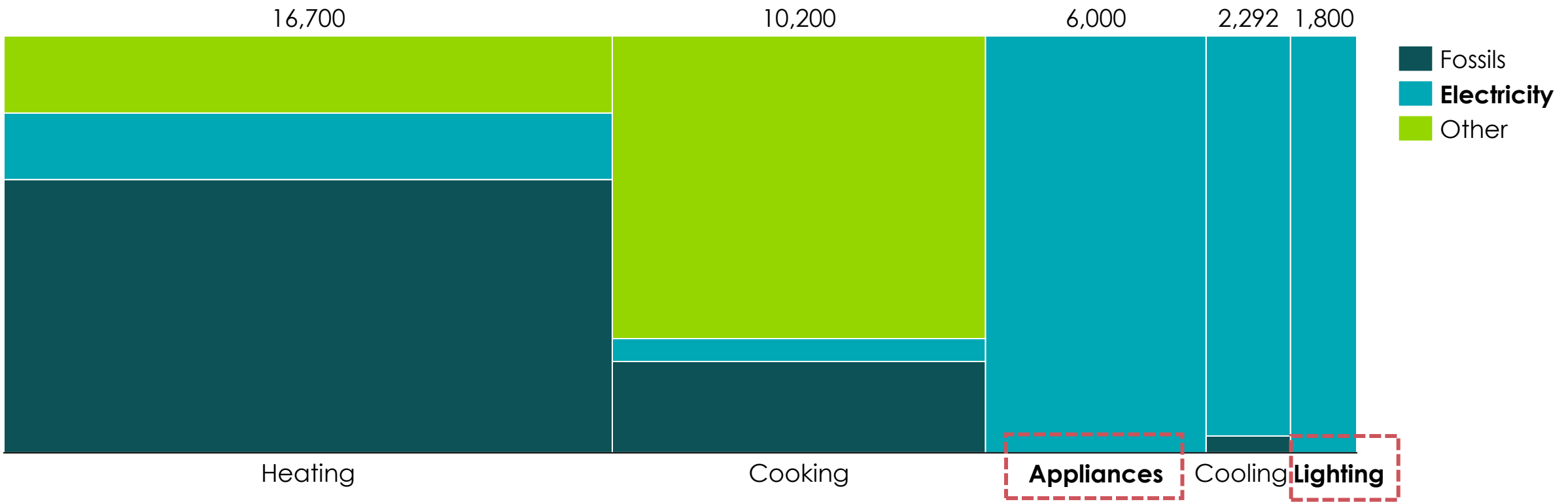
2.30 – 3pm – discussion

Introduction

Lighting and appliances account for ~20% of total building energy consumption and are fully electrified

Buildings operational energy use

TWh, 2022



Categorisation of all household technologies

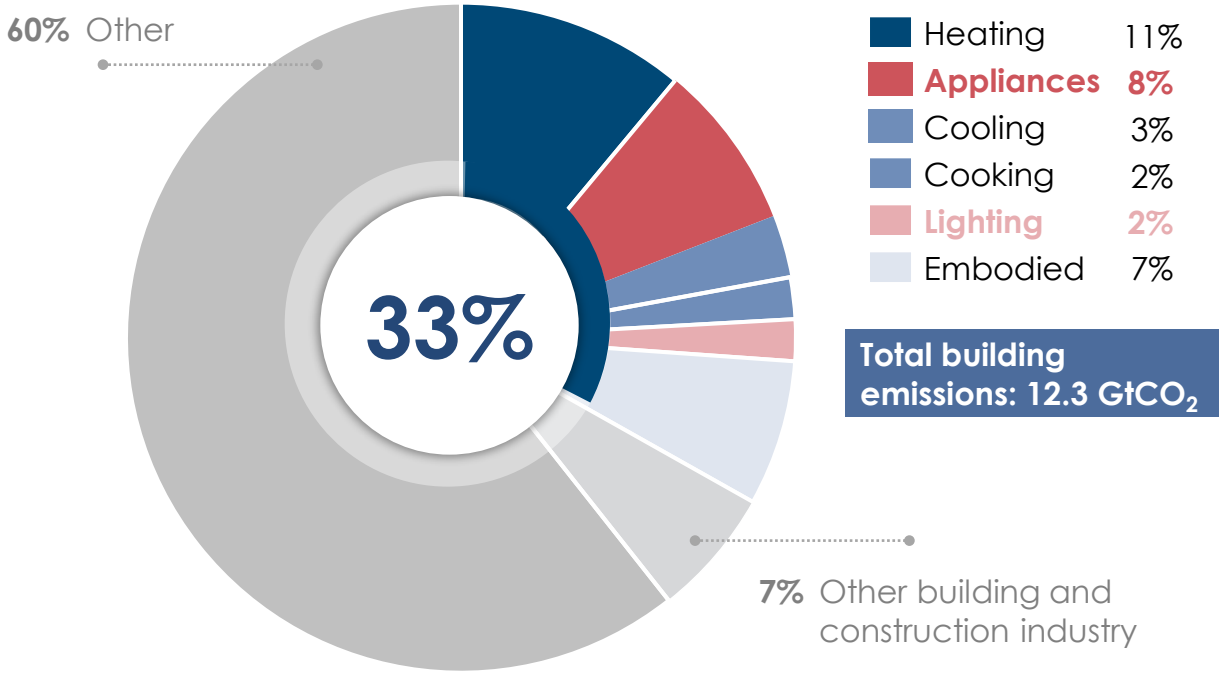
Heating	Cooking	Appliances	Cooling	Lighting
Heat pumps, electric heaters	*Electric stoves and hobs*	*Fridge, TVs, dishwashers, computers, washing machine, fans*	*AC*	*Lamps*

Source: IEA (2022), World Energy Outlook 2021; IEA (2023), World Energy Outlook 2022
Note: Shares of building energy by end use from 2021 applied to 2022 actuals. Heating includes both space and water heating

Together, they account for 10% of global emissions; these emissions will fall as electricity is decarbonised

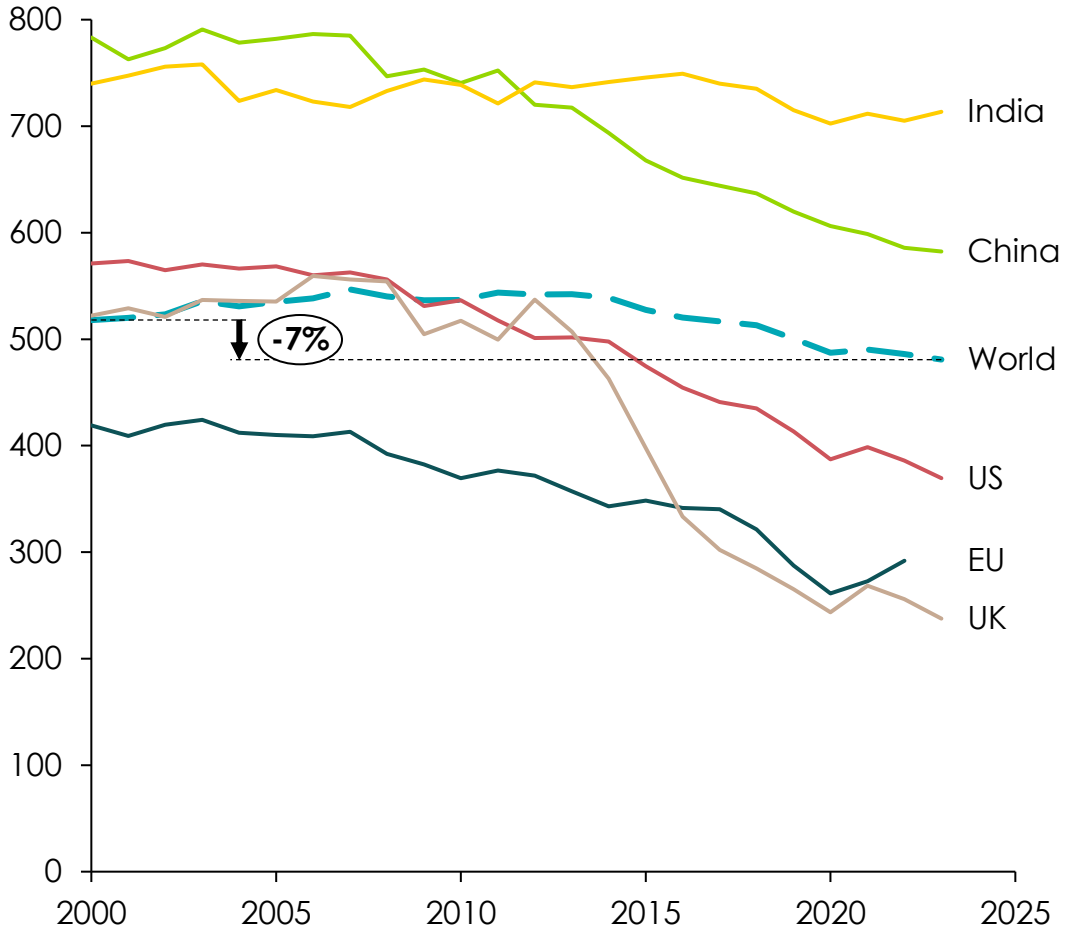
Global emissions by sector, 2022

$GtCO_2$



Carbon intensity of electricity generation, 2000-2023

gCO2e/kWh of electricity generated



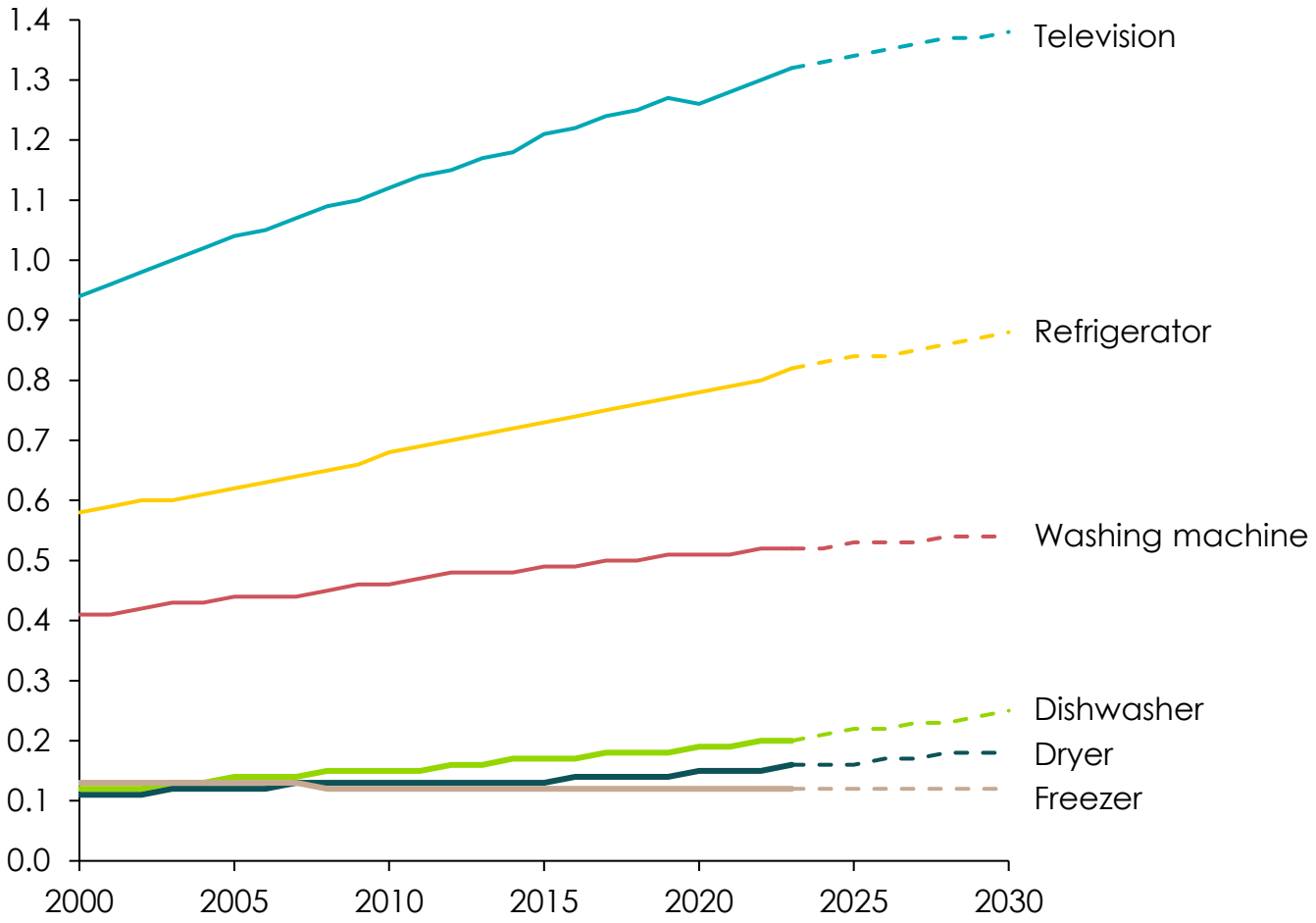
Appliance emissions are nearly as high as heating, despite using 3 times less energy because:

- ~50% of heating is **natural gas**, which has a carbon intensity of **~200gCO2/kWh**
- **Grid carbon intensity** has an average carbon intensity globally of **~440gCO2/kWh**

Source: IEA (2023), *World Energy Outlook 2023*; Our World in Data (2023), *Carbon intensity of electricity generation.*
Note: this shows annual carbon flows as opposed to stock.

Currently, 10% of the world's population do not have lighting and 20% don't have a fridge; income growth and falling prices will increase access and improve living standards

Global average household ownership of appliances, 2000-2030
Average units per household; IEA NZE



	Share of population which owns appliance
Lighting	91%
Refrigerators / freezers	78%
TVs	87%
Mobile phones	76%
Radios	28%

Rising incomes will drive further energy demand as households:

- **Own more** appliances (e.g., having more than one TV and phone)
- **Use appliances more** frequently (e.g., use a washing machine more than once a week)
- **Choose larger models** (e.g., bigger TV)

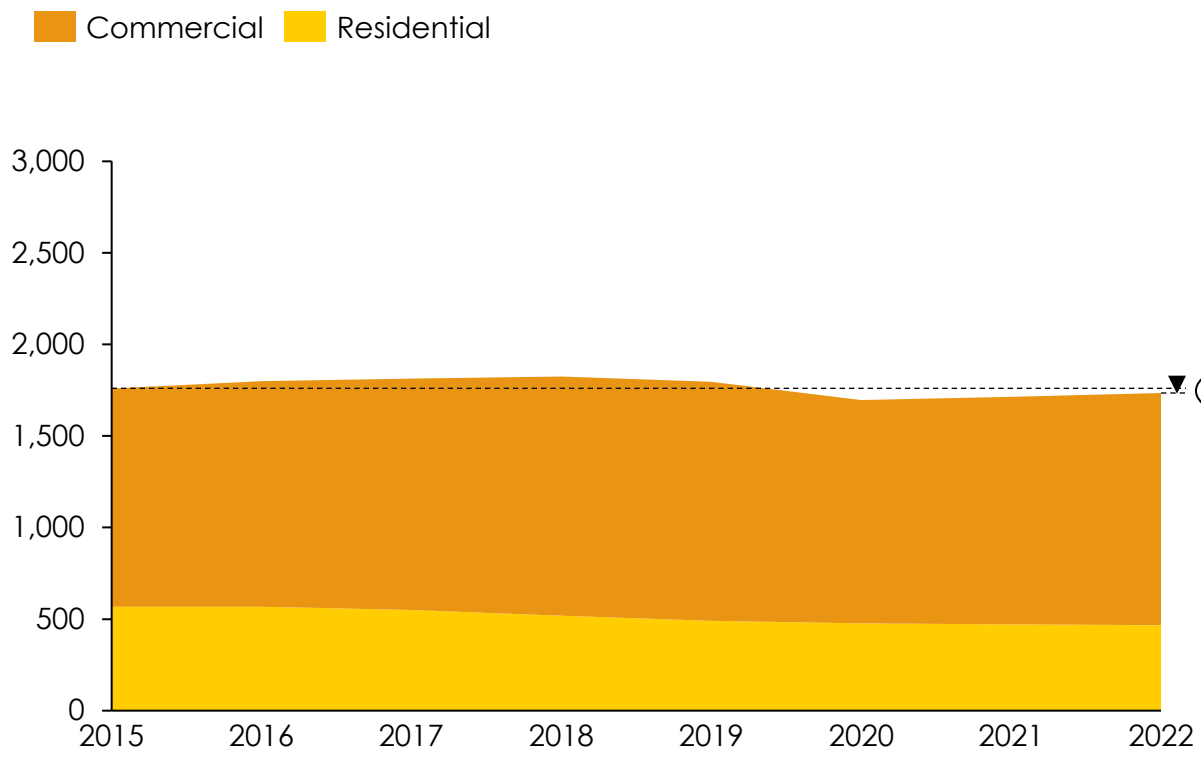
Source: IEA (2023), *World Energy Outlook 2023*; IEA (2023), *CO2 emissions and implied emissions intensity factor for appliances in the Net Zero Scenario, 2000-2030;* CLASP (2024), *Net Zero Heroes: Scaling Efficient Appliances for Climate Change Mitigation, Adaptation & Resilience.*

Despite rising demand, electricity use has only grown 10% over the past decade for appliances and remained constant for lighting, offset by efficiency improvements

Despite rising demand, electricity consumption has remained constant over the past decade due to efficiency improvements

Global electricity consumption for lighting

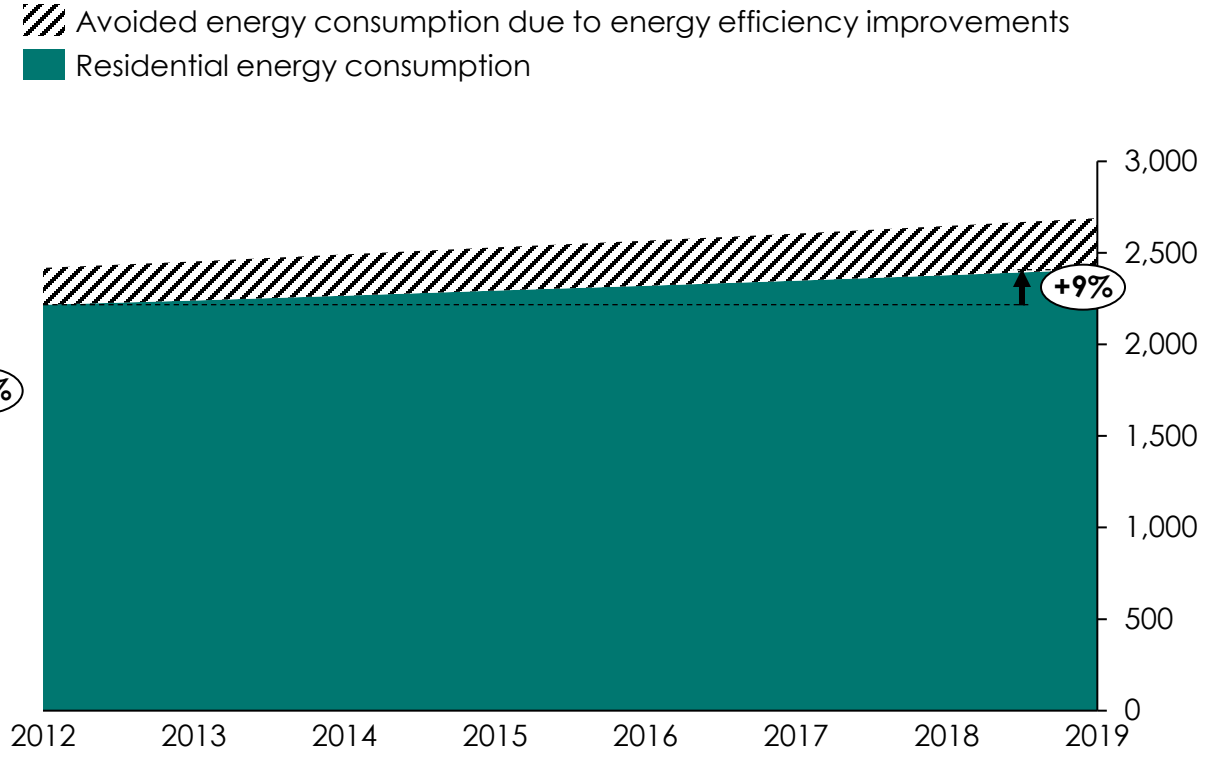
TWh, 2015 – 2022



Cumulative electricity consumption over the past decade would have been 10% higher without efficiency improvements

Global energy consumption for household appliances

TWh, 2012 – 2019

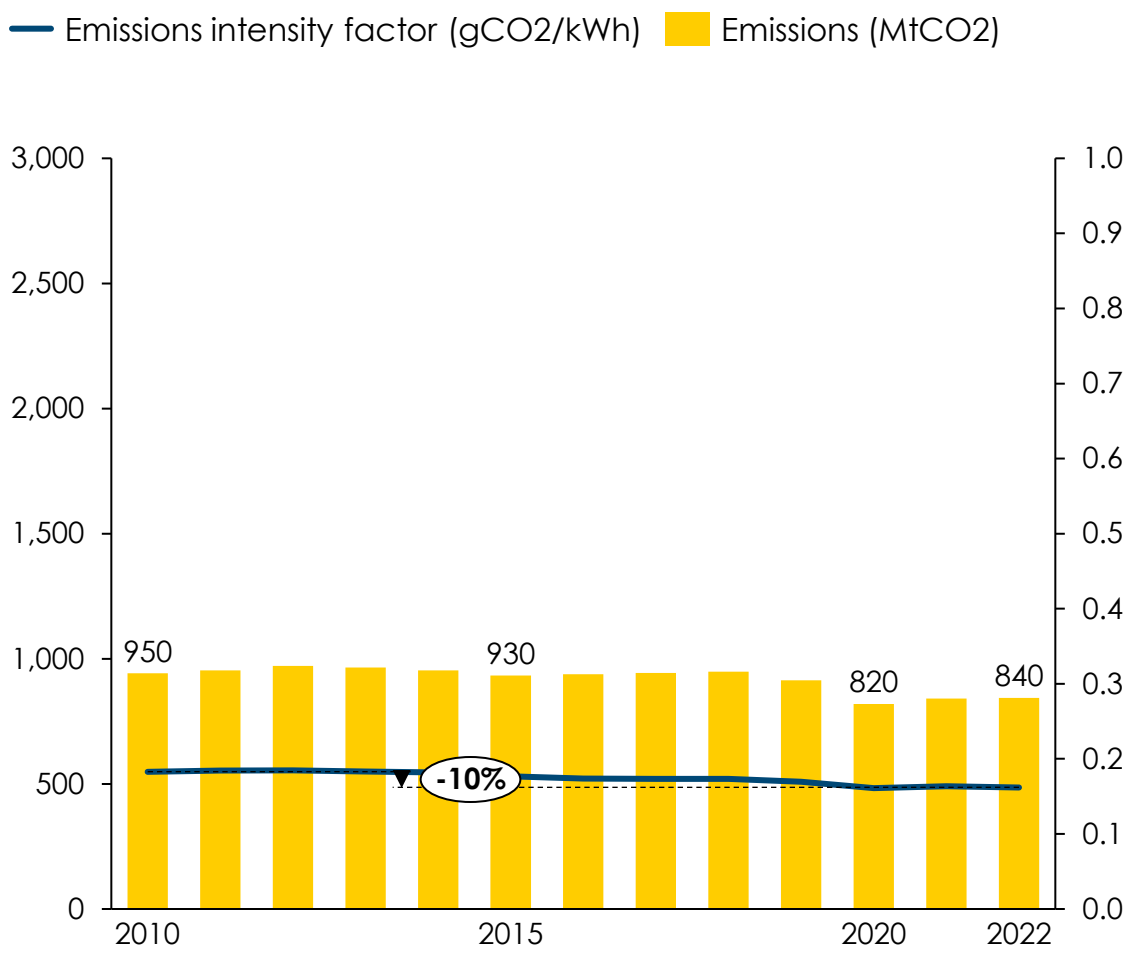


Note: Plug-in appliances include refrigeration equipment, televisions and miscellaneous. Cooling, cooking and lighting are separate.
Source: IEA (2023), *Global electricity consumption in lighting in the Net Zero Scenario*, 2010-2030; IEA (2020), Consumption by household appliances and plug loads by region in the Sustainable Development Scenario, 2000-2030; IEA (2020), Key drivers of changes in household appliance energy consumption in the Sustainable Development Scenario, 2000-2030

As a result of cleaner grids, the emissions intensity of lighting and appliance energy use has fallen 10-15% since 2010

CO2 emissions and emissions intensity for lighting, 2010-2030

Mt CO2 / gCO2/kWh



CO2 emissions and emissions intensity for appliances, 2010-2030

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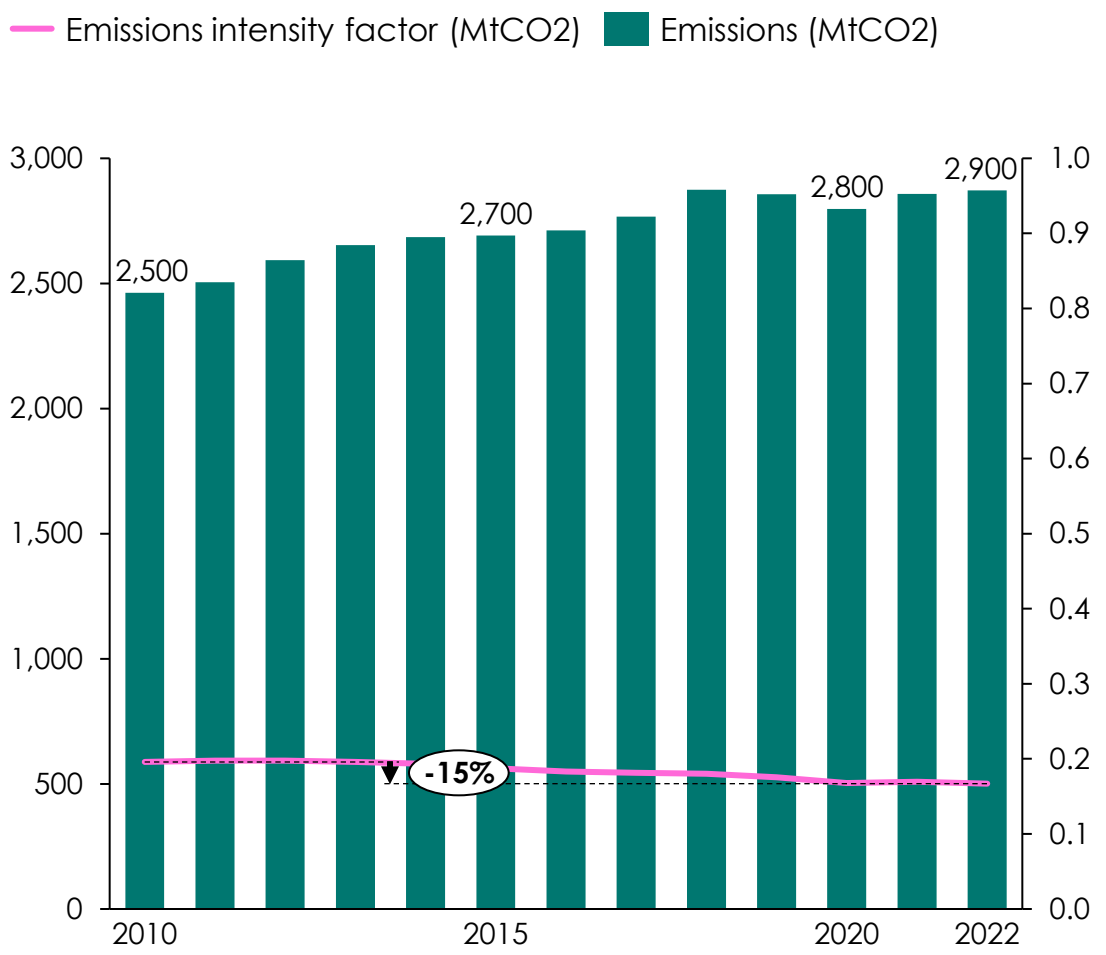
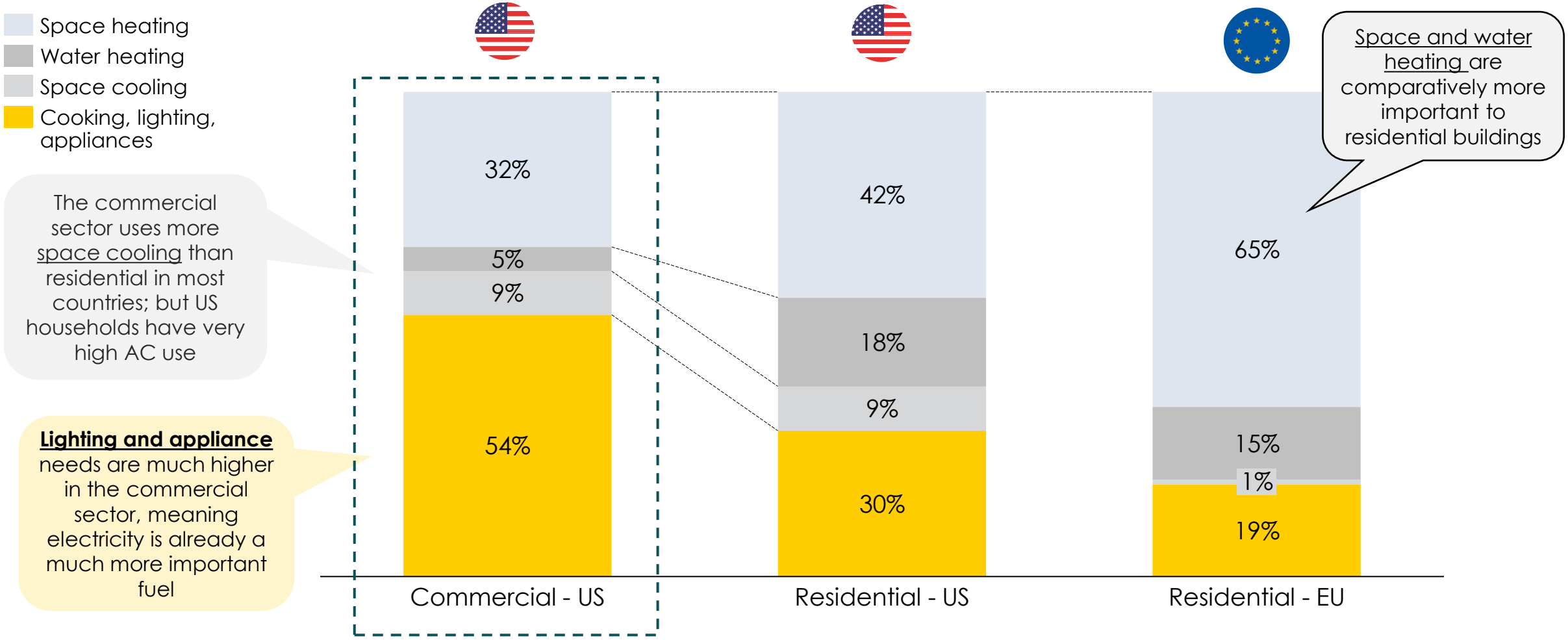


Source: IEA (2023), *CO2 emissions and emissions intensity for lighting in the Net Zero Scenario, 2000-2030;* IEA (2023), *CO2 emissions and implied emissions intensity factor for appliances in the Net Zero Scenario, 2000-2030*

Lighting and appliances are a larger share of building energy use in commercial buildings

Energy end-use, commercial vs residential in the US and EU

% of total energy use



Source: US Energy Information Administration (2018), *2018 Commercial Buildings Energy Consumption Survey*; EIA (2023), *Annual household site end-use consumption, 2020*; Eurostat (2023), *Energy consumption in households*; Building Performance Institute Europe (2015), *Europe's Buildings Under the Microscope*

With no technology transition required, what are the interesting questions for lighting and appliances?

- To what extent will rising demand increase electricity requirements?
- What is the potential to realise greater efficiency improvements in new lighting and appliances?
  - How far could electricity requirements be reduced?
  - What is the role of regulation?
- What can be done about the stock of older, less efficient appliances?
- What additional policies and incentives are needed?

Lighting

There are three main types of light bulb; today, LED bulbs are over 80% more efficient and last for much longer

Older and less efficient

Newer and more efficient

Incandescent

- Filament (e.g., halogen gas) is heated until it glows
- 90% of energy is heat
- Lasts for around 1,000-2,000 hours

Fluorescent

- Glass tubes filled with argon and mercury vapour, which emits ultraviolet radiation when ionised
- 80% of energy is heat
- Last for 15,000 hours

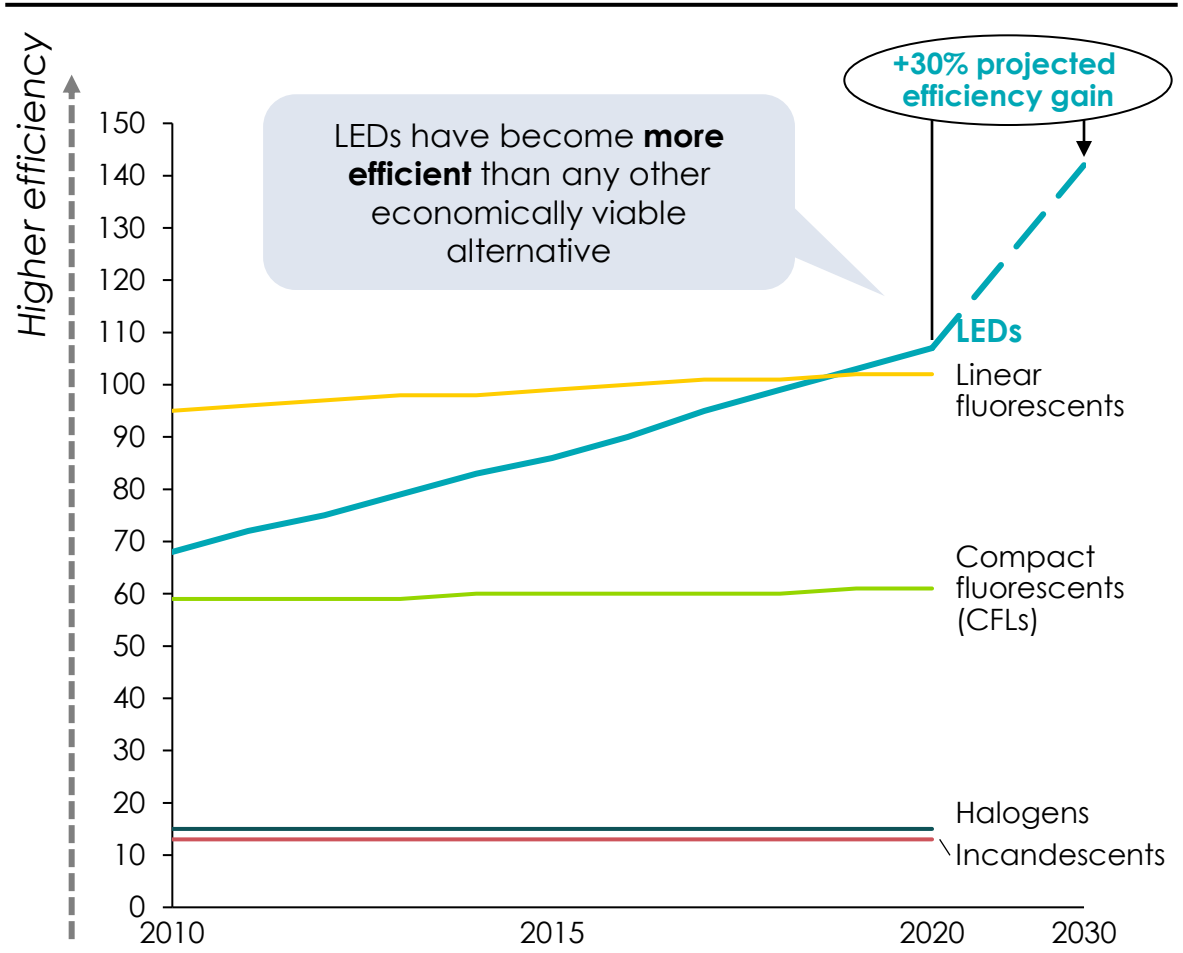
LED

- Able to emit light in a specific direction, reducing the need for reflectors and diffusers which trap light
- Minimal energy lost as heat
- Last for 30,000 – 50,000 hours

LED bulbs are now the leading lighting technology, but a continued effort on increasing LED lighting is needed for achieving net zero

Global lighting efficacies

Lumens/Watt



The efficacy of new LEDs continues to rise due to technological advancements in

- **Improved semiconductor materials**
- **Advanced optics**
- **Integration with smart technology**

Further advances could be made through:

- **Advanced LED modules** (e.g., consisting of multiple-chip packages on a printed circuit board)
- Continuous **improvements in optics**
- **Direct current (DC) grids** to reduce losses from converting alternating current (AC) to DC (as LEDs run on DC)

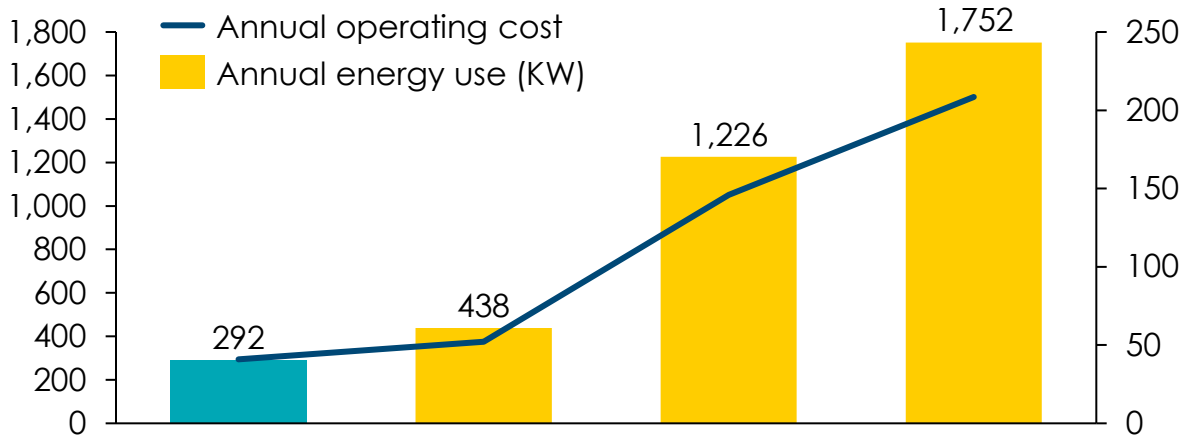
Source: IEA (2023), Global residential lighting sales share by technology in the Net Zero Scenario, 2010-2030

LED lamps are a far superior technology in terms of efficiency and run time, offering huge total cost of ownership savings for households; today, they also cost roughly the same to buy

Cost and energy use over the lifetime of different light bulbs

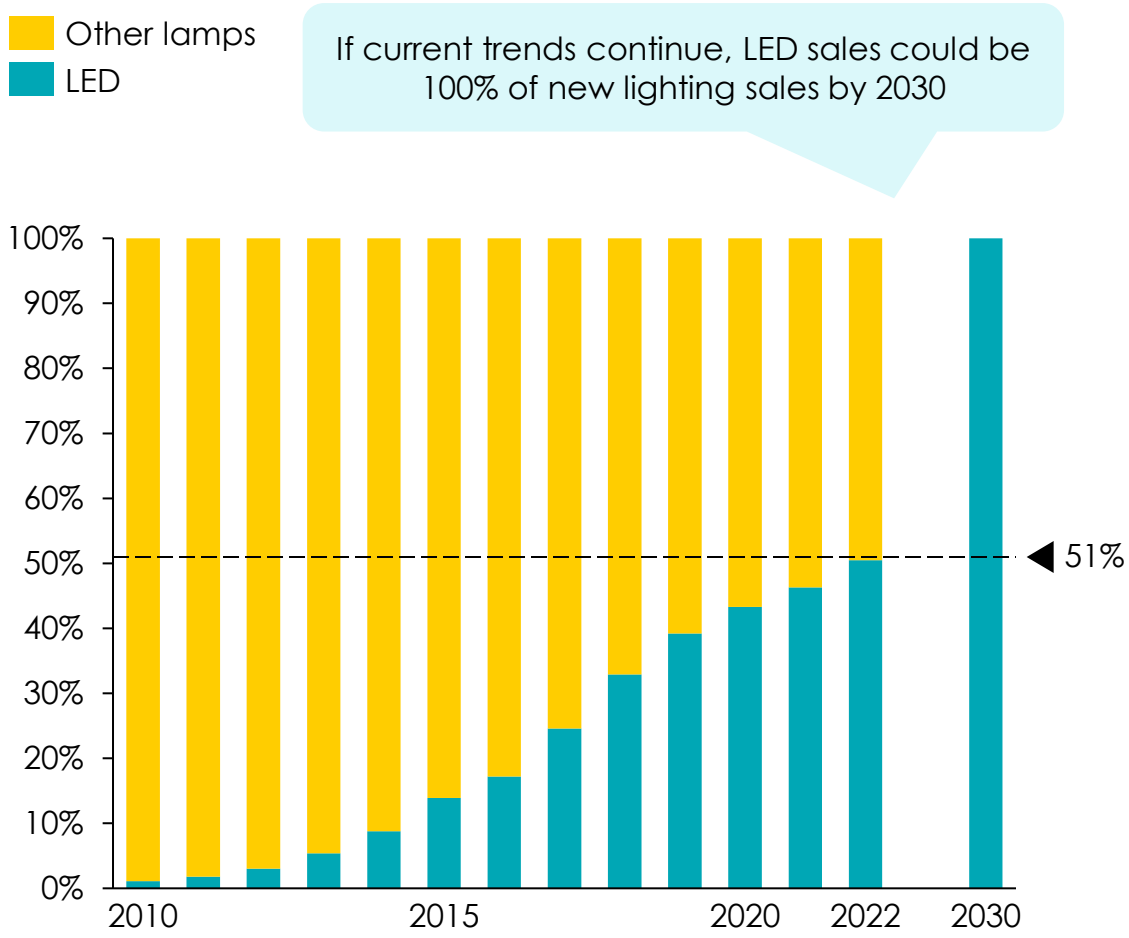
	LEDs	CFL	Halogen	Incandescents
Life span (Avg)	Up to 50,000 hrs	Up to 15,000 hrs	Up to 2,000 hrs	Up to 1,000 hrs
Watt used	10W 810 Lumen	15W 800 Lumen	42W 630 Lumen	60W 610 Lumen
Price range	£2 - £10 per bulb	£1 - £5 per bulb	£1 - £3 per bulb	£0.50 - £2 per bulb

Lifetime cost analysis (using 20 lamps for 4 hours a day, £14p per kWh)



Global residential lighting sales share by technology

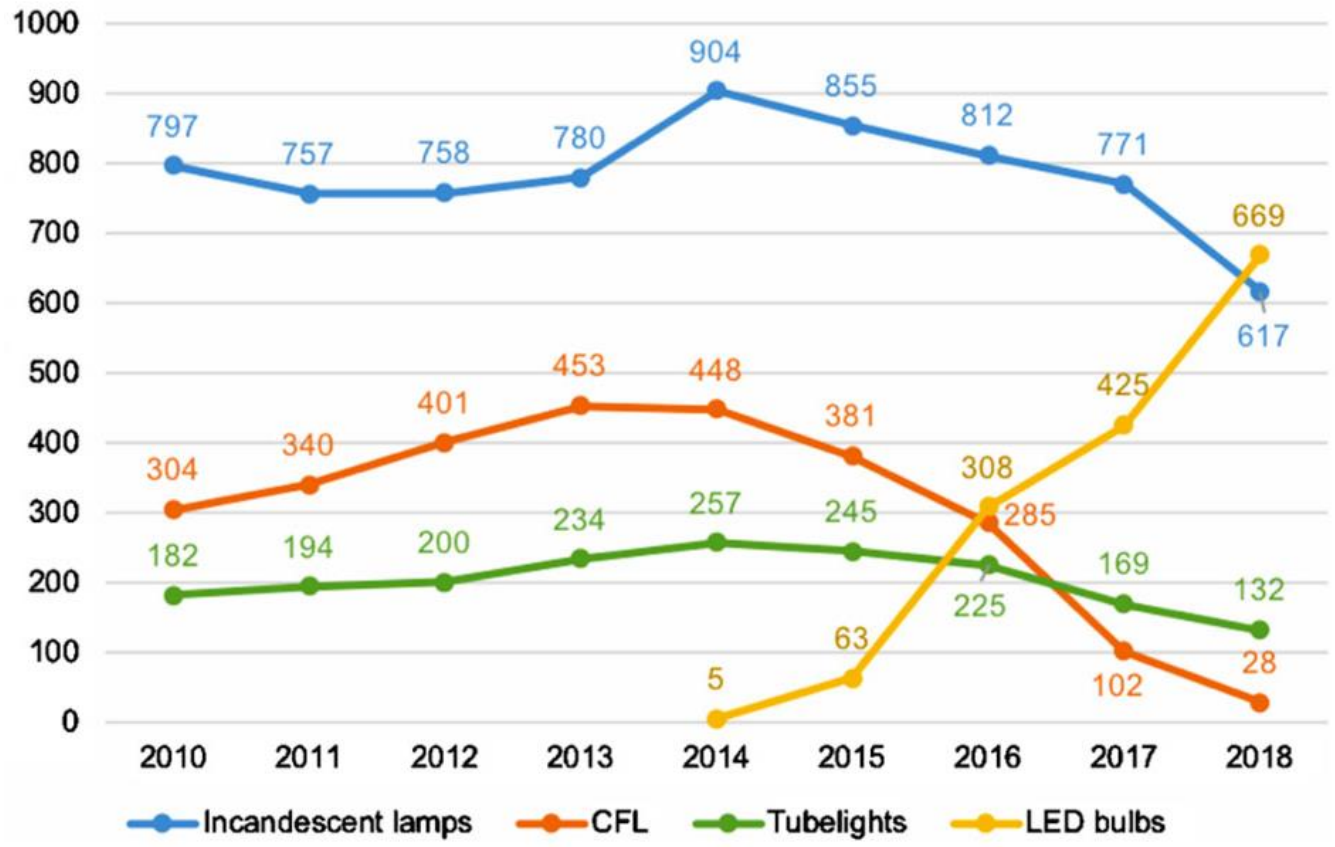
Proportion of sales (%)



Source: Dunelm, *LED Lighting Buying Guide*; IEA (2023), *Global residential lighting sales share by technology in the Net Zero Scenario, 2010-2030*

In India, a government bulk procurement scheme has been critical to lowering costs of LED bulbs and resulting in an unprecedented market scale up

Lighting sales in India by bulb type
Number of lamps, millions



In 2015, India launched a bulk procurement scheme of LED light bulbs at competitive prices, much lower than those in local markets. These were then distributed to households subsidy-free via a replacement scheme.

Key outcomes:

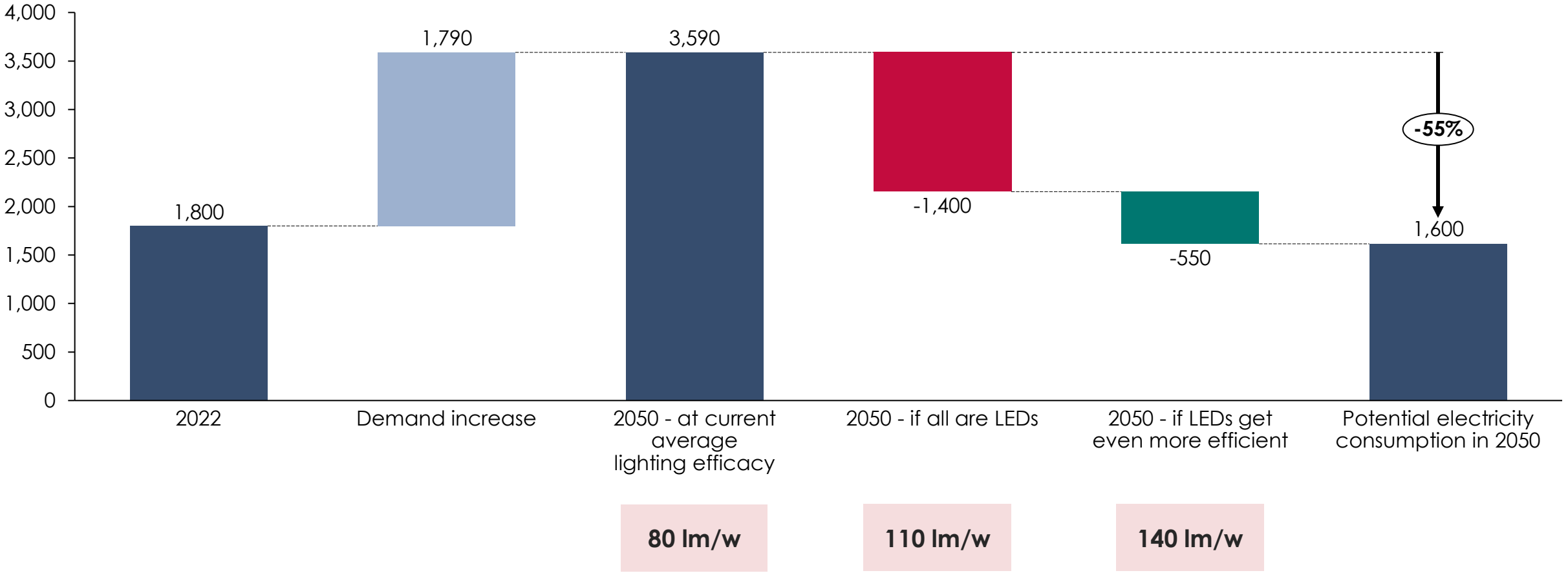
- As of January 2022, the program had distributed over **360m LED bulbs**, **saving over 47TWh** and avoiding **37 MtCO2 a year**.
- Between 2014 and 2017, LED bulb **retail costs fell 75-80%**, from INR 300-350 per bulb in 2014, to INR 70-80 per bulb in 2017.
- India's **LED lighting market grew 130-fold** in just five years, from annual sales of 5m bulbs per year in 2014, to about 670m in 2018.

Source: ELCOMA, *Lighting industry data in India, 2010-18;* India Ministry of Power (2022), *Salient Features of UJALA and SLNP Programmes.*

With action to limit sales of non-LED lightbulbs and continued improvements to LED efficacy, efficiency improvements could more than offset the rise in demand for lighting

Global lighting electricity consumption, 2022 to 2050

Annual TWh



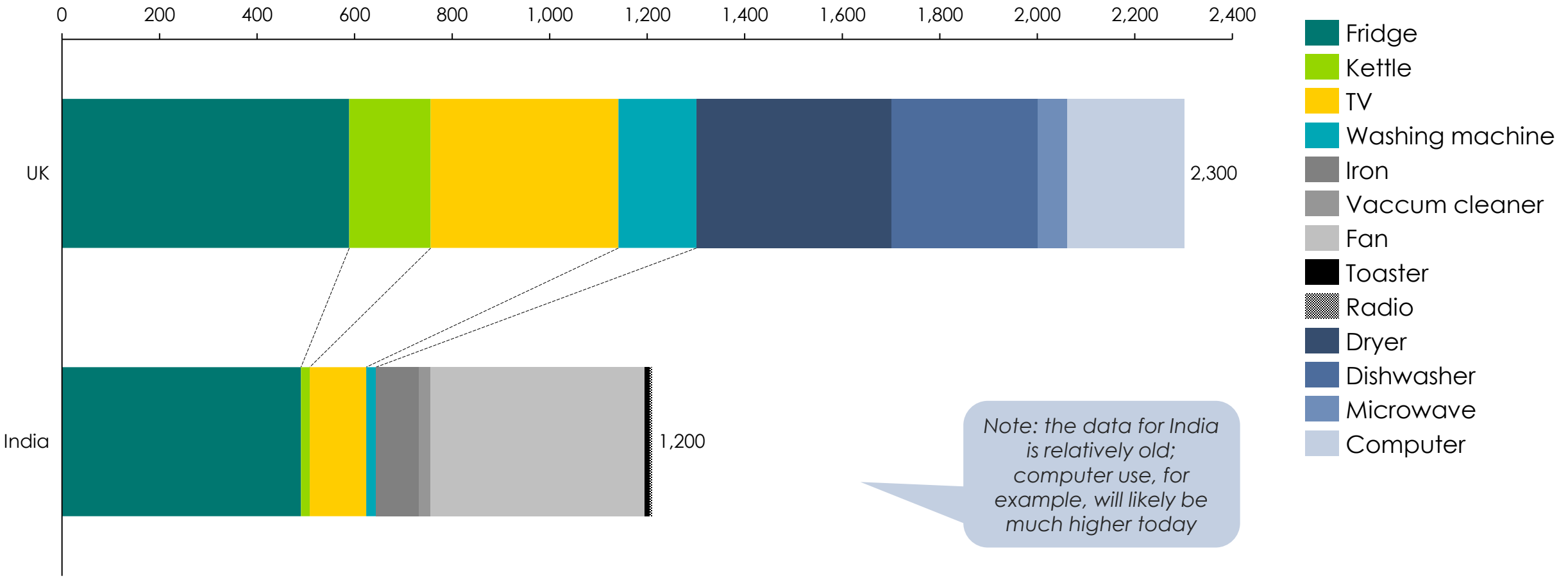
Sources: Systemiq analysis for ETC (2024); IEA for global floor area and 2022 electricity consumption in lighting

Appliances

Appliances covers a wide range of household, kitchen and digital electronics which improve productivity, living standards, access to information and health

Average household energy use from common appliances in the UK and India (in households that own specific appliances)

kWh/year



Source: Intertek (2012), *Household Electricity Survey: A Study of Domestic Electrical Product Usage;* Narasimha Murthy, K.V., et al. (2001), *End Uses of Electricity in Karnataka Households.*
Note: excludes heating and cooling appliances.

In commercial buildings, ventilation, computing and motors are more important appliances

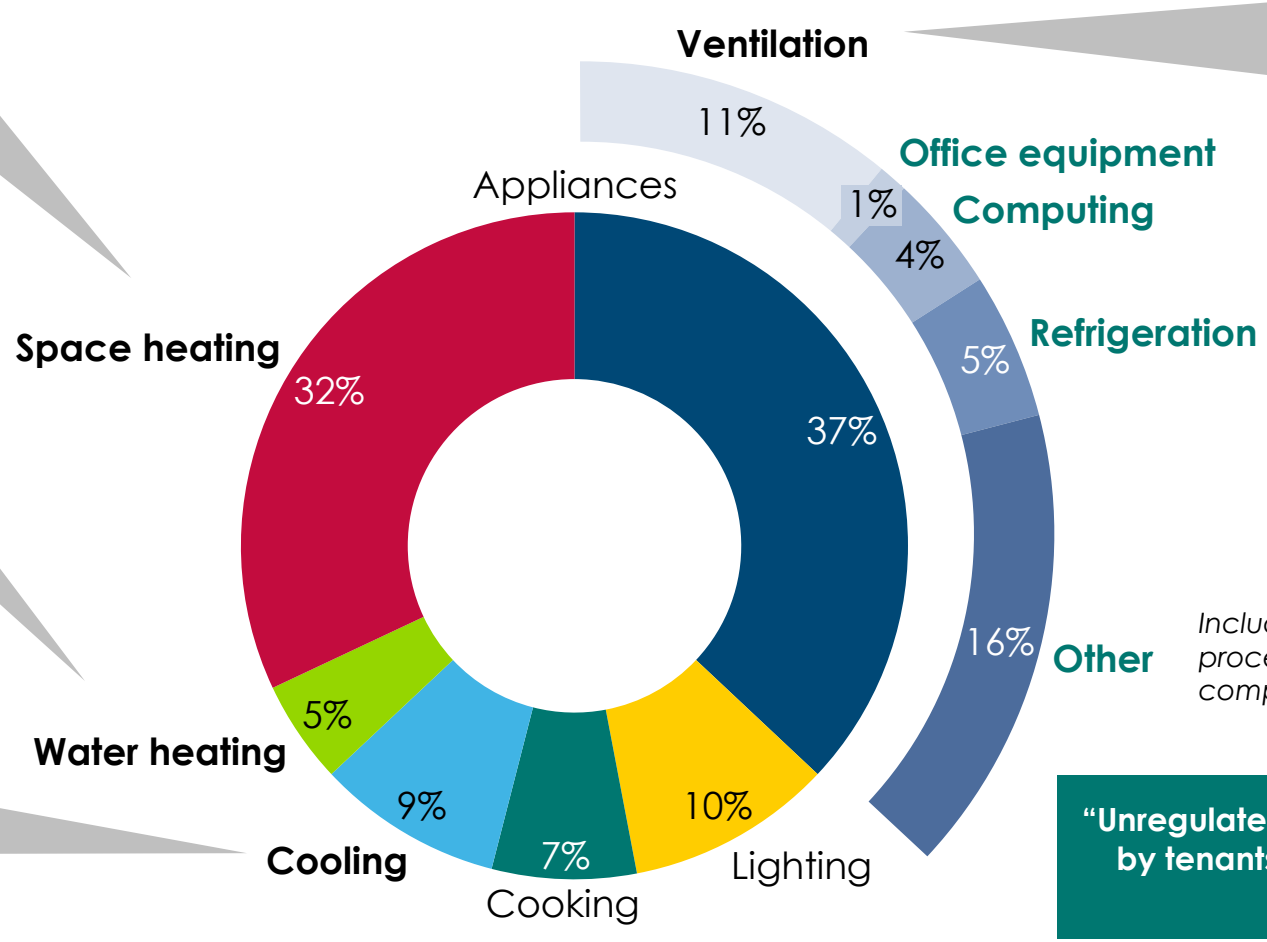
Commercial buildings energy consumption by end-use in the US
% of energy consumption

Heating, ventilation and air conditioning (HVAC) in bold

Refers to ambient space heating needs for human occupants

Hot water needs for human occupants (e.g., washing hands, showers)

Air conditioning needs – does not include any business needs for cooling (e.g., data centre cooling)



Air quality and ventilation needs in commercial buildings are significant, becoming more so post-COVID

Separate to space cooling

Includes miscellaneous plug loads, process equipment, motors, air compressors, and natural gas dryers

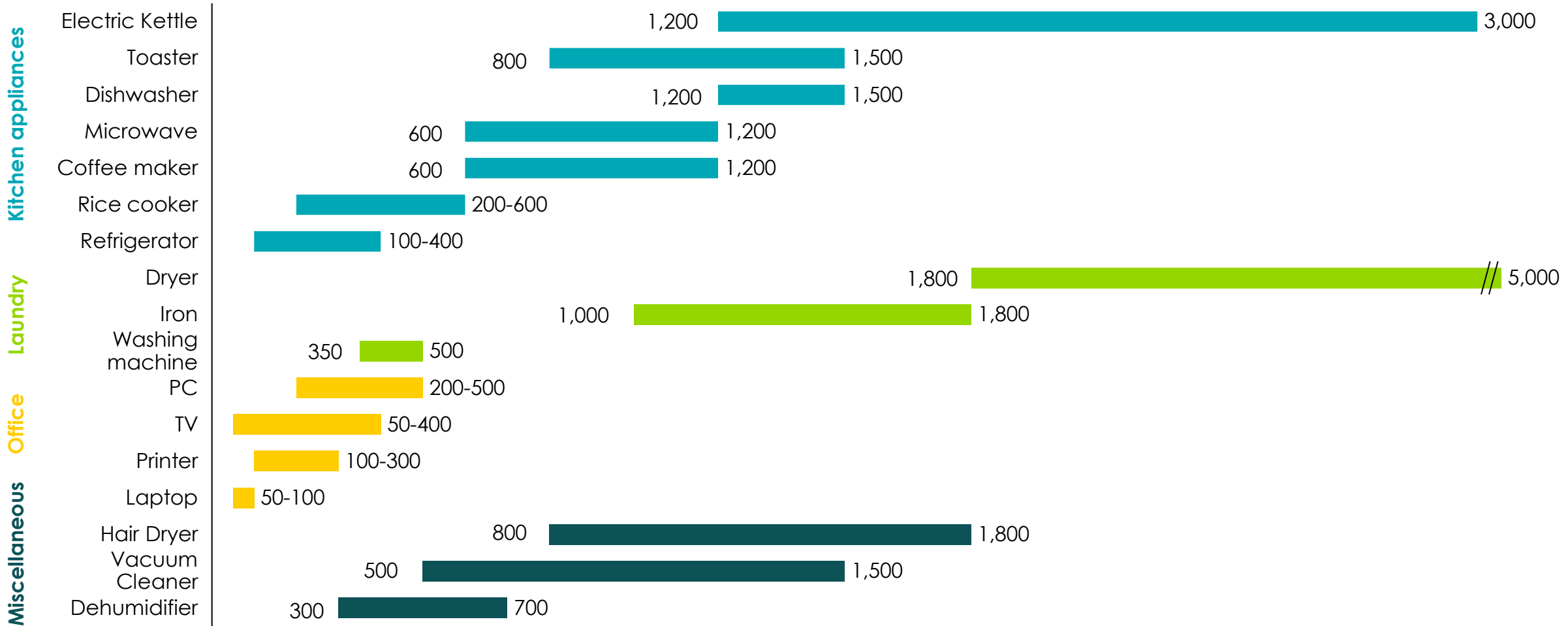
"Unregulated" energy use which is determined by tenants and unable to be controlled by building managers

Sources: US Energy Information Administration (2018), *2018 Commercial Buildings Energy Consumption Survey.*

Different appliances have different wattages, but also differ in how long they are used for meaning wattage does not necessarily translate into higher electricity requirements

Typical wattage ranges of common appliances

Watts



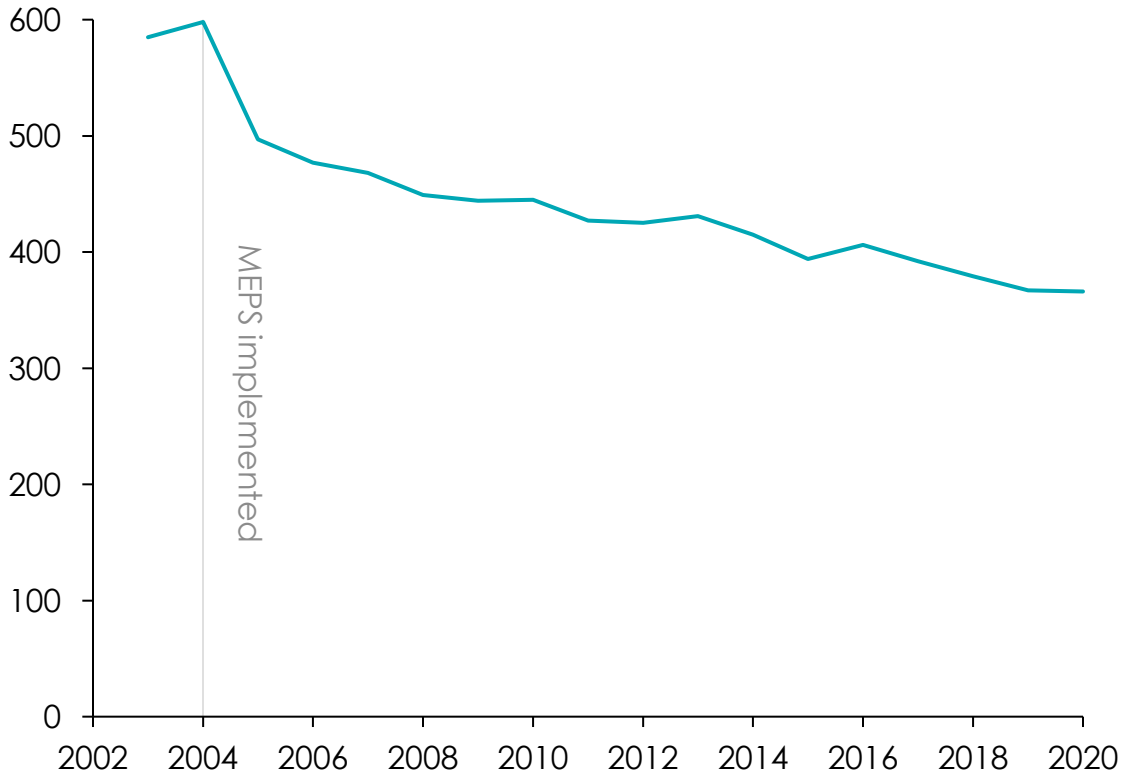
Source: Sparks Direct (2022), *Which Household Appliances Use the Most Electricity?*

Technological advancement and minimum energy performance standards have both played a key role in improving the efficiency of appliances

Energy performance standards and labelling

Annual energy demand from refrigerators and freezers

kWh, market average, New Zealand, 2003–2020



Source: IEA (2023), Energy Efficiency 2023.

Technological developments

Refrigerators and freezers

- **Inverter compressors**: these adjust their speed according to cooling demand
- **Improved insulation**: better insulation materials reduce the loss of cold air
- **Smart temperature controls**: sensors and microprocessors optimize cooling cycles

Washing machines

- **Inverter Motors**: more efficient motors that adjust speed based on load
- **Load sensing technology**: automatically adjusts water and energy use based on the size of the load
- **Improved drum designs**: enhanced drum patterns and materials

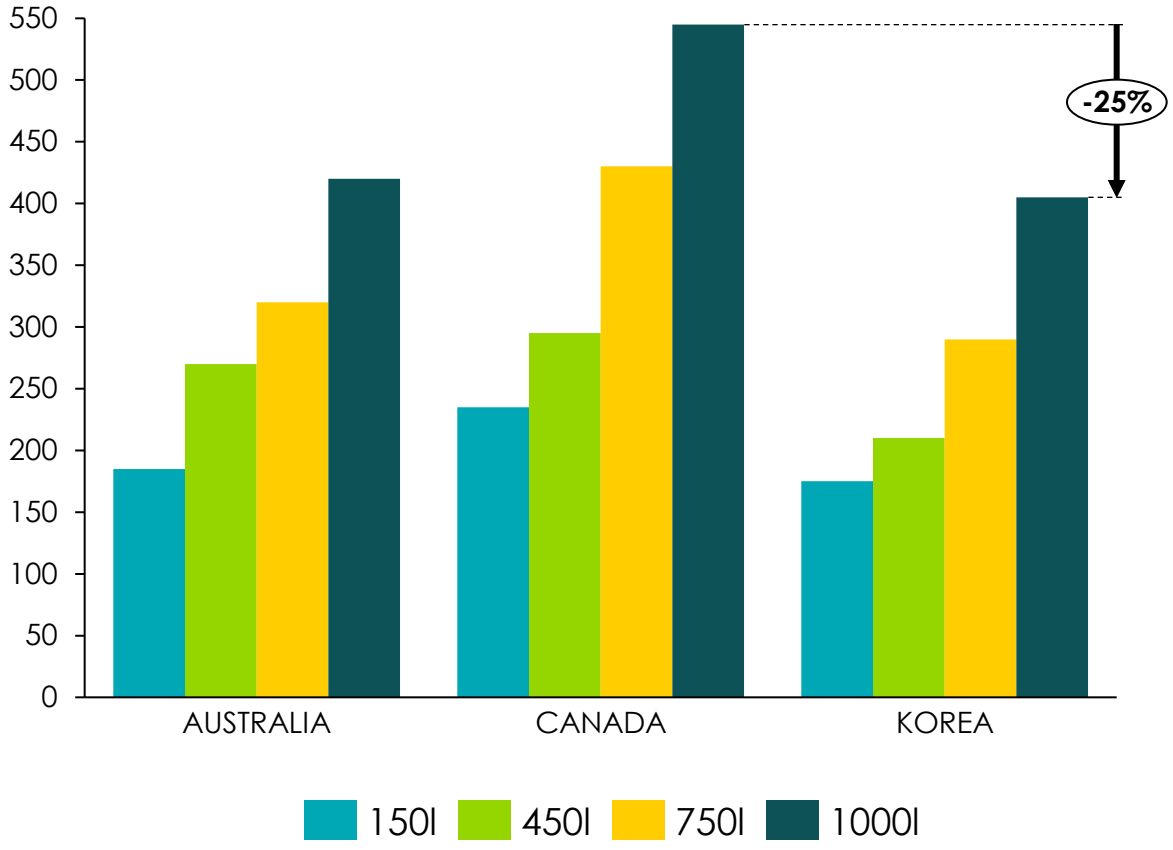
Dryers

- **Heat pump technology**: recirculates warm air instead of venting it out
- **Moisture sensors**: detects moisture levels and stops the cycle when clothes are dry
- **Improved airflow systems**: enhanced designs improve air circulation

However, large differences in efficiency persist across countries; fridge-freezers of the same size can be 25% more efficient in Korea than Canada

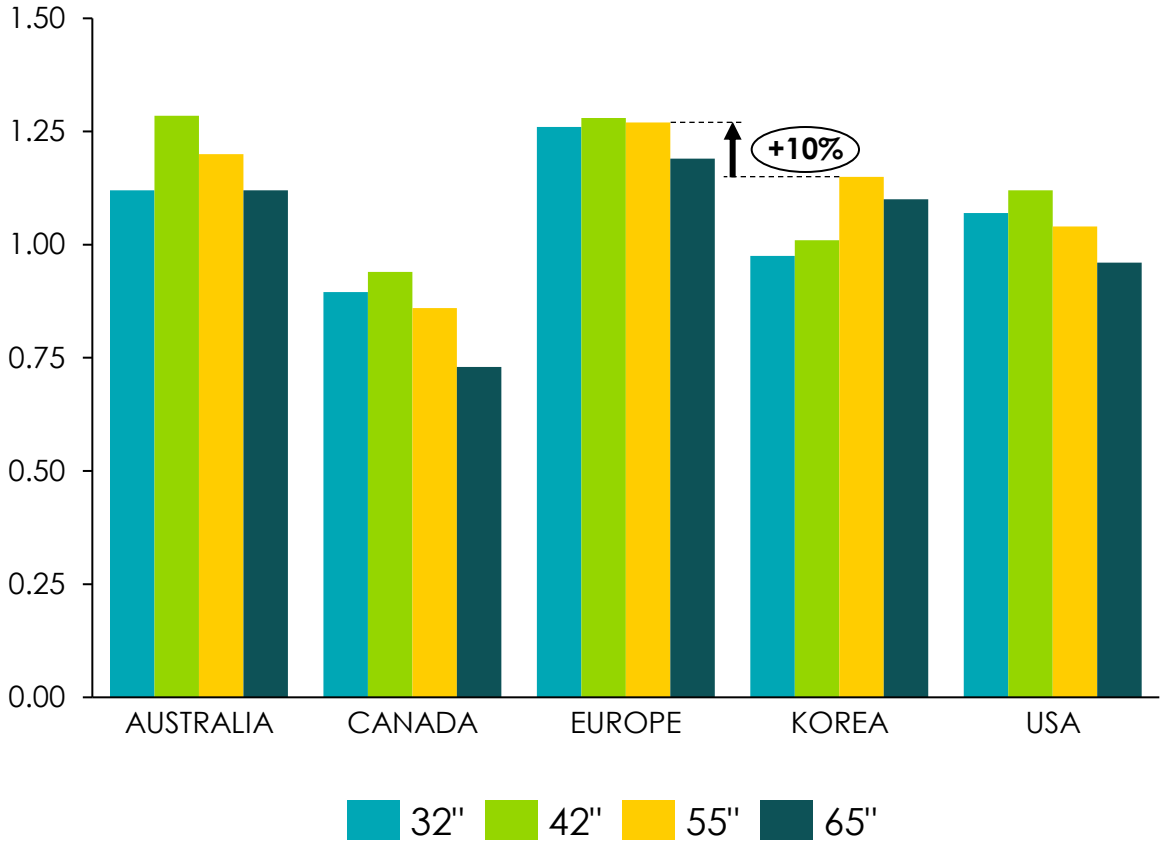
Average annual energy consumption for refrigerator-freezers by size, 2019

kWh/year



Average efficiency of TVs by screen size, 2018

W/dm2

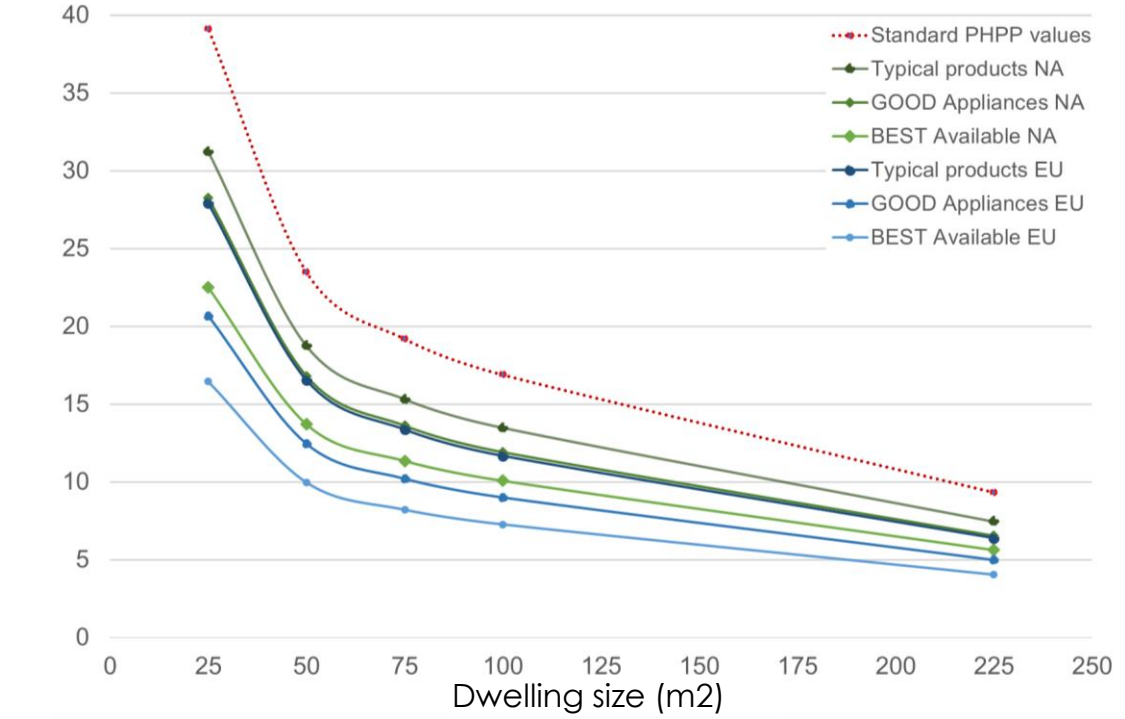


Source: Technology Collaboration Programme on Energy Efficient End-Use Equipment (2021), *PEET Efficiency Trends Analysis.*

In addition, there are huge variations in average efficiency within regions; in some markets, the market average efficiency can be half that of the best available models

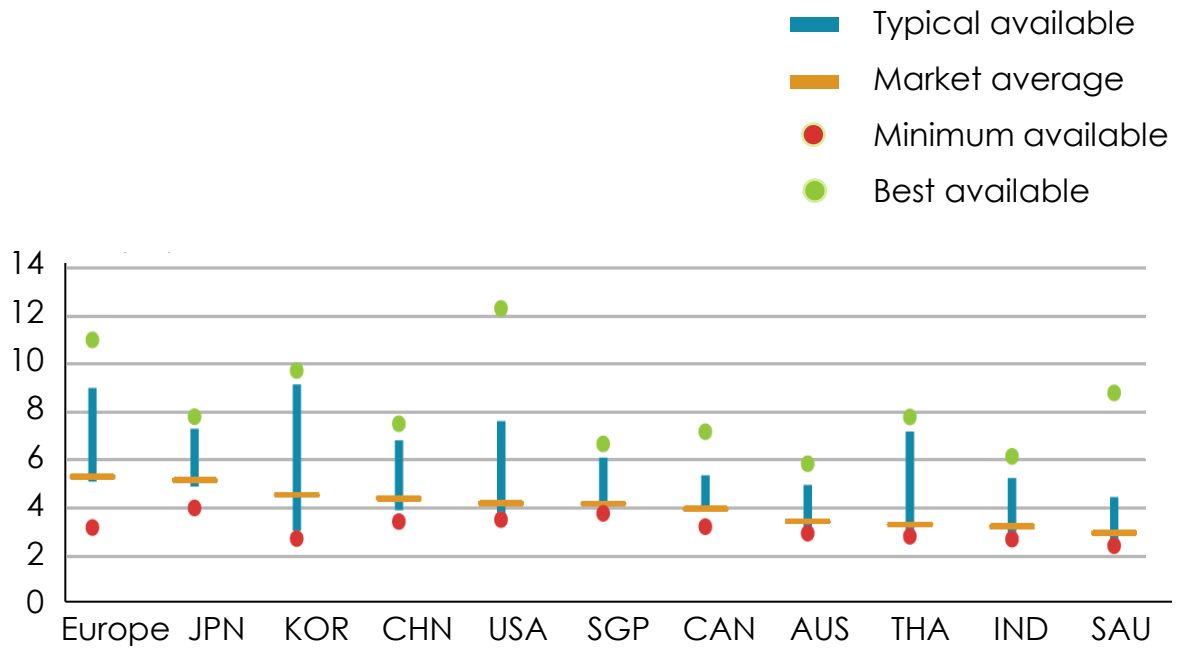
Final energy demand from household appliances available in the European and North American markets

Annual kWh/m2



SEERs of market available residential AC units in selected regions, 2018

SEER, Watt of output per Watt of input



In all regions, noticeable variation exists – in some countries this reflects price dynamics, but in other countries a low efficiency appliance can cost the same as a very efficient one

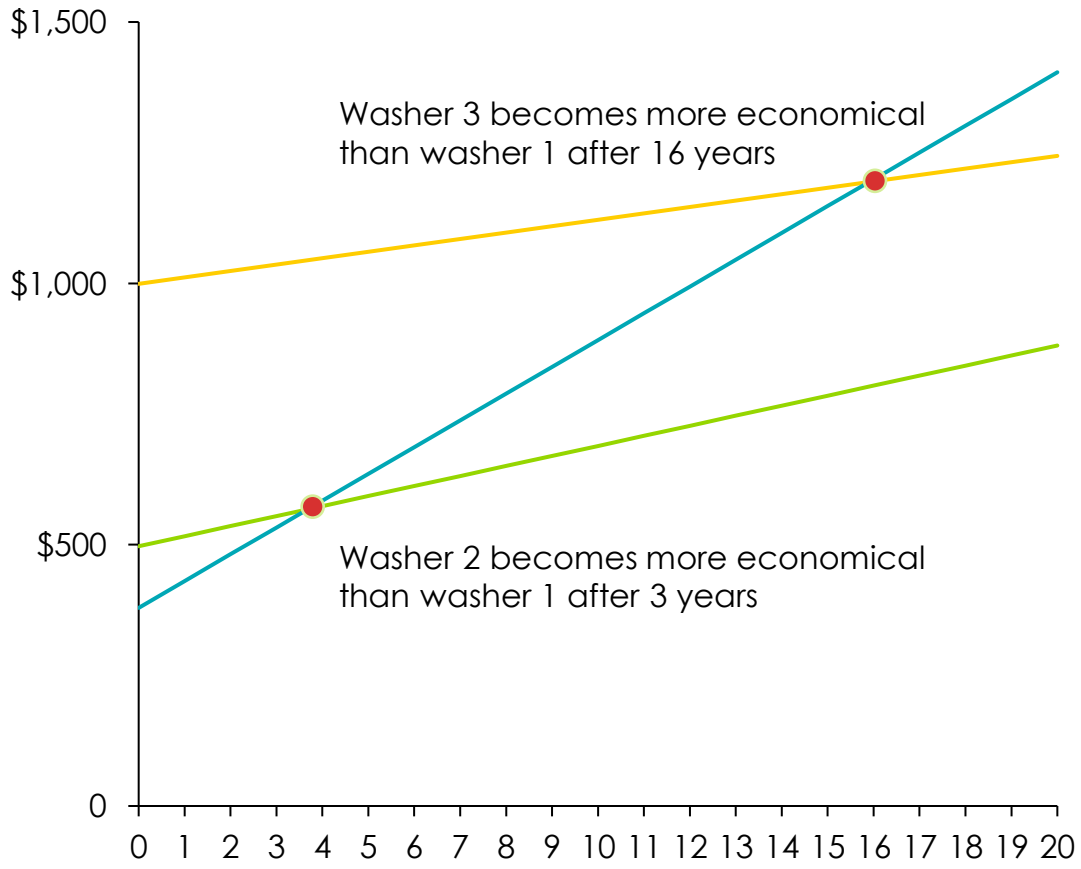
Source: Passive House Institute (2020), Efficiency of household appliances and their impact on the primary energy demand of residential buildings; IEA (2018), The Future of Cooling. Note: PHPP refers to Passive House Standard minimum values for appliance efficiency.

Even with higher purchase prices, more efficient appliances can typically pay back within 5 years…

Cost over the 20-year lifetime of different washing machines, US

$ a year

	Washer 1	Washer 2	Washer 3
Original cost	$379	$497	$999
Estimated annual electricity use	427 kWh	160 kWh	102 kWh
Operating cost per year ($0.12 per kWh of electricity)	$51.24	$19.20	$12.24

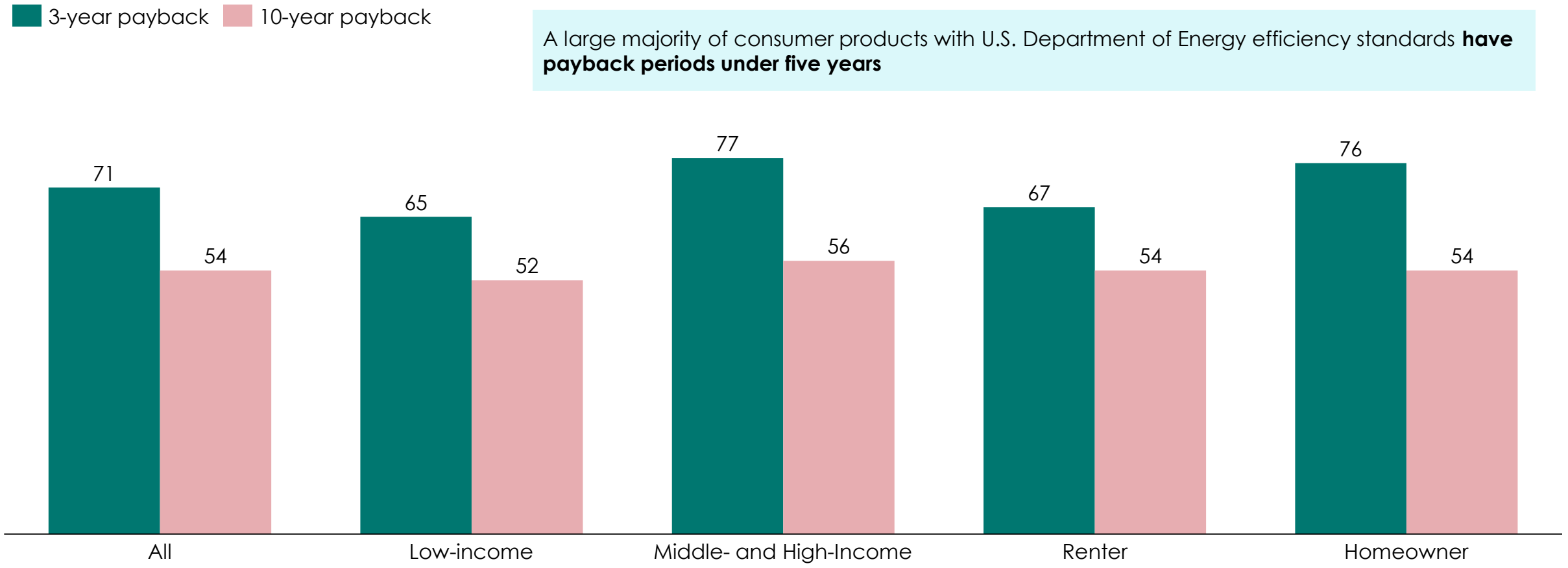


Source: Cape Light Compact (2020), *Appliances and Electrical Devices*; CLASP & CFA (2022), *U.S. Consumer Attitudes Toward Appliance Efficiency Standards and Purchasing Behaviors by Income, Race, and Homeownership.*

…50% of households in the US would even support a 10 year payback

Support for appliance efficiency standards by payback periods

% share; sorted by Income and Homeownership Status (Renter vs. Owner), USA

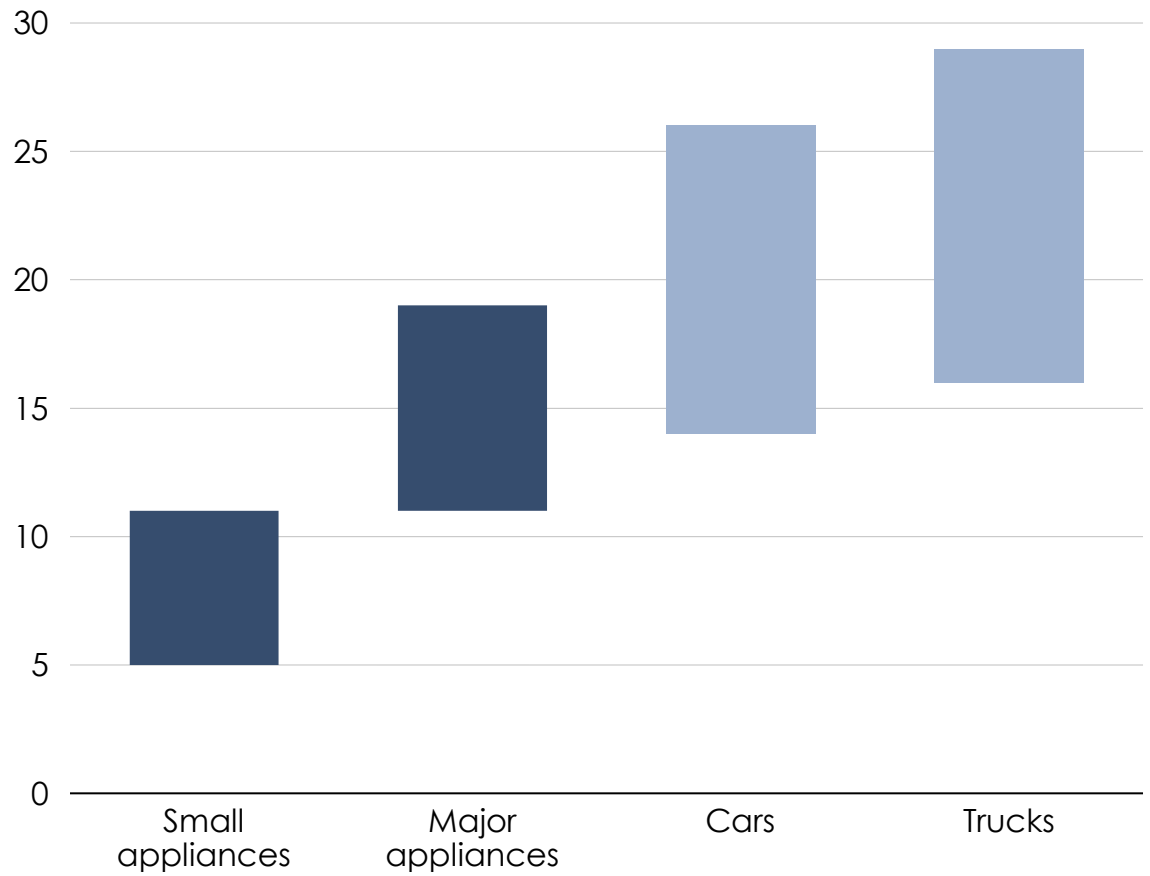


Source: Cape Light Compact (2020), *Appliances and Electrical Devices*; CLASP & CFA (2022), *U.S. Consumer Attitudes Toward Appliance Efficiency Standards and Purchasing Behaviors by Income, Race, and Homeownership.*

Labelling, standards and R&D can improve the efficiency of new appliances, but older stock can take 5-20 years to be replaced; a key question is how much this stock turnover should be accelerated

Estimated time required to replace 90% of the existing stock under normal replacement rates

Years required to replace 90% of the stock



There are trade-offs to consider between promoting faster stock turnover versus maintaining older appliances until end of life

Embodied Carbon

- Producing more appliances has an embodied carbon impact
- As the **grid decarbonises**, it will take longer for energy savings to pay this embodied carbon back

Waste generation

- Rapid stock turnover increases **waste**
- **Battery waste** needs to be carefully managed
- This can be managed by **effective circular approaches** (e.g., recycling, reusing components)

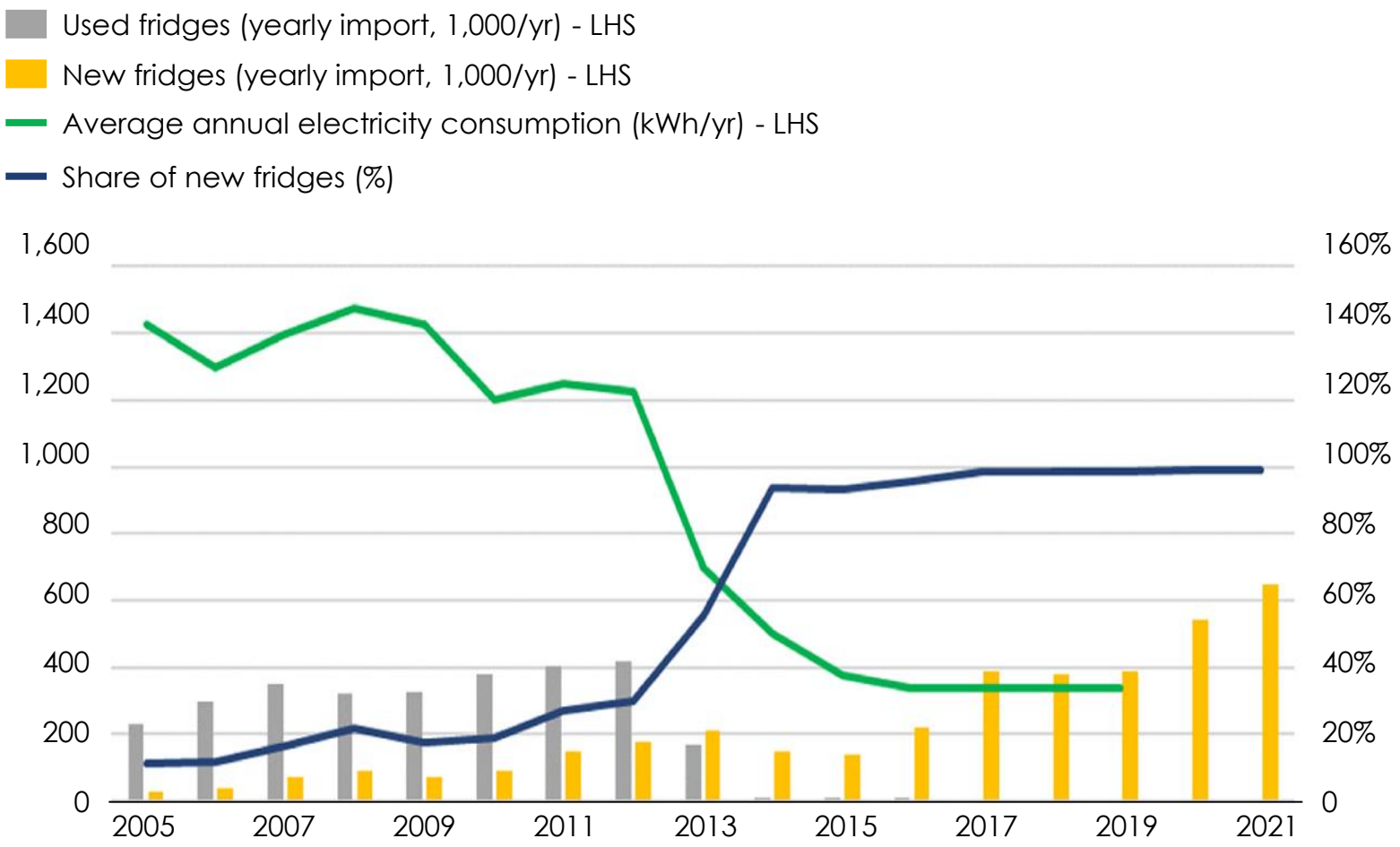
Affordability and equality

- **Restricting second hand markets** could prevent lower-income households being **able to access** appliances

Source: IEA (2023), *Energy Efficiency 2023*

In some developing countries, a key issue is dumping and a second-hand market of very inefficient products; the energy consumption of fridges fell 70% after imports were banned

Import of new and used fridges in Ghana, 2005 – 2021



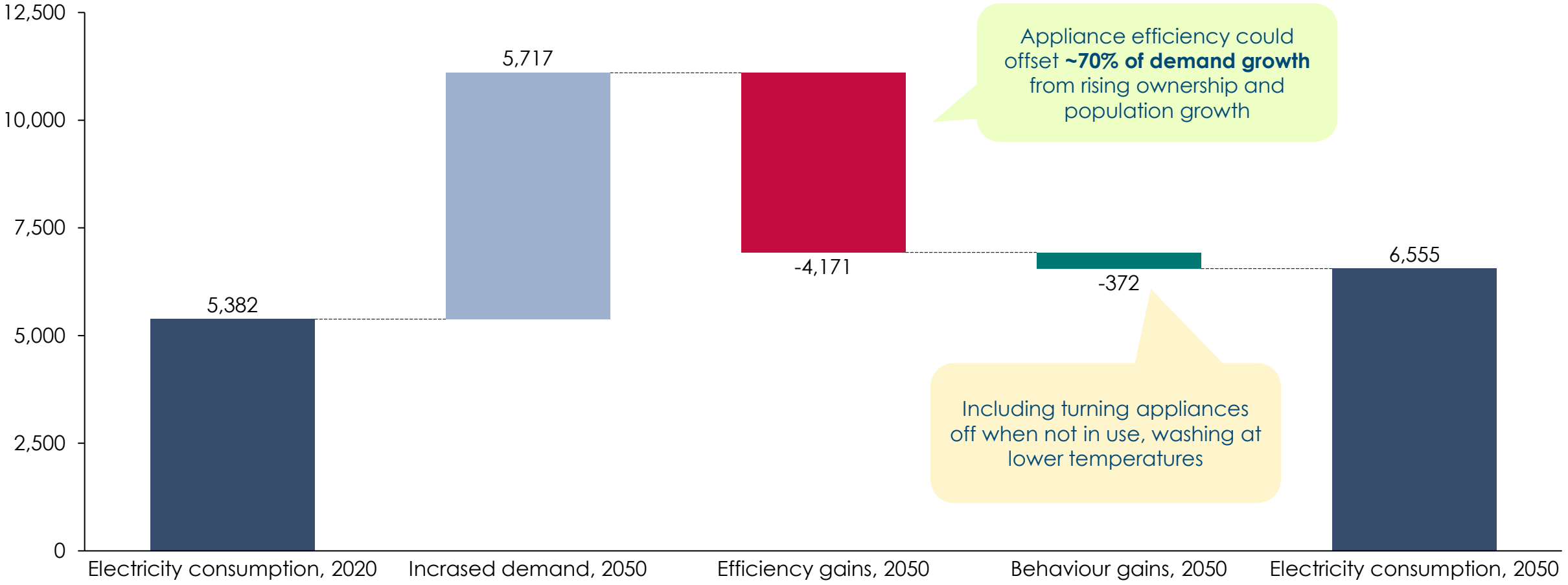
- Between 2005 and 2019, **2.8m used refrigerators were imported** into Ghana
- Second hand fridges contained **CFC refrigerants** (damaging to Ozone layer) and were **less energy efficient**
- In 2013, Ghana's banned imports of used **cooling appliances**
- Rebates offered to replace old appliances – between 2013 and 2017, **40,000 used fridges and 10,000 used AC units** were destroyed
- Average consumption of refrigerators **fell from 1,200kWh to 385kWh per annum**

Source: Durand et al. (2024), *Environmental assessment of used refrigerating appliances: Why does an import ban make sense and what could other countries learn from Ghana?*

Improving the technical efficiency of appliances could offset 70% of rising energy demand

Global electricity consumption by appliances and equipment, 2020 to 2050

Annual TWh



Sources: IEA (2021), *Net Zero by 2050.*

Actions to realise efficiency gains

A combination of regulation, education and financial incentives are needed to realise efficiency improvements, underpinned by gradual behaviour change and recycling

1

Set an efficiency floor

- Minimum energy performance standards

2

Grow the market for efficient appliances

- Energy performance labelling
- Bulk procurement
- Financial incentives
- Education campaigns
- International collaboration to stop dumping

3

Drive further innovation

- R&D support
  - Efficiency
  - Smart appliances

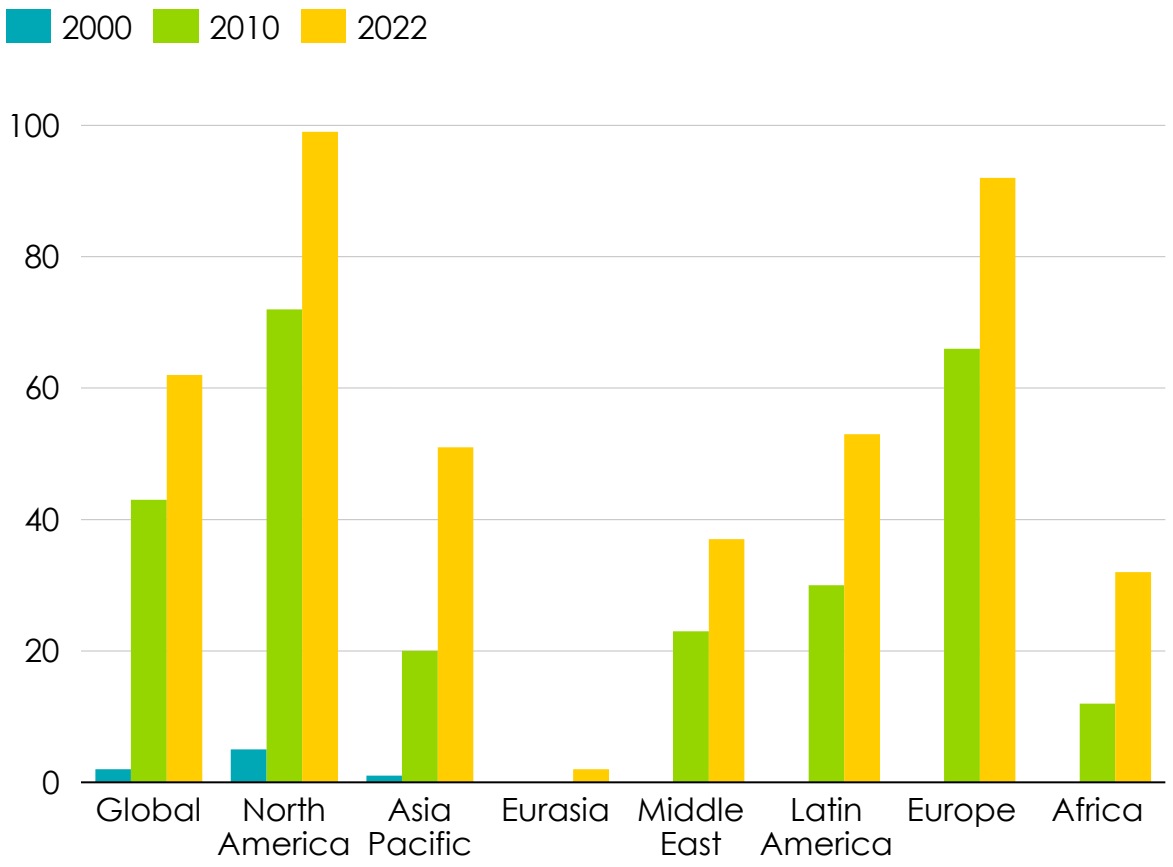
Behaviour change

Recycling and reuse

Over 110 countries now have minimum energy performance standards in force for new lighting and appliances placed on the market

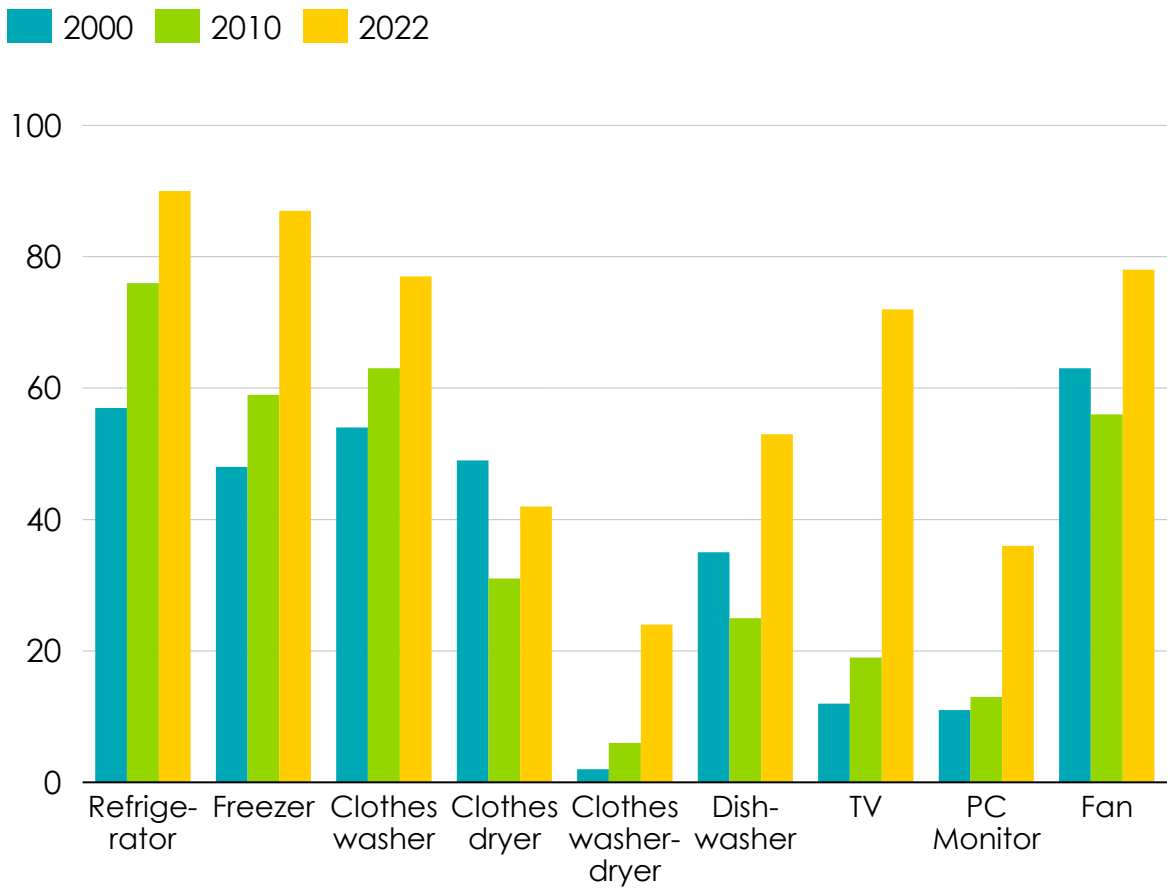
Proportion of lighting final electricity use covered by MEPS by regions, 2000-2022

% share



Global energy consumption covered by MEPS for selected appliances in 2000, 2010 and 2022

% share

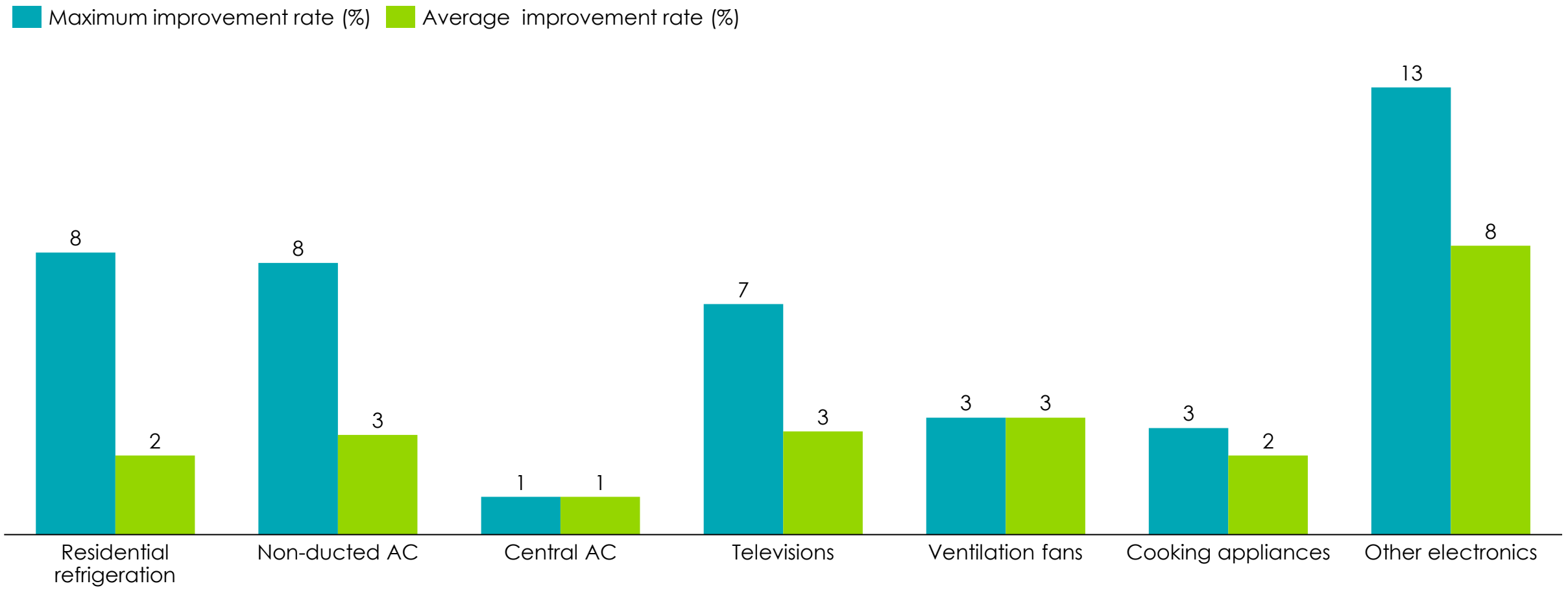


Source: IEA (2023), Proportion of lighting final electricity use covered by minimum energy performance standards, 2000-2022; IEA (2023), Global energy consumption covered by minimum energy performance standards for selected appliances in 2000, 2010 and 2022

Standards and labelling have been proven to increase the average rate of energy efficiency improvements by 2-3 times

Annual energy reduction in new-product energy consumption from energy efficiency standards and labelling (EES&L) programmes

Annual energy improvement rate by % increase



Source: IEA/4E TCP (2021), *Achievements of Energy Efficiency Appliance and Equipment Standards and Labelling Programmes.*

Targeted financial strategies can support the development, commercialisation, and widespread adoption of energy-efficient appliances

- China has implemented a series of **fiscal and taxation policies** to incentivise LED technologies
- LED lighting has been on China's **compulsory government procurement list** since 2013
- LED lighting is now eligible for government **green bonds support**

- **Bulk procurement programmes** have distributed **more than 100 million LED bulbs across 120 cities and 14 major states of India,** driving down the cost of LED lamps and made them affordable for very poor households
- As of 2022, the program was saving households **INR 191 billion** on their electricity bills per year and curbed India's annual CO2 emissions by **37 million tonnes of CO2**

- UK Green Investment Bank (GIB) offers UK local authorities **a low, fixed rate Green Loan** over a period of up to 20 years, which has been specifically designed to **finance public sector energy efficiency projects (e.g., LED streetlighting)**, ensuring that repayments are made from within savings

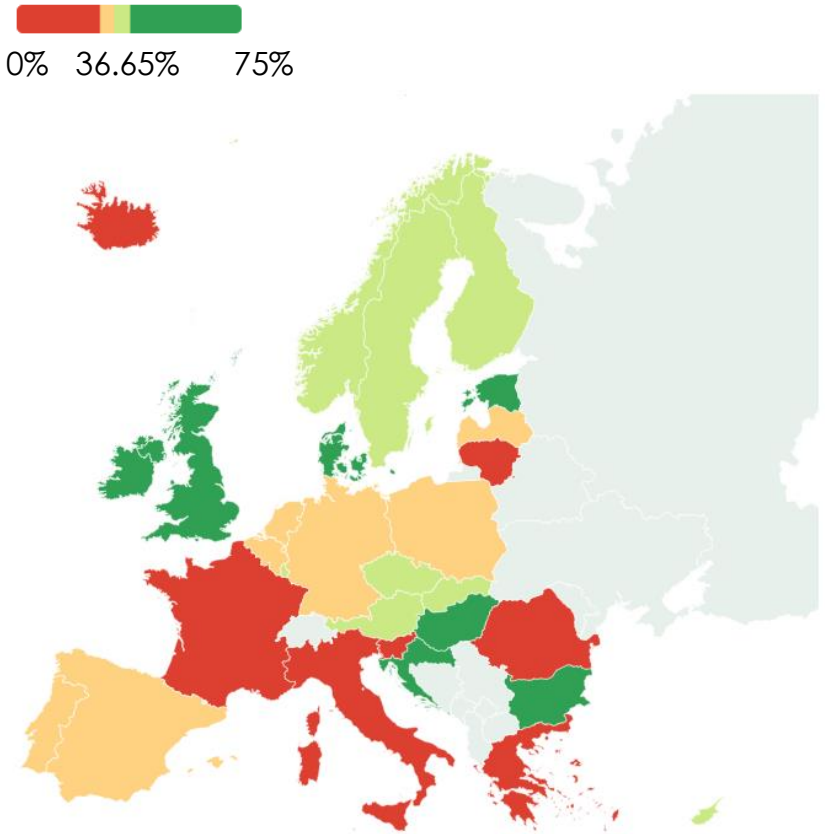
- Ghana's ECOFRIDGES Green On-wage (GO) financing scheme – a credit facility with **flexible repayment terms at 0% interest for 12 months**
- Eligible refrigerators were required to have a **five-star energy rating** and use R-600a refrigerants
- Since its inception, the financing facility has deployed over **$1m**, reduced energy demand by 25 MWh, and avoided over 20,0000 tons of CO2

Source: IEA, Lighting; CLASP (2023), *Lighting a Billion: The UJALA Program's Transformational Impact in India*; LED inside (2014), *UK Green Investment Bank Launches New Loan to Finance the UK's Switch to Low Energy Street Lighting*; CLASP (2024), *Net Zero Heroes.*

In developed countries, proper regulations and incentives should be implemented to facilitate appliance circularity and ensure responsible disposal at the end of life

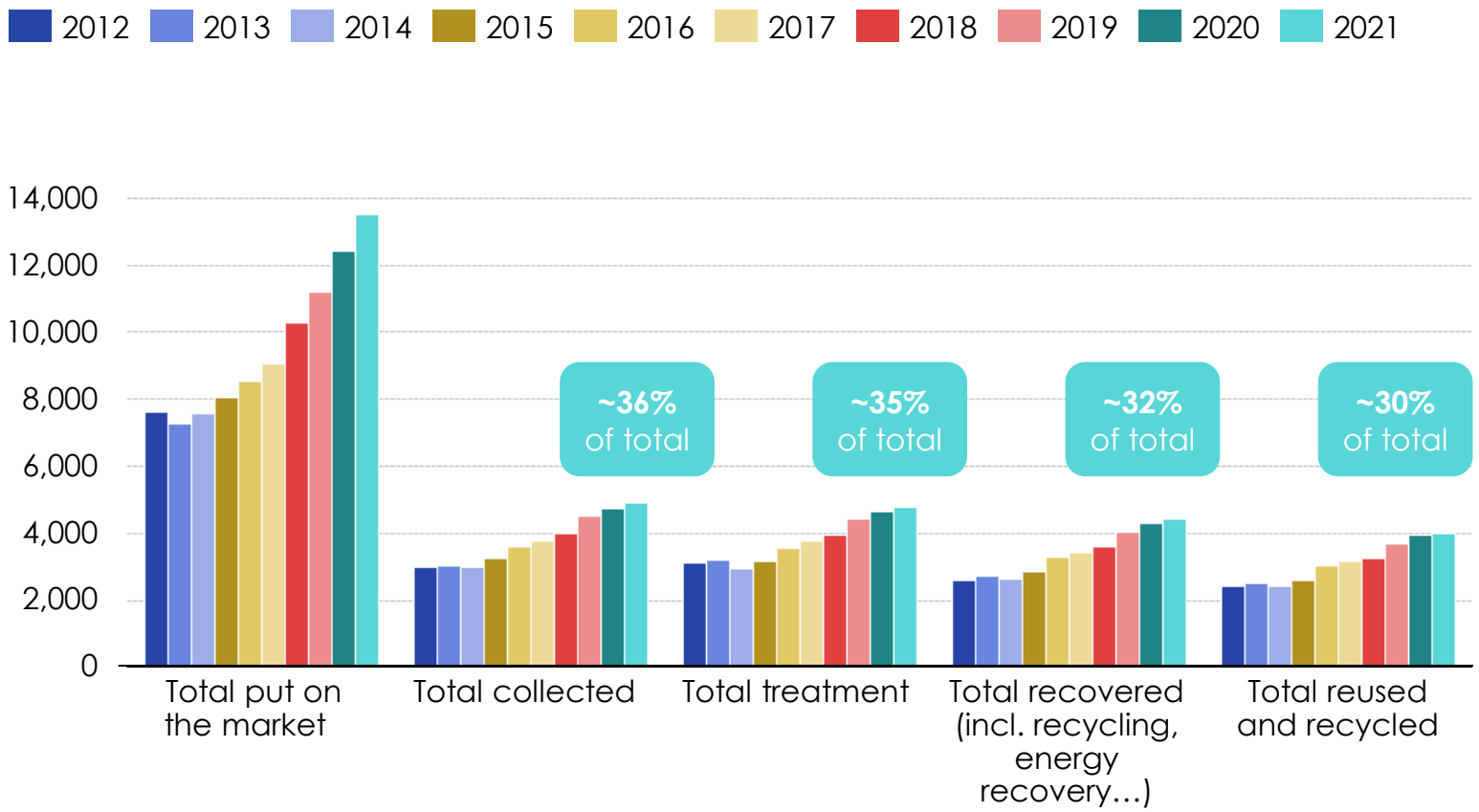
Recycling rate of electrical and electronic waste, Europe, 2018

% share



Electrical & electronic equipment put on the market and waste EEE collected, treated, recovered, recycled and prepared for resue electrical equipment collected

Thousand tonnes, 2012–2021

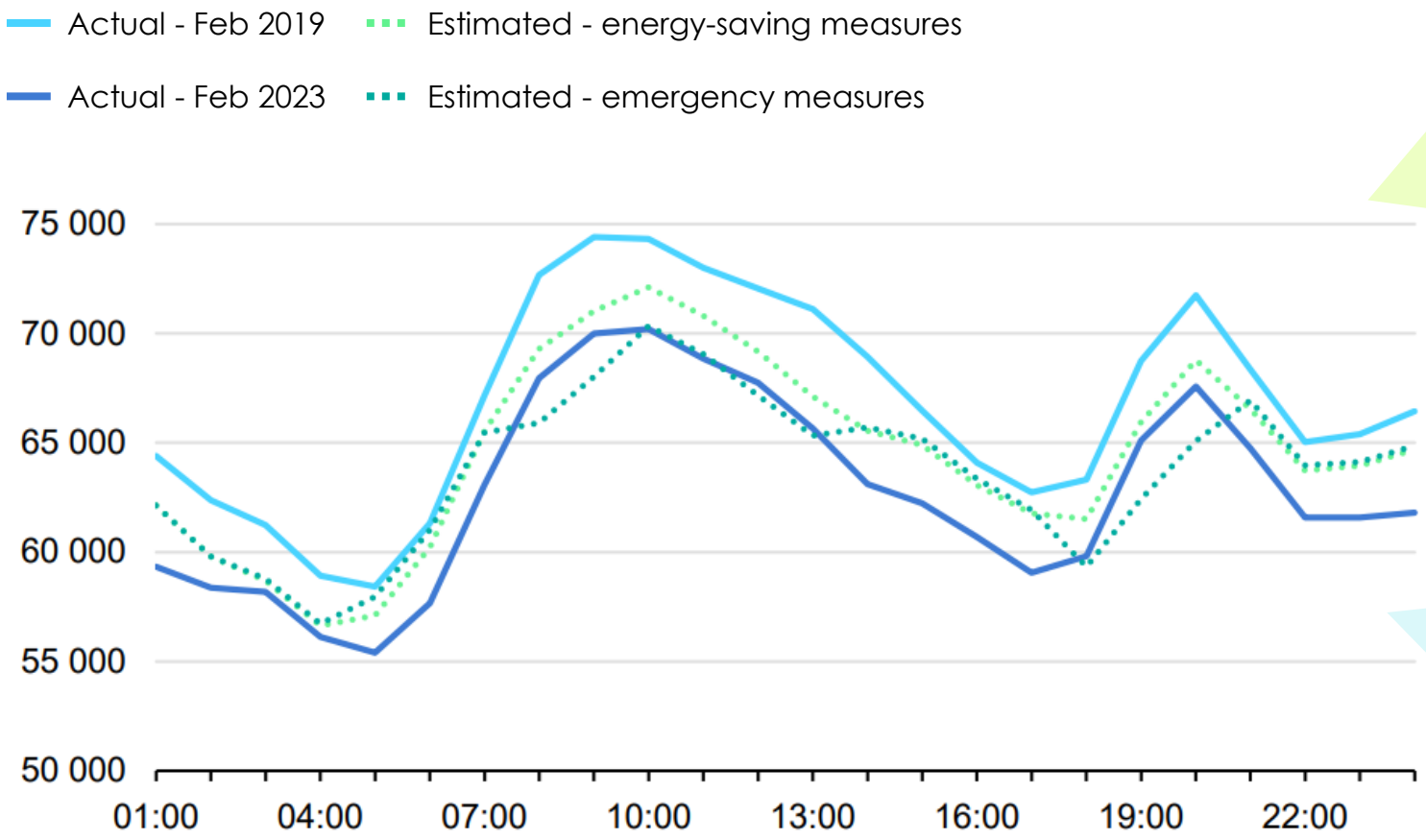


Source: Euro News (2022), *How much e-waste does Europe generate, recycle and repair?;* Eurostat (2021), *Waste statistics - electrical and electronic equipment*

Energy saving behaviours have had a significant impact lowering energy consumption during energy crisis and peak

Hourly electricity consumption in France in Feb 2019 and 2023, compared with estimated effects of behaviour campaign saving and emergency recommendations

Hourly electricity demand (MW)



In February 2023 during the energy crisis, **consumers lowered energy consumption significantly** during the period when the government's Energy "Sobriété" Campaign was actively encouraging energy saving measures as part the "sobriety plan"

Recommended actions included

- Lowering of thermostat for heating
- Banning leaving doors open in heated shops
- Switching to LEDs
- Moving consumption to off-peak times

The French Transmission System Operator RTE estimated the potential of **behavioural actions could save up to 9 GW in peak time**

Real-time data show that peak electricity consumption on a cold day in February 2023 was indeed around **6% lower** than on comparable days in 2019 during a period with similar temperatures

Source: IEA (2023), *Energy Efficiency 2023*

Discussion

Energy
Transitions
Commission

The Energy Transitions Commission is hosted by SYSTEMIQ Ltd.